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U.S. Geological Survey

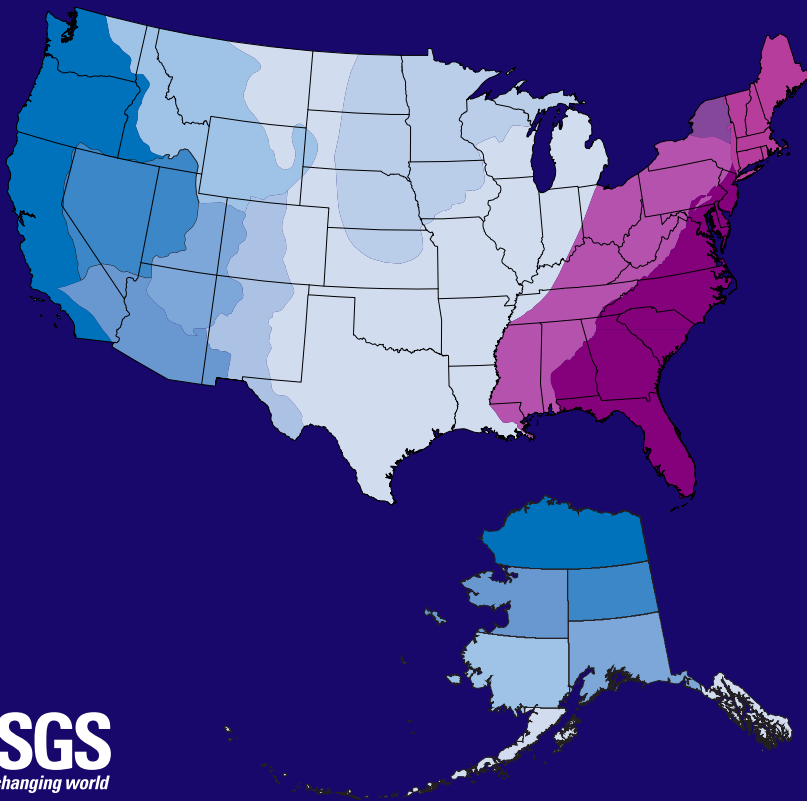
U.S. GEOLOGICAL SURVEY OPEN-FILE REPORT 02-198

ASSESSMENT OF UNDISCOVERED DEPOSITS OF GOLD,
SILVER, COPPER, LEAD, AND ZINC IN THE UNITED STATES

A Portable Document Format (PDF) Recompile
of USGS OFR 96-96 and Circular 1178

By: the USGS National Mineral Resource Assessment Team

Recompiled by: Paul Schruben
As a Subtask of The Global Minerals Resources Assessment Project



1) OVERVIEW

This publication contains the results of a national mineral resource assessment study. The study (1) identifies regional tracts of ground believed to contain most of the nation's undiscovered resources of gold, silver, copper, lead, and zinc in conventional types of deposits; and (2) includes probabilistic estimates of the amounts of these undiscovered resources in most of the tracts. The disc also contains a table of the significant known deposits in the tracts, and includes descriptions of the mineral deposit models used for the assessment.

The assessment was previously released in two major publications. The conterminous United States assessment was published in 1996 as USGS Open-File Report 96-96. Subsequently, the Alaska assessment was combined with the conterminous assessment in 1998 and released as USGS Circular 1178.

This new recompilation release was undertaken for several reasons. First, the graphical browser software used in Circular 1178 was ONLY compatible with the Microsoft Windows operating system. It was incompatible with the Macintosh operating system, Linux, and other types of Unix computers. Second, the browser on Circular 1178 is much less intuitive to operate, requiring most users to follow a tutorial to understand how to navigate the information on the CD. Third, this release corrects several errors and numbering inconsistencies in Circular 1178.

This publication includes OFR 96-96 and many files modified from those on Circular 1178. The GIS software from Circular 1178 is not included. Both of the original national assessment publications can be downloaded from the following Internet sites:
<http://pubs.usgs.gov/openfile/of96-096/>
<http://pubs.usgs.gov/circular/c1178/>

One way to begin examining the results of the national assessment immediately is to proceed as follows:

1. Install Adobe Acrobat or Adobe Acrobat Reader as described below, or check to be certain you already have one of these programs installed.
2. Open the file "1_NATIONAL_ASSESSMENT.PDF."
3. Look for the bookmark named: "Deposit Tract Maps." Click on the triangles (Macintosh) or boxes with plus sign (Windows) to the left of the underlying bookmarks titled: "Alaska" and the "Conterminous U.S." This will display lists of tracts by mineral deposit type for each of these two regions. Some mineral deposit types have multiple tract maps. For example, there are three tract maps for porphyry copper deposits: Porphyry Cu deposits I, II, and III. Each map delineates areas permissive for the occurrence of undiscovered porphyry copper deposits by age. See the Rationale files for descriptions of each tract.

4. Click on a mineral-deposit-type name on one of the lists. This will open a map showing tracts judged to contain undiscovered gold, silver, copper, lead, or zinc in mineral deposits of this type.
5. Each map's key has clickable buttons that will bring up for each tract most of the following data sets:
 - **Cumulative Distribution** graph of estimated metal and mineralized rock.
 - **Histogram** of estimated metal and mineralized rock.
 - **Table** showing the probabilistic estimates of numbers of undiscovered deposits, and the estimated amounts of contained metal and mineralized rock.
 - **Model** lists briefly describing this mineral deposit type.
 - **Mineral Deposits** list and descriptions of known deposits.
 - **Rationale** for selecting the mineral deposit model, delineating tracts, and making numerical estimates of numbers of undiscovered deposits.

2) SYSTEM REQUIREMENTS

The Acrobat file **1_NATIONAL_ASSESSMENT.PDF** was developed in Acrobat 5. At publication time Acrobat 5 for Unix was still not available, so the file was modified and saved in Acrobat 4. It has not been tested with earlier versions of Acrobat Reader. OFR 96-96 was developed in Acrobat 2.1. Here are the system requirements for several versions of Acrobat Reader:

A color display monitor is strongly recommended with all platforms.

Acrobat Reader 5 requirements:

Macintosh

- PowerPC® processor
- Mac OS software version 8.6, 9.0.4, 9.1, or Mac OS X
- 32 MB of RAM (with virtual memory on) (64 MB recommended)
- 150 MB of available hard-disk space
- Additional 70 MB of hard-disk space for Asian fonts (optional)
- CD-ROM drive

Windows

- Intel® Pentium® processor
- Microsoft® Windows® 95 OSR 2.0, Windows 98, Windows Millennium, Windows NT®* 4.0 with Service Pack 5 or 6, Windows 2000, or Windows XP
- 32 MB of RAM (64 MB recommended)
- 150 MB of available hard-disk space
- Additional 70 MB of hard-disk space for Asian fonts (optional)
- CD-ROM drive

Acrobat Reader 4 requirements:

IBM AIX

- IBM AIX® 4.2.1
- Common Desktop Environment (CDE) 1.0 or Motif®
- 32 MB of available RAM
- 12 MB of available hard-disk space

DEC OSF/1

- DEC OSF/1 version 4.0
- 32 MB of available RAM
- 12 MB of available hard-disk space

HP-UX

- HP 9000 Series Workstation model 700 or higher

Hewlett-Packard HP-UX version 9.0.3
 X Window System™ X11R5 with HP-VUE or Common Desktop Environment
 (CDE) 1.0 or later
 32 MB of available RAM
 12 MB of available hard-disk space

SGI IRIX

Silicon Graphics® IRIX™ 5.3
 32 MB of available RAM
 12 MB of available hard-disk space

Linux

Red Hat® Linux® 5.1 (non glibc versions) or Slackware® Linux 2.0
 (non-glibc versions)
 32 MB of available RAM
 12 MB of available hard-disk space

Sun Solaris X86 and Sun Solaris SPARCstation®

Sun™ Solaris™ 2.3
 Sun OpenWindows™ 3.0 or later, Motif 1.2.3 or later, OpenLook 3.0, or Common
 Desktop Environment (CDE) 1.0 or later
 32 MB of available RAM
 12 MB of available hard-disk space
 Note: Acrobat Reader 4.0 will not run under SunOS™ or Solaris 2.0, 2.1, or 2.2.

Acrobat Reader 3 requirements:

Macintosh:

Mac OS 7.0 or later
 Macintosh 68020-040: 2MB of application RAM
 Power Macintosh: 4.5MB of application RAM
 5 MB hard disk space

Windows:

386, 486, or Pentium (R) processor-based personal computer
 Microsoft(R) Windows 3.1, Windows 95, Windows NT(TM) 3.5 or later
 4 MB of RAM
 5 MB hard disk space

DOS:

386- or 486-based personal computer (486 recommended)
 DOS version 3.3 or later
 2 MB of application RAM (4 MB recommended)
 5 MB hard disk space

Unix:

Sun(TM) SPARCstation(R) workstation

SunOS(TM) version 4.1.3 or later, Solaris(R) 2.3 or 2.4

OpenWindows(TM) (3.0 or later) or the Motif(TM) window manager
(version 1.2.3 or later)

32 MB of RAM

8 MB of disk space

HP Series 9000 workstation, model 700 or higher

HP-UX 9.0.3 or later

HPVUE desktop environment

32 MB of RAM

6 MB of disk space

5) DISC ORGANIZATION AND CONTENTS

The assessment files are in several formats on the disc - Adobe Acrobat 4, Adobe Illustrator 8, ESRI ArcGIS 8.1 coverages and shapefiles, Microsoft Excel, and Microsoft Word. Acrobat Reader installers are included on the disc. The following section describes the files on the CD-ROM.

A) OFR 02-198 FILES

The Open-File Report 02-198 desktop file icons are red in Mac OS. Descriptions follow in alphabetical order:

- **1_NATIONAL_ASSESSMENT.PDF**— Portable Document File (Acrobat)

This file combines the information stored in all the files as a single browsable, 2718 page, 37 MB file. The file format is Adobe Portable Document File (PDF), which is readable by means of the freeware program, Acrobat Reader, included on the CD-ROM. Instructions below describe how to install and launch Acrobat, as well as how to, view, navigate, and search the file.

- **ACROBAT_4_AND_5** (Folder) — Acrobat Reader installers for most platforms

B) ALASKA ASSESSMENT FILES

In Mac OS the Alaska file icons are blue. Descriptions for the most important files and folders follow in alphabetical order:

- Alaska_Assessment**Doc-ReadMe1st.html** (file), **Documentation** (folder) — User manual for Circular 1178

(Internet Explorer, Netscape Navigator)

This file launches the file documentation\userman.html, containing the [PDF part of Circular 1178](#), tutorial for the graphical interface, etc. However, it will not launch the Circular 1178 graphical interface, which is not included in this disc.

- Alaska_Assessment**KNOWNDEP_AK.XLS** — Significant Known Deposits of Alaska
(Excel 4)

This file consists of a select list of significant known deposits for the Alaska assessment. The deposits are located by 1:250,000 scale map sheet, latitude, and longitude. Most deposits have been classified by using the models described in MODLLIST.XLS. Deposits were selected by using guidelines for minimum amounts of contained metal (production + remaining resources). The guidelines are, in metric tons, Au - 2; Ag - 85; Cu - 50,000; Pb - 30,000; and Zn - 50,000. Singer (1995) indicated that deposits of this size should represent close to 99 percent of the metal that has been discovered.

- Alaska_Assessment**MODELLIST_AK.XLS** — Description of Deposit Models
(Excel 4)

This file applies to both the Alaska and conterminous U.S. assessments. It presents brief geologic descriptions of the deposit models and principal geological references, as well as references to the grade and tonnage models upon which the assessments were based. Model number refers to the numerical designation used in Cox and Singer (1986) and subsequent publications. It is used for classification and refers to occurrence models. The Mark3 index is the serial identification number used in the simulation program and refers to exactly which grade and tonnage model is to be used.

- Alaska_Assessment**RATIONALE_AK.DOC** — Permissive Tract Text
Descriptions and Rationale for Estimates
(Word 97-98)

This file explains, for each tract and wherever estimates were made, the rationales for selecting the deposit model, for delineating the permissive tract, and for making the numerical estimates, as well as brief descriptions of typical deposits in the tract. The rationales are sorted by descriptive model.

- Alaska_Assessment**REFERENCE_AK.DOC** — References for the Alaska assessment
(Word 97-98)

This file contains a list of references for the Alaska assessment.

- Alaska_Assessment**SHAPEFILES_AK** (folder) — Tract maps in ESRI ArcGIS shapefile format.

(ARC/INFO 7.0.3)

This folder contains 165 tract maps in ESRI ArcGIS vector polygon shapefile format. Also included are the region and Alaska coastline polygon shapefiles.

- Alaska_Assessment**TRACTLIST_AK.XLS** — Permissive Tracts and Estimated Numbers of Undiscovered Deposits

(Excel 2000)

This file shows the map layer (TRACTMAP file name, such as AKBS, AKCY, AKGQ2, and so forth), identifying number (Tract ID such as AK-AP01, AK-AP02, and so forth), deposit type, region, metallogenic age, probabilistic estimates of the numbers of undiscovered deposits, identity of estimators, and areal extent for each of the 165 permissive tracts in Alaska.

- Alaska_Assessment**TRACTMAPS_AK.AI** — Tracts and regions in vector graphics format.

(Adobe Illustrator 8)

This 40 MB file contains all the tract maps organized into 39 separate layers in Adobe Illustrator format.

C) OFR 96-96 FILES

See the **OFR 96-96** folder for these files. In Mac OS the file icons are green. Descriptions of the files follow in the [OFR 96-96 section](#) below.

6) ACROBAT READER INSTALLATION

Installation procedures vary slightly among the five platforms listed below, but, generically, the procedure is as follows:

1. Copy the 1_NATIONAL_ASSESSMENT.PDF file to your hard drive if 37 MB is available.

2. Install Acrobat Reader 4 or later on your hard drive if not already installed. The installers for most platforms are included in the disc in the folder Acrobat_Reader_4_and_5.

The Macintosh Acrobat Reader Installer may ask for a web connection. For Macintosh OS 9.x and earlier, after installation and before launching Acrobat Reader, set the application memory size to 12 MB or greater. This is accomplished by single clicking on the Acrobat Reader application to highlight it, then go to the File menu, Get Info. Drag on General Information to go to the Memory section and set Preferred Size to 12000 K.

3. Launch Acrobat Reader and then open the 1_NATIONAL_ASSESSMENT.PDF file. Double-clicking on the file may open the wrong version of Acrobat Reader.

7) HINTS FOR USING ADOBE ADOBE ACROBAT

The Acrobat toolbar is located along the top of the Acrobat screen. Most of the tools are self-explanatory. The arrow keys on the left move one page at a time. The bar-arrow tools go to the first or last page in the file. The arrow tools on the right allow the user to go back and retrace previous views. This is important because most documents lack a "back" button.

The maps, spreadsheets, and text files are browsable by single clicking on the blue hypertext links and selectable areas on the maps. The cursor changes to a pointing hand over links. For instance, the zoom tool, which is a magnifying glass, works by clicking on a point or dragging a rectangle. However, if the magnifying glass changes to a pointing hand, indicating that it is over a link, a mouse click will select the link instead of zooming.

The bookmarks in the left-hand column allow random access to all pages. The small triangles at the extreme left expand individual bookmark chapter headings.

In the Acrobat file, the words, including those in the maps, are searchable with the binocular tool. The second and third tools from the left allow switching between bookmark and thumbnail views in the left-side scrollable area.

Owners of older computers may wish to interrupt a slow-drawing map. If this is the case simply select another destination in the bookmarks. This stops the current map drawing and displays the next document. On the Macintosh, hold down the Command and period keys to interrupt the current map draw.

8) ACROBAT TUTORIAL

The following Acrobat Tutorial demonstrates the major parts of the data base. The user can open the NATLASMT.PDF document twice to keep these instructions available in another window. Use the Window menu to switch between screens.

In the bookmarks column on the left, select the triangle in front of "Region Maps" to expand it.

Expand the Conterminous U.S. bookmark.

Select the "GB: Great Basin" bookmark.

Select "GB30 Sediment-hosted Au" deposit type.

Select any of the tracts or tract labels to see the map key.

Select the GB30 row blue button under Rationale.

Select "Cumulative Distribution".

Select the "Go to Previous View" arrow on the tool bar above the graph.

Select "Histogram" in the rationale.

Select the "Go to Previous View" arrow on the tool bar above the graph.

Select "Table" in the rationale.

Select the "print version" text in the upper right. This is the same information as the last screen, formatted for a laserwriter.

Select the File menu, Print. Type in ONLY the current page number shown in the bottom margin in both "From" and "To" boxes. Otherwise it will try to print all 2677 pages.

Select the "Go to Previous View" arrow on the tool bar TWICE to return to the rationale.

Select "Model". The correct model is number 17 at the bottom.

Select the "Go to Previous View" arrow on the tool bar.

Select "Mineral Deposits" in the rationale.

Select the GB30 text in the deposit list.

Select any of the tracts or tract labels to see the map key.

9) DISCLAIMER

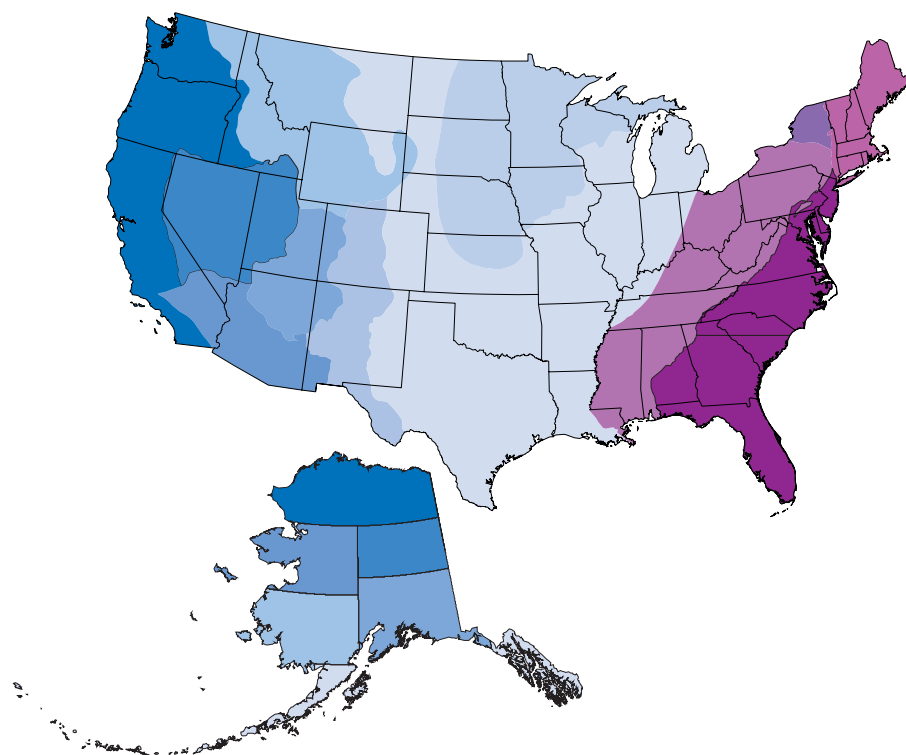
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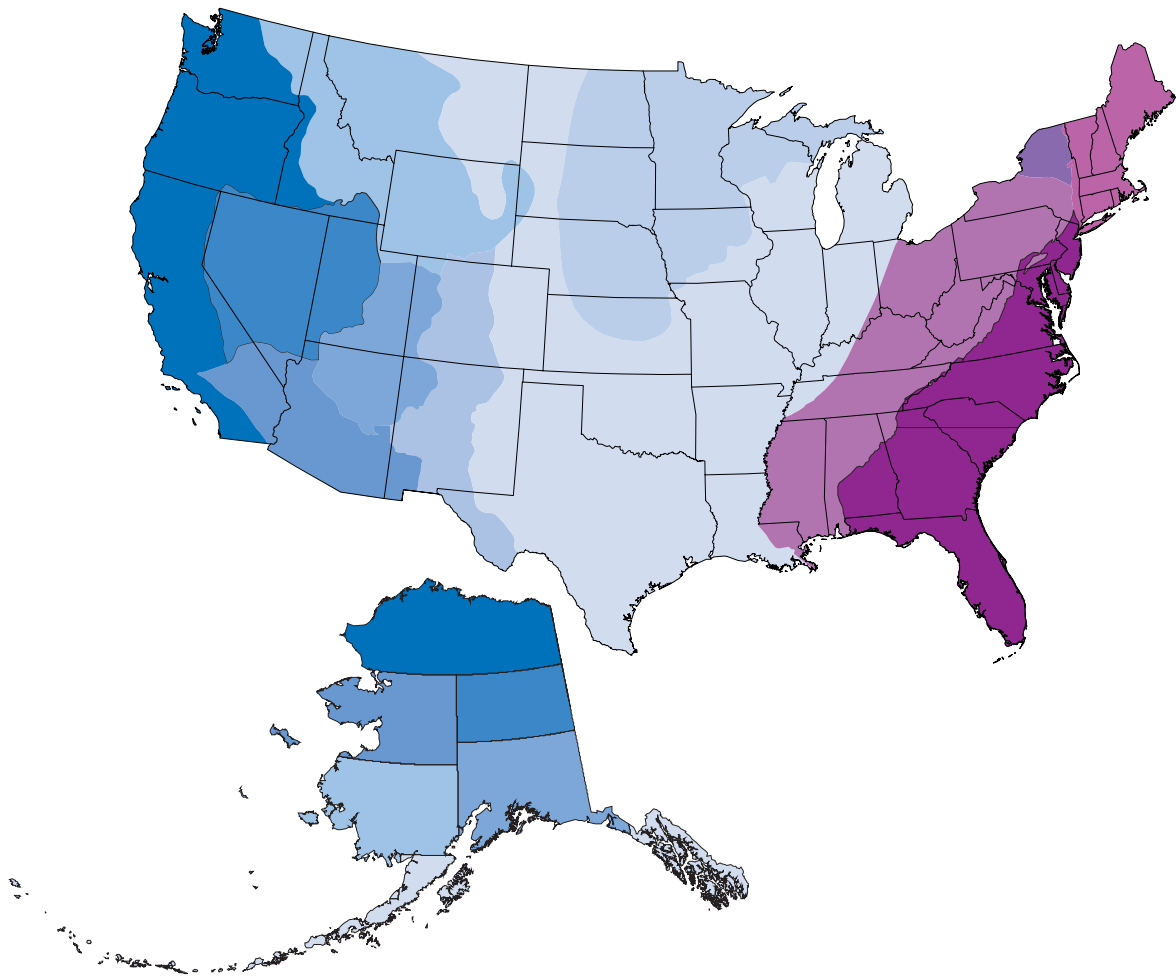
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Graphical map depictions on this disc are intended to be used within the map scale limits applicable to the source data. Although software enables the user to view images on the disc at various scales, the user is cautioned that enlarging the maps beyond a scale of 1:1,000,000 is not warranted.

1998 Assessment of Undiscovered Deposits of Gold, Silver, Copper, Lead, and Zinc in the United States

U.S. GEOLOGICAL SURVEY CIRCULAR 1178





- | | |
|--|--|
|  Region 1, Northern Appalachian Mountains |  Region 11, Great Basin |
|  Region 2, Adirondack Mountains |  Region 12, Southern Basin and Range |
|  Region 3, Southern Appalachian Mountains |  Region 13, Brooks Range |
|  Region 4, East-central |  Region 14, East-central Alaska |
|  Region 5, Great Plains |  Region 15, West-central Alaska |
|  Region 6, Lake Superior |  Region 16, Southeastern Alaska |
|  Region 7, Northern Rocky Mountains |  Region 17, South-central Alaska |
|  Region 8, Central and Southern Rocky Mountains |  Region 18, Southwestern Alaska |
|  Region 9, Colorado Plateau |  Region 19, Alaska Peninsula and Aleutian Islands |
|  Region 10, Pacific Coast | |

Cover. Geographic regions assessed in this report. See figure 3 for region numbers.

**U.S. Department of the Interior
U.S. Geological Survey**

1998 Assessment of Undiscovered Deposits of Gold, Silver, Copper, Lead, and Zinc in the United States

By the U.S. Geological Survey National Mineral Resource Assessment Team

U.S. GEOLOGICAL SURVEY CIRCULAR 1178

Overview of the 1998 National Mineral Resource Assessment

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
CHARLES G. GROAT, Director

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COMPACT DISC

[In pocket]

1998 Assessment of Undiscovered Deposits of Gold, Silver, Copper, Lead, and Zinc in
the United States—CD-ROM Containing Circular Report, Data Base, and Graphical
Display Program

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METRIC CONVERSION FACTORS

For readers who wish to convert measurements from the metric system of units to the inch-pound system of units, the conversion factors are listed below:

Multiply	By	To obtain
gram (g)	0.03215	ounce (troy)
metric ton (t)	1.102	short ton
kilometer (km)	0.6214	miles

Note: Throughout this report, the amounts of gold and silver are expressed in metric tons; the amounts of copper, lead, and zinc are expressed in thousand metric tons (kilotons).

1998 Assessment of Undiscovered Deposits of Gold, Silver, Copper, Lead, and Zinc in the United States

By the U.S. Geological Survey National Mineral Resource Assessment Team

SUMMARY OF RESULTS

This report summarizes the results of the 1998 National Mineral Resource Assessment that estimated the gold, silver, copper, lead, and zinc in undiscovered deposits in the United States. This project also estimated the identified resources and past production of these five metals. Assessment results include the following:

- It is estimated that 18,000 metric tons (t) of gold, 460,000 t of silver, 290,000 kilotons (kt) of copper, 85,000 kt of lead, and 210,000 kt of zinc are in undiscovered deposits minable with existing technology.
- In addition, it is estimated that 15,000 t of gold, 160,000 t of silver, 260,000 kt of copper, 51,000 kt of lead, and 55,000 kt of zinc remain in identified resources.
- Past production from the largest identified resources of gold, silver, copper, lead, and zinc is estimated to be 12,000 t of gold, 170,000 t of silver, 91,000 kt of copper, 41,000 kt of lead, and 44,000 kt of zinc. These deposits account for about 99 percent of cumulative domestic production in the United States.

Estimated total resources of gold, silver, copper, lead, and zinc in the United States are listed in table 1 and shown in figure 1.

INTRODUCTION

How much of our Nation's total mineral wealth has already been discovered? How much is left? These are important questions, and discovering the answers to them is an ongoing part of the mission of the U.S. Geological Survey (USGS). To address these questions, the USGS undertook to estimate, for the first time in probabilistic terms, the amounts of gold, silver, copper, lead, and zinc in undiscovered deposits believed to exist 1 kilometer (km) or less below the surface of the ground in the United States. This effort has resulted in the 1998 National Mineral Resource Assessment.

As the Nation's population grows and its economy matures, greater attention is being paid to such issues as land use and environmental quality, as well as to

sustainability of mineral supplies to provide for the needs of future generations. National Mineral Resource Assessments provide a framework for addressing these issues by monitoring the continuing depletion of the Nation's nonrenewable mineral wealth and by contributing information required to manage resource extraction while minimizing consequent environmental effects. For responsible stewardship of the Nation's lands and resources, it is important to know in which areas future mineral resources may be located and how much metal such resources might contain (McCammon and Briskey, 1992).

ACKNOWLEDGMENTS

The USGS wishes to thank numerous individuals in industry, academia, and State geological organizations for their help. The State Geologists of many of the States were particularly helpful in reviewing material that related to the significant deposits in their States.

COMMODITIES ASSESSED

The commodities gold, silver, copper, lead, and zinc were chosen as the subject for this National Mineral Resource Assessment because, after iron and aluminum, they are the most valuable metals in our economy. These commodities have been produced widely and extensively. They also tend to occur together in nature, thereby introducing efficiencies in the estimation of undiscovered resources. Other mineral commodities may be the subject of future assessments.

ASSESSMENT CATEGORIES

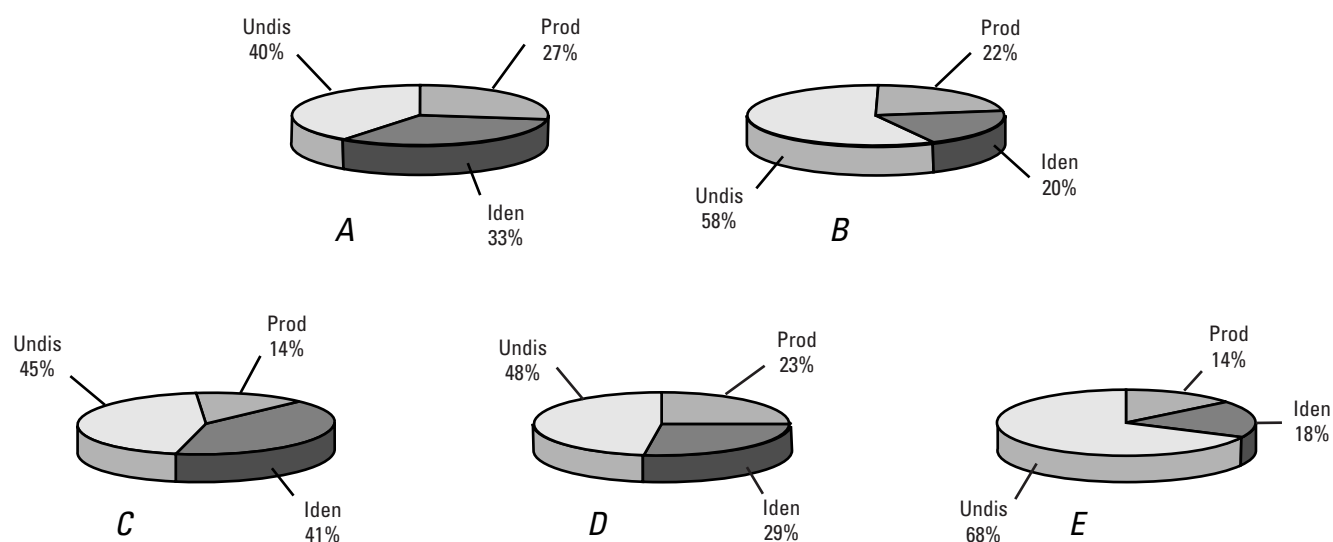
The resource classification used in this report is illustrated in figure 2, a modified "McKelvey diagram" (McKelvey, 1972). Resources are classified along two axes—geologic certainty that the resource exists and economic feasibility of their development. The degree of geologic certainty decreases to the right, and the degree of economic feasibility decreases downward. Cumulative past

Table 1. Estimates of undiscovered deposits, identified resources, past production, and discovered resources of gold, silver, copper, lead, and zinc in the United States.

[Undiscovered deposits, deposits believed to exist 1 kilometer or less below the surface of the ground within a geologically defined area; identified resources, resources whose location, grade, quality, and quantity are known or estimated from specific geologic evidence. Totals rounded to two significant figures]

Category	Gold (tons)	Silver (tons)	Copper (kilotons)	Lead (kilotons)	Zinc (kilotons)
Undiscovered U.S. deposits, estimated -----	18,000	460,000	290,000	85,000	210,000
Identified U.S. resources ¹ -----	15,000	160,000	260,000	51,000	55,000
Past U.S. production-----	12,000	170,000	91,000	41,000	44,000
Discovered U.S. resources ¹ ----	27,000	330,000	350,000	92,000	99,000

¹Estimates from Long and others (1998). Discovered U.S. resources are the sum of identified U.S. resources and past U.S. production.

**Figure 1.** Estimated resources and past production (as percentage of estimated total resources) of gold, silver, copper, lead, and zinc in the United States. A, gold; B, silver; C, copper; D, lead; E, zinc. Prod, past production; Iden, identified resources; Undis, undiscovered resources.

	Cumulative production	IDENTIFIED RESOURCES		UNDISCOVERED RESOURCES		
		Demonstrated		Inferred	Probability range	
		Measured	Indicated		Hypothetical	Speculative
ECONOMIC FEASIBILITY	ECONOMIC	Reserve base		Inferred	<div>This report</div>	
	MARGINALLY ECONOMIC			reserve base		
	SUBECONOMIC	-----		-----		
GEOLOGIC CERTAINTY						

Figure 2. Mineral resource classification used in this report (modified from McKelvey, 1972; U.S. Bureau of Mines and U.S. Geological Survey, 1980; U.S. Geological Survey, 1998). The degree of geologic certainty decreases to the right; the degree of economic feasibility decreases downward.

production is not part of identified resources and thus is not indicated in figure 2. The undiscovered resources estimated in this report include the hypothetical category and part of the speculative category. Identified resources include the demonstrated and inferred categories.

TERMINOLOGY

The terminology used in this report is intended to represent standard definitions and usage by the minerals industry and the resource assessment community (U.S. Bureau of Mines and U.S. Geological Survey, 1980; American Geological Institute, 1997). No attempt has been made to include a detailed listing of all the definitions; rather, those definitions that are essential to the proper understanding of this report are presented. Some of the definitions are intended to be generally explanatory rather than strictly technical. A few of the definitions are specific to this report.

Mineral deposit. A mineral concentration of sufficient size and grade richness that it might, under the most favorable of

circumstances, be considered to have potential for economic development.

Undiscovered mineral deposit. A mineral deposit believed to exist 1 km or less below the surface of the ground, or an incompletely explored mineral occurrence or prospect that could have sufficient size and grade to be classed as a deposit.

Significant mineral deposit. A mineral deposit known or believed to contain at least 2 t of gold, or 85 t of silver, or 50,000 t of copper, or 35,000 t of lead, or 50,000 t of zinc (Singer, 1995).

Descriptive mineral deposit model. A set of data in a convenient form that describes a group of mineral deposits having similar characteristics.

Grade and tonnage model. Frequency distributions of the grade and size of well-explored individual mineral deposits.

Permissive tract. A geographic area delineated such that the probability of deposits of the type delineated occurring outside the boundary is negligible.

Resource. A mineral concentration of sufficient size and grade and in such form and amount that economic extrac-

tion of a commodity from the concentration is currently or potentially feasible.

Identified resources. Resources whose location, grade, quality, and quantity are known or are estimatable from specific geologic evidence.

Demonstrated resource. The sum of measured plus indicated resources.

Measured resource. Quantity computed from dimensions revealed in outcrops, trenches, workings, or drill holes; grade and (or) quality computed from the results of detailed sampling. The sites for inspection, sampling, and measurement are spaced so closely and the geologic character is so well defined that size, shape, depth, and mineral content of the resource are well established.

Indicated resource. Quantity and grade and (or) quality computed from information similar to that used for measured resources. However, the sites for inspection, sampling, and measurement are farther apart or are otherwise less adequately spaced. The degree of assurance, although lower than that for measured resources, is high enough to assume continuity between points of observation.

Reserve base. That part of an identified resource that meets specified minimum physical and chemical criteria related to current mining and production practices. The reserve base is the in-place demonstrated (measured plus indicated) resource from which reserves are estimated and includes those resources that are currently economic (reserves), those that are marginally economic, and some of those that are currently subeconomic.

Reserves. That part of the reserve base that can be economically extracted or produced at the time of determination.

Inferred resource. Estimates of resource that are based on an assumed continuity beyond measured and (or) indicated resources for which there is geologic evidence. Inferred resources may or may not be supported by samples or measurements.

Inferred reserve base. The postulated extension of the reserve base. The inferred reserve base is an estimate based on an assumed continuity beyond identified resources for which there is geologic evidence. The inferred reserve base is the in-place part of an identified resource from which inferred reserves are estimated.

Inferred reserves. The postulated extension of reserves. Inferred reserves are estimates that are based on an assumed continuity beyond measured and (or) indicated reserves for which there is geologic evidence.

Undiscovered resources. Resources in undiscovered mineral deposits whose existence is postulated on the basis of indirect geologic evidence.

Hypothetical resources. Undiscovered resources in known types of mineral deposits postulated to exist in favorable geologic settings where other deposits of the same types have been mined.

Speculative resources. Undiscovered resources that may occur either in known types of deposits in favorable geologic settings where mineral discoveries have not been made or in types of deposits as yet unrecognized for their economic potential.

Cumulative past production. The total amount of all past production.

Discovered resources. The total amount of identified resources and cumulative past production.

DATA BASE

The National Mineral Resource Assessment is based mainly on data collected and reviewed from 1993 to 1998. The data were either published, commercially available, or from unpublished USGS studies. Data sources included the following:

- Published and unpublished USGS geologic, geochemical, geophysical, mineral deposit, and mineral-occurrence data at scales of 1:500,000 and 1:1,000,000 that were used to define the boundaries of tracts of land permissive for the occurrence of undiscovered mineral deposits.
- USGS data on mineral deposit models that included descriptive and grade and tonnage models.
- Data from the USGS and the former U.S. Bureau of Mines on past production.
- Production and resource data from Securities and Exchange Commission 10K forms.
- Geologic, geochemical, geophysical, mineral deposit, and mineral-occurrence data maintained by State geological surveys.
- Published articles in the academic literature.
- Periodicals and newsletters that serve the mining industry.

The data base of the tracts that were used to generate the resource estimates obtained in the National Mineral Resource Assessment is stored on a Compact Disc-Read Only Memory (CD-ROM), which is included in a pocket at the end of this report. The CD-ROM also contains this circular and a browser that can be used to examine the tracts by region and by major deposit model type and the significant mineral deposits that occur in the tracts. The data base consists of the following:

- Estimates of the tonnages and amounts of contained metal in undiscovered deposits,

- A table that lists the mineral deposit model types used in the National Mineral Resource Assessment,
- A table that lists the tonnages and amounts of contained metal in the significant mineral deposits in the United States,
- The rationale that was used to assess each of the tracts in the National Mineral Resource Assessment, and
- A list of references for each tract in the National Mineral Resource Assessment.

The browser is a map-based, stand-alone Windows application that can be installed from the CD-ROM. The browser allows a user to click on a tract for a selected mineral deposit model type and to display either the tabular data associated with the tract or the rationale that was used to assess the tract. The rationale contains hypertext links to the tonnage and amounts of contained metal in undiscovered deposits, the mineral deposit model type used to assess the particular tract, and the significant mineral deposits associated with the tract. A user can also choose to display the assessment regions, mining districts, and the significant mineral deposits, as well as several standard thematic layers such as political boundaries, cities, airports, rivers, and color-shaded relief.

AREAS OF STUDY

The undiscovered resources of gold, silver, copper, lead, and zinc in the United States were evaluated by interpreting the known geology of the 19 assessment regions shown in figure 3. The regions were constructed to provide broad geologic groupings of the Nation's mineral-producing regions. The regions are named for structural or geographic features within their boundaries.

METHOD OF ASSESSMENT

The method used to estimate the quantity and quality of undiscovered deposits of gold, silver, copper, lead, and zinc was based on the three-part form of quantitative assessment described by Singer (1993). In three-part assessments, areas are delineated according to the types of deposits permitted by the geology, the amount of metal in typical deposits is estimated by using grade and tonnage models, and the number of undiscovered deposits of each type is estimated by using a variety of subjective methods. Estimates of the number of undiscovered deposits are consistent in that the geologic settings of the delineated areas are consistent with the geologic settings for the descriptive models, as well as for the identified resources in the area and the deposits that constitute the grade and tonnage models. Every effort is made to incorporate the available information in the estimates, and the uncertainty is explicitly represented. The three-part form of quantitative assessment has been applied by the USGS since 1975.

UNDISCOVERED DEPOSITS

The national assessment was conducted by 19 regional assessment teams of scientists from the USGS. Each team comprised geologists, geochemists, geophysicists, and resource analysts. To begin an assessment, existing data for large (Alaska) and multi-State assessment regions were compiled into maps at scales of 1:500,000 and 1:1,000,000. For each region, a team reviewed the geology and decided upon the appropriate mineral deposit models to be used in making the assessment. On the basis of all the available information, permissive tracts then were delineated for each deposit model type such that the probability was negligible that undiscovered deposits for a particular deposit model type would occur outside the tract boundary.

Maps showing the geology and the locations and types of mineral deposits and occurrences were used in outlining these permissive tracts. Geophysical and geochemical maps also were useful, as well as knowledge of the exploration history of the areas.

Estimates of the undiscovered resources were made to a depth of 1 km beneath the surface. If an area of otherwise permissive rock was covered by more than 1 km of rock known or was inferred to be barren, then the area was excluded from the tract. The somewhat arbitrary depth of 1 km was chosen as the limit below which the existence of undiscovered deposits would not be considered because of difficulties in acquiring and (or) extrapolating geologic, geochemical, and geophysical data to greater depths. Because some mineral deposits have vertical extents of more than 1 km, the rule was adopted such that if any part of a deposit was judged to be within 1 km of the surface, then the whole deposit was counted. This rationale is consistent with mining practice. Although direct mineral exploration is seldom conducted below 1 km, deposits may be explored and developed up to 3 km deep once they have been discovered at lesser depths.

The regional assessment teams reviewed grade and tonnage data for all identified resources in a tract, then decided whether worldwide models were applicable, and modified the models if necessary. In most cases, the models used were those described in Cox and Singer (1986) and Bliss (1992). In cases for which it was not possible to use these worldwide models, local models were used. The undiscovered deposits estimated to exist in the tract were treated as if they would be similar in grade and tonnage to the deposits in the deposit model (either accepted or modified).

Where available information warranted making quantitative estimates, the teams then estimated the number of undiscovered deposits of each deposit model type that might exist in each permissive tract. These estimates were made by subjective interpretation and extrapolation of available earth science information. The number of undiscovered deposits was estimated at different levels of

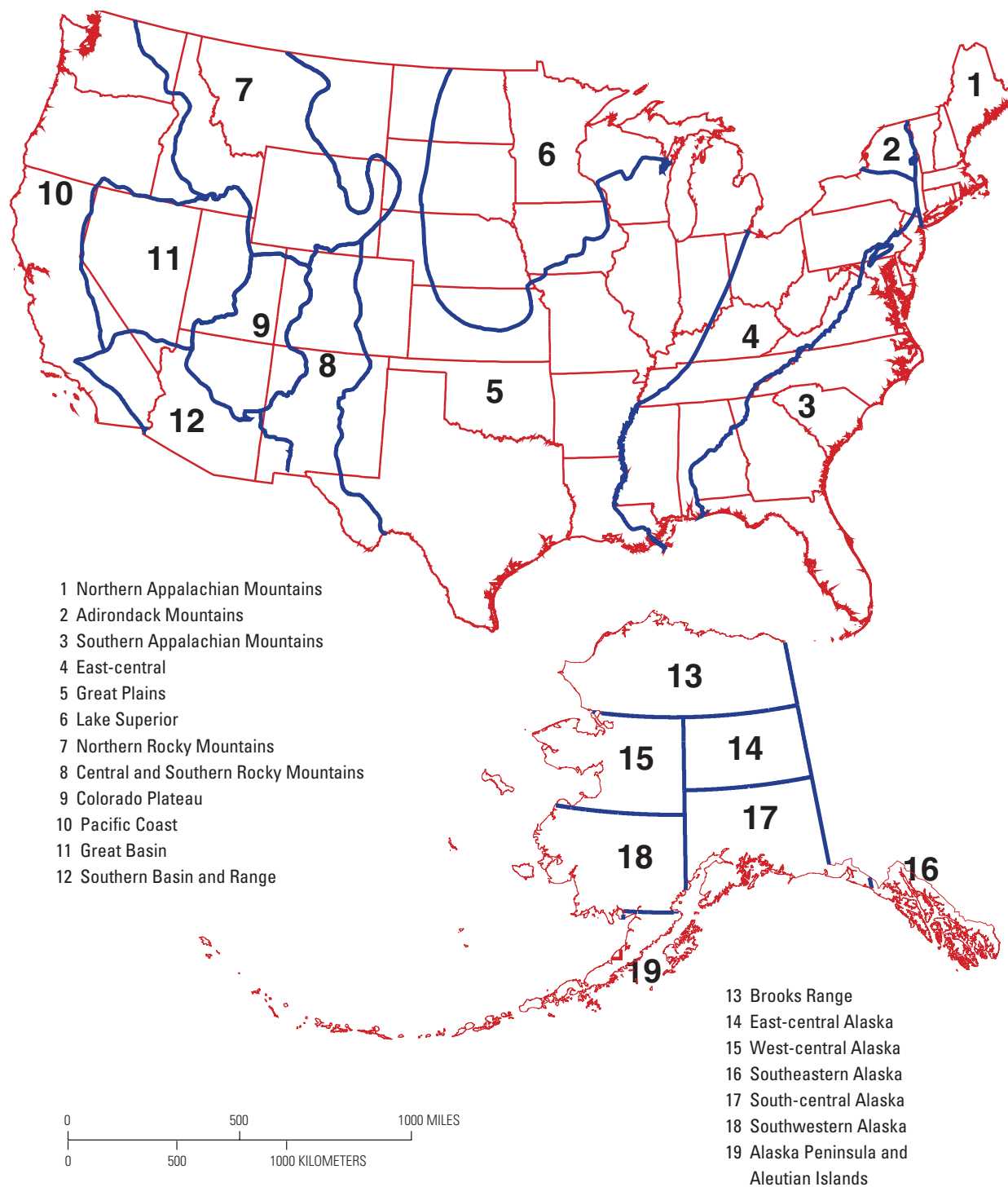


Figure 3. Geographic regions assessed in this report. Heavy lines, region boundaries; light lines, State boundaries.

certainty. For example, on the basis of all the available information, a team might estimate that there was a 90-percent chance or better that one or more undiscovered deposits existed; a 50-percent chance or better that three or more existed; and a 10-percent chance or better that five or more existed. Commonly, estimators made estimates for five levels of certainty—90th, 50th, 10th, 5th, and 1st percentiles.

The estimates were made by scientists who had detailed knowledge of an area and (or) the selected deposit model. The teams used a variety of methods to arrive at a consensus. The most common method was simply to continue their discussion until general agreement was reached. Decision-aiding tools, such as deposit spatial density models and assumptions about the extent of exploration, also were used to guide the final estimates (Singer, 1993). The result of the estimation process was a probability distribution of the number of undiscovered deposits. In cases where the grade and tonnage model was based on data for a mineral district rather than for individual deposits, the result was a probability distribution of the number of undiscovered districts.

PROBABILITY OF NO DEPOSITS

In some cases, it was necessary to estimate the probability of no deposits. This was done primarily when estimates of the numbers of undiscovered deposits at all levels of certainty were small and the estimators wished to further constrain the probability density estimates.

MONTE CARLO SIMULATION

A Monte Carlo simulation computer program was used to combine the probability distribution of the number of undiscovered deposits with the grade and tonnage data sets associated with each deposit model to obtain the probability distribution for undiscovered metal in each tract (Root, Menzie, and Scott, 1992; Root, Scott, and Selner, 1997). Estimates of the undiscovered metal in each tract were represented as a range of values corresponding to probabilities of occurrence to express the uncertainty inherent in the assessment of unknown quantities. The input variables—the number of undiscovered deposits and the tonnages and grades of the deposits in the deposit models—were expressed as cumulative probability distributions of uncertain values. The resulting cumulative probability distributions represented the estimated quantity of gold, silver, copper, lead, and zinc. From these distributions, various fractiles, including the low (F_{90}), the high (F_{10}), and the mean estimates, were obtained.

Unrealistically large values for grades and tonnages of undiscovered deposits can result from the highly skewed cumulative probability distributions, which are often characteristic of deposit data. To avoid such unrealistic values,

piecewise linear approximations of the tonnage and grades of metals in the deposit data were used in the simulations. To preserve the dependencies of grades in the deposit data, the deposits within each model were grouped into suites according to the metals they contained, and each suite was sampled proportionally to its frequency of occurrence for that deposit model. Also, the tonnages of the deposits in each suite had different distributions depending upon the suite of metals present.

AGGREGATION AND DEPENDENCY

To arrive at the estimated quantity of undiscovered deposits of gold, silver, copper, lead, and zinc for large areas, such as geographic regions or the Nation as a whole, distributions estimated for individual tracts were progressively aggregated, with geologic dependency incorporated at each level of aggregation. To aggregate tracts within regions, tracts assessed by the same team of estimators were assumed to be perfectly correlated, whereas tracts assessed by different teams were assumed to be uncorrelated. In aggregating regions to obtain a national total, regions were assumed to be statistically independent.

SIGNIFICANT DEPOSITS

As a part of the 1998 National Mineral Resource Assessment, a data base was compiled for the largest identified resources of gold, silver, copper, lead, and zinc in the United States (Long and others, 1998). The resources in this data base accounted for about 99 percent of domestic production of these metals and probably a similar share of identified resources.

Production data for deposits in the data base were stated in terms of metals recovered. Generally, between 40 and 97 percent of the metal originally contained in the ores was recovered, depending on the efficiency of the extractive processes used and the quality of labor and management. The data included those situations in which the initial mining operations recovered so little of the contained metal that the resulting waste heaps were reprocessed later. Resource data for deposits in the data base were stated in terms of metals contained in remaining material. The sum of the past production and the remaining (identified) resources was the total discovered resources reported herein.

RESULTS OF THE ASSESSMENT

A total of 55 major deposit model and submodel types were used to delineate 447 permissive tracts for the 1998 assessment. Quantitative assessments were made for 305 of these tracts (CD-ROM, in pocket). The 30 major deposit model types used in the quantitative assessments are listed in table 2.

Table 2. Deposit models and their descriptions and major metals used in quantitative assessment of 305 of the 447 permissive tracts delineated in the 1998 National Mineral Resource Assessment.

[Deposit models based on Cox and Singer (1986) and Bliss (1992). The plutonic porphyry gold deposit model is based on Hollister (1992). For grade and tonnage data for specific models, refer to Root, Scott, and Selner (1997)]

Deposit model	Description	Major metals
Alaskan platinum group elements (PGE) -----	Crosscutting ultramafic to felsic intrusive rocks with approximately concentric zoning of rock types that contain chromite, platinum, and titanium-vanadium-magnetite.	Cr, PGE, Ti, V, Cu, Ni
Alkaline gold-tellurium -----	Veins or breccias associated with alkalic igneous rocks that contain gold \pm gold tellurides \pm vanadian micas.	Au, Te
Gold skarn-----	Gold in skarns near intrusive igneous contacts. Includes copper, zinc, lead, and iron skarns with gold as a major commodity.	Au
Basaltic copper -----	Disseminated native copper and copper sulfides in the upper parts of thick sequences of subaerial basalt.	Cu
Besshi massive sulfide-----	Thin, sheetlike bodies of massive to well-laminated pyrite, pyrrhotite, and chalcopyrite within thinly laminated clastic sediments associated with basalt flows and tuffs.	Cu, Ag, Au, Zn
Comstock epithermal vein -----	Gold, electrum, silver sulfosalts, and argentite in vuggy quartz-adularia veins hosted by felsic to intermediate volcanic rocks that overlie predominantly clastic sedimentary rocks and their metamorphic equivalents.	Au, Ag
Creede epithermal vein-----	Galena, sphalerite, chalcopyrite, sulfosalts, \pm tellurides, \pm gold in quartz-carbonate veins hosted by felsic to intermediate volcanics.	Cu, Pb, Zn, Ag, Au
Copper skarn-----	Chalcopyrite in calc-silicate metasomatic rocks near contacts with weakly mineralized igneous intrusives.	Cu, Ag, Au
Distal disseminated silver-gold---	Disseminated silver and gold mainly in sedimentary rocks distal to porphyry copper, skarns, and polymetallic veins.	Au, Ag
Homestake, stratiform gold -----	Gold in massive persistent quartz veins mainly in shear zones in regionally metamorphosed Archean and Proterozoic volcanic rocks and volcanic sediments.	Au, Ag
Hot spring gold-silver -----	Fine-grained silica and quartz in silicified breccia with gold, pyrite, and antimony and arsenic sulfides.	Au, Ag
Kuroko massive sulfide-----	Copper- and zinc-bearing massive sulfide deposits in marine volcanic rocks of intermediate to felsic composition.	Cu, Pb, Zn, Au, Ag
Low-sulfide gold-quartz vein ----	Gold in massive persistent quartz veins mainly in shear zones in regionally metamorphosed volcanic rocks and volcanic sediments.	Au, Ag
Mississippi Valley/southeast Missouri lead-zinc -----	Stratabound, carbonate-hosted deposits of galena, sphalerite, and chalcopyrite in rocks having primary and secondary porosity, commonly related to reefs on paleotopographic highs.	Zn, Pb, Ag
Mississippi Valley/Appalachian zinc-----	Stratabound deposits of sphalerite and minor galena in primary and secondary voids in favorable beds or horizons in thick platform dolostone and limestone.	Zn, Pb, Ag
Native copper -----	Native copper filling vesicles, breccias, and fractures in subaerial basalt.	Cu
Placer gold -----	Elemental gold and platinum-group alloys in grains and (rarely) nuggets in gravel, sand, silt, and clay and their consolidated equivalents, in alluvial, beach, eolian, and (rarely) glacial deposits.	Au, Ag
Plutonic porphyry gold -----	Gold in stockwork veinlets in hydrothermally altered granodiorite and quartz monzonite porphyry.	Au

Deposit model	Description	Major metals
Polymetallic replacement -----	Hydrothermal, epigenetic, silver, lead, zinc, and copper minerals in massive lenses, pipes, and veins in limestone, dolomite, or other soluble rock near igneous intrusive contacts.	Pb, Zn, Cu, Ag, Au
Polymetallic vein-----	Quartz-carbonate veins with gold and silver associated with base metal sulfides related to hypabyssal intrusions in sedimentary and metamorphic terranes.	Ag, Au, Pb, Zn, Cu
Porphyry copper-----	Generalized model includes various subtypes, all of which contain chalcopyrite in stockwork veinlets in hydrothermally altered porphyry and adjacent country rock.	Cu, Ag, Au, Mo
Porphyry copper, skarn-related---	Chalcopyrite in stockwork veinlets in hydrothermally altered and mineralized porphyry and in calc-silicate contact metasomatic rocks with extensive retrograde alteration.	Cu, Ag, Au, Mo
Porphyry copper-gold -----	Stockwork veinlets of chalcopyrite, bornite, and magnetite in porphyritic intrusions and coeval volcanic rocks. Ratio of gold (parts per million) to molybdenum (percent) is greater than 30.	Cu, Au, Ag, Mo
Porphyry copper-molybdenum ---	Stockwork veinlets of quartz, chalcopyrite, and molybdenite in or near a porphyritic intrusion. Ratio of gold (in parts per million) to molybdenum (percent) is less than 3.	Cu, Mo, Au, Ag
Quartz-adularia epithermal vein -	Gold, electrum, silver sulfosalts, and argentite in vuggy quartz-adularia veins hosted by felsic-to-intermediate volcanic rocks that overlie unspecified basement.	Au, Ag, Cu, Zn, Pb
Sediment-hosted gold -----	Very fine grained gold, pyrite, and arsenic-antimony sulfides disseminated in carbonaceous calcareous and siliceous sedimentary rocks and associated jasperoids.	Au, Ag
Sediment-hosted copper-----	Stratabound, disseminated copper sulfides in reduced beds of red-bed sequences.	Cu, Ag, Co
Sedimentary exhalative zinc-lead	Stratiform basinal accumulations of sulfides and barite interbedded with euxinic marine sediments form sheet- or lenslike ore bodies tens of meters thick, distributed through a stratigraphic interval of more than 1,000 m.	Zn, Pb, Ag
Synorogenic-synvolcanic nickel-copper -----	Massive lenses, matrix and disseminated sulfide in small to medium-sized gabbroic intrusions in greenstone belts.	Ni, Cu
Zinc-lead skarn -----	Sphalerite and galena in calc-silicate rocks near igneous intrusive contacts.	Zn, Pb, Ag, Au, Cu

Examples of submodels that were used include a British Columbia/Alaska porphyry copper submodel, a North America porphyry copper submodel, a modified gold-skarn deposit model for the Western United States, a reduced-facies submodel for the sediment-hosted copper deposit model, a Precambrian-only submodel for the kuroko massive sulfide deposit model, and an Archean submodel for the low-sulfide gold-quartz vein deposit model. In one case, a single deposit, Chicken Mountain in Alaska, was the sole representative of a plutonic porphyry gold submodel. Submodels were constructed and used when the teams' detailed knowledge of the local geology suggested that the general models did not adequately represent identified mineral deposits in a permissive tract for which undiscovered resources were being estimated.

It is easiest to discuss the results of the 1998 National Mineral Resource Assessment one metal at a time.

GOLD

The estimate of the amount of gold in undiscovered mineral deposits in the United States ranged from 13,000 t at a 90-percent probability to 22,000 t at a 10-percent probability. The mean estimate of gold in undiscovered deposits was 18,000 t. Estimated amounts of gold are listed by region in table 3 and shown by major deposit type in figure 4.

Nearly one-quarter of the gold was estimated to be contained in undiscovered porphyry copper deposits. Other major deposit types were hot spring gold, epithermal vein, plutonic porphyry gold, sediment-hosted gold, Au-Ag-Te veins, and low-sulfide gold-quartz vein deposits. The identified gold resource was estimated to be 15,000 t. Past production was estimated to be 12,000 t. The total discovered gold resource in the United States was estimated to be 27,000 t.

SILVER

The estimate of the amount of silver in undiscovered mineral deposits ranged from 290,000 t at a 90-percent probability to 660,000 t at a 10-percent probability. The mean estimate of silver in undiscovered deposits was 460,000 t. Estimated amounts of silver are listed by region in table 3 and shown by major type in figure 5.

Nearly one-half of the silver was thought to be contained in undiscovered sediment-hosted copper and epithermal vein deposits. Other major deposit types were polymetallic replacement, sedimentary exhalative, porphyry copper, and volcanogenic massive sulfide deposits. The identified silver resource was estimated to be 160,000 t. Past production was estimated to be 170,000 t. The total discovered silver resource in the United States was estimated to be 330,000 t.

COPPER

The amount of copper in undiscovered mineral deposits was estimated to range from 170,000 kt at a 90-percent probability to 440,000 kt at a 10-percent probability. The mean estimate of copper in undiscovered deposits was 290,000 kt. Estimated amounts of copper are listed by region in table 3 and shown by major type in figure 6.

More than two-thirds of the copper was thought to be contained in undiscovered porphyry copper deposits. Other major deposit types were sediment-hosted copper and volcanogenic massive sulfide deposits. The identified copper resource was estimated to be 260,000 kt. Past production was estimated to be 91,000 kt. The total discovered copper resource in the United States was estimated to be 350,000 kt.

LEAD

The estimate of the amount of lead in undiscovered mineral deposits ranged from 47,000 kt at a 90-percent probability to 130,000 kt at a 10-percent probability. The mean estimate of lead in undiscovered deposits was 85,000 kt. Estimated amounts of lead are listed by region in table 3 and shown by major type in figure 7.

Nearly one-half of the lead was thought to be contained in undiscovered sedimentary exhalative deposits. Other major deposit types were Mississippi Valley and polymetallic replacement deposit types. The identified lead resource was estimated to be 51,000 kt. Past production was estimated to be 41,000 kt. The total discovered lead resource in the United States was estimated to be 92,000 kt.

ZINC

The estimate of the amount of zinc in undiscovered deposits ranged from 130,000 kt at a 90-percent probability to 290,000 kt at a 10-percent probability. The mean estimate of zinc in undiscovered deposits was 210,000 kt. Estimated amounts of zinc are listed by region in table 3 and shown by major type in figure 8.

Nearly 40 percent of the zinc was thought to be contained in undiscovered Mississippi Valley-type deposits. Other major deposit types were sedimentary exhalative, volcanogenic massive sulfide, and polymetallic replacement deposit types. The identified zinc resource was estimated to be 55,000 kt. Past production was estimated at 44,000 kt. The total discovered zinc resource in the United States was estimated to be 99,000 kt.

Table 3. Estimates of contained metal in undiscovered deposits in the United States.

[Mean value totals may not be equal to the sums of the component means given elsewhere because numbers have been independently rounded. Fractile values (F_{90} , F_{10}) are derived from the cumulative probability distributions of the contained metals for each area or of the total area and are nonadditive. F_{90} represents a 9-in-10 chance, and F_{10} represents a 1-in-10 chance, of the occurrence of at least the amount tabulated. NM, no metal]

Assessment region	Gold (tons)			Silver (tons)			Copper (kilotons)			Lead (kilotons)			Zinc (kilotons)		
	F_{90}	F_{10}	Mean	F_{90}	F_{10}	Mean	F_{90}	F_{10}	Mean	F_{90}	F_{10}	Mean	F_{90}	F_{10}	Mean
Alaska															
Alaska Peninsula and Aleutian Islands-----	110	1,400	680	1,900	26,000	12,000	2,000	20,000	10,000	60	1,100	500	30	820	360
Brooks Range-----	0	140	54	660	34,000	14,000	32	1,400	580	580	23,000	9,500	1,600	39,000	17,000
East-central-----	120	1,300	660	0	2,000	710	58	4,500	1,800	NM	NM	NM	NM	NM	NM
South-central-----	320	3,100	1,700	1,200	2,200	10,000	3,600	36,000	19,000	5	1,500	580	130	7,700	3,100
Southeastern-----	0	280	100	78	11,000	3,900	10	1,800	5,700	8	1,200	510	8	2,300	1,000
Southwestern-----	360	2,000	1,100	14	14,000	5,200	120	6,000	2,500	1	9,900	3,600	10	20,000	6,500
West-central-----	0	37	18	0	1	2	NM	NM	NM	NM	NM	NM	NM	NM	NM
Statewide-----	280	700	480	1,500	56,000	24,000	2	860	310	2,100	50,000	22,000	5,100	86,000	41,000
TOTAL, Alaska-----	3,400	6,200	4,800	36,000	110,000	72,000	23,000	57,000	39,000	13,000	69,000	38,000	30,000	110,000	69,000
United States exclusive of Alaska															
Adirondack Mountains----	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	0	0	640
Central and Southern Rocky Mountains-----	180	2,700	1,200	1,200	40,000	17,000	1,300	14,000	6,700	97	5,600	2,300	85	6,800	2,700
Colorado Plateau-----	NM	NM	NM	0	1	0	0	350	100	NM	NM	NM	NM	NM	NM
East-central-----	NM	NM	NM	110	15,000	5,400	NM	NM	NM	900	14,000	7,100	7,800	104,000	52,000
Great Basin-----	1,600	6,400	3,800	31,000	170,000	92,000	3,700	86,000	39,000	1,800	14,000	7,300	2,400	17,000	9,200
Great Plains-----	NM	NM	NM	0	47,000	19,000	180	42,000	17,000	29	19,000	7,200	1,000	37,000	16,000
Lake Superior-----	260	1,700	880	3,800	170,000	61,000	6,800	70,000	35,000	130	1,600	900	3,300	31,000	14,000
Northern Appalachians---	32	460	220	2,400	35,000	16,000	1,300	15,000	8,100	500	20,000	7,900	2,600	38,000	17,000
Northern Rocky Mountains-----	220	4,100	1,900	11,000	130,000	65,000	4,900	52,000	24,000	120	18,000	6,700	210	28,000	11,000
Pacific Coast-----	1,000	3,300	2,100	11,000	66,000	33,000	2,400	19,000	9,800	1	710	340	31	3,800	1,700
Southern Appalachians---	350	1,900	1,100	2,500	29,000	16,000	1,900	20,000	9,600	140	4,300	1,800	960	15,000	7,300
Southern Basin and Range-----	770	3,200	1,800	25,000	110,000	64,000	18,000	220,000	110,000	1,100	12,000	5,800	1,300	14,000	6,800
TOTAL, United States including Alaska-----	13,000	22,000	18,000	290,000	660,000	460,000	170,000	440,000	290,000	47,000	130,000	85,000	130,000	290,000	210,000

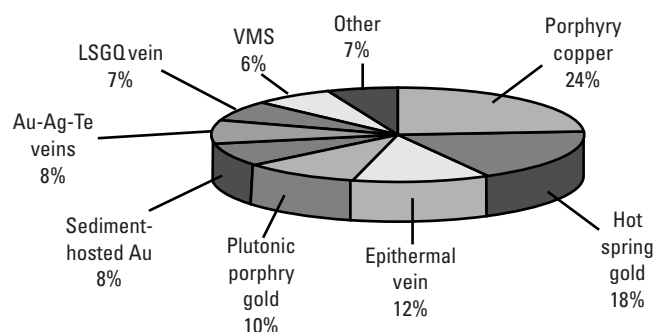


Figure 4. Gold in undiscovered mineral deposits, by major deposit type. LSGQ vein, low-sulfide gold-quartz vein; VMS, volcanogenic massive sulfide (includes Besshi-, Cyprus-, and kuroko-type deposits); epithermal vein (includes Comstock-, Creede-, and quartz-adularia-type deposits).

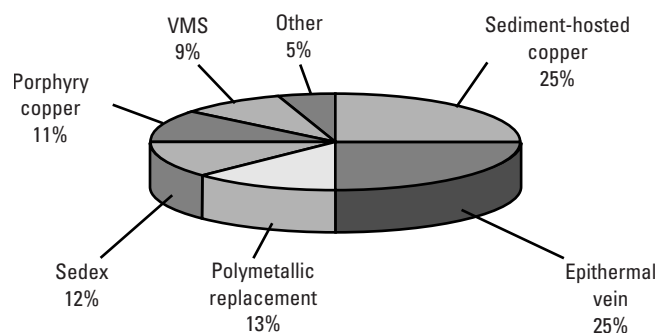


Figure 5. Silver in undiscovered mineral deposits, by major deposit type. Sedex, sedimentary exhalative; VMS, volcanogenic massive sulfide (includes Besshi-, Cyprus-, and kuroko-type deposits); epithermal vein (includes Comstock-, Creede-, and quartz-adularia-type deposits).

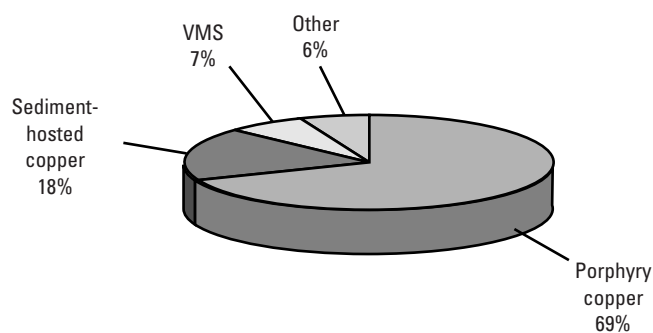


Figure 6. Copper in undiscovered mineral deposits, by major deposit type. VMS, volcanogenic massive sulfide (includes Besshi-, Cyprus-, and kuroko-type deposits).

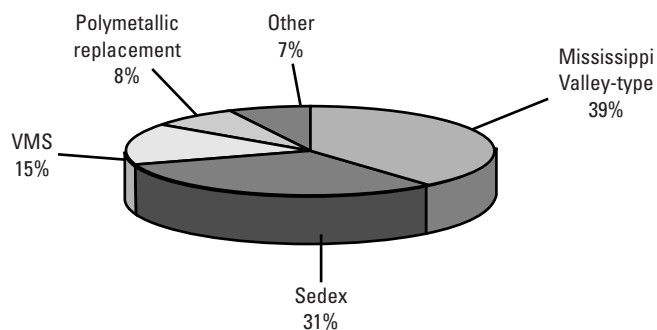


Figure 8. Zinc in undiscovered mineral deposits, by major deposit type. Sedex, sedimentary exhalative; VMS, volcanogenic massive sulfide (includes Besshi-, Cyprus-, and kuroko-type deposits).

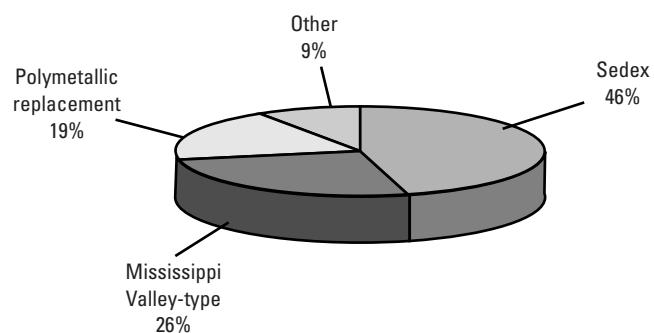


Figure 7. Lead in undiscovered mineral deposits, by major deposit type. Sedex, sedimentary exhalative.

DISCUSSION AND COMPARISON OF RESULTS WITH THE 1973 NATIONAL MINERAL RESOURCE ASSESSMENT

As a part of the response to the Mining and Minerals Policy Act of 1970, the USGS published Professional Paper 820 (Brobst and Pratt, 1973), which included the first overall assessment of mineral resources in the United States since the Paley Commission report in 1952 (President's Materials Policy Commission, 1952). Prior to Professional Paper 820, traditional resource appraisals mainly inventoried measured reserves. In the professional paper, the geologic availability of resources that would be needed by future generations was considered for the first time. Each chapter of the professional paper was devoted to a single commodity and was written by geologists, most of whom had many years of experience studying the geology of mineral deposits and the commodity about which they were writing. Because of the large number and varied nature of the commodities that were examined, Brobst and Pratt provided the authors with a suggested outline of general topics to be covered and some guidelines as to scope and philosophy of approach. Beyond that, however, no attempt was made to impose a fixed format. Consequently, the chapters ranged from comprehensive summary reports to general essays. Each chapter reflected the individuality of the authors, as well as such variations among commodities as geologic occurrence, physical and chemical properties, use, and economics. One of the difficulties in interpreting the results of the assessment was the lack of a common method for estimating the amounts of undiscovered resources. Consequently, it was difficult, if not impossible, to disaggregate the estimates provided according to geographic area or by deposit type. Moreover, it was not always possible to gain insight into how the authors arrived at their estimates or to evaluate the level of confidence in the estimates they reported.

Most of the chapters in Professional Paper 820, including those for gold, silver, copper, lead, and zinc, contained summaries of the geologic environment, types of deposits, resources, prospecting techniques, and problems for future research. The authors divided the resources into two categories—identified and undiscovered. Whenever possible, they also divided the undiscovered resources into two categories—hypothetical and speculative. In some cases, the authors further categorized resources according to type of deposit and geographic region of occurrence. Because of the nonuniform and (or) uncertain methods of assessment used by the different authors, it is easiest to compare their results with the 1998 National Mineral Resource Assessment one metal at a time.

GOLD

According to Simon and Prinz (1973), hypothetical and speculative gold resources, although they could not be estimated as accurately as reserves, were probably large compared with then-current U.S. gold production or consumption but small compared with total world reserves. If one correlates their words with figures for U.S. gold production and total world reserves for 1972, then an estimate of undiscovered gold resources can be obtained that ranges from 56 t to 31,000 t. The largest potential resources of gold were considered to be contained in Tertiary or Cretaceous placer deposits or auriferous conglomerates, followed, in decreasing order of magnitude, by disseminated, lode, "bonanza," and other placer deposits (Simon and Prinz, 1973).

The USGS 1998 mean estimate of 18,000 t of gold in undiscovered deposits, with a range of 13,000 to 22,000 t, was well within the range of the 1973 estimate. Even though significant undiscovered gold placer deposits remain in Tertiary or Cretaceous placer deposits in the Northern Rocky Mountain region, the 1998 team was unable to estimate the quantity of gold because of difficulties in applying grade and tonnage concepts. As a result, these potential resources in the Northern Rocky Mountains have been supplanted by potential resources for undiscovered sediment-hosted and hot spring gold deposits in the Great Basin and undiscovered plutonic porphyry gold deposits in Alaska. In addition, it was estimated that the amounts of gold contained in undiscovered porphyry copper deposits in the Basin and Range province and in epithermal vein and low-sulfide gold-quartz vein deposits in the Western United States and Alaska were significant.

SILVER

Heyl and others (1973) gave an estimate of 68,000 t for the identified resources of silver and 99,000 t for the hypothetical resources of silver. Roughly one-half of their identified resources and less than one-tenth of their hypothetical resources were in deposits in which silver was the main product. With respect to speculative resources, they indicated that the best possibilities for new discoveries were in disseminated copper, porphyry copper, and massive sulfide deposits.

The 1998 mean estimate of 460,000 t of silver in undiscovered deposits and the estimate of 160,000 t of silver in identified resources represent a substantial increase over the 1973 estimates. The increase is due, in large part, to the greater present-day knowledge about the geologic occurrence and distribution of silver-rich sediment-hosted copper deposits and also of epithermal vein and polymetallic replacement deposits. Possibilities of new discoveries that contain significant silver also exist for porphyry copper, sedimentary-exhalative, and volcanogenic massive sulfide deposits.

COPPER

Cox and others (1973) gave an estimate of 69,000 kt for the identified resources of copper, 90,500 kt for the hypothetical resources of copper, and 109,000 kt for the speculative resources of copper. Because of the large amount of information available on the copper resources in the United States, they were able to further estimate the amount of copper in the different resource categories according to geographic region and by major deposit type. Table 4 lists the identified and hypothetical copper resources reported by Cox and others (1973).

The hypothetical resources in the Western United States comprised concealed porphyry copper deposits in the Basin and Range province and the Absaroka Range of Wyoming and sedimentary copper deposits in the Belt Supergroup of Idaho and Montana. Alaskan hypothetical resources were considered to include porphyry copper deposits in eastern Alaska and replacement deposits in the Brooks Range.

Table 5 lists the speculative copper resources as reported by Cox and others (1973). They estimated that the greatest likelihood for new discoveries of copper resources was in the American Southwest, primarily in the southwestern, western, and northwestern parts of the Basin and Range province. These areas had not been evaluated as intensively as those in southeastern Arizona where many known porphyry copper deposits in a similar geologic setting have been found. Undiscovered porphyry copper deposits of Paleozoic age were believed to exist in the Appalachian Mountains. Finally, in southwestern Alaska and the Aleutian Islands, geologic conditions were considered to be similar to those of the southwest Pacific, which permitted the occurrence and possible discovery of porphyry copper deposits. Together, the hypothetical and speculative copper resources estimated by Cox and others (1973) totaled 199,500 kt in the United States.

The 1998 mean estimate of the amount of copper in undiscovered deposits of 290,000 kt was roughly one-half again as much as the 1973 estimate. The increase bore out the earlier estimators' optimism for the existence of then-undiscovered porphyry copper deposits in the Southwestern United States. Continuing discoveries of new deposits and extensions of known ones, together with increasingly detailed mapping and exploration, support continuing expectations for further discoveries of these deposits in the region. Additional, more detailed mapping of the Rocky Mountain region also has resulted in expectations of new discoveries of sediment-hosted copper deposits. For the same reasons, British Columbia/Alaska-type porphyry copper deposits probably will be discovered in the Alaskan Range. The discovery of the Crandon massive sulfide deposit in the Lake Superior region in 1976, together with other subsequent discoveries in the region, led to expecta-

tions for further discoveries of volcanogenic massive sulfide deposits there.

LEAD

Morris and others (1973) estimated that hypothetical world lead resources could be equal to one-half or more of world reserves and that the speculative world lead resources could equal or exceed the world reserves. Using world reserves for 1972 as a basis yielded an estimate of undiscovered lead resources for the world of 190,000 kt. Assuming that roughly 30 percent of the world reserves for 1972 were in the United States and that a similar percentage held for undiscovered lead resources in the United States, Morris and others' estimate of the undiscovered lead resources in the United States would translate into 57,000 kt. Morris and others concluded that the areas that held the best promise for new discoveries were located in active or formerly active mining districts, namely, central Tennessee, central and south-central Missouri, northern Arkansas, central Texas, northeastern Washington, and central Kentucky. Deposits have remained undiscovered in these areas either because they are concealed by barren rocks or because insignificant exposures do not indicate their true size or grade.

The 1998 mean estimate of the amount of lead in undiscovered deposits of 85,000 kt was roughly one-half again as much as the estimate of Morris and others (1973). In large part, this increase was due to the discovery of the Red Dog deposit in the Brooks Range, Alaska, and the resulting expectation for further undiscovered sedimentary exhalative deposits throughout Alaska. The rest of the increase was due to the probable existence of undiscovered Mississippi Valley-type deposits in the east-central and northern Appalachian regions.

Table 4. Summary of identified and hypothetical copper resources in the United States, 1973.

[In kilotons. Modified from Cox and others (1973, table 39)]

Area	Identified	Hypothetical
Eastern -----	9,000	4,500
Western, except Alaska -----	58,000	68,000
Alaska -----	2,000	18,000
Total -----	69,000	90,500

Table 5. Summary of speculative copper resources in the United States, 1973.

[In kilotons. Modified from Cox and others (1973, table 40)]

Area	Speculative
Basin and Range porphyry copper -----	91,000
Alaska porphyry copper -----	9,000
Appalachian Mountains-----	9,000
Total -----	109,000

ZINC

Wedow and others (1973) estimated the recoverable identified zinc resources of the United States to be 45,000 kt and the undiscovered recoverable resources to be 60,000 kt. They postulated that the undiscovered or potential resources would be dominated by the massive sulfide ores in metamorphic rocks, in which zinc occurs chiefly with copper and lead, and by the stratabound Mississippi Valley-type deposits in carbonate rocks.

The 1998 mean estimate of the amount of zinc in undiscovered deposits was 210,000 kt, which is more than three times the estimate of Wedow and others (1973). In large part, this difference was due to the increased expectation of large resources of zinc that may occur in major undiscovered zinc districts of the Mississippi Valley/Appalachian-type in an area that extends from Tennessee to the Canadian border. The discovery of the Red Dog deposit in the Brooks Range, Alaska, combined with increased exploration in the area, also resulted in increased expectations for future discoveries of sedimentary exhalative deposits throughout Alaska and in parts of the conterminous United States. The balance of the larger estimate was due to the likelihood of further discoveries of volcanogenic massive sulfide deposits in the Lake Superior region, the northern Appalachians, and the Western United States.

SOME CONSIDERATIONS FOR OTHER USES OF THE ASSESSMENT

Care must be exercised when using the results of the 1998 National Mineral Resource Assessment to answer questions that involve the potential for economic development of the estimated undiscovered resources. These estimates were based on grade and tonnage models, and the present-day economic viability of the deposits used to construct the models varies widely from deposit to deposit, from model to model, and from submodel to submodel. In addition, large parts of the areas delineated as permissive are unavailable for mineral development. Some areas are already being developed as urban areas, transportation corridors, and so forth. Mining and exploration are prohibited by law in the public interest in areas such as Wilderness and Scenic Areas and National Parks. Some areas are owned by those not interested in mineral development.

Estimated amounts of metals contained in undiscovered deposits are derived from estimates of numbers of deposits that are likely to exist, not necessarily from those likely to be discovered. For example, although concealed deposits were included in the assessment, they may be so expensive to search for that they are unlikely to be discovered in the near term.

It also is important to understand the distinctions among identified resources and districts, undiscovered

deposits and districts, and extensions to identified resources and districts. An identified deposit or district is one for which an estimate of the metal contained in the deposit can be made directly. The total consists of the sum of past production, if any, and any identified resource remaining in the ground. In some cases, the teams were aware of prospects, revealed by past or current exploration efforts, that were believed to be significant deposits but that did not yet have a documented grade and tonnage. Such deposits are treated herein as undiscovered deposits, albeit ones with a high degree of certainty of existence. Finally, it should be remembered that initial exploration leading to an announced discovery almost never identifies the total resource that exists and (or) ultimately may be mined. As exploration continues and (or) mining begins, an accompanying increase in knowledge about the deposit geology almost always results in increasing estimates of the size of the deposit.

One further note of caution should be given to users of the 1998 National Mineral Resource Assessment. Because the assessment methodology depended on deposit models, the teams were unable to estimate resources in types of deposits that were too poorly characterized for a deposit model to be constructed. An example is the copper-gold deposits in Washington. To better appreciate lack of understanding as a potential source of error in the assessment, imagine such an assessment being completed in 1905 before the recognition of porphyry copper-type deposits or in 1960 before the discoveries of sediment-hosted gold deposits. The consequent underestimation of copper and gold resources would have been so large as to undermine the conclusions about undiscovered resources at the time. Although the United States is much better explored and geologically known now than it was in 1905, new deposit types unimagined today can be expected to contribute substantially to the mineral resources of the United States in the future. Such considerations make it all the more imperative to conduct national assessments on a recurring basis.

EXTENSIONS TO IDENTIFIED RESOURCES

What are missing from the 1998 National Mineral Resource Assessment are estimates of the amounts of gold, silver, copper, lead, and zinc in extensions to identified resources. Experience shows that almost all estimates of mineral deposit sizes increase during production. Discovery and initial exploration almost never identify the total resource that exists. Mineral producers generally lack the financial incentive to prove reserves in excess of 10 to 20 years production. The exceptions are those cases where pit and plant design or permitting requirements necessitate a complete inventory for the mine plan. Thus, most mining operations actually have lifetimes that are much longer than

originally reported. Proved reserves increase with normal deposit development as boundaries of proved areas are extended by drilling, as extensions or new deposits are found and confirmed by drilling, as new infill drilling (vertical or horizontal) contacts previously inaccessible portions of the deposit, and with the introduction of improved recovery methods that allow lower grade material to be mined. Because a methodology that takes reserve growth into account is currently lacking, reserve growth is missing from the teams' estimates. The teams, however, believe reserve growth is of the same order of magnitude as that of the identified resources.

IMPLICATIONS

The 1998 National Mineral Resource Assessment achieved its primary goal—to provide quantitative, probabilistic estimates of the gold, silver, copper, lead, and zinc in undiscovered deposits for the country as a whole. There is every reason to believe that, for conventional-type deposits that contain gold, silver, copper, lead, or zinc, about as much is left to be discovered in the United States as has already been discovered. Furthermore, the method that was used in carrying out the assessment can serve as a guide to assess other commodities of national interest. The data base that was created for the assessment can be useful to land-management agencies and resource-planning organizations for land- and resource-planning and decisionmaking. Such information permits, at least at some minimum level, evaluation of the impact of land-use decisions on the Nation's undiscovered mineral resources. The availability of such a data base provides a unique opportunity for Federal, State, and local governments, industry, and the public to work cooperatively to plan the disposition of the Nation's long-term mineral supply. Federal, State, and local land-management agencies can use the information provided by the assessment to estimate potential cumulative environmental impact of possible exploration and mining activities, to evaluate the potential economic benefits of mining in comparison with other possible land uses, to evaluate and plan for the potential impact of mining activities on other land uses, and to appraise the fair market value of land proposed for leasing, sale, exchange, or taking. The permissive tracts delineated as part of the 1998 National Mineral Resource Assessment permit industry to focus mineral-exploration programs on the most promising areas for discoveries.

Looking to the future, the likelihood of finding new deposits presents new challenges, given that undiscovered deposits do not crop out, access is more difficult, environmental constraints are more severe, landownership is more fragmented, and foreign suppliers are cheaper. If the past can be used as a guide, deposits that are not yet recognized as economic targets, new technologies (for example, biome-

diated heap leaching) that might convert formerly discarded rock into ore, or some heretofore unrecognized source of metals (for example, gold in oil-field brines) that would define new targets for exploration are, without a doubt, in the Nation's future. Carrying out national assessments on a recurring basis will ensure adequate mineral supplies and effective stewardship of resources in the future.

REFERENCES CITED

- American Geological Institute, 1997, Dictionary of mining, mineral, and related terms (2d ed.): Alexandria, Va., American Geological Institute, 646 p.
- Bliss, J.D., ed., 1992, Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, 168 p.
- Brobst, D.A., and Pratt, W.P., eds., 1973, United States mineral resources: U.S. Geological Survey Professional Paper 820, 722 p.
- Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, 379 p.
- Cox, D.P., Schmidt, R.G., Vine, J.D., Kirkemo, Harold, Tourtelot, E.B., and Fleischer, Michael, 1973, Copper, *in* Brobst, D.A., and Pratt, W.P., eds., United States mineral resources: U.S. Geological Survey Professional Paper 820, p. 163–190.
- Heyl, A.V., Hall, W.E., Weissenborn, A.E., Stager, H.K., Puffett, W.P., and Reed, B.L., 1973, Silver, *in* Brobst, D.A., and Pratt, W.P., eds., United States mineral resources: U.S. Geological Survey Professional Paper 820, p. 581–603.
- Hollister, V.F., 1992, On a proposed plutonic porphyry gold deposit model: *Nonrenewable Resources*, v. 1, no. 4, p. 293–302.
- Long, K.R., DeYoung, J.H., Jr., and Ludington, S.D., 1998, Data base of significant deposits of gold, silver, copper, lead, and zinc in the United States; pt. A, Data base description and analysis; pt. B, Digital data base: U.S. Geological Survey Open-File Report 98–206, 33 p., one 3.5-inch diskette.
- McCammon, R.B., and Briskey, J.A., Jr., 1992, A proposed national mineral-resource assessment: *Nonrenewable Resources*, v. 1, no. 4, p. 259–266.
- McKelvey, V.E., 1972, Mineral resource estimates and public policy: *American Scientist*, v. 60, no. 1, p. 32–40.
- Morris, H.T., Heyl, A.V., and Hall, R.B., 1973, Lead, *in* Brobst, D.A., and Pratt, W.P., eds., United States mineral resources: U.S. Geological Survey Professional Paper 820, p. 313–332.
- President's Materials Policy Commission, 1952, Resources for freedom: Washington, U.S. Government Printing Office, 5 v., 818 p.
- Root, D.H., Menzie, W.D., III, and Scott, W.A., 1992, Computer Monte Carlo simulation in quantitative resource assessment: *Nonrenewable Resources*, v. 1, no. 2, p. 125–138.
- Root, D.H., Scott, W.A., Jr., and Selner, G.I., 1997, Computer program for aggregation of probabilistic assessments of mineral resources: U.S. Geological Survey Open-File Report 96–94, 1 diskette.
- Simon, F.S., and Prinz, W.C., 1973, Gold, *in* Brobst, D.A., and Pratt, W.P., eds., United States mineral resources: U.S. Geological Survey Professional Paper 820, p. 263–275.

- Singer, D.A., 1993, Basic concepts in three-part quantitative assessments of undiscovered mineral resources: *Nonrenewable Resources*, v. 2, no. 2, p. 69–81.
- 1995, World class base- and precious-metal deposits—A quantitative analysis: *Economic Geology*, v. 90, no. 1, p. 88–104.
- U.S. Bureau of Mines and U.S. Geological Survey, 1980, Principles of a resource/reserve classification for minerals: U.S. Geological Survey Circular 831, 5 p.
- U.S. Geological Survey, 1998, Mineral Commodity Summaries: U.S. Geological Survey, 197 p.
- Wedow, H., Jr., Kiilsgaard, T.H., Heyl, A.V., and Hall, R.B., 1973, Zinc, *in* Brobst, D.A., and Pratt, W.P., eds., United States mineral resources: U.S. Geological Survey Professional Paper 820, p. 697–711.

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About the Compact Disc

1998 Assessment of Undiscovered Deposits of Gold, Silver, Copper, Lead, and Zinc
in the United States—
CD-ROM Containing Circular Report, Data Base, and Graphical Display Program

The data base of the tracts that were used to generate the resource estimates obtained in the National Mineral Resource Assessment is stored on a Compact Disc-Read Only Memory (CD-ROM), which is included in a pocket at the end of this report. The CD-ROM also contains this circular and a browser that can be used to examine the tracts by region and by major deposit model type and the significant mineral deposits that occur in the tracts. The data base consists of the following:

- Estimates of the tonnages and amounts of contained metal in undiscovered deposits,
- A table that lists the mineral deposit model types used in the National Mineral Resource Assessment,
- A table that lists the tonnages and amounts of contained metal in the significant mineral deposits in the United States,
- The rationale that was used to assess each of the tracts in the National Mineral Resource Assessment, and
- A list of references for each tract in the National Mineral Resource Assessment.

The browser is a map-based, stand-alone Windows application that can be installed from the CD-ROM. The browser allows a user to click on a tract for a selected mineral deposit model type and to display either the tabular data associated with the tract or the rationale that was used to assess the tract. The rationale contains hypertext links to the tonnage and amounts of contained metal in undiscovered deposits, the mineral deposit model type used to assess the particular tract, and the significant mineral deposits associated with the tract. A user can also choose to display the assessment regions, mining districts, and significant mineral deposits, as well as several standard thematic layers such as political boundaries, cities, airports, rivers, and color-shaded relief.

This CD-ROM was produced in accordance with the ISO 9660 Level 2 standard. The included browser installs only under Windows 95, 98, or NT operating systems.

To get started: Launch the “NASetup.exe” program in the main directory of the disc. It installs a Start menu item called “National Assessment.”

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1) OVERVIEW

The results of the mineral-resource assessment for undiscovered resources of gold, silver, copper, lead, and zinc in the conterminous United States that was conducted from 1993 through 1995 are presented in an interactive Compact Disc–Read Only Memory (CD–ROM). The user may view, navigate, and print on demand any page of the Adobe Portable Document File (PDF) which is included on the CD–ROM. A search tool provided with this file also allows the user to find information anywhere in the data base easily.

The assessment consists of probabilistic estimates of the amounts of undiscovered gold, silver, copper, lead, and zinc in conventional types of deposits. The data base also contains a table of the significant known deposits and descriptions of the mineral deposit models used for the assessment.

2) TITLE AND AUTHORS

Data Base for a National Mineral-Resource Assessment of Undiscovered Deposits of Gold, Silver, Copper, Lead, and Zinc in the Conterminous United States
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4) SYSTEM REQUIREMENTS

A color display monitor is strongly recommended with all platforms.

Macintosh:

- Mac OS 7.0 or later
- Macintosh 68020-040: 2Mb of application RAM
- Power Macintosh: 4.5Mb of application RAM
- 5 MB hard disk space

Windows:

- 386, 486, or Pentium (R) processor-based personal computer
- Microsoft(R) Windows 3.1, Windows 95, Windows NT(TM) 3.5 or later
- 4 MB of RAM
- 5 MB hard disk space

DOS:

- 386- or 486-based personal computer (486 recommended)
- DOS version 3.3 or later
- 2 MB of application RAM (4 MB recommended)
- 5 MB hard disk space

Unix:

- Sun(TM) SPARCstation(R) workstation
- SunOS(TM) version 4.1.3 or later, Solaris(R) 2.3 or 2.4
- OpenWindows(TM) (3.0 or later) or the Motif(TM) window manager (version 1.2.3 or later)
- 32 MB of RAM
- 8 MB of disk space

- HP Series 9000 workstation, model 700 or higher
- HP-UX 9.0.3 or later
- HPVUE desktop environment
- 32 MB of RAM
- 6 MB of disk space

5) DISC ORGANIZATION AND CONTENTS

In the data base files is information about undiscovered deposits that may contain significant amounts of gold, silver, copper, lead, and zinc. The computer files are stored in a variety of formats, such as Microsoft Excel 4.0, Adobe Illustrator 5.5, Microsoft Word 5.1a, and Adobe Acrobat 2.1. An Acrobat Reader is included on the disc that allows the user to view the Acrobat file. The other computer files contain the data in their original form for those who prefer to use it that way. The following section contains brief descriptions of the files on the CD-ROM and the way they can be used.

- **NATLASMT.PDF**— Portable Document File (Acrobat)

This file combines the information stored in all the files as a single browsable, 2,036 page file. The format used is Adobe Portable Document File, which is readable by means of the freeware program, Acrobat Reader 2.1, that is included on the CD-ROM. Instructions below describe how to [install Acrobat](#), as well as [launch](#), [view](#), [navigate](#), and [search](#) the file.

Descriptions of the other computer files follow in alphabetical order:

- **INTRO** — Abstract of assessment terms and methods (Word 5.1a)

This explains the methods, terminology, computer programs, and statistical techniques used in the assessment.

- **KNOWNDEP** — Significant Known Deposits (Excel 4.0)

This file consists of a select list of significant known deposits. The deposits are located by State, county, latitude, and longitude. Most deposits have been classified by using the models described in MODLLIST. Deposits were selected by using guidelines for minimum amounts of contained metal (production + remaining resources). The guidelines are, in metric tons, Au - 2; Ag - 85; Cu - 50,000; Pb - 30,000; and Zn - 50,000. Singer (1995) indicated that deposits of this size should represent close to 99 percent of the metal that has been discovered.

LAYER and TRACT ID in blue indicates deposits that have been classified by using the models and that were associated with an assessment tract. LAYER and TRACTID in black (Groups FFTG, MOCX, MOLF, NONE, PLAC, PMVC, PMVD, PMVG, PMVN, PMVP, PMVS, and SEDZ) indicates deposits that were not associated with an assessment tract.

This file was assembled from the contributions of numerous individuals. It is incomplete, and production and remaining resource data are not yet ready for release. We encourage all who review this product to provide more information and to suggest other ways to improve this file.

- **EXPORT** (folder) — Tractmaps in ARC/INFO export format. (ARC/INFO 7.0.3)

In this folder are 32 tractmap coverages in ARC/INFO export format. See TRACTMAP section below for further explanation.

- **METLPLOT** (folder) — Probabilistic Estimates of Amounts of Metal (Excel 4.0)

In this folder are 236 Excel files, one for each permissive tract for which a numerical estimate of undiscovered deposits was made. Each is a stand-alone representation of the subjective estimate of resources made for that tract. Each file contains an input page, where all the original output of the Mark3 simulator is stored, and various output pages; the latter is selectable by using the View tool, which is an Excel Add-in located on the Window menu. These data include listings of the model type, various quantiles and mean amounts of estimated metal, and cumulative and class-interval histograms of the amounts of estimated metal.

- **MODLLIST** — Description of Deposit Models (Excel 4.0)

This file presents brief geologic descriptions of the deposit models and principal geological references, as well as references to the grade and tonnage models upon which this assessment is based. Model number refers to the numerical designation used in Cox and Singer (1986) and subsequent publications. It is used for classification and refers to occurrence models. The Mark3 index is the serial identification number used in the simulation program and refers to exactly which grade and tonnage model is to be used.

- **MODLMETL** (folder) — Tonnage and Contained Metals of Deposit Models (Excel 4.0)

This folder contains 42 Excel files, 1 for each grade and tonnage model used in the assessment. Each file contains an input page, where the results of the Mark3 simulator are stored, and an output page, which is a report based on those data that includes quantiles and means of estimated metal, and cumulative and class-interval histograms of the amounts of estimated metal. The input data for these files were created by running the Mark3 simulator for the case where there is exactly one undiscovered deposit, known with 100 percent certainty.

- **RATIONAL** (folder) — Permissive Tract Descriptions and Rationale for Estimates (Word 5.1a)

In this folder are 13 Word files, one file for each assessment region and one file for areas and deposit types that were not formally assessed. These files explain, for each tract and wherever estimates were made, the rationales for selecting the deposit model, for delineating the permissive tract, and for making the numerical estimates, as well as brief descriptions of typical deposits in the tract. The files are identified as follows:

AD: Adirondack Mountains

CP: Colorado Plateau
 CR: Central and Southern Rocky Mountains
 EC: East-central United States
 GB: Great Basin
 GP: Great Plains
 LS: Lake Superior
 NA: Northern Appalachian Mountains
 NR: Northern Rocky Mountains
 PC: Pacific Coast
 SA: Southern Appalachian Mountains
 SB: Southern Basin and Range
 UN: Unassessed

The tract descriptions are sorted alphabetically by the four-character Tract ID, such as CR01, CR02, and so forth. This numbering system generally follows a north or northwest to south or southeast trend.

• [REFERENC](#) — References for MODLLIST
(Word 5.1a)

This file contains a list of references for the file MODLLIST.

• [TRACLIST](#) — Permissive Tracts and Estimated Numbers of Undiscovered Deposits
(Excel 4.0)

This file shows the map layer (TRACTMAP file name, such as ALKG, BVMS, CVMS, and so forth), identifying number (Tract ID such as CR01, CR02, and so forth), State or States, deposit type, region, metallogenic age, probabilistic estimates of the numbers of undiscovered deposits, identity of estimators, and areal extent for each of the 282 permissive tracts in the conterminous United States.

• [TRACTMAP](#) (folder) — Maps Showing Permissive Tracts and Mineral Provinces
(Illustrator 5.5)

In this folder are 33 Illustrator files, 32 of which are maps showing the outlines of the permissive tracts described in TRACLIST and 1 file which is a base map showing State and assessment region boundaries. The locations of the deposits in KNOWNDEP that have been classified by model are shown by small numbered dots in the tract to which they belong: the numbers correspond to those used in KNOWNDEP. Maps are provided only for deposit types for which assessments were made; thus, some deposits in KNOWNDEP (Groups FFTG, MOCX, MOLF, NONE, PLAC, PMVC, PMVD, PMVG, PMVN, PMVP, PMVS, and SEDZ) are not depicted on any map.

The 32 maps are named with the four-character layer abbreviations shown in the Acrobat bookmarks and TRACLIST. The file names are ALKG, BVMS, CVMS, and so forth. When printing maps from Illustrator, the map scale and the area to be printed can be changed with the Page Setup dialog and the Page tool, respectively. When printing maps from Acrobat, only the scale can be changed. The default Page Setup is for tabloid 11- x 17-inch paper, which is about 1:13 million scale.

6) ADOBAT READER INSTALLATION

Installation procedures vary slightly among the five platforms listed below, but, generically, the procedure is as follows:

1. Copy the NATLASMT.PDF file to your hard drive if 18Mb is available.
2. Install Acrobat Reader 2.1 on your hard drive if not already installed.
3. Launch Acrobat Reader and then open the NATLASMT.PDF file.

DOS:

Choose a hard disk drive with 18Mb free. Assuming "D" is the CD-ROM drive and "C" is the hard drive, type:

```
COPY D:NATLASMT.PDF C:  
D:\ACROBAT\ACRODOS.EXE  
C:\ACRODOS\ACROBAT.EXE
```

At the Open File dialog, select the NATLASMT.PDF file on the hard drive.

Macintosh:

Drag the NATLASMT.PDF file to a hard drive with 18Mb free. Double-click on the "ACROBAT" folder. Double-click on the "ACROREAD.MAC" icon to install Acrobat Reader 2.1.

Double-click on Acrobat Reader 2.1. At the Open-File dialog, select the NATLASMT.PDF file on the hard drive.

Unix:

For SunOS, Solaris, HP-UX, Silicon Graphics, or AIX, refer to generic instructions above.

Windows 3.1:

Double-click on the File Manager icon and select the CD-ROM disc. Drag the NATLASMT.PDF file to a hard drive with 18mb free.

On the CD-ROM, double-click on "ACROBAT\ACROREAD.EXE" to install Acrobat Reader 2.1. Exit the File Manager and double-click on the Acrobat Reader icon. At the Open dialog, select the NATLASMT.PDF on the hard drive.

Windows 95:

Use the AMBR32A1.EXE installer and the generic instructions above.

7) HINTS FOR USING ACROBAT

The Acrobat toolbar is located along the top of the Acrobat screen. Most of the tools are self-explanatory. The arrow keys move one page at a time. The bar-arrow tools go to the first or last page in the file. The double-arrow tool allows the user to go back and retrace previous views. This is important because most documents lack a "back" button.

The maps, spreadsheets, and text files are browsable by single-clicking on the blue hypertext links and selectable areas on the maps. The cursor changes to a pointing hand over links. For instance, the zoom tool, which is a magnifying glass, works by clicking on a point or dragging a rectangle. However, if the magnifying glass changes to a pointing hand, which indicates that it is over a link, a mouse click will select the link instead of zooming.

The bookmarks in the left-hand column allow random access to all pages. The small triangles at the extreme left expand individual bookmark chapter headings.

In the Acrobat file, the words which include those in the maps, are searchable with the binocular tool. The second and third tools from the left allow switching between bookmark and thumbnail views in the left-side scrollable area.

Owners of older computers may wish to interrupt a slow-drawing map. In this situation, simply select another destination in the bookmarks. This stops the current map drawing and displays the next document. On the Macintosh, hold down the Command and period keys to interrupt the current map draw.

8) ACROBAT TUTORIAL

The following Acrobat Tutorial demonstrates the major parts of the data base. The user can open the NATLASMT.PDF document twice to keep these instructions available in another window. Use the Window menu to switch between screens.

Select the "Region Map - U.S." bookmark in the column on the left.

Select the "Great Basin" text in the map.

Select "GB30 Sediment-hosted Au" deposit type.

Select any of the tracts or tract labels to see the map key.

Select the GB30 blue button under Rationale.

Select "Cumulative Distribution".

Select the double arrow icon on the tool bar above the graph.

Select "Histogram" in the rationale.

Select the double arrow icon on the tool bar above the graph.

Select "Table" in the rationale.

Select the "print version" text in the upper right. This is the same information as the last screen formatted for a laserwriter.

Select the File menu, Print. Type in the current page number shown in the bottom margin in both "From" and "To" boxes, otherwise it will try to print all 2038 pages.

Select the double arrow icon repeatedly until you arrive back at the rationale.

Select "Model". The correct model is number 17 at the bottom.
Select the double arrow icon on the tool bar above the model table.
Select "Mineral Deposits" in the rationale.
Select the double arrow icon in the tool bar above the table.
Select "GB30" in the upper right to return to the map.
Select any of the tracts or tract labels to see the map key.

9) DISCLAIMER

This Compact Disc-Read Only Memory (CD-ROM) publication was prepared by an agency of the U. S. Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed in this report, or represents that its use would not infringe privately owned rights. Reference therein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the Government or any agency thereof. Any views and opinions of the authors expressed herein do not necessarily state or reflect those of the Government or any agency thereof.

Although all data and software published on this CD-ROM have been used by the USGS, no warranty, expressed or implied, is made by that agency as to the accuracy of the data and related materials and/(or) the functioning of the software. The act of distribution shall not constitute any such warranty, and no responsibility is assumed by the USGS in the use of these data, software, or related materials.

Graphical map depictions on this disc are intended to be used within the map scale limits applicable to the source data. Although software enables the user to show images on the disc at various scales, the user is cautioned that enlarging the maps beyond a scale of 1:1,000,000 is not warranted.

DATA BASE FOR A NATIONAL MINERAL RESOURCE ASSESSMENT OF UNDISCOVERED DEPOSITS OF GOLD, SILVER, COPPER, LEAD, AND ZINC —Conterminous United States

INTRODUCTION

Mineral-resource assessments provide land managers and decision makers with information on where undiscovered mineral deposits may be located, what kinds of deposits are likely to occur, and how much metal may exist. This database is the first compilation of probabilistic estimates for base and precious metals in undiscovered deposits on a national scale, and contains numerical estimates of amounts of gold, silver, copper, lead, and zinc in undiscovered mineral deposits in the conterminous United States. The database consists of a series of computer files in Microsoft Excel, Microsoft Word, and Adobe Illustrator formats, that can be used to generate tables, text files, maps, and graphs, along with an executable Adobe Acrobat file that can be used with the following operating systems: Macintosh OS™, MS-DOS™, WINDOWS 3.1™, WINDOWS 95™, and UNIX. We release this prototype database to the technical community while we continue to examine and evaluate resource information and assessment methodology.

WHAT IS A RESOURCE ASSESSMENT?

An assessment is an estimation or evaluation, in this instance of undiscovered resources of base and precious metals, within specific volumes of rock. Mineral resources are materials that are in such form that economic extraction of a commodity is currently or potentially feasible. This assessment is quantified, in that the result is expressed in numbers. Because of the uncertainty inherent in assessment of the unknown, the results are presented probabilistically.

We provide a numerical estimate of the amount and quality of mineralized rock and metal present within a specific area (known here as a "tract") to a specified depth (1 km in this assessment). An assessment may be well done or poorly done, but because it is an estimate, it cannot be right or wrong. Because this assessment is of undiscovered resources, the results of future exploration will serve to verify these estimates.

WHY THIS ASSESSMENT?

This resource assessment marks the beginning of an ongoing assessment of all mineral resources in the United States. The purpose of the assessment is to maintain a consistent, minimum level of current mineral-resource information so that such information can be considered in planning for the optimum use of the Nation's public lands, and for obtaining secure, long-term mineral supplies from domestic and international sources. A full discussion of the background to and reasons for a national assessment are given by McCammon and Briskey (1992).

The presentation of the results of this assessment is on a technical level, and requires some degree of technical knowledge on the part of the user. This is an experimental effort that we acknowledge is incomplete and even inconsistent in many regards. It is presented at this time as a preliminary product to aid, direct, and stimulate work toward improved National mineral resource assessments in the future.

The commodities gold, silver, copper, lead, and zinc were chosen as the subject for a National assessment because, after iron and aluminum, they are the most important metals in our economy, and they have been produced widely and extensively. They also tend to occur

together in nature, thereby introducing efficiencies in identifying deposit types and permissive tracts. While we recognize the importance of iron, aluminum, and other metals, they are outside the scope of this prototype database. At a future date, information may become available that will lead to consideration of these two commodities as well as others.

WHAT IS A DEPOSIT?

Because this assessment is based on characteristics of known deposits, and because the output is expressed as a function of the number of undiscovered deposits, it is important to define some terms. A mineral deposit is a mineral concentration of sufficient size and grade that it might, under the most favorable of circumstances, be considered to have economic potential (Cox and others, 1986, p. 1). Other concentrations that do not meet this criterion are described as occurrences or prospects. An undiscovered deposit is a deposit that is believed to exist within a geologically defined area. An incompletely explored mineral occurrence or prospect that could have sufficient size and grade to be classed as a deposit can be considered to be an undiscovered deposit. In the present study, the term significant deposit means one that appears to contain enough metal to meet our criteria for inclusion in the compilation of known deposits (see README file, and Singer, 1995).

WHAT IS A DEPOSIT MODEL?

Methods used in this study are based on mineral deposit models. Deposit models are sets of data in a convenient form that describe a group of deposits that have similar characteristics. They are based on compilation of worldwide literature and on observation, and they contain information on the common geologic attributes of the deposits and the environments in which they are found. Grade and tonnage models consist of frequency distributions of the grade and size of the individual well explored deposits which serve as examples for that deposit type. All of the deposits that make up these grade and tonnage models and all of the known deposits considered in this database have been drilled, mined, or otherwise examined in the subsurface and their size and grade are known. Investments of time and money were made in exploring these deposits because they are, or were in the past, considered to have economic potential. Thus, there is a linkage between the definition of a deposit, given above, and its inclusion in a grade and tonnage model such that a mineral concentration can be considered to be a deposit if its size and grade is consistent with the grade and tonnage model for that deposit type. Similarly, the grade and tonnage models are used to represent the frequency distributions of grade and tonnage of undiscovered deposits.

HOW THE ASSESSMENT WAS DONE

The assessment was conducted by regional assessment teams of scientists from the U.S. Geological Survey. These teams compiled existing data for multi-State areas (mineral provinces) at a scale of 1:500,000 and 1:1,000,000.

To begin the assessment, teams reviewed the geology of the area and selected appropriate deposit models. They then delineated permissive tracts for each type of deposit. The permissive tracts were defined by the environments of formation described in the deposit model such that the probability of deposits of the type delineated occurring outside the tract is negligible (i.e., less than 0.00001 to 0.000001) (Singer, 1993).

Geologic maps and maps showing the location and type of mineral deposits and occurrences, if any exist, were used in outlining these permissive tracts. Geophysical and geochemical maps were also useful, as well as knowledge about the exploration history.

Estimates of undiscovered resources were made to a depth of 1 km beneath the surface of the Earth. If an area of permissive rock is covered by more than 1 km of rock known to be barren or

younger sediment, it was excluded from the tract. The somewhat arbitrary depth of 1 km was chosen as the limit below which deposits would not be estimated. Because some ore deposits have vertical extents of well over a kilometer, we have adopted the rule that if any part of a deposit is judged to occur in the upper kilometer of the Earth, it is counted. This rationale is consistent with mining practice; although direct exploration is seldom conducted at these depths, deposits may be explored and developed deeper (up to 3 km) once they have been discovered (usually at depths of less than 1 km).

The teams reviewed the grade and tonnage data for known deposits in the tract (if any exist), decided whether or not the worldwide models were appropriate for the tract, and modified them if necessary. Reasoning by analogy, the undiscovered deposits estimated in the area should be similar in grade and tonnage to known examples. For many deposit types, these data are available in the form of grade and tonnage models in Bliss (1992) and Cox and Singer (1986). Complete references for all the models used are included here, along with frequency distributions of contained metals per deposit for each model.

The teams estimated the number of undiscovered deposits of each type in the permissive areas. These estimates are subjective, and are expressed in terms of least numbers of deposits for specified cumulative probabilities. Commonly, estimators were asked for the least number of deposits at a specified cumulative probability, and the answer is a specific number of deposits. A series of these questions for several quantiles (generally 0.9, 0.5, 0.1, and 0.05) was used to develop a cumulative probability distribution. Estimates were made by teams of geoscientists who knew about the deposit type or about the area, preferably both. Teams used a variety of methods to arrive at consensus. The most common method was simply to continue the discussion until all agreed. However, many tools, including deposit density estimates and assumptions about exploration adequacy, may be, and were used to guide the final estimates (Singer, 1993). The result of the estimation process is a probability distribution of numbers of undiscovered deposits. Some details regarding the deposit estimation procedure are also found in Root and others (1992).

The deposits estimated should be consistent with the grade and tonnage model. That is, if 10 deposits are estimated, 5 of them are considered to be larger than the median tonnage, and 5 of them are considered to have a higher grade than the median grade. If the grade and tonnage model is based on district data rather than data for individual deposits, then the numbers of undiscovered districts are estimated.

For some estimates, a separate probability of zero deposits was specified. This was done, primarily when estimates of numbers of undiscovered deposits were small, to constrain the probability density estimates.

There are many geologic, geochemical, and geophysical guides to estimating undiscovered deposits. Estimates can be guided by counting mineral occurrences, geochemical anomalies, or exploration "plays" and assigning to each a probability of its being a member of the grade and tonnage distributions. Estimates can also be guided by analogy with well-explored areas that contain known numbers of deposits and that are geologically similar to the study area. One important factor in assessment of a particular tract is the degree of previous and current exploration activity. Exploration intensity may have two opposing influences. First, because many types of ore deposits tend to occur in clusters, success in finding one deposit stimulates the search for others. When that search is not yet exhaustive, additional deposits are likely; this has been a common experience during exploration for sediment-hosted gold deposits in Nevada. On the other hand (and more rarely), exploration activity may be so thorough that the probability of an undiscovered deposit is minimal; an example would be the vicinity of the Viburnum Trend lead-zinc deposits in southeast Missouri.

SIMULATION

To obtain the probability distribution for undiscovered metal, the probability distribution of numbers of undiscovered deposits is combined with probability distributions for tonnage and grades. A Monte Carlo simulation technique is used to select randomly, from each distribution, a number, a tonnage, and a grade. This is done repeatedly by computer many thousands of times and a new probability distribution is derived, a distribution of contained metal.

The Mark3 simulator (Root and others, 1992) is used to combine information about grade, tonnage, and number of deposits into information about amounts of contained metal.

Probabilities for the existence of undiscovered deposits are stated as inequalities because mineral deposits occur only as discrete numbers of deposits. A simulator must be used because the probability distributions used to describe grade, tonnage, and number of deposits are empirical (i.e., not mathematical functions) and cannot easily be combined mathematically without several simplifying assumptions. The quantiles of the grade and tonnage distributions cannot be multiplied to generate the quantiles of contained metal. Multiplying quantiles could be successful only if the ordinal lists of grades and tonnages were identical, a very unlikely event. The result of the simulation is a probability distribution of contained metal.

The results of this assessment are a series of numerical, probabilistic representations of the expert judgment of the teams of geoscientists that made the estimates, and can be presented in various ways. Class-interval histograms emphasize those amounts of metal which are estimated as most likely to exist. Cumulative histograms are especially useful because all the information generated by the simulation can be read from a single plot. Various quantiles and the means are best used for comparisons between and among estimates for different deposit types or different permissive tracts. No single number can adequately represent the magnitude of an estimate, because no single number can represent the spectrum in judgment that is inherent in the estimation process or the distribution of values that make up the grade and tonnage models.

CAVEATS

Care must be exercised when using the results of this assessment to answer questions that involve economics. The estimates are based on the grade and tonnage models at hand, and the economic viability of the deposits that make up the models varies widely, from deposit to deposit, and from model to model. In addition, large amounts of the land delineated as permissive is unavailable for mineral development. Some is already developed as urban areas, transportation corridors, etc. Some is withdrawn in the public interest as Wilderness areas, National Parks, etc. And some is owned privately by those who are not interested in mineral development. Also, these estimates are of numbers of deposits that are likely to exist, not necessarily those likely to be discovered. Although they are included in our assessment, some concealed deposits may be so expensive to search for that they will not be discovered in the near term.

It is important to keep clear the distinctions between known (identified) deposits, undiscovered deposits, and extensions to known deposits and districts. A known deposit or district is one for which an estimate of the metal contained in the deposit can be made. That total consists of the sum of past production, if any, and any known resource remaining in the ground. In some cases, assessment teams were aware of prospects, revealed by past or current exploration efforts, that are believed to be significant deposits, but that do not yet have a citable grade and tonnage. These probable deposits are treated here as undiscovered deposits, albeit ones with a high degree of certainty of existence.

In addition, experience has shown that almost all mineral deposits grow during their active lifetime. Discovery and initial exploration almost never identifies the total resource that exists.

There are several reasons for this fact. Some deposit types are simply not amenable to extensive exploration. Once it has been determined that there is an economically viable amount of metal, it is often less expensive to continue exploration piecemeal, using the mining operation itself as an exploration tool. A good example of this is the ASARCO operation at the Black Cloud mine, in the Leadville district in Colorado. Here, a small operation continues to win metal from a major polymetallic replacement district. In recent years, production has been relatively constant, at about 200,000 tons of ore per year. Yet, each year, the ore reserves remain about the same as exploration keeps pace with the mining operation. In such a case, the magnitude of the known resource is always in error (and too small), even though the descriptive aspects, including the general location of the ore which may well continue to be discovered and produced for decades, are well known.

In some districts, this type of ore, strongly suspected to exist, but whose magnitude is unknown, may constitute a major part of the ultimate resource. Because this ore which lies conceptually somewhere between known and undiscovered is not estimated in this assessment, it would be misleading to use the results here to directly estimate total resources. The amount of undiscovered metal in known districts may, in some cases, be of the same order of magnitude of that in known and undiscovered deposits.

One last note of caution should be given to users of this database. Because our assessment methodology depends on deposit models, we are unable to estimate resources in types of deposits which are, at present, too poorly characterized to construct a model. To see that this is a large source of error in our assessment, imagine such a study being completed in 1905 before the recognition of porphyry copper as a deposit type, or in 1960 before we knew about sediment-hosted gold. The underestimation of copper and gold resources would have been so large as to make any conclusions of limited value. We have tried to compensate for our lack of models by describing a number of poorly understood deposit types in the Unassessed Deposit (UN) file, while realizing that many other types of deposits, unimagined today, will be used as guides to exploration in the future.

HOW TO USE THIS DATABASE

A key to using this database effectively lies in understanding the concept of a permissive tract. Permissive tracts are discrete areas of the United States for which (usually) estimates of numbers of undiscovered deposits of a particular deposit type were made. A permissive tract is defined by 1) its geographic boundaries, and 2) the type of deposit for which it is permissive.

Many tracts have different geographic boundaries and refer to the same deposit type. Some tracts have identical geographic boundaries to each other, yet refer to different deposit types. In some cases, where the metallogeny of a region is well understood, several tracts were defined with the same (or different only in detail) geographic boundaries, the same deposit model, but discrete estimates for deposits formed during different metallogenic epochs. Throughout this database, the individual tracts are identified by a unique Tract ID (for example, PC27). The alphabetic part of this Tract ID corresponds to the mineral province; within provinces, the tracts are numbered by deposit type and by geographic location, generally from northwest to southeast.

The way you will use this database depends in large part on what questions you want to answer. The easiest and most direct way to access the database is through the NATLASMT.PDF file. This file combines all of the information stored in all of the files as a single browseable 2000 page document. Once this file is opened, all of the stored information is accessible and allows the user to view, navigate, and search anywhere in the database. The remaining files that accompany the database may be accessed separately. Information about the

location of known resources can be found in TRACTMAP (maps) and KNOWNDEP (table). Information about the location of undiscovered resources can be found in TRACTMAP and TRACLIST (table). Information about known deposits is in KNOWNDEP. Information about estimated amounts of undiscovered metals is in the files in METLPLOT (graphs and tables). Descriptive information about the tracts and the geologic reasoning behind the estimates can be found in the files in RATIONAL (text and references). The README file however should be read prior to any use of the database.

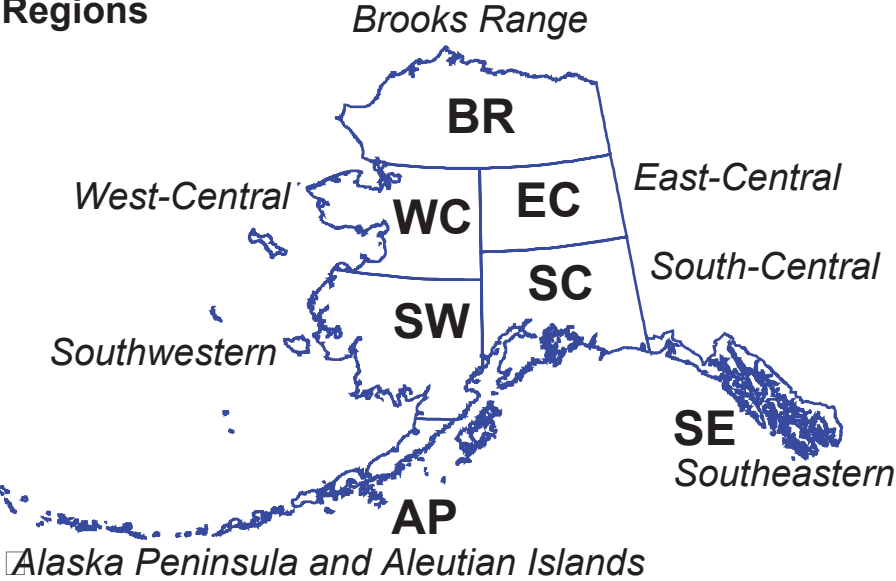
REFERENCES CITED

- Bliss, J.D., ed., 1992, Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, 168 p.
- Cox, D.P., Barton P.B., and Singer, D.A., Introduction, *in* Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, 379 p.
- McCammon, R.B., and Briskey, J.A., Jr., 1992, A proposed national mineral-resource assessment: Nonrenewable Resources, v. 1, p. 259–266.
- Root, D.H., Menzie, W.D., and Scott, W.A., 1992, Computer Monte Carlo simulation in quantitative resource assessment: Nonrenewable Resources, v. 1, p. 125–138.
- Singer, D.A., 1993, Basic concepts in three-part quantitative assessments of undiscovered mineral resources: Nonrenewable Resources, v. 2, no. 2, p. 69–81.
- Singer, D.A., 1995, World class base- and precious-metal deposits—A quantitative analysis: Economic Geology, v. 90, no. 1, p. 88–104.

USGS National Mineral Resource Assessment

AKPT: Alaskan PGE

Assessment Regions



Cumulative Distribution

Histogram

Table

Model

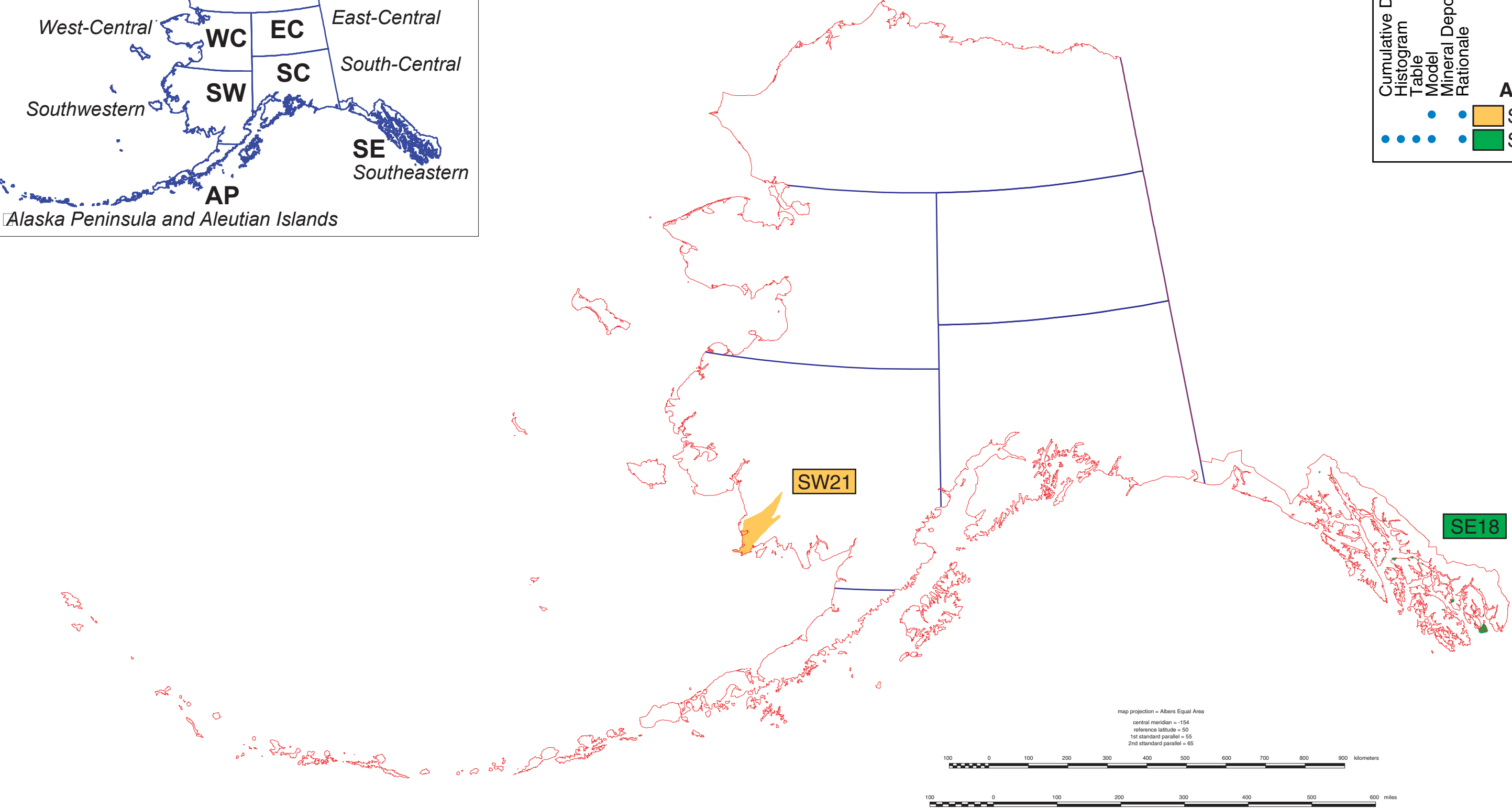
Mineral Deposits

Rationale

AKPT

SW21

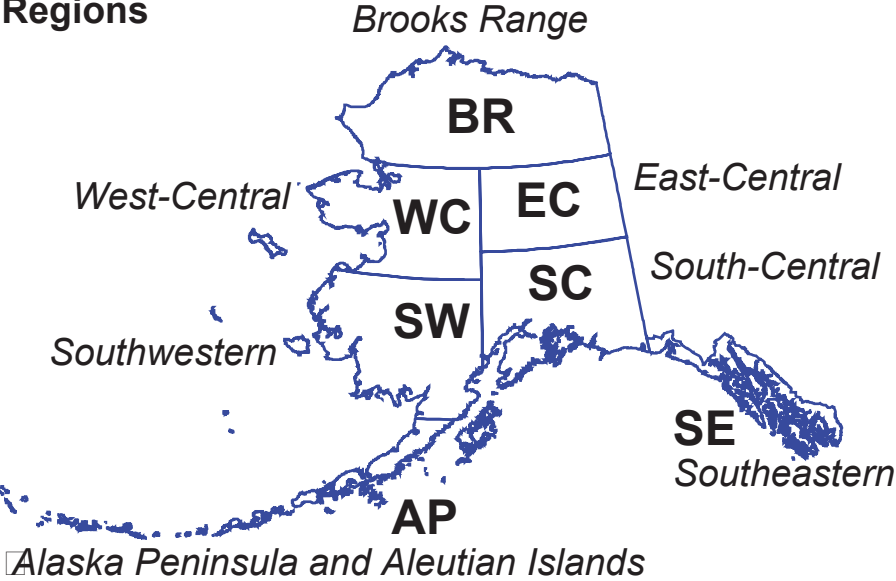
SE18



USGS National Mineral Resource Assessment

AKBC: Basaltic Cu/Kennecott Cu

Assessment Regions



Cumulative Distribution

Histogram

Table

Model

Mineral Deposits

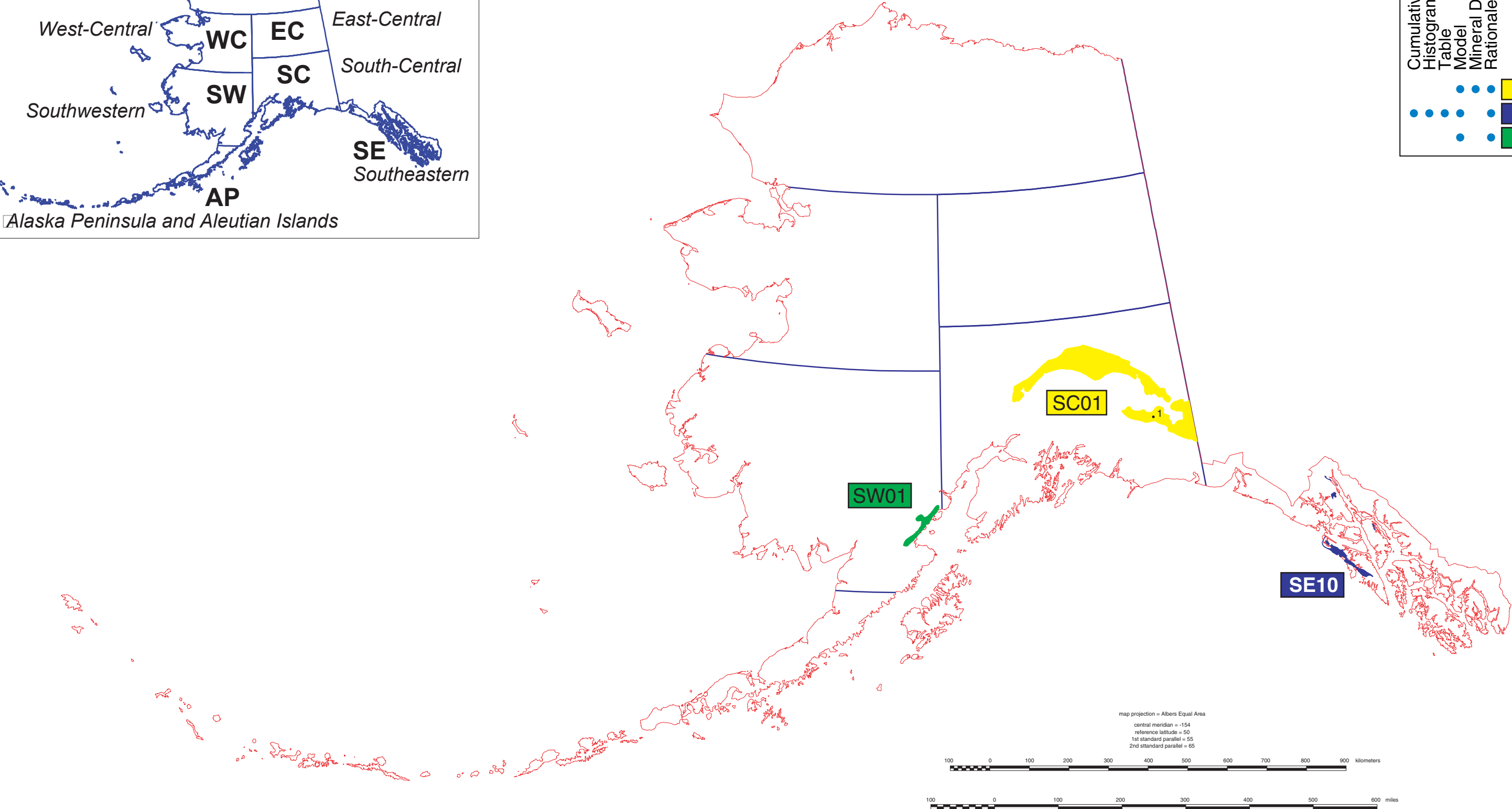
Rationale

AKBC

SC01

SE10

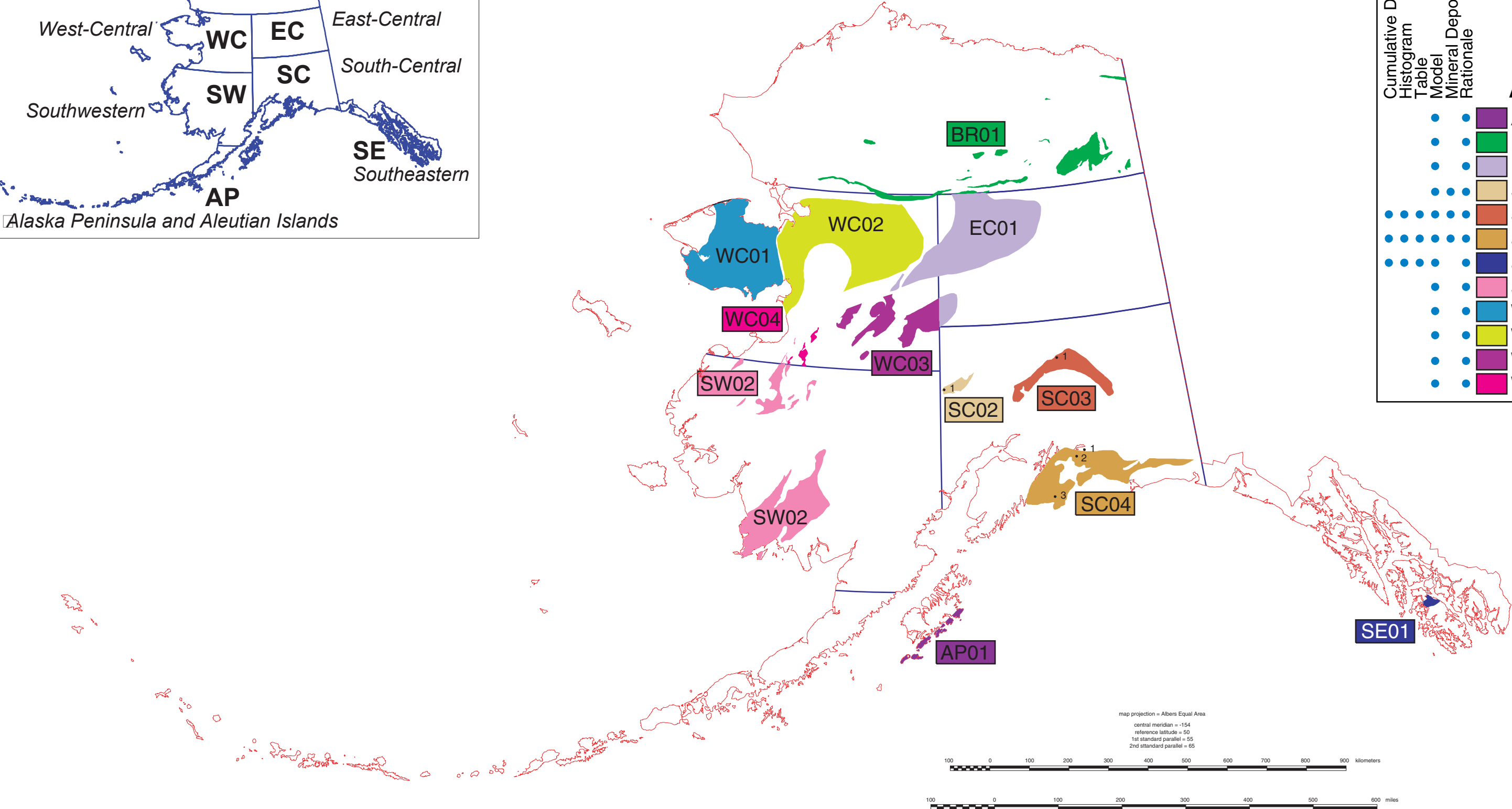
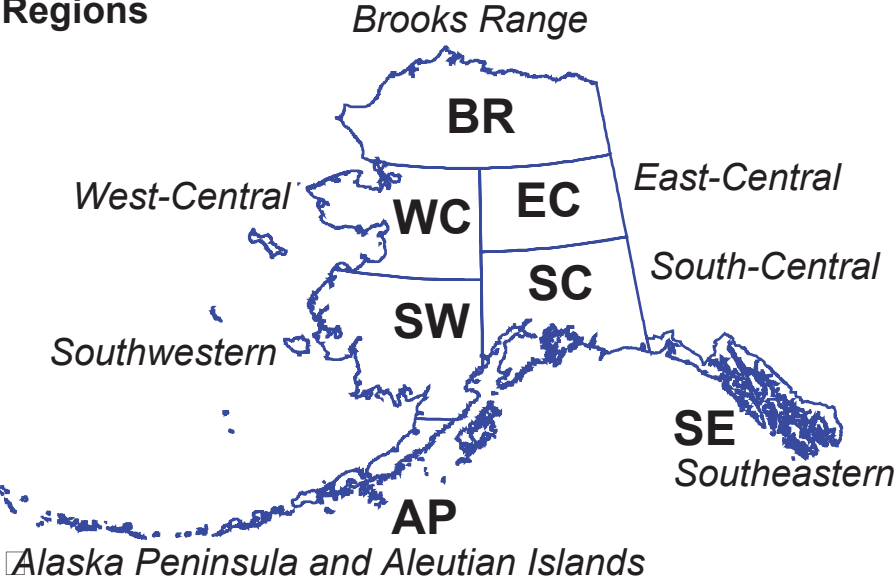
SW01



USGS National Mineral Resource Assessment

AKBS: Besshi Massive Sulfide

Assessment Regions

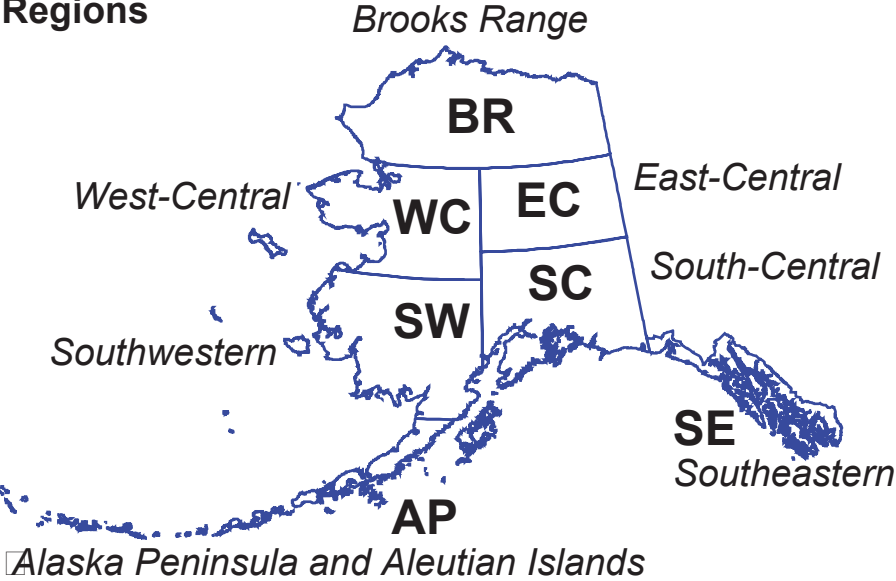


Cumulative Distribution Histogram	Table	Model	Mineral Deposits	Rationale	AKBS
•	•	•	•	•	AP01
•	•	•	•	•	BR01
•	•	•	•	•	EC01
•	•	•	•	•	SC02
•	•	•	•	•	SC03
•	•	•	•	•	SC04
•	•	•	•	•	SE01
•	•	•	•	•	SW02
•	•	•	•	•	WC01
•	•	•	•	•	WC02
•	•	•	•	•	WC03
•	•	•	•	•	WC04

USGS National Mineral Resource Assessment

AKCS: Cu-Ag Quartz Vein Deposits

Assessment Regions



Cumulative Distribution

Histogram

Table

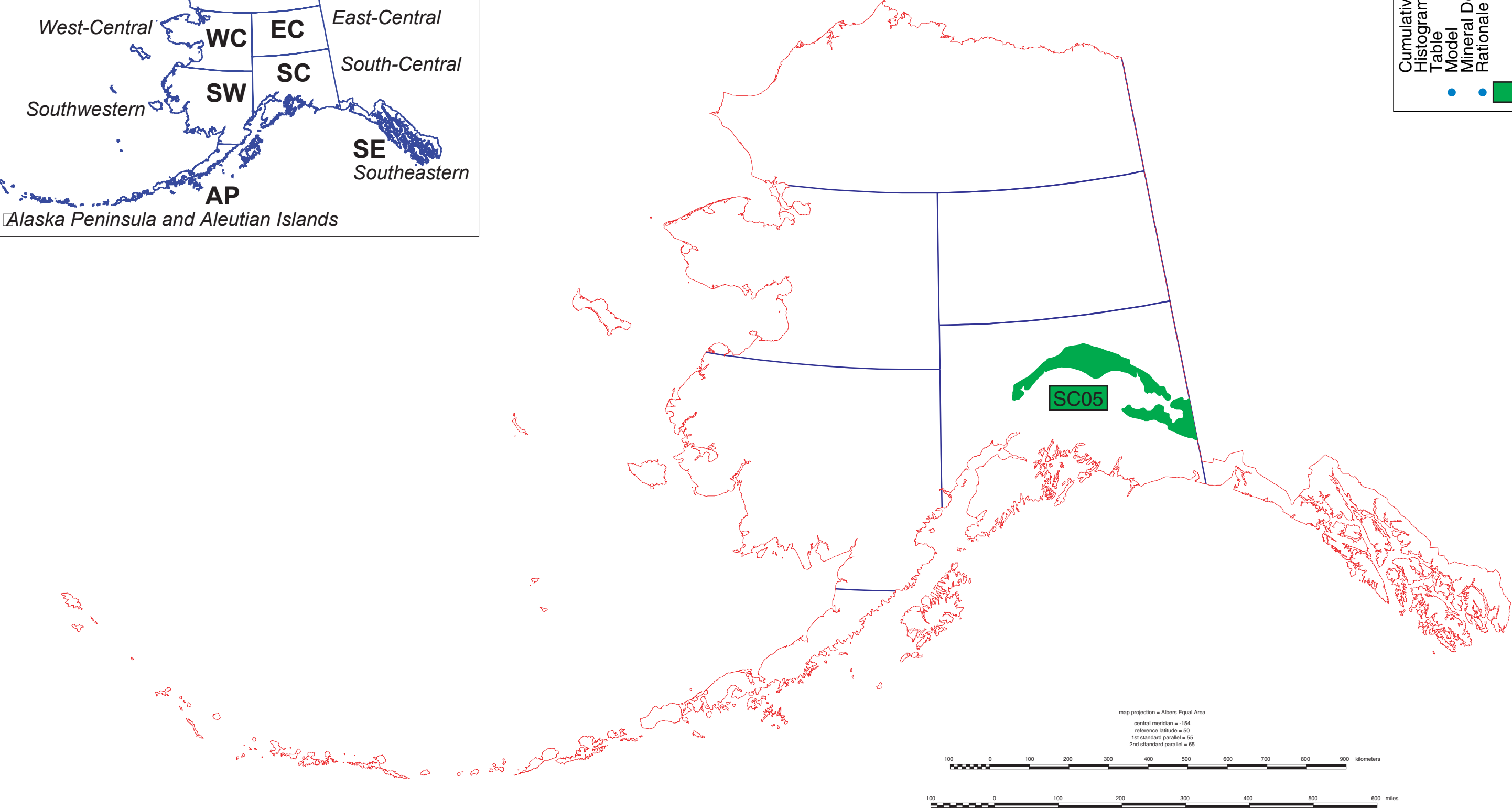
Model

Mineral Deposits

Rationale

AKCS

SC05



Assessment Regions

Brooks Range

West-Central

East-Central

WC

EC

South-Central

SW

Southwestern

SE

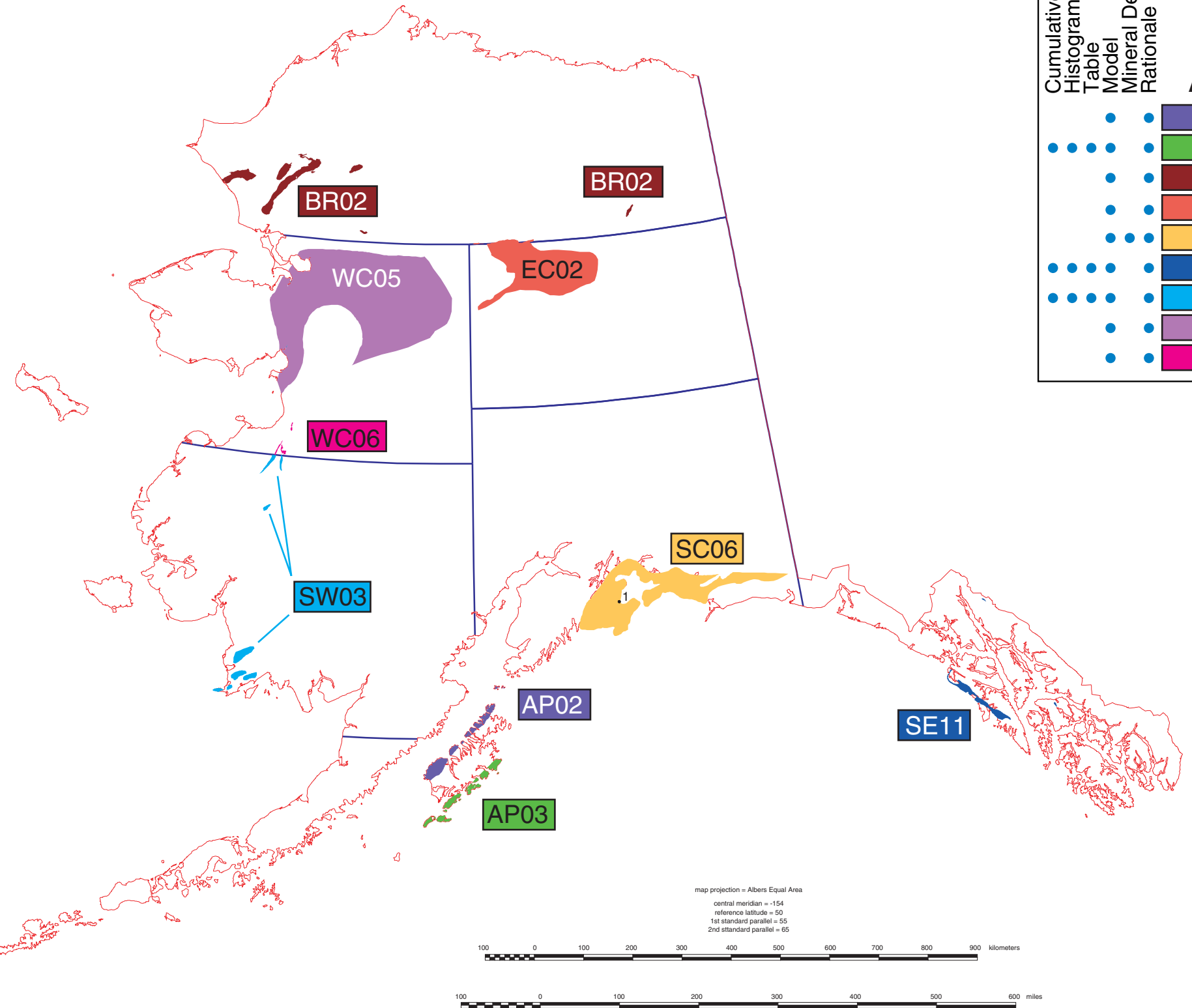
Southeastern

AP

☐ *Alaska Peninsula and Aleutian Islands*

USGS National Mineral Resource Assessment

AKCY1: Cyprus Massive Sulfide Deposits I

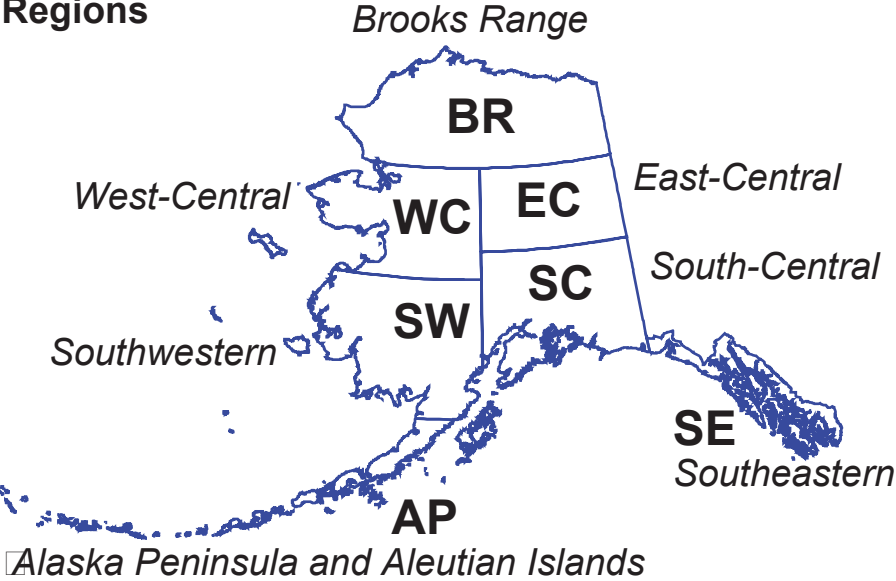


Cumulative Distribution Histogram Table	Model	Mineral Deposits Rationale		
•	•	•	AP02	
•	•	•	AP03	
•	•	•	BR02	
•	•	•	EC02	
•	•	•	SC06	
•	•	•	SE11	
•	•	•	SW03	
•	•	•	WC05	
•	•	•	WC06	

USGS National Mineral Resource Assessment

AKCY2: Cyprus Massive Sulfide Deposits II

Assessment Regions



Cumulative Distribution
Histogram
Table
Model
Mineral Deposits
Rationale

AKCY2

BR03

BR03

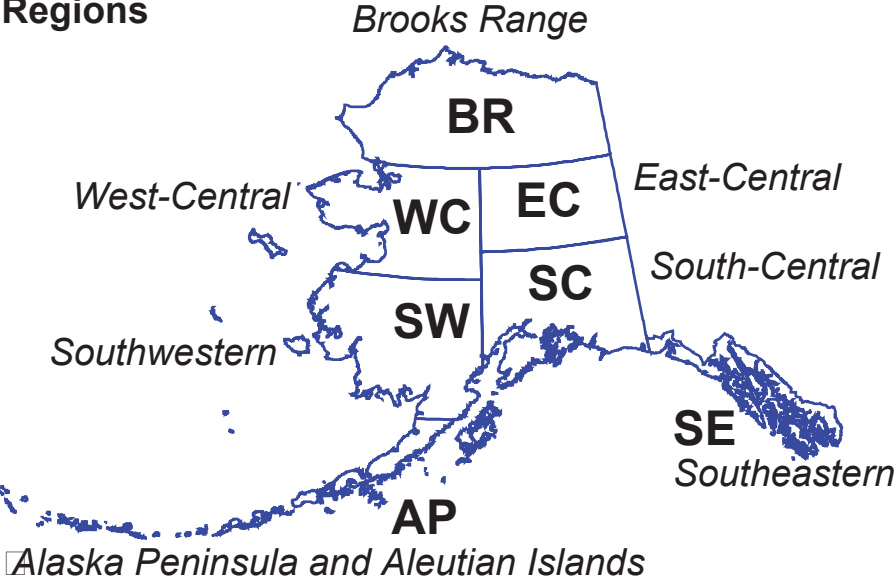
map projection = Albers Equal Area
central meridian = -154
reference latitude = 50
1st standard parallel = 55
2nd standard parallel = 65



USGS National Mineral Resource Assessment

AKCY3: Cyprus Massive Sulfide Deposits III

Assessment Regions



Cumulative Distribution

Histogram

Table

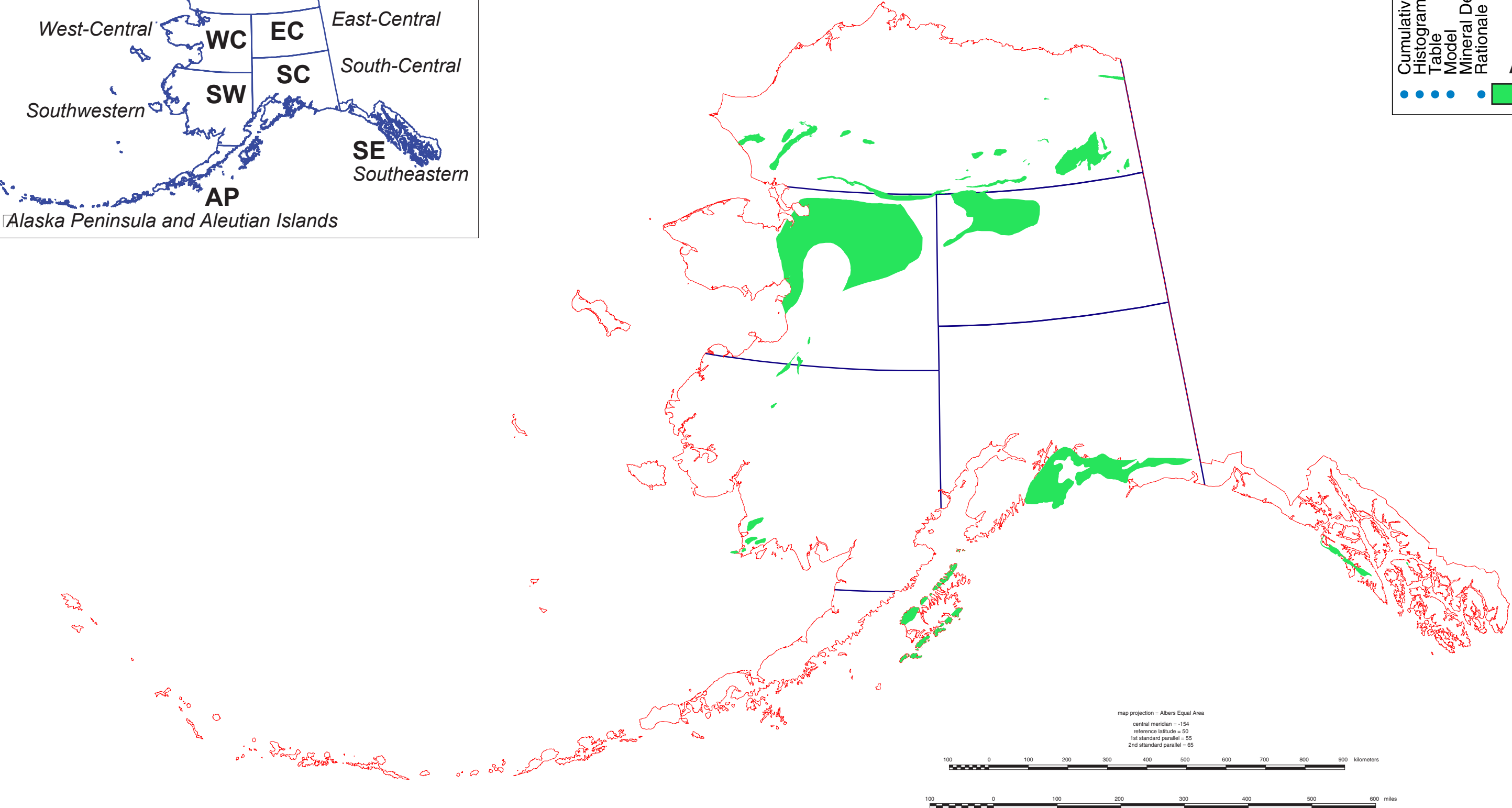
Model

Mineral Deposits

Rationale

AKCY3

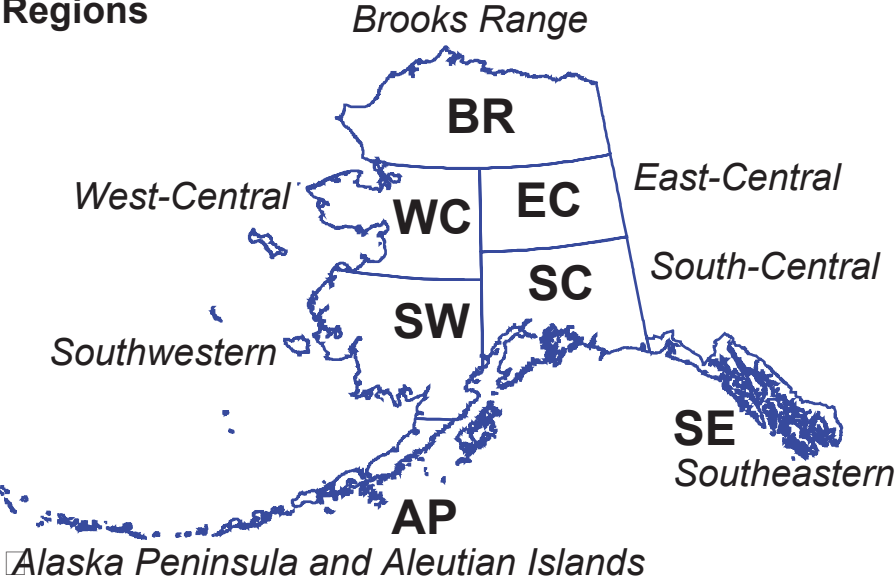
AK01



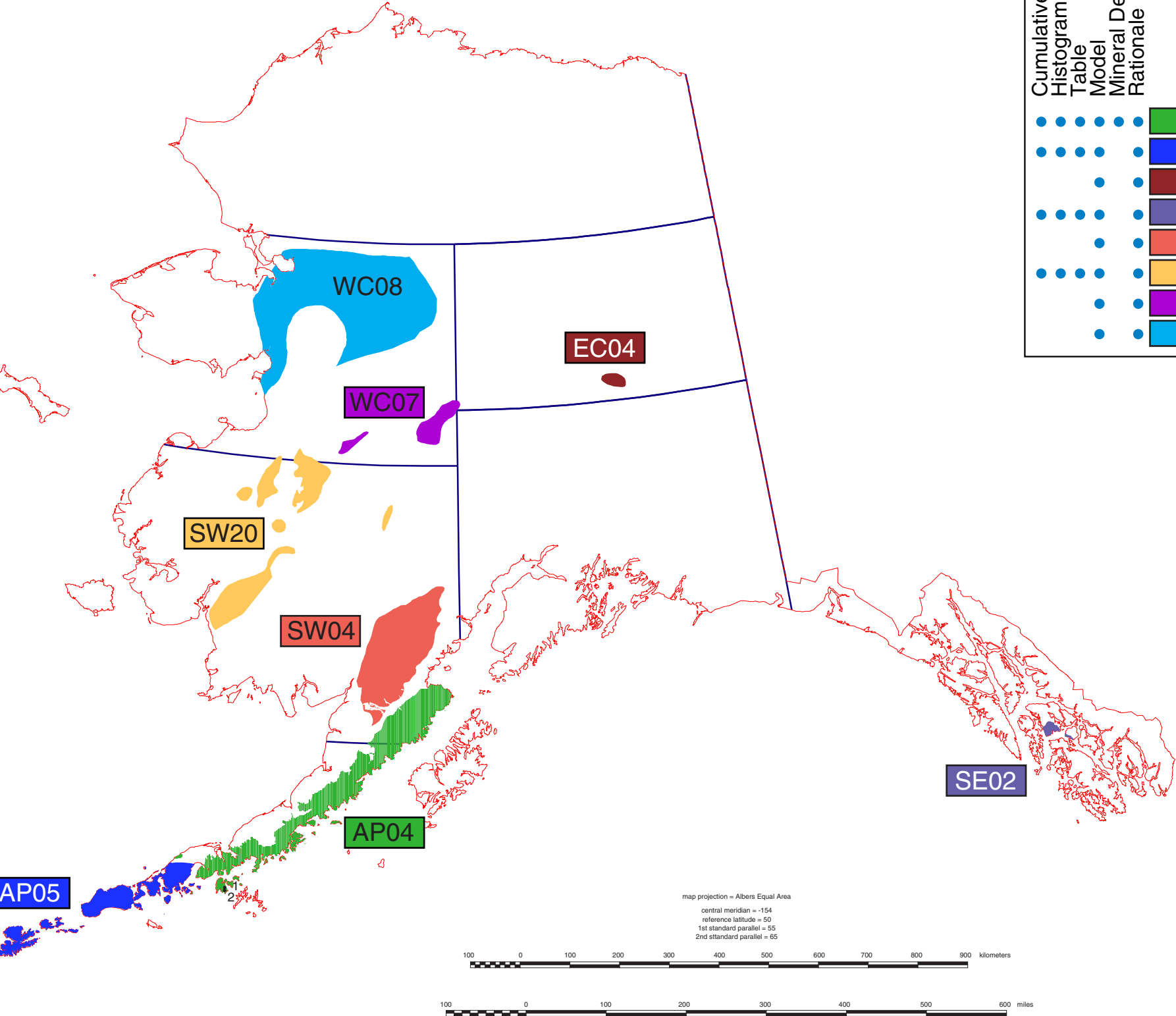
USGS National Mineral Resource Assessment

AKEV: Epithermal Vein Deposits

Assessment Regions



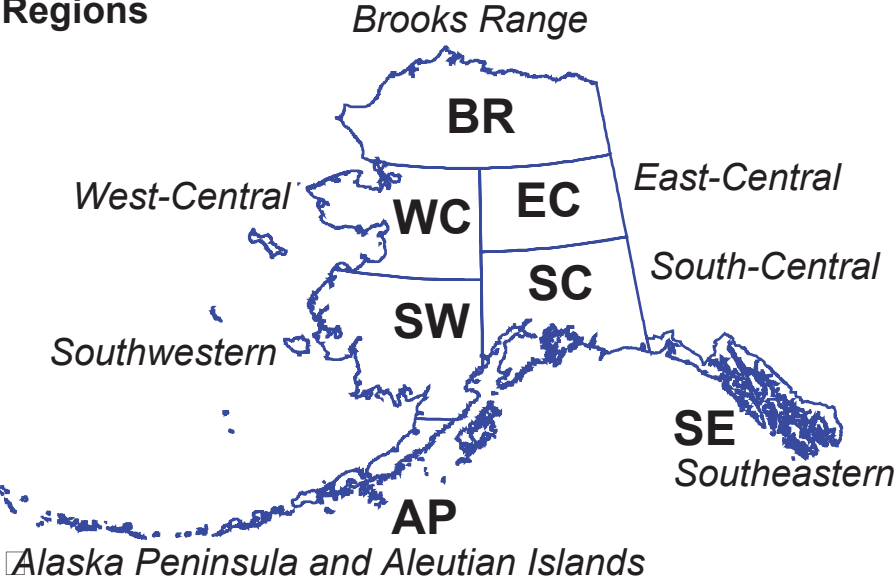
Cumulative Distribution		Mineral Deposits		AKEV
Histogram	Table	Model	Rationale	
•••••	•••••	•••••	•••••	AP04
•••••	•••••	•••••	•••••	AP05
•••••	•••••	•••••	•••••	EC04
•••••	•••••	•••••	•••••	SE02
•••••	•••••	•••••	•••••	SW04
•••••	•••••	•••••	•••••	SW20
•••••	•••••	•••••	•••••	WC07
•••••	•••••	•••••	•••••	WC08



USGS National Mineral Resource Assessment

AKGA: Gold-Antimony Vein Deposits

Assessment Regions



Cumulative Distribution

Histogram

Table

Model

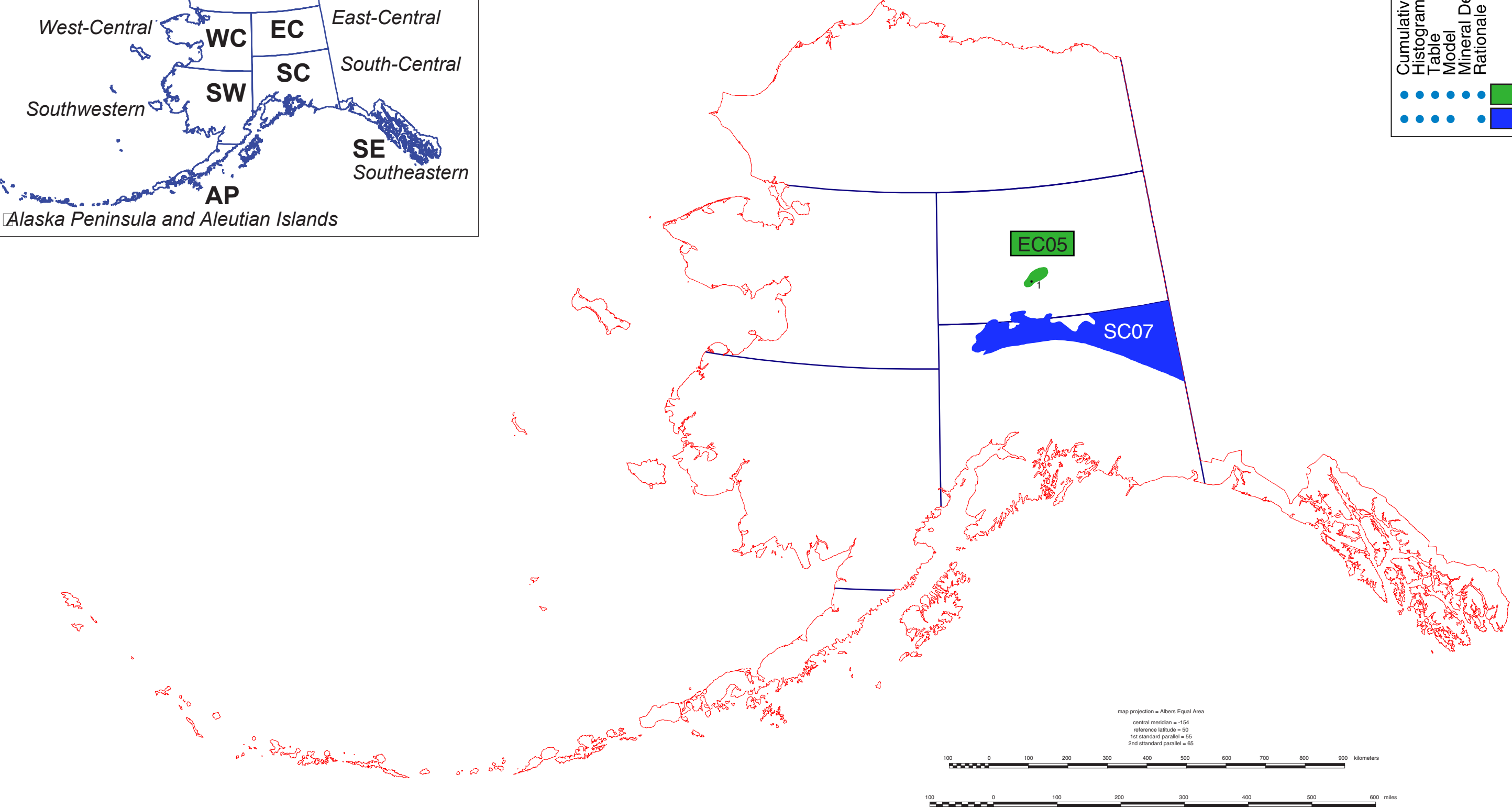
Mineral Deposits

Rationale

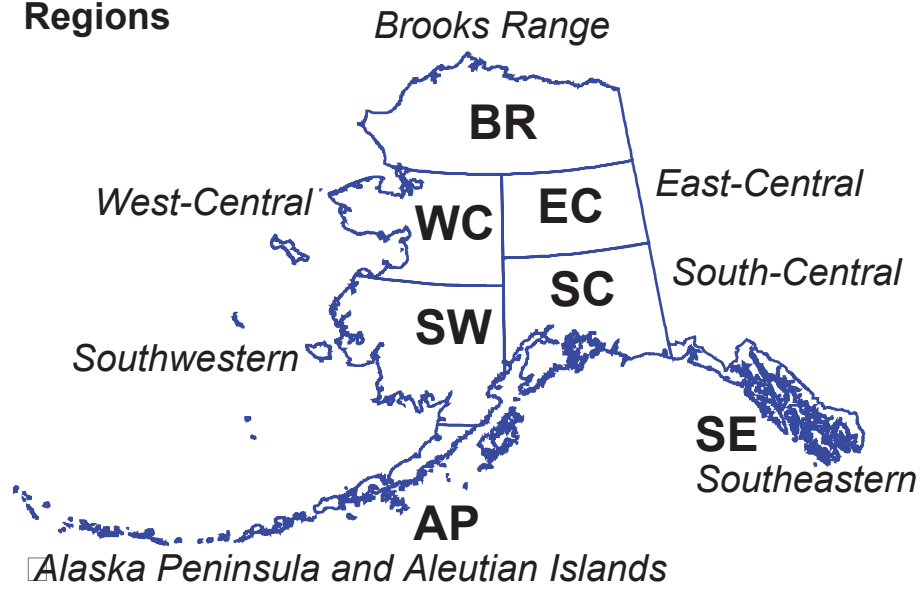
AKGA

EC05

SC07



Assessment
Regions



USGS National Mineral Resource Assessment

AKGP: Peraluminous Granite Porphyry Gold Deposits

Cumulative Distribution

Histogram

Table

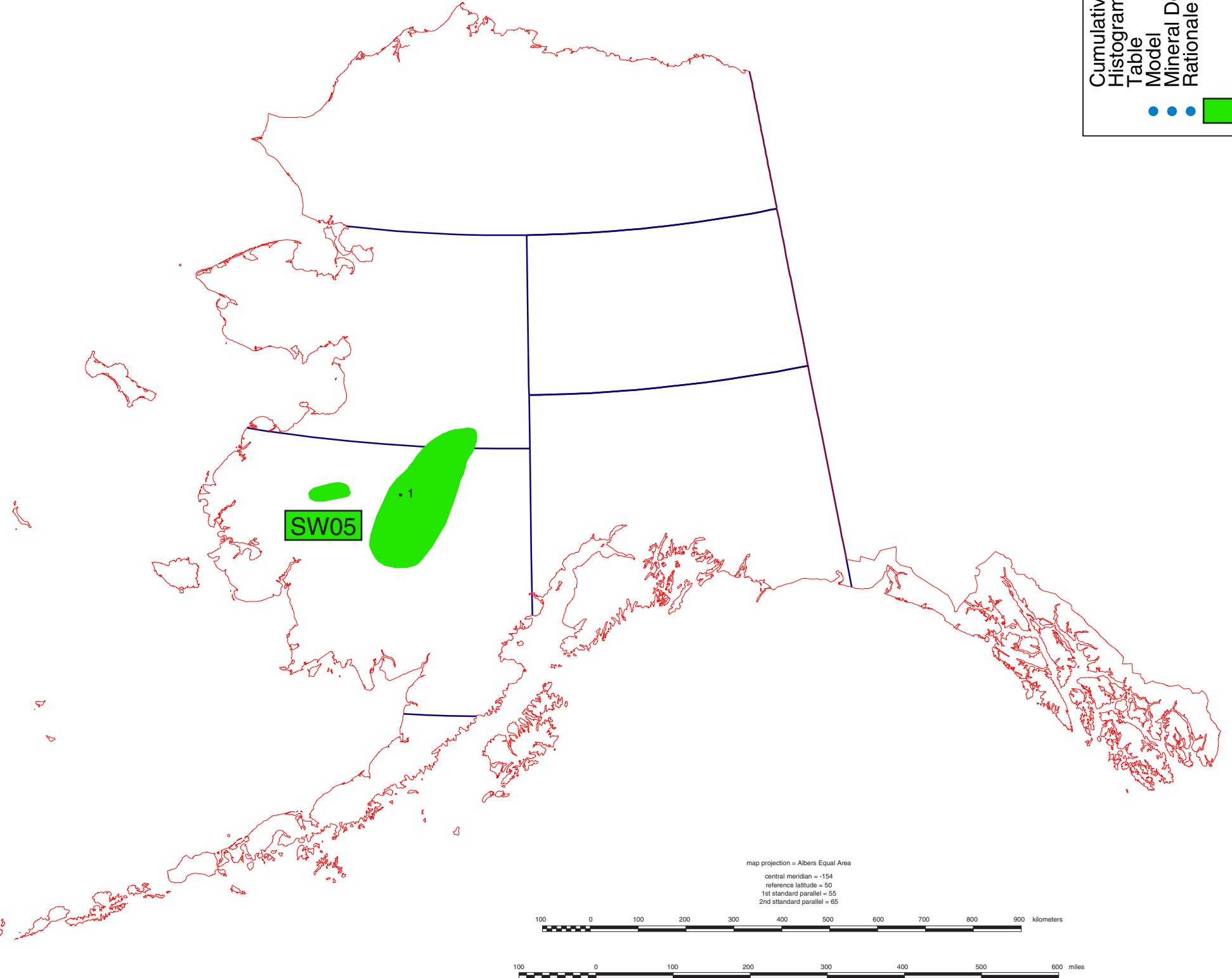
Model

Mineral Deposits

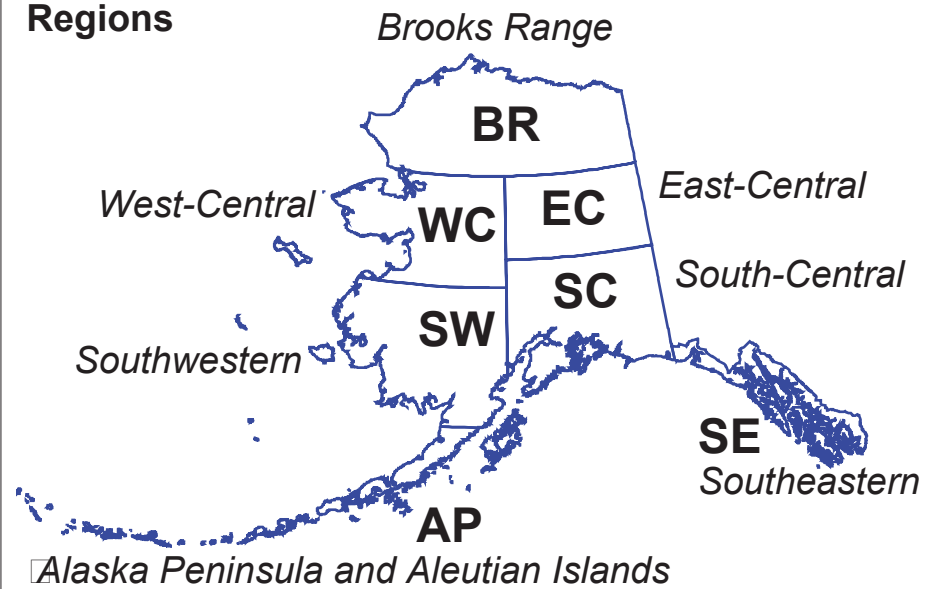
Rationale

AKGP

SW05

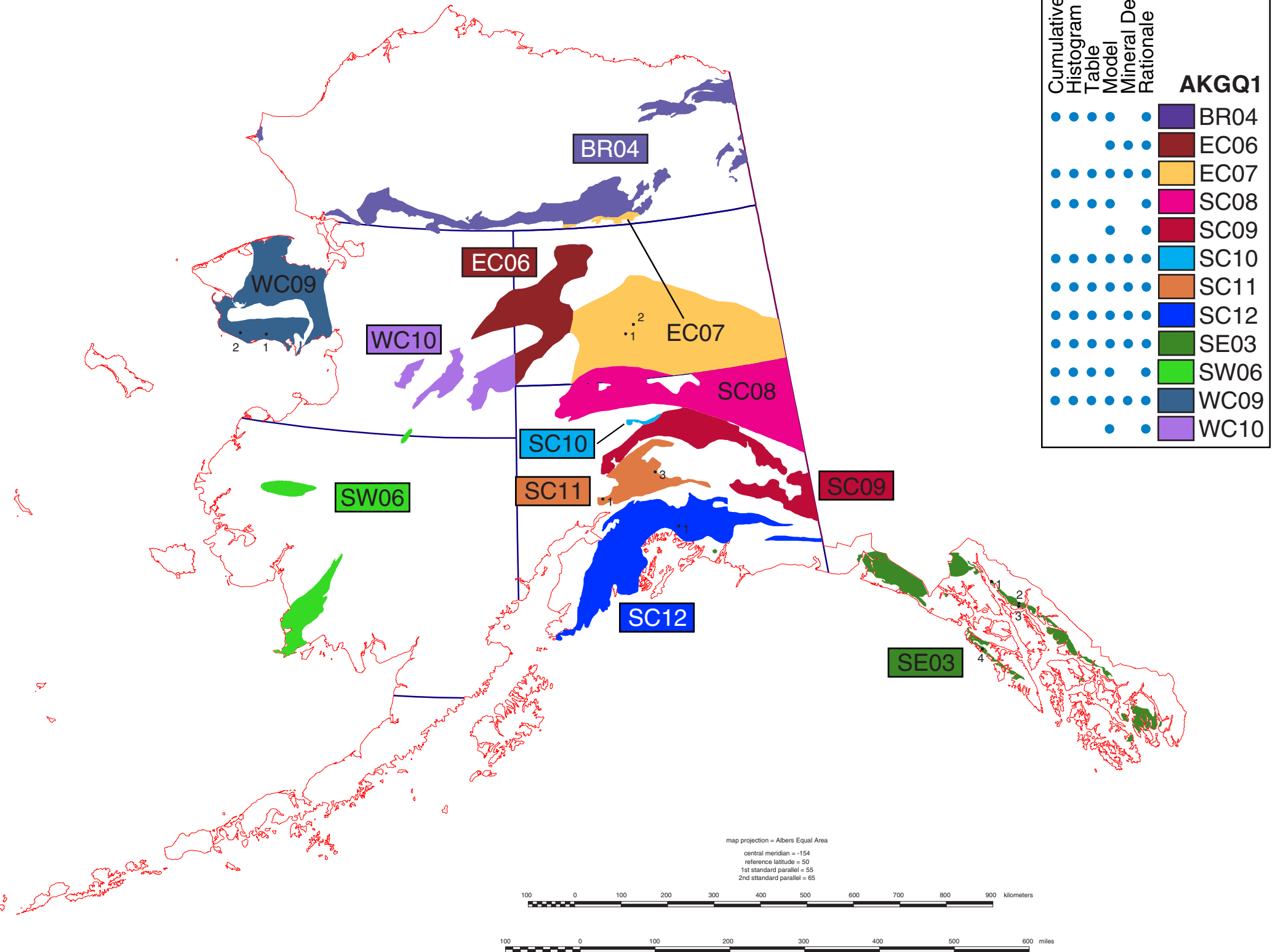


Assessment Regions



USGS National Mineral Resource Assessment

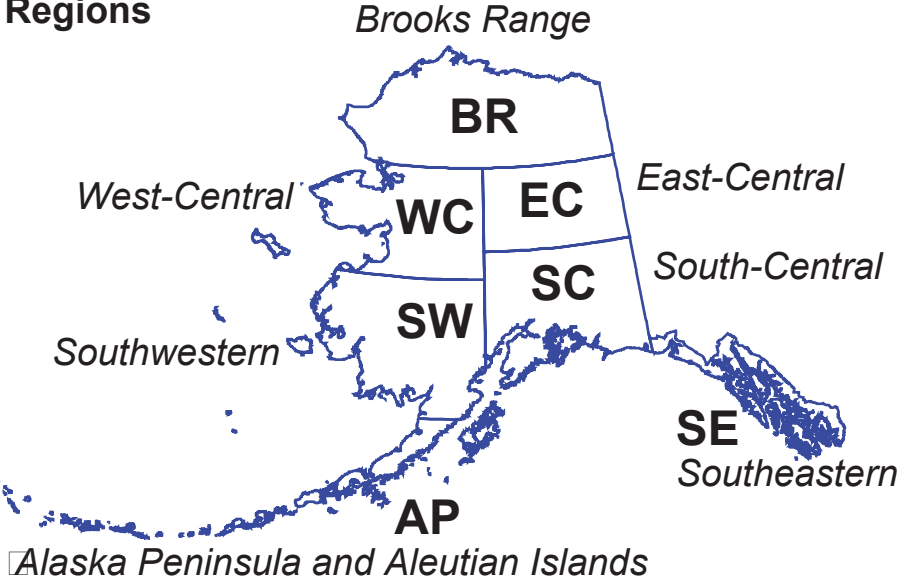
AKGQ1: Low-Sulfide Au-Quartz Vein Deposits I



USGS National Mineral Resource Assessment

AKGQ2: Low-Sulfide Au-Quartz Vein Deposits II

Assessment Regions



Cumulative Distribution Histogram Table Model Mineral Deposits Rationale

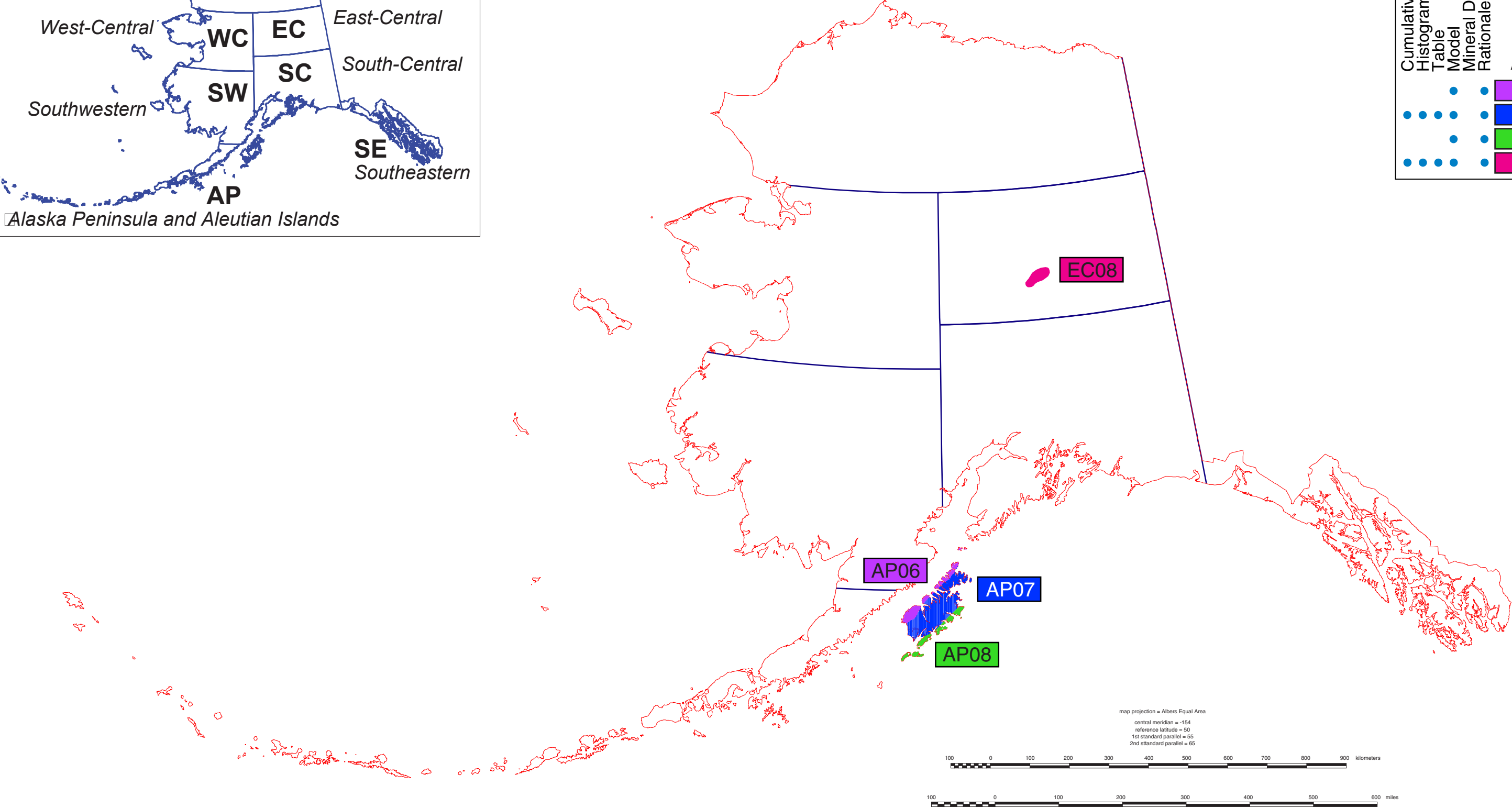
AKGQ2

AP06

AP07

AP08

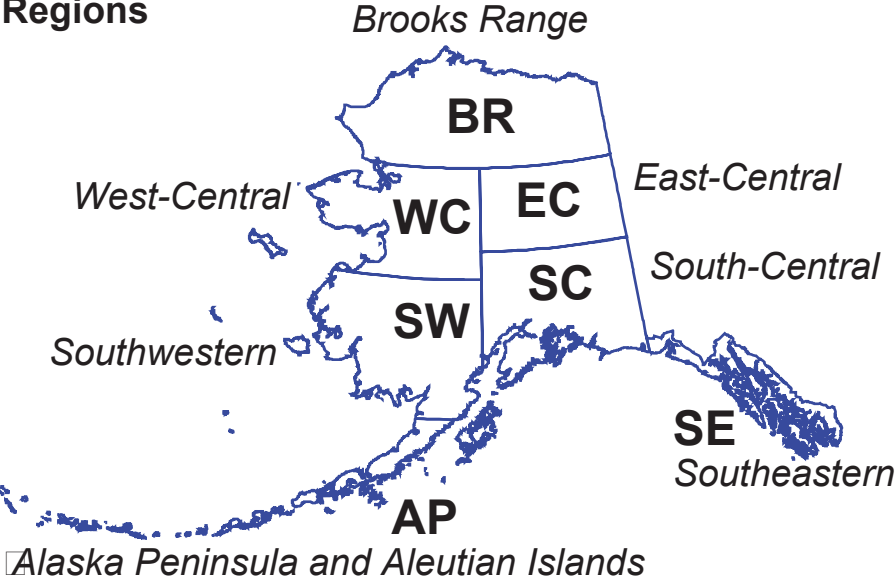
EC08



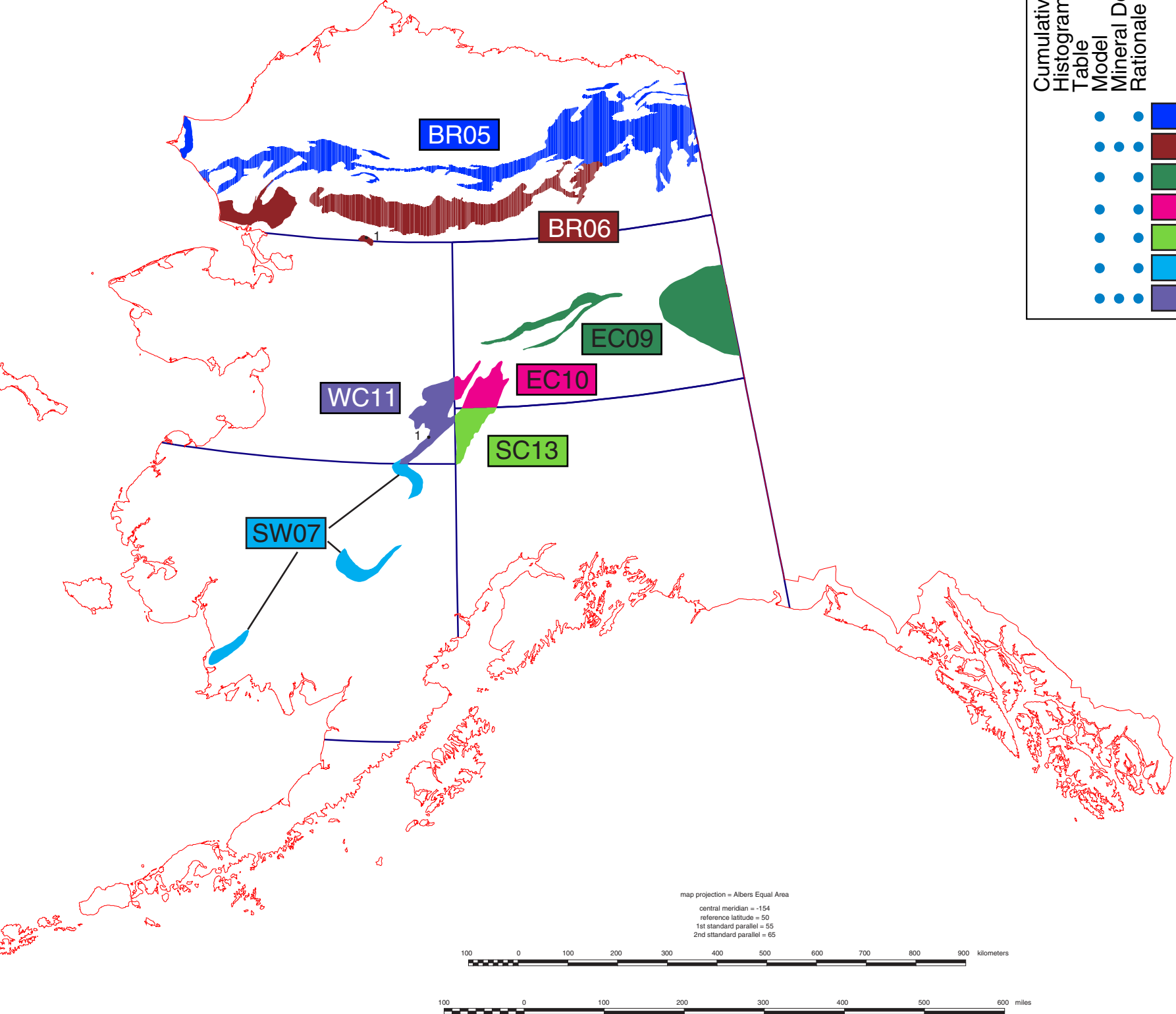
USGS National Mineral Resource Assessment

AKKC: Kipushi Cu-Pb-Zn

Assessment Regions



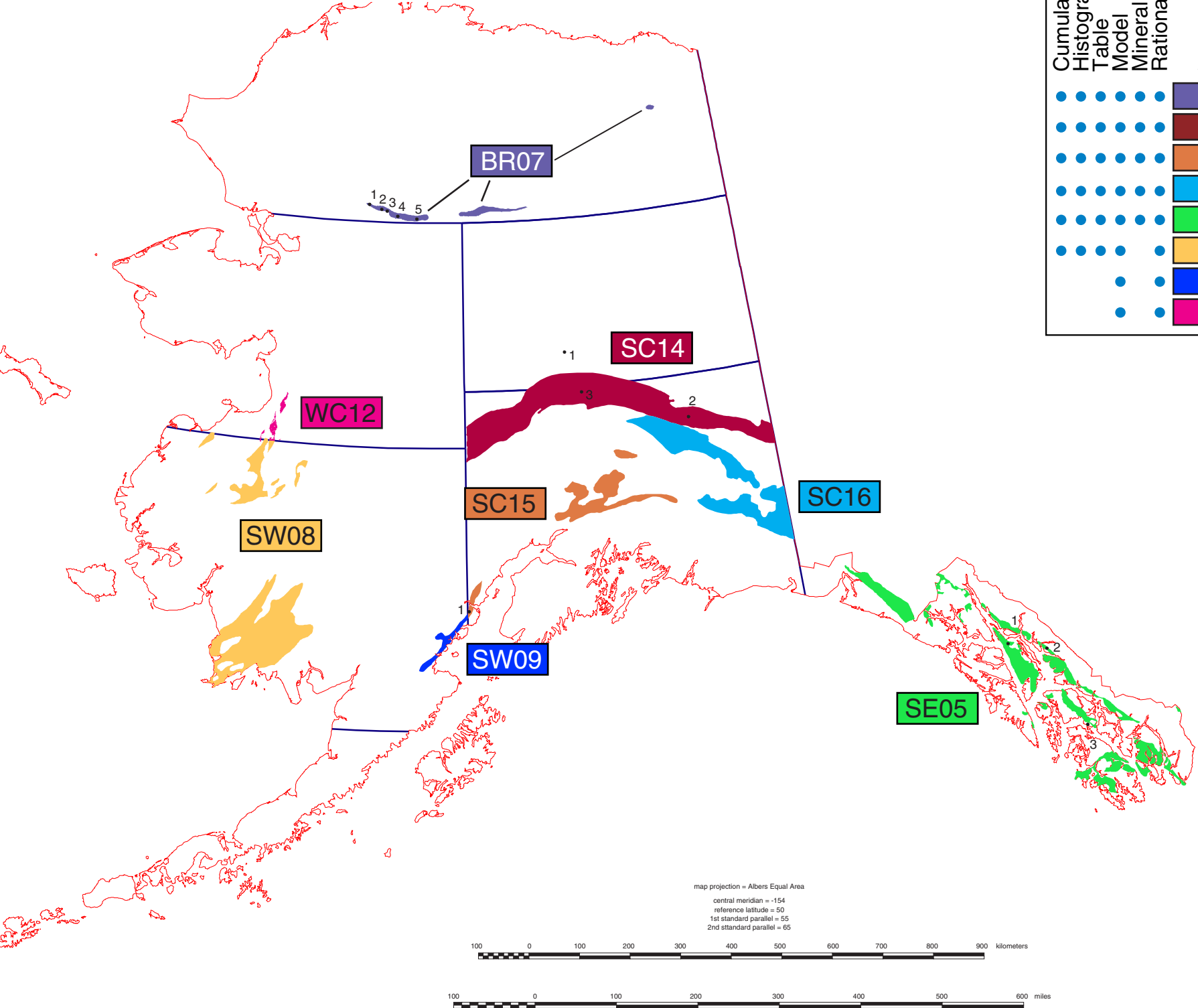
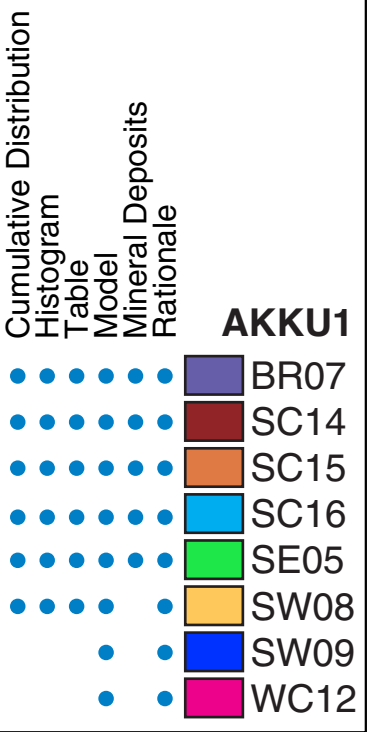
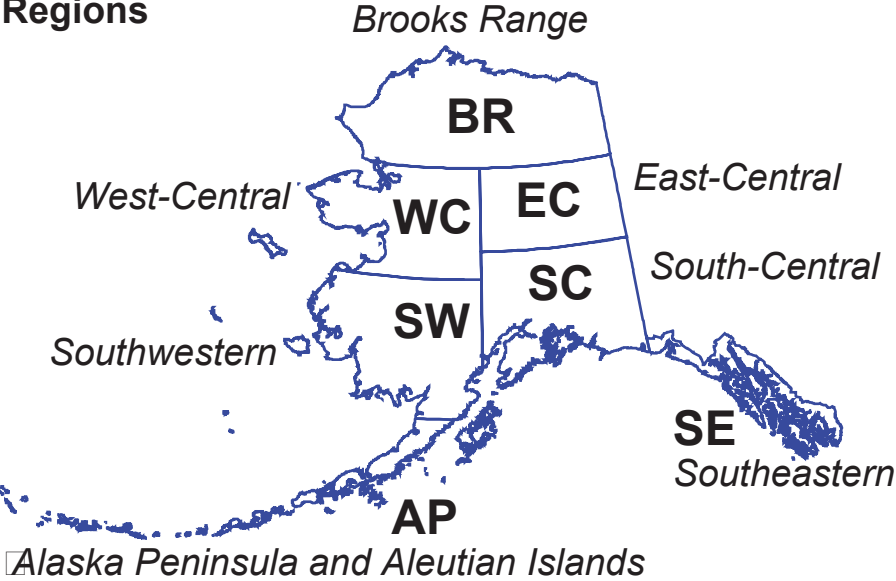
Cumulative Distribution	Histogram	Table	Model	Mineral Deposits	Rationale	AKKC
•	•	•	•	•	•	BR05
•	•	•	•	•	•	BR06
•	•	•	•	•	•	EC09
•	•	•	•	•	•	EC10
•	•	•	•	•	•	SC13
•	•	•	•	•	•	SW07
•	•	•	•	•	•	WC11



USGS National Mineral Resource Assessment

AKKU1: Kuroko Massive Sulfide Deposits I

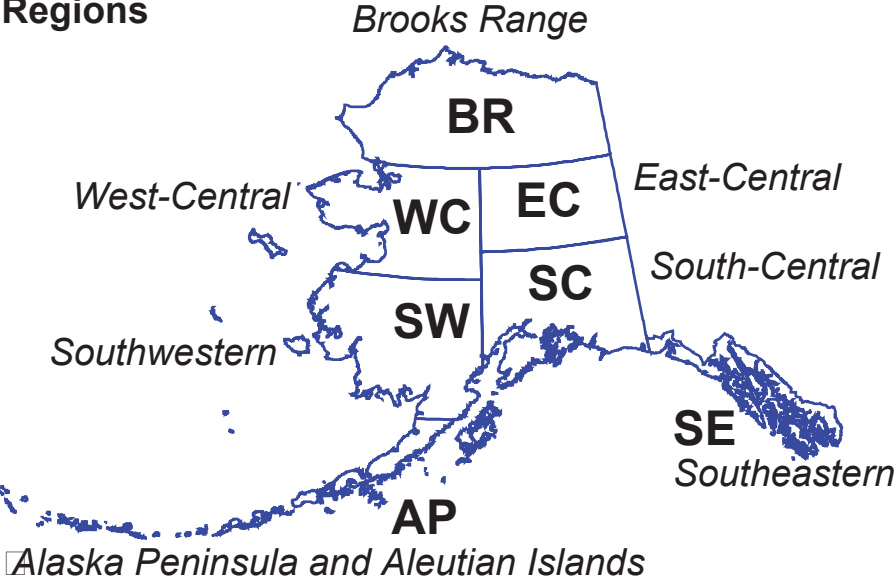
Assessment Regions



USGS National Mineral Resource Assessment

AKKU2: Kuroko Massive Sulfide Deposits II

Assessment Regions



Cumulative Distribution

Histogram

Table

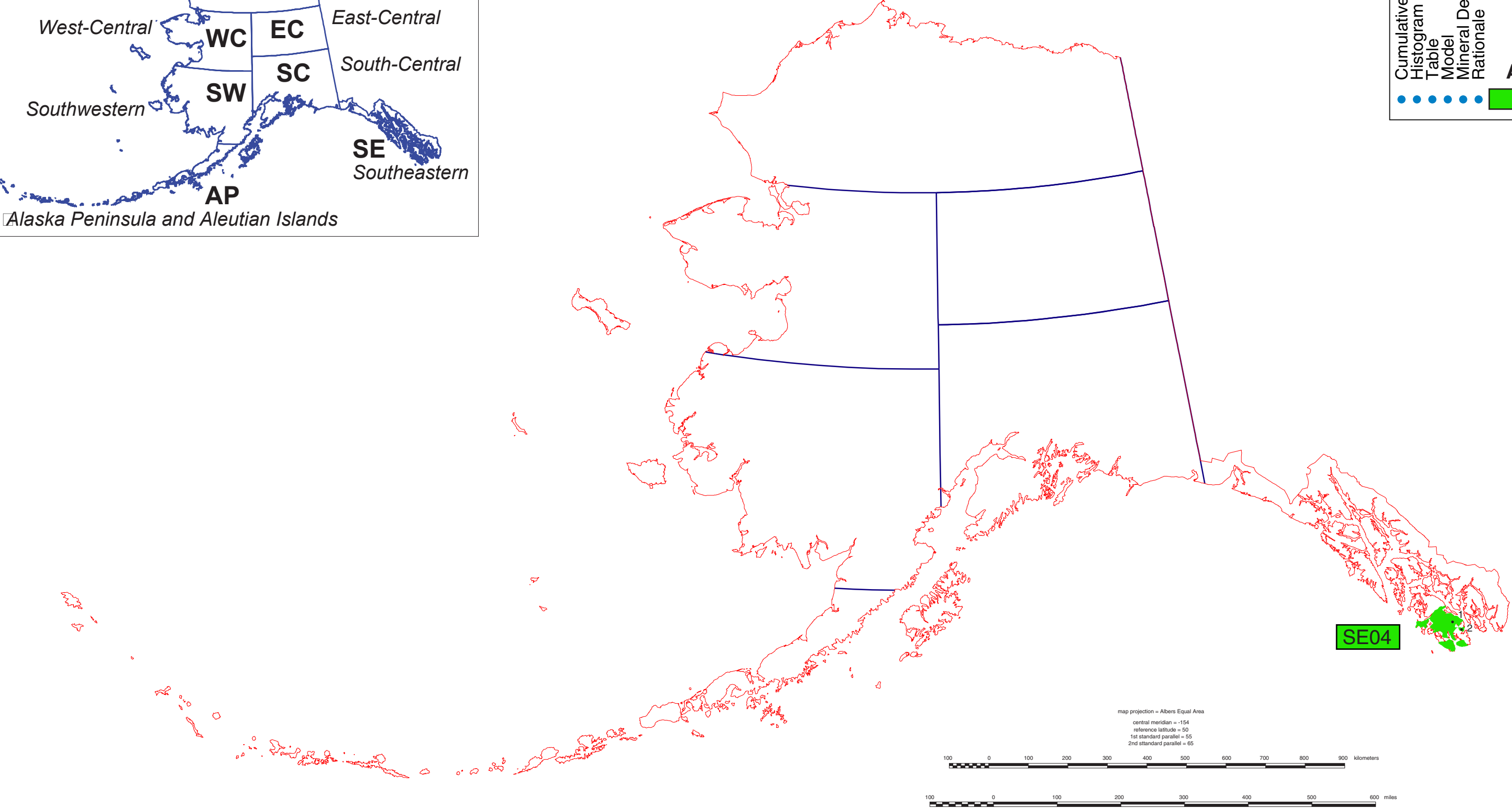
Model

Mineral Deposits

Rationale

AKKU2

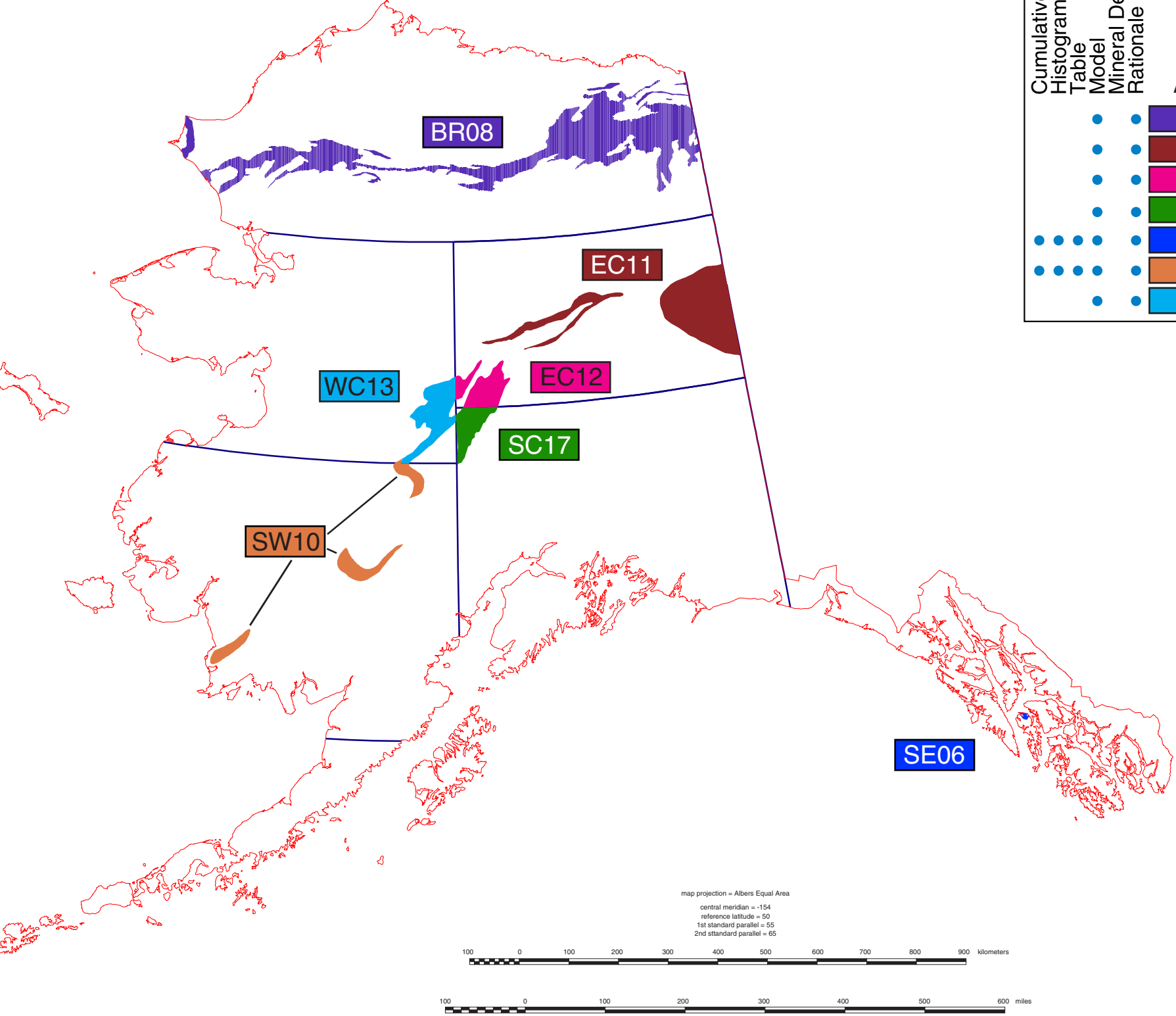
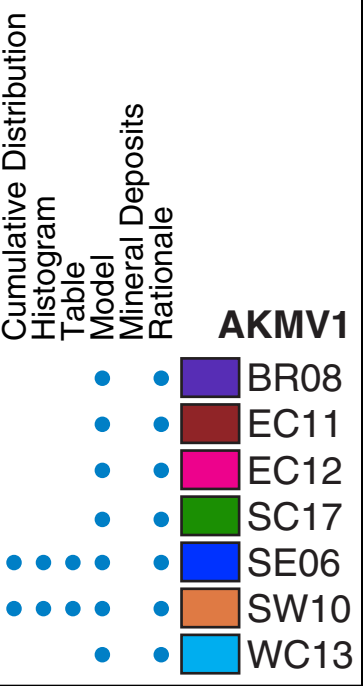
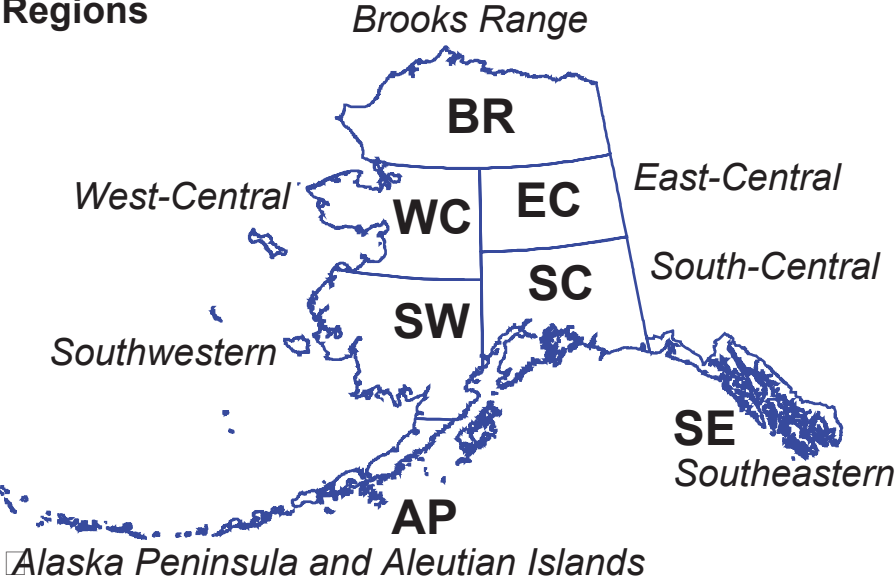
SE04



USGS National Mineral Resource Assessment

AKMV1: Mississippi Valley Type Deposits I

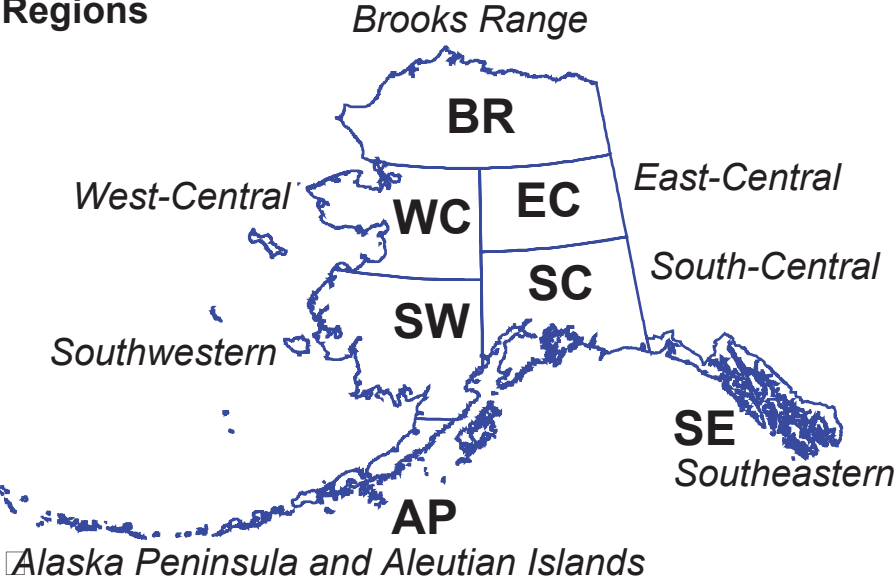
Assessment Regions



USGS National Mineral Resource Assessment

AKMV2: Mississippi Valley Type Deposits II

Assessment Regions



Cumulative Distribution

Histogram

Table

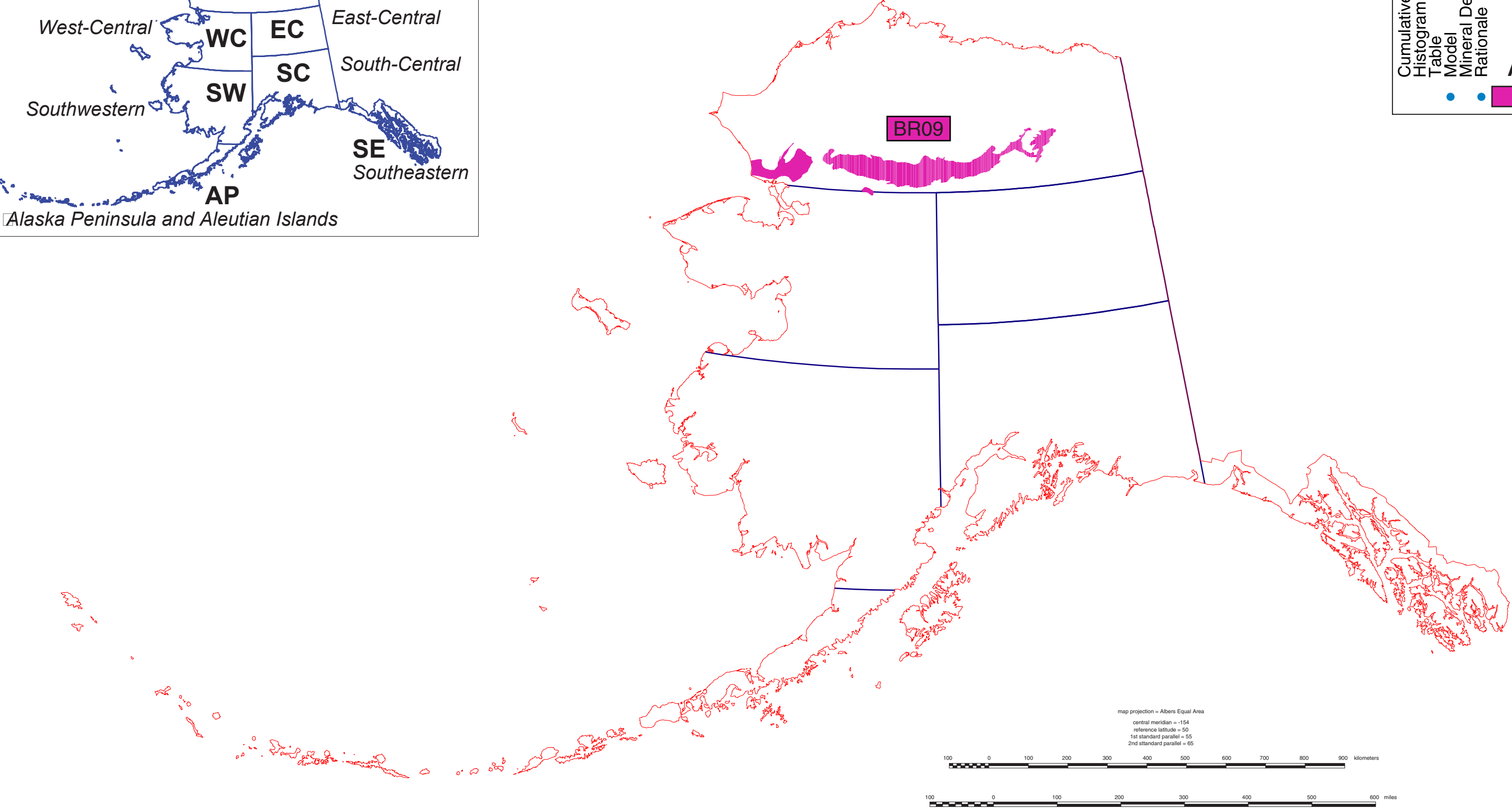
Model

Mineral Deposits

Rationale

AKMV2

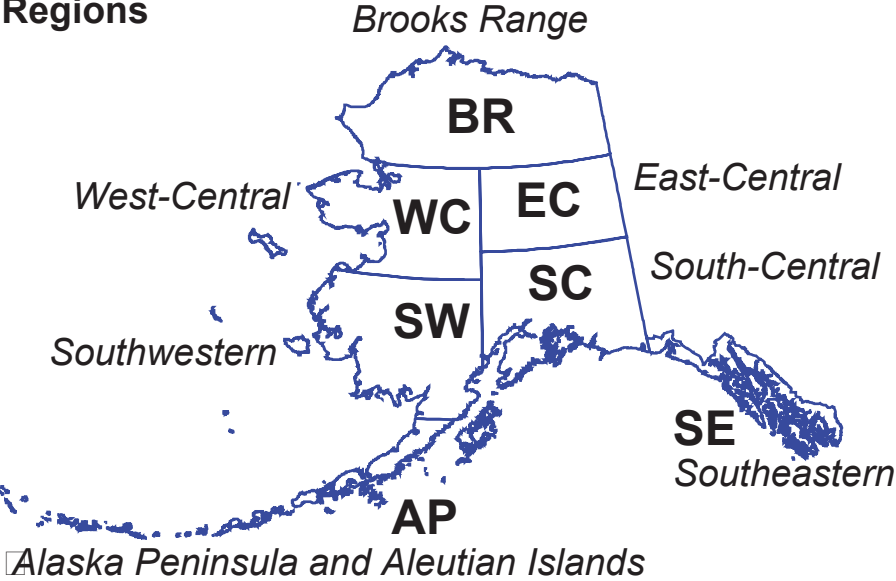
BR09



USGS National Mineral Resource Assessment

AKMV3: Mississippi Valley Type Deposits III

Assessment Regions



Cumulative Distribution

Histogram

Table

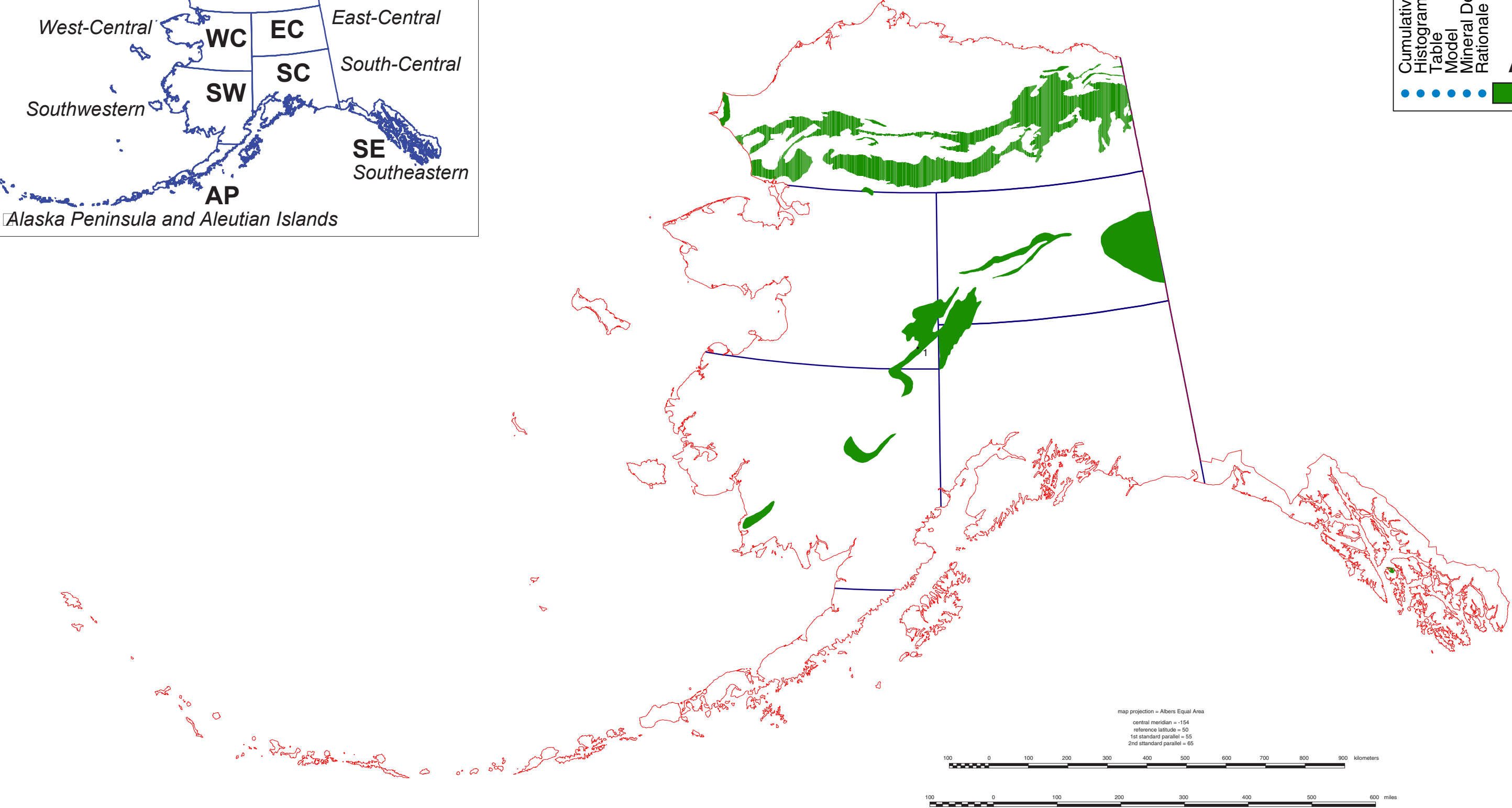
Model

Mineral Deposits

Rationale

AKMV3

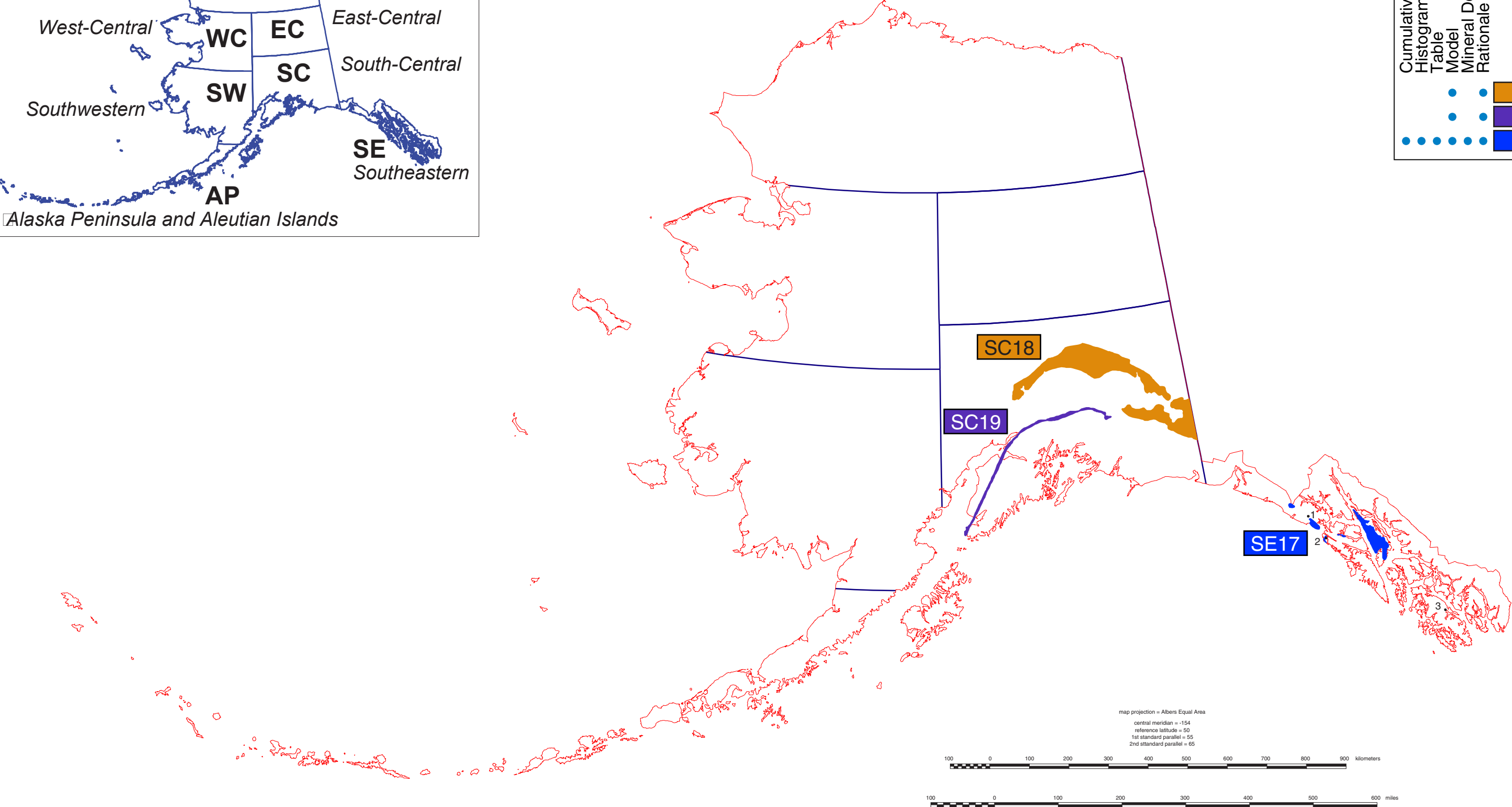
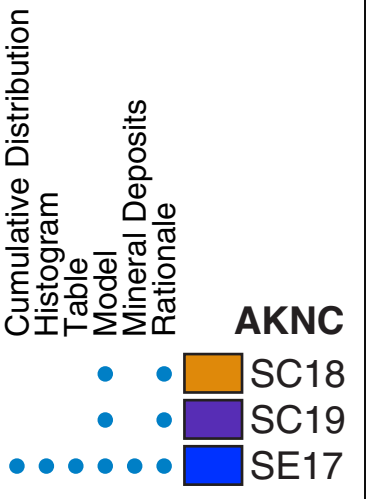
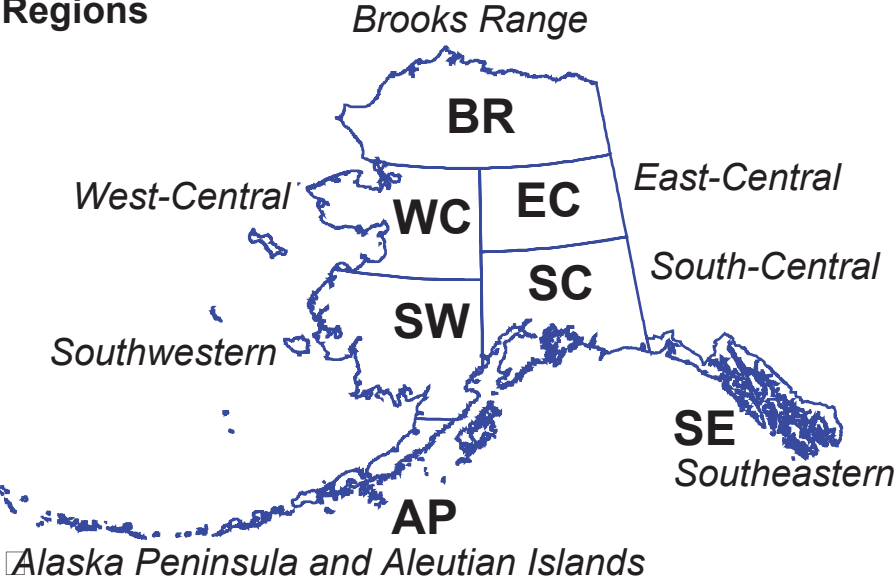
AK02



USGS National Mineral Resource Assessment

AKNC: Synorogenic-Synvolcanic Ni-Cu

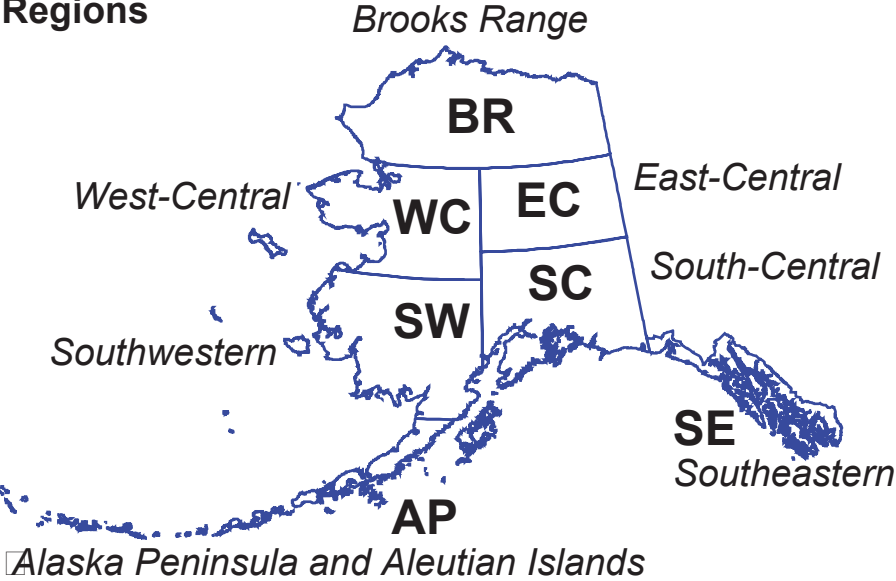
Assessment Regions



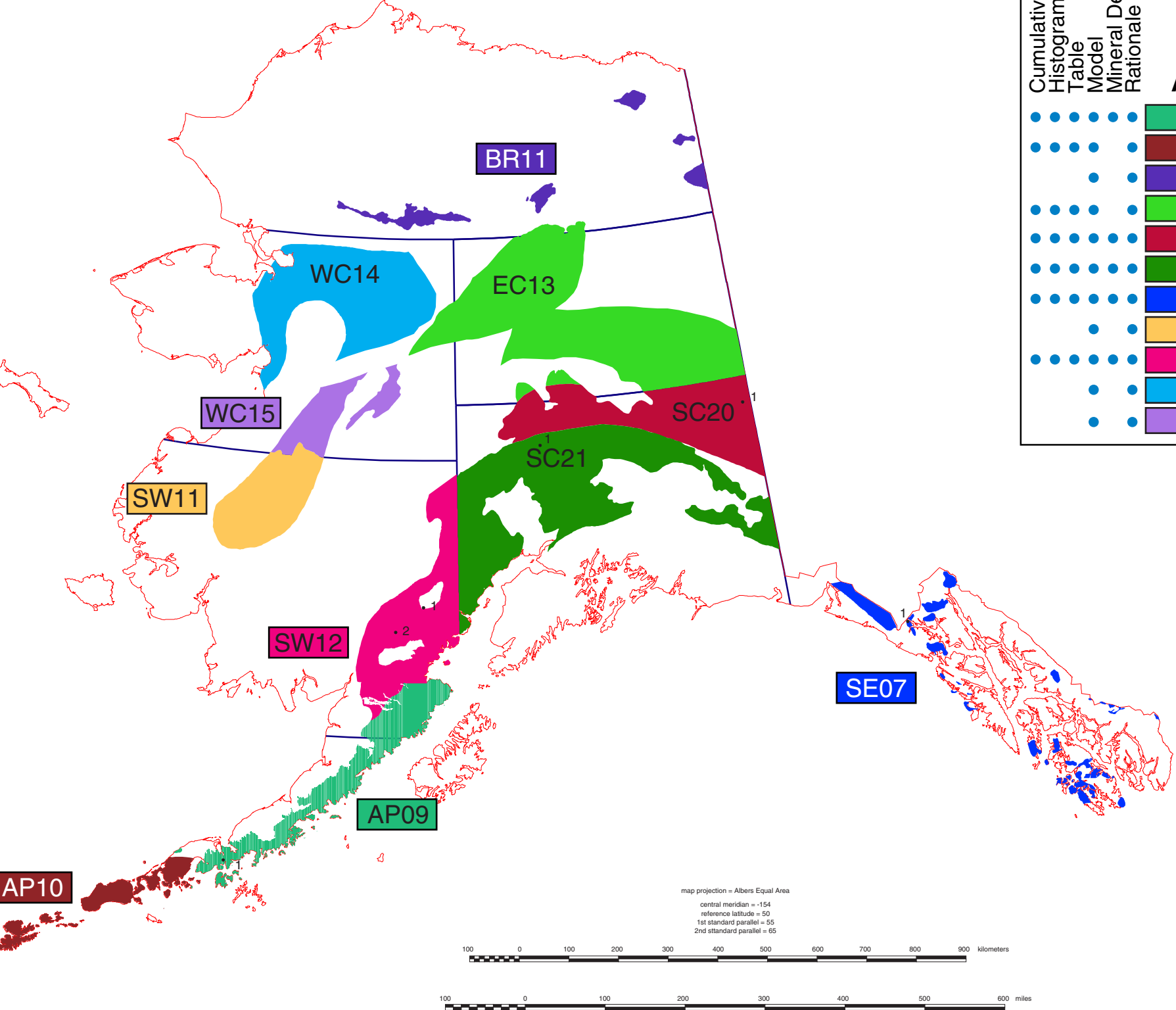
USGS National Mineral Resource Assessment

AKPC1: Porphyry Copper I

Assessment Regions



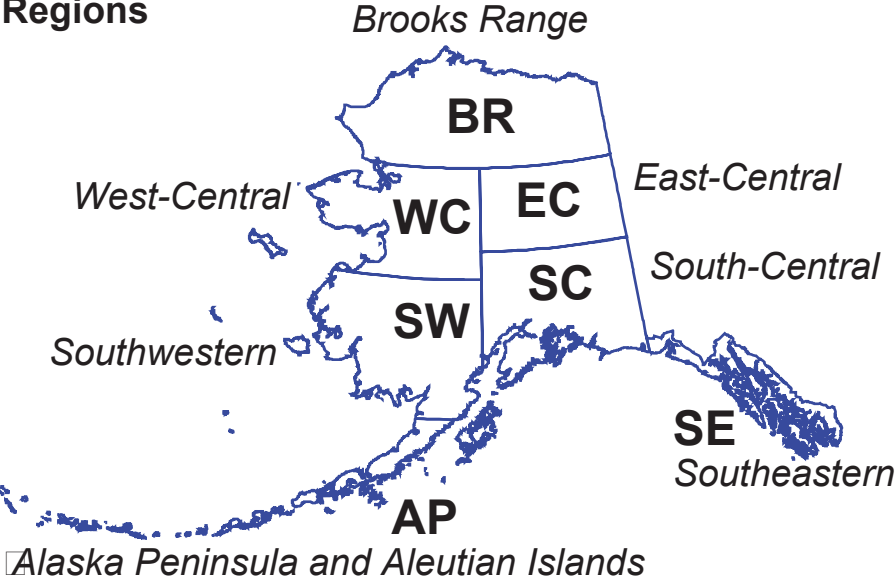
Cumulative Distribution	Histogram	Table	Model	Mineral Deposits	Rationale	AKPC1
•••••	•••••	•••••	•••••	•••••	•••••	AP09
•••••	•••••	•••••	•••••	•••••	•••••	AP10
•••••	•••••	•••••	•••••	•••••	•••••	BR11
•••••	•••••	•••••	•••••	•••••	•••••	EC13
•••••	•••••	•••••	•••••	•••••	•••••	SC20
•••••	•••••	•••••	•••••	•••••	•••••	SC21
•••••	•••••	•••••	•••••	•••••	•••••	SE07
•••••	•••••	•••••	•••••	•••••	•••••	SW11
•••••	•••••	•••••	•••••	•••••	•••••	SW12
•••••	•••••	•••••	•••••	•••••	•••••	WC14
•••••	•••••	•••••	•••••	•••••	•••••	WC15



USGS National Mineral Resource Assessment

AKPC2: Porphyry Copper II

Assessment Regions



Cumulative Distribution

Histogram

Table

Model

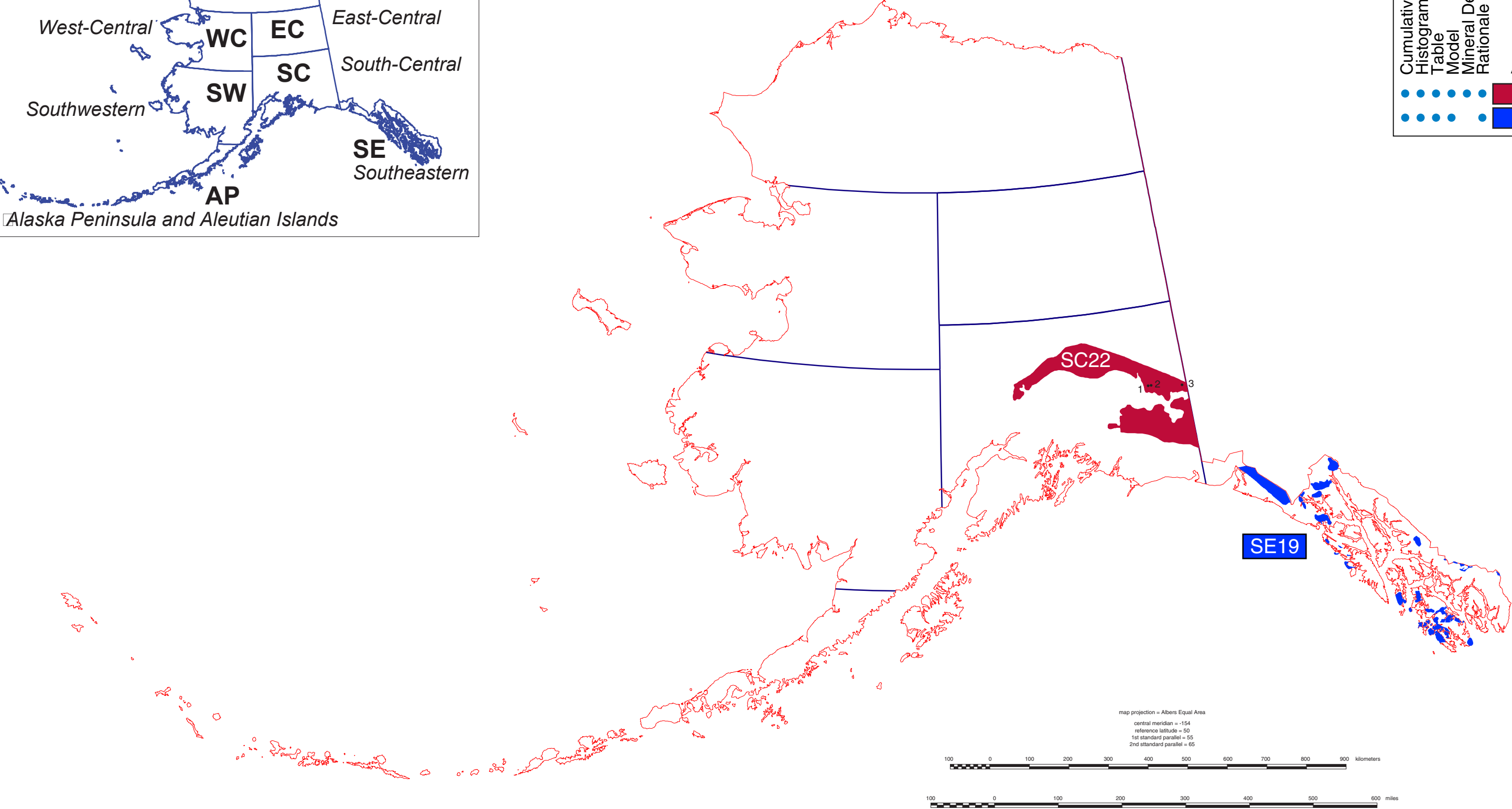
Mineral Deposits

Rationale

AKPC2

SC22

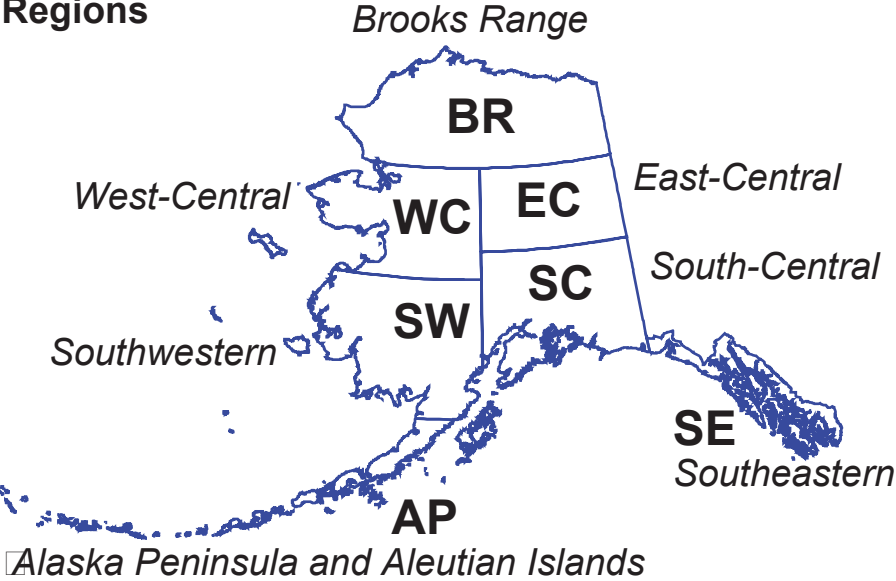
SE19



USGS National Mineral Resource Assessment

AKPC3: Porphyry Copper III

Assessment Regions



Cumulative Distribution

Histogram

Table

Model

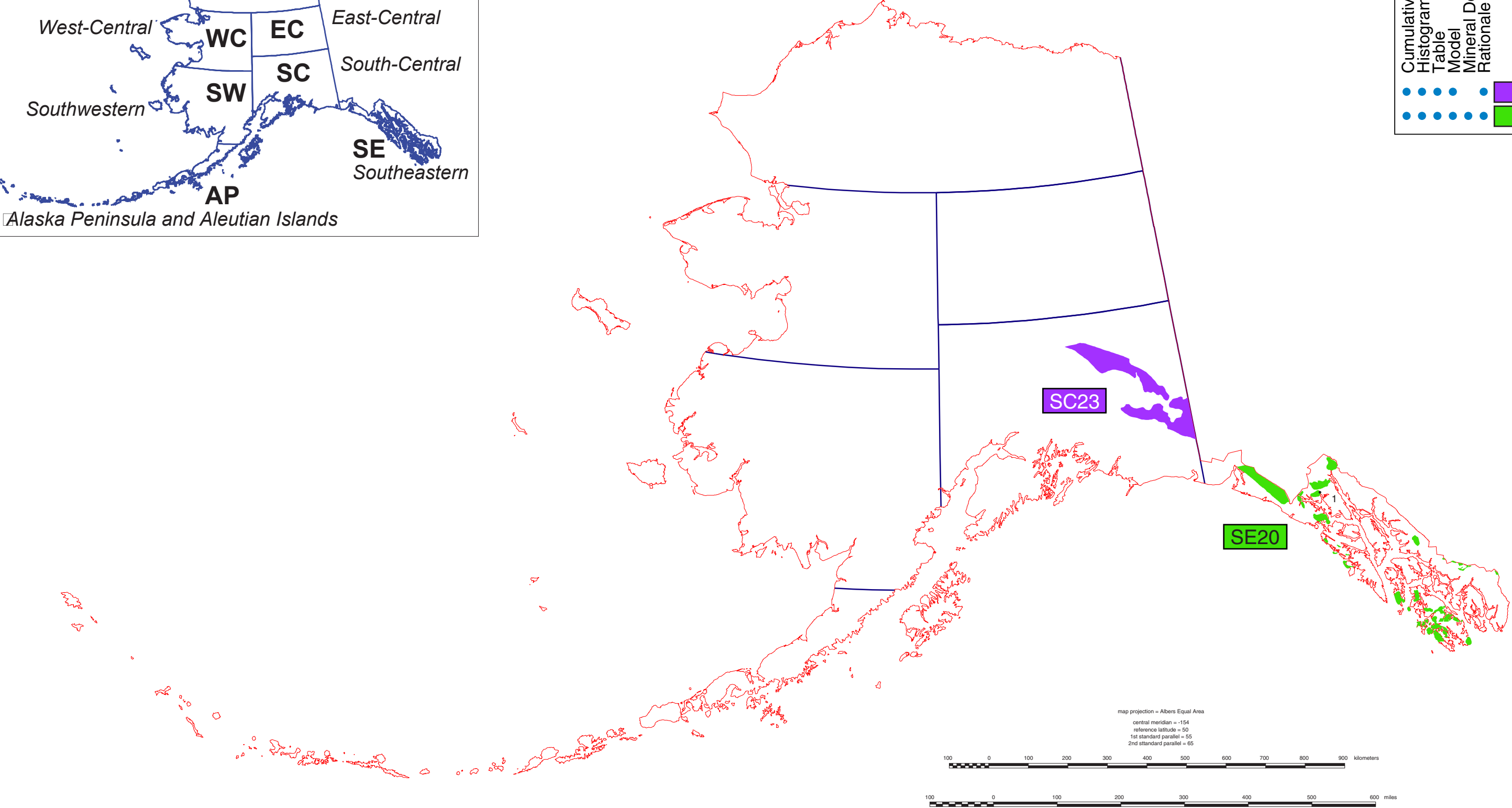
Mineral Deposits

Rationale

AKPC3

SC23

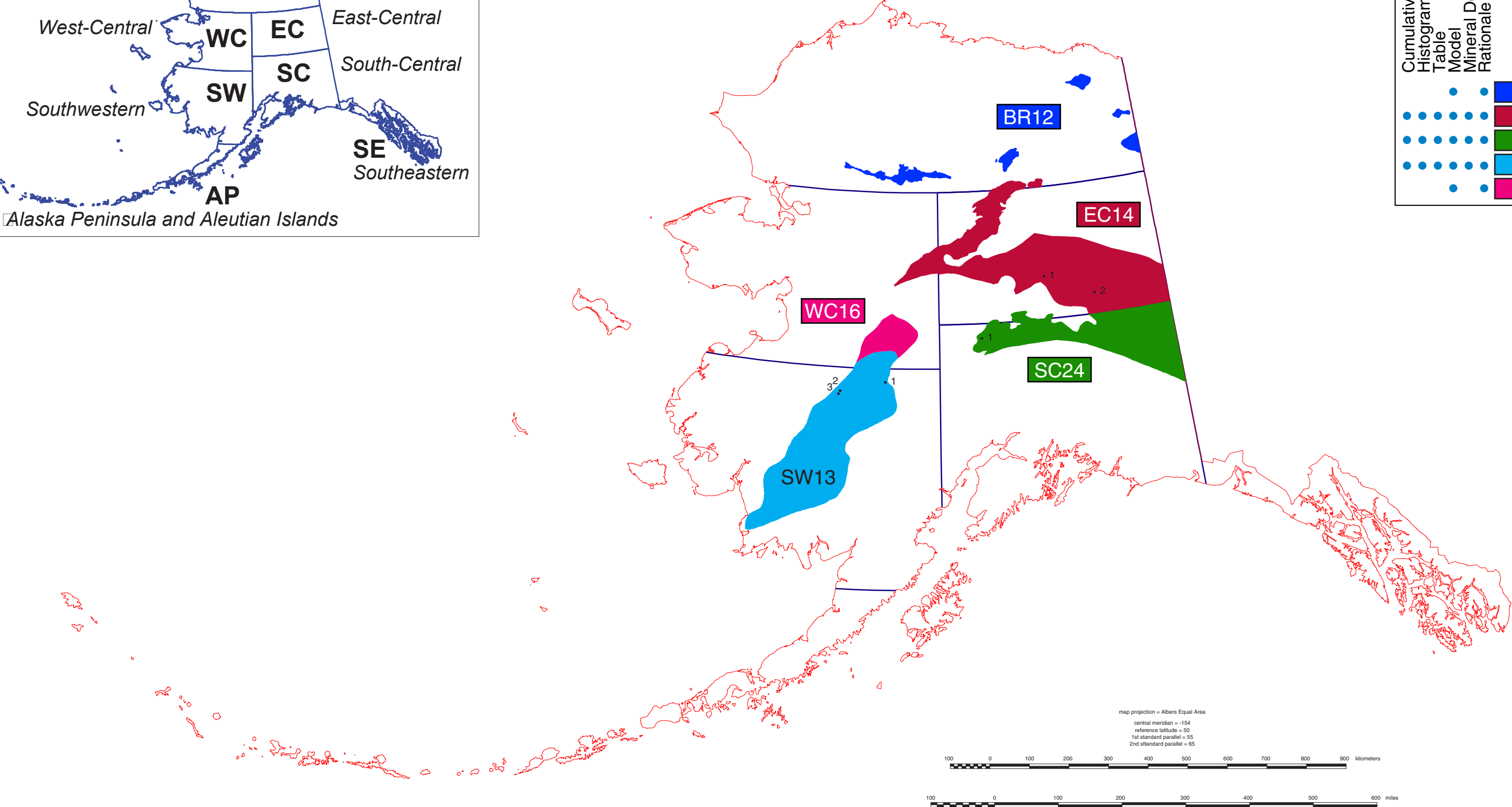
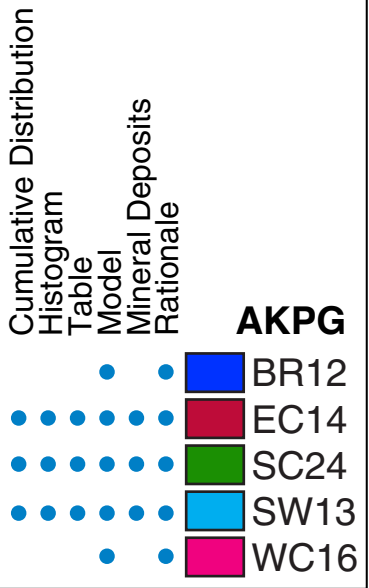
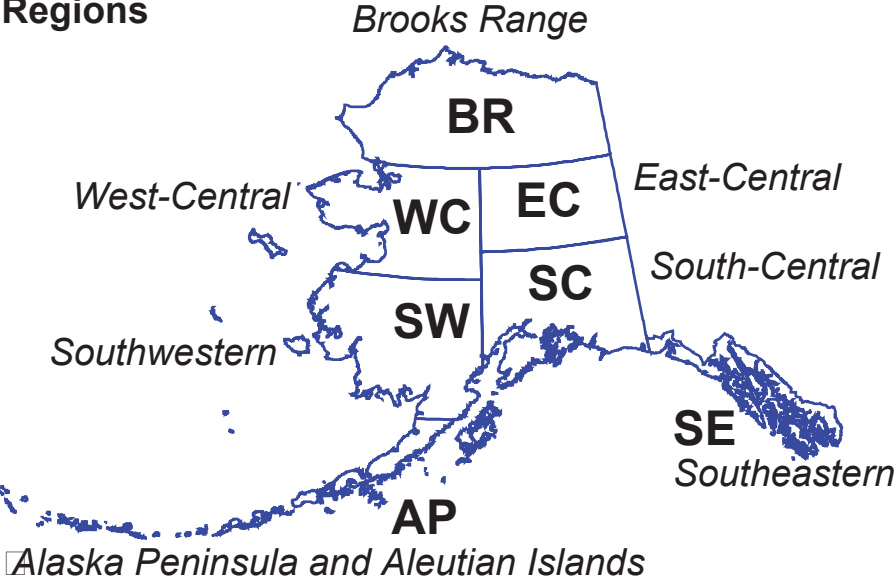
SE20



USGS National Mineral Resource Assessment

AKPG: Plutonic Porphyry Gold

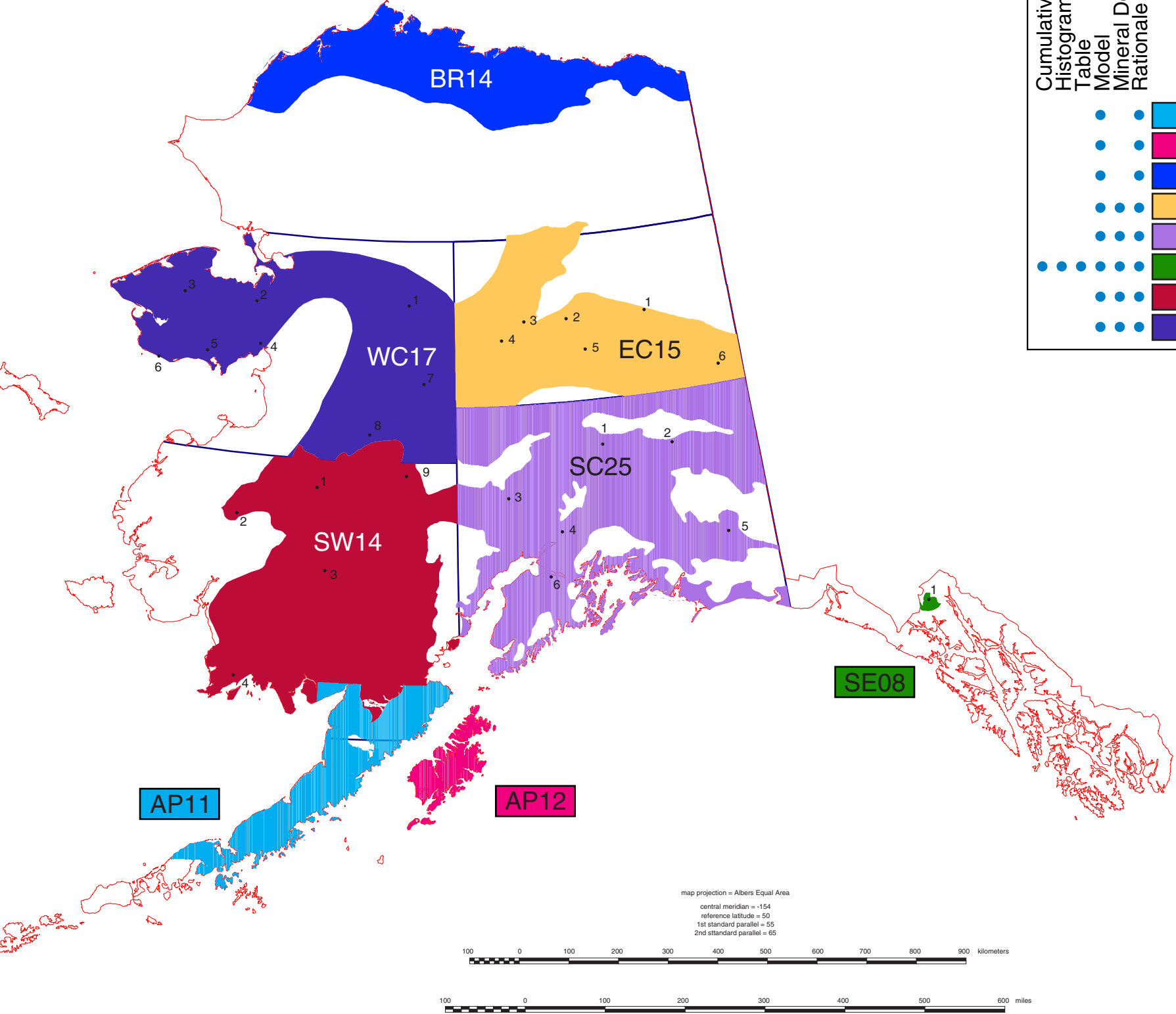
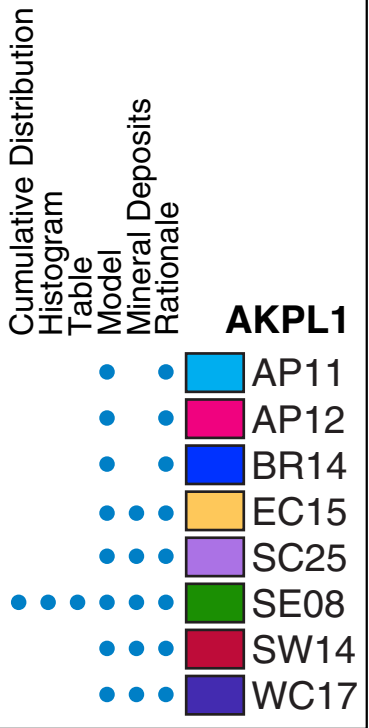
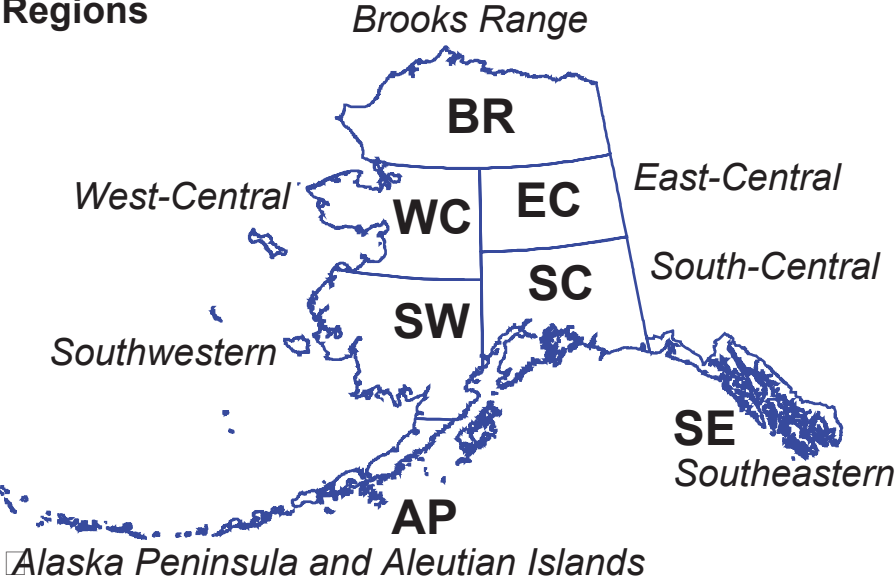
Assessment Regions



USGS National Mineral Resource Assessment

AKPL1: Placer Gold I

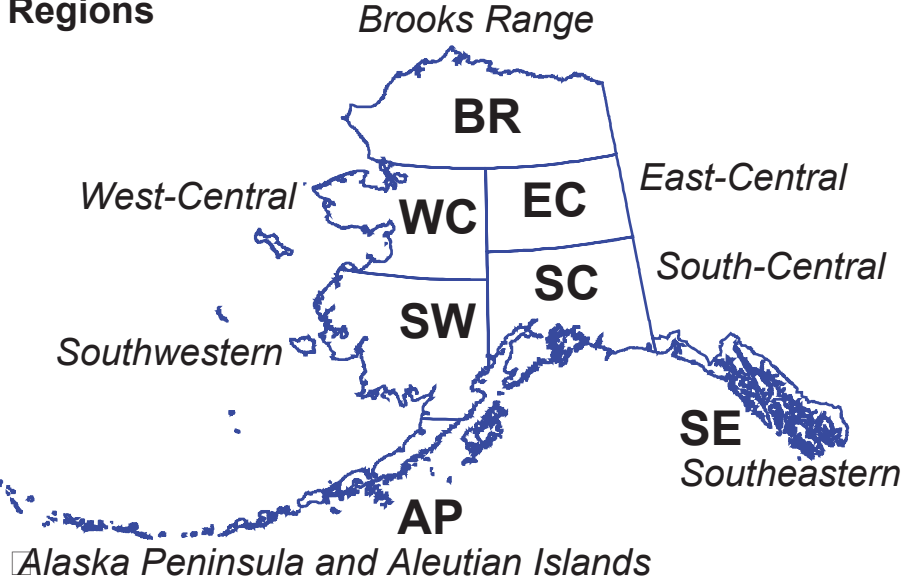
Assessment Regions



USGS National Mineral Resource Assessment

AKPL2: Placer Gold II

Assessment Regions



Cumulative Distribution

Histogram

Table

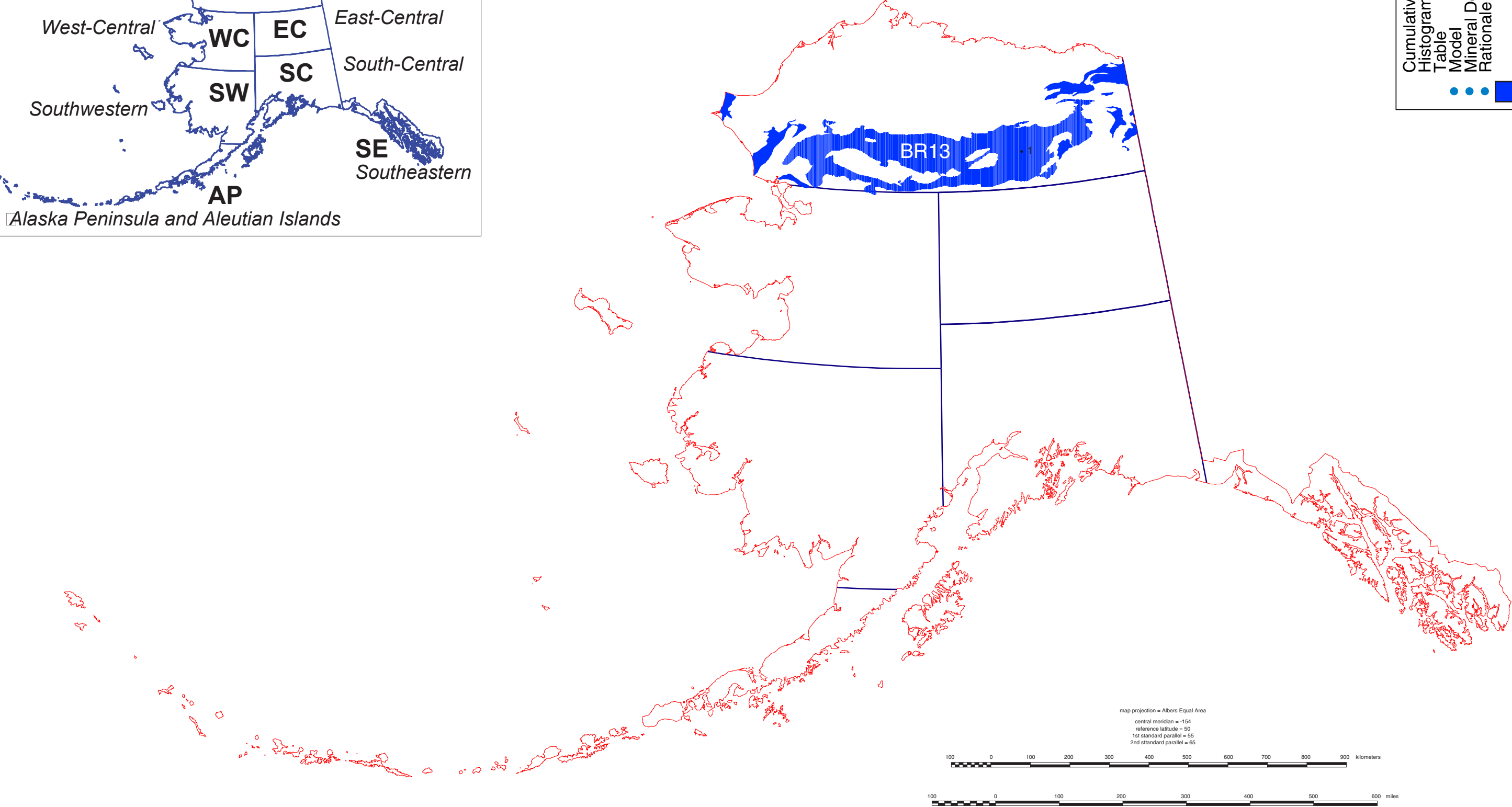
Model

Mineral Deposits

Rationale

AKPL2

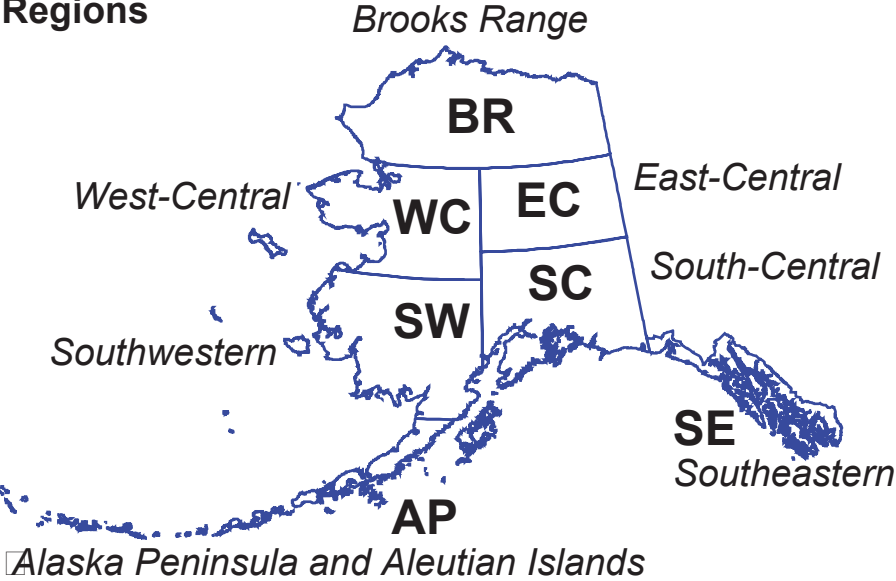
BR13



USGS National Mineral Resource Assessment

AKPL3: Placer Gold III

Assessment Regions



Cumulative Distribution

Histogram

Table

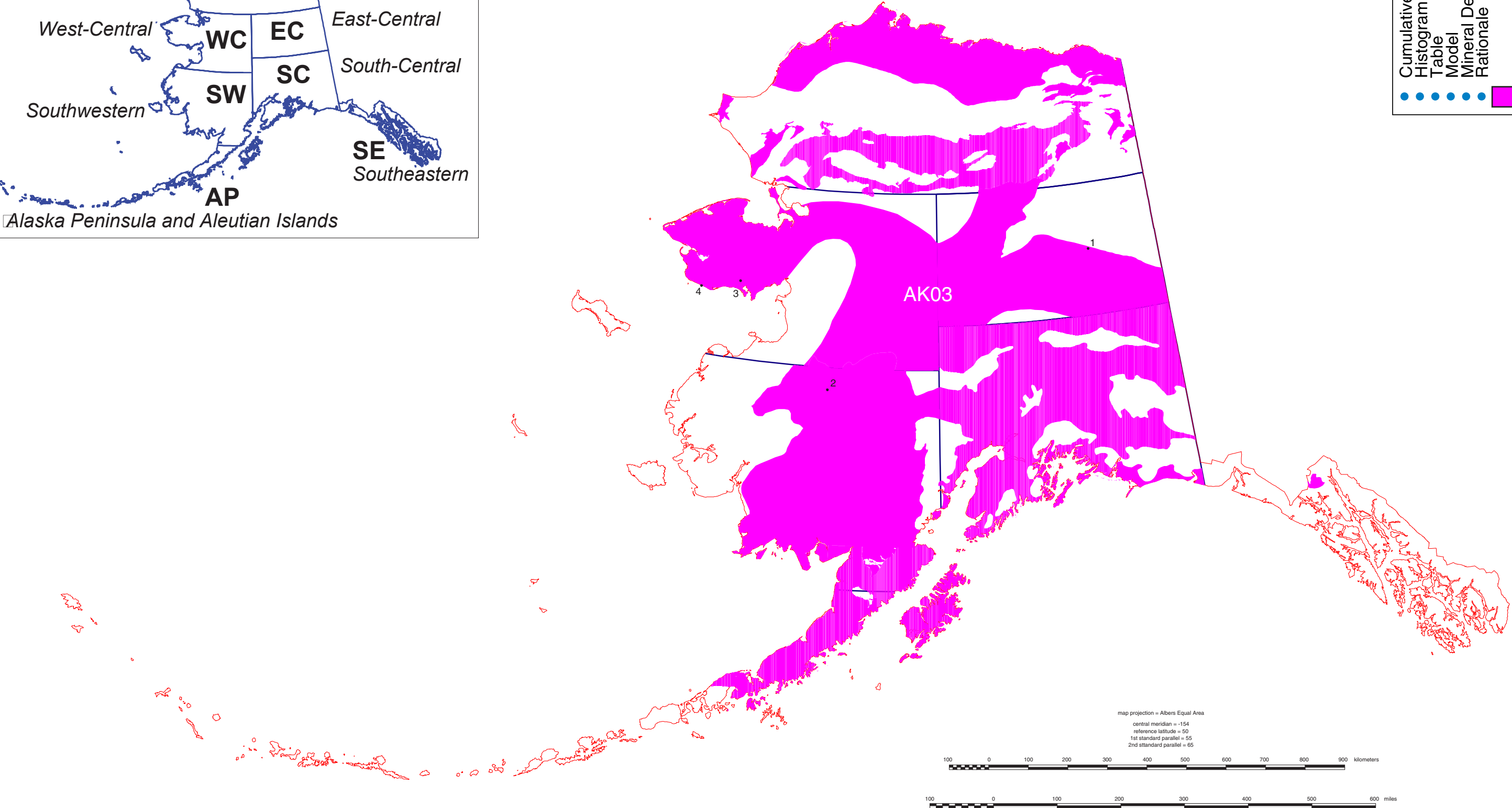
Model

Mineral Deposits

Rationale

AKPL3

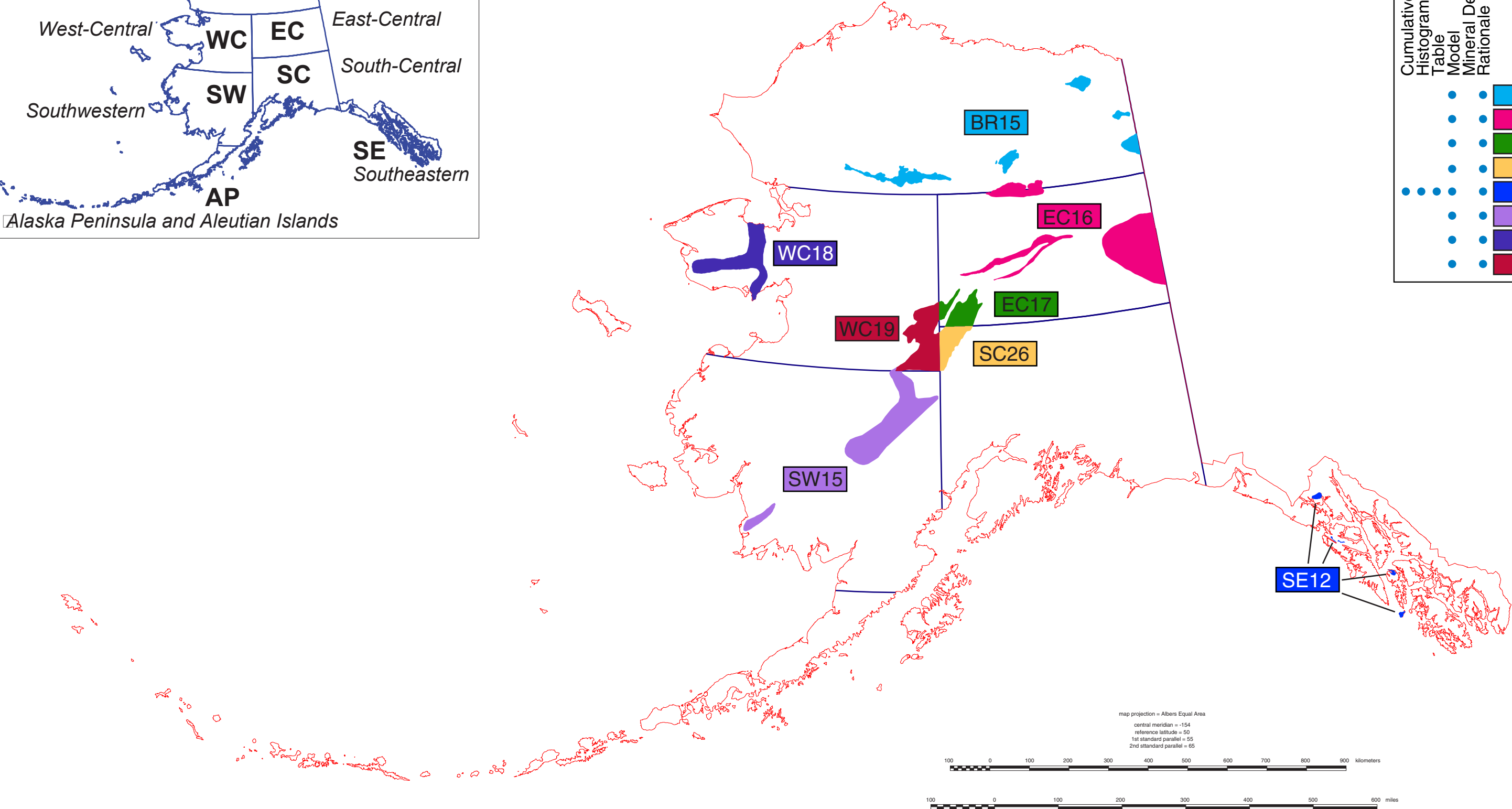
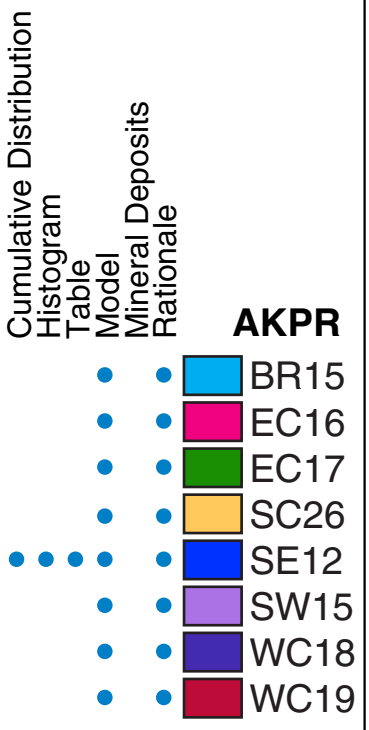
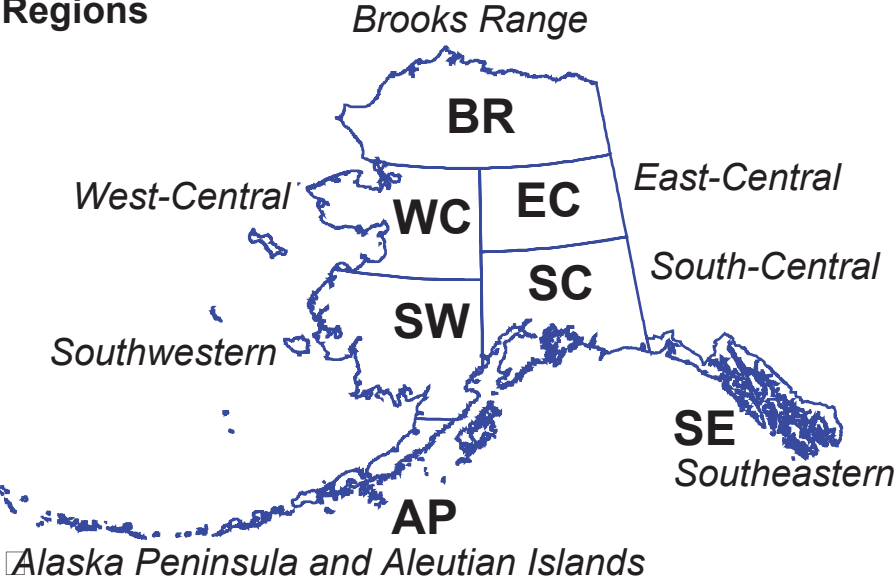
AK03



USGS National Mineral Resource Assessment

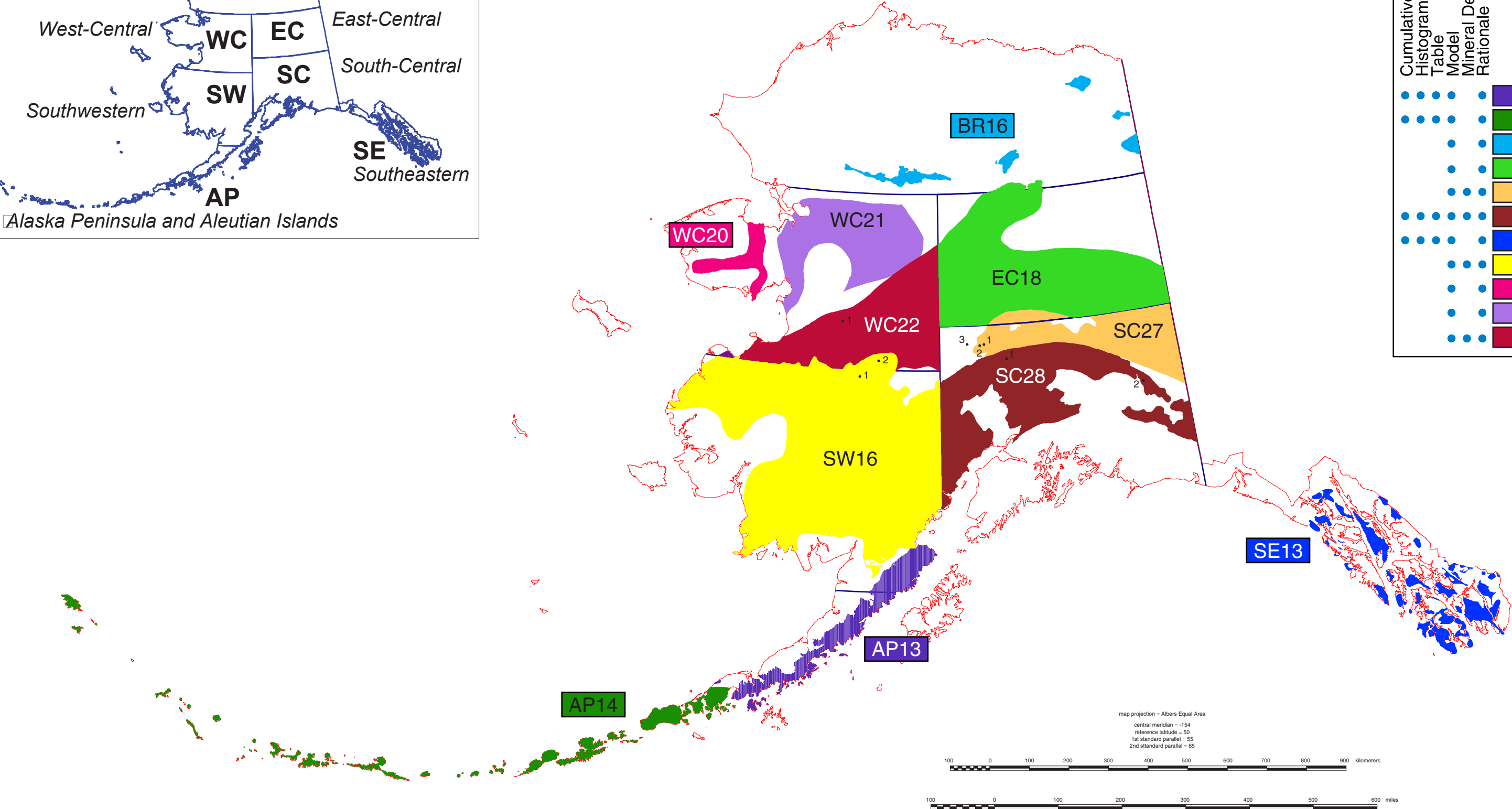
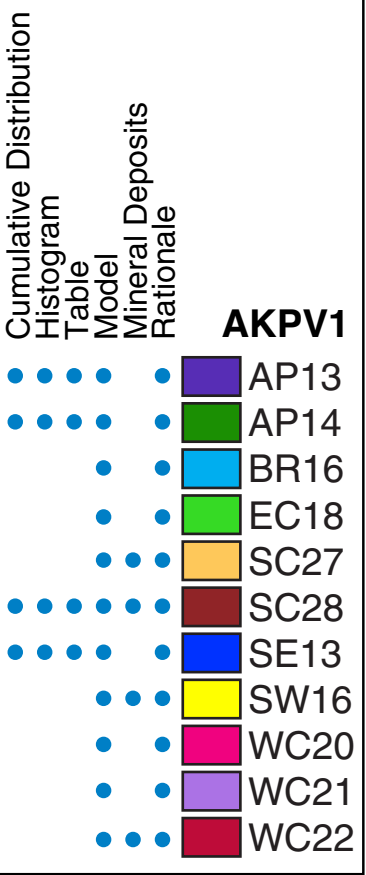
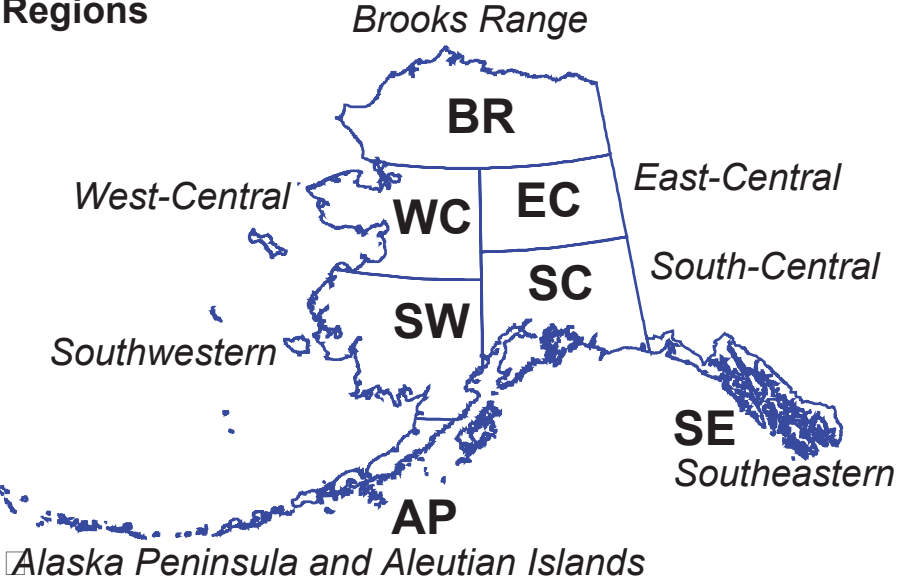
AKPR: Polymetallic Replacement

Assessment Regions



USGS National Mineral Resource Assessment
AKPV1: Polymetallic Vein I

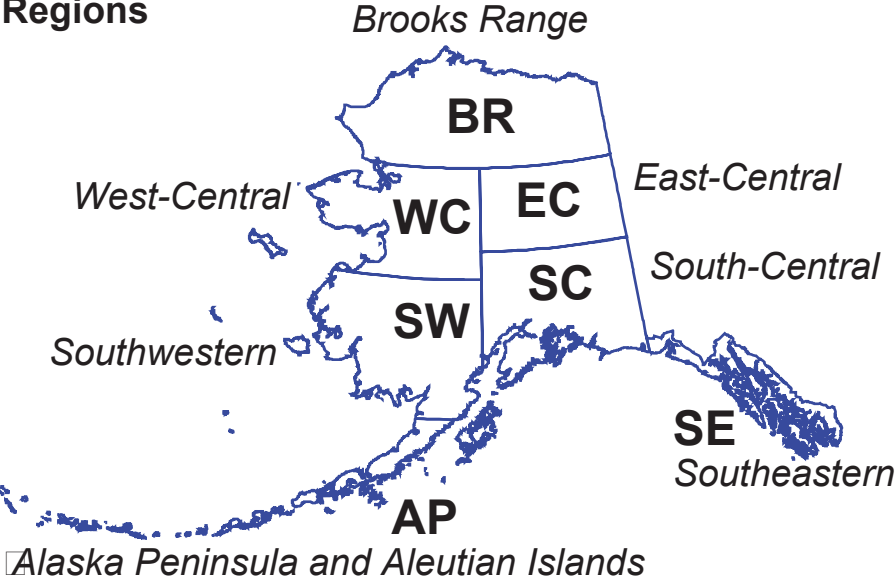
Assessment
Regions



USGS National Mineral Resource Assessment

AKPV2: Polymetallic Vein II

Assessment Regions



Cumulative Distribution

Histogram

Table

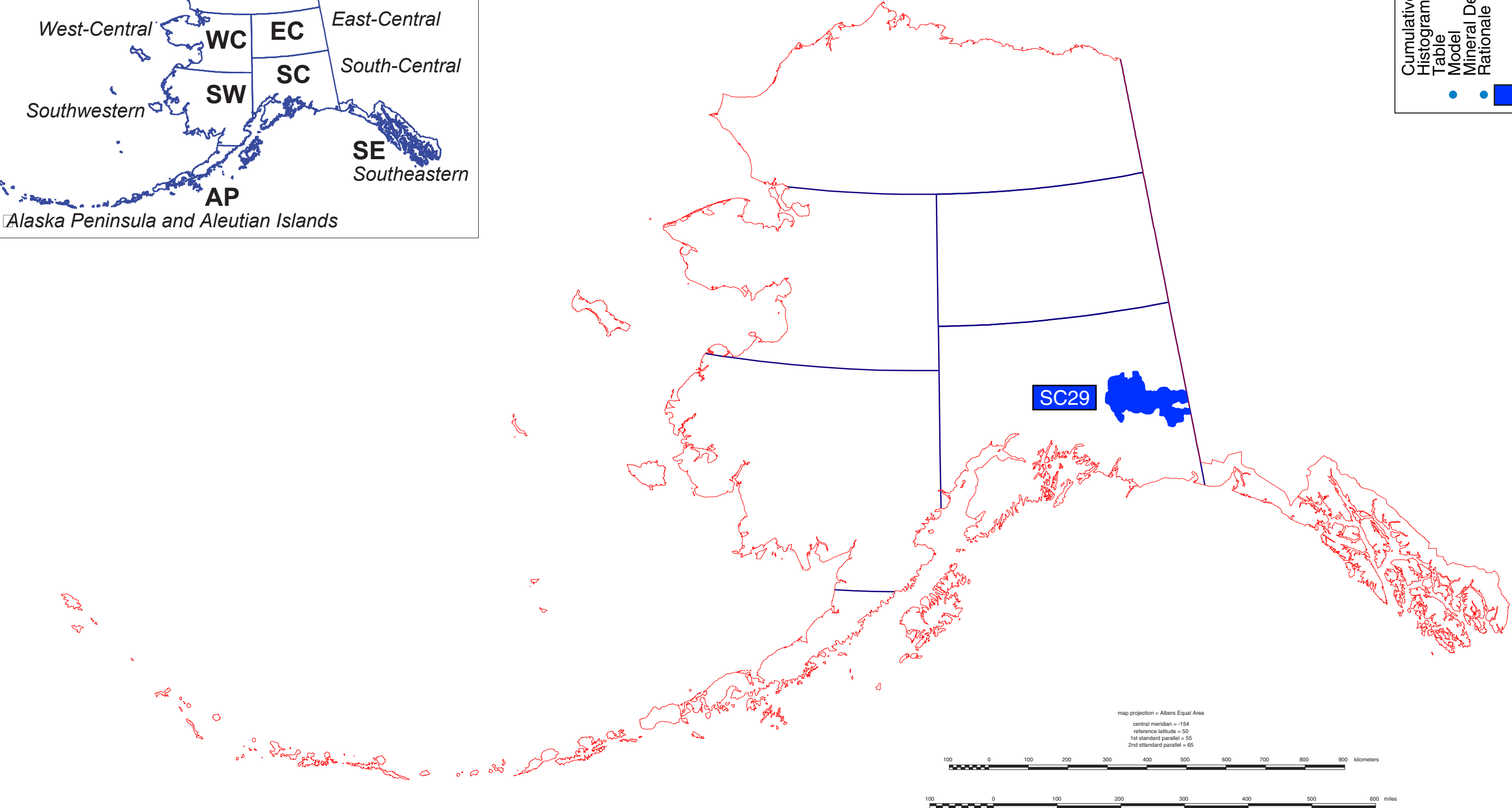
Model

Mineral Deposits

Rationale

AKPV2

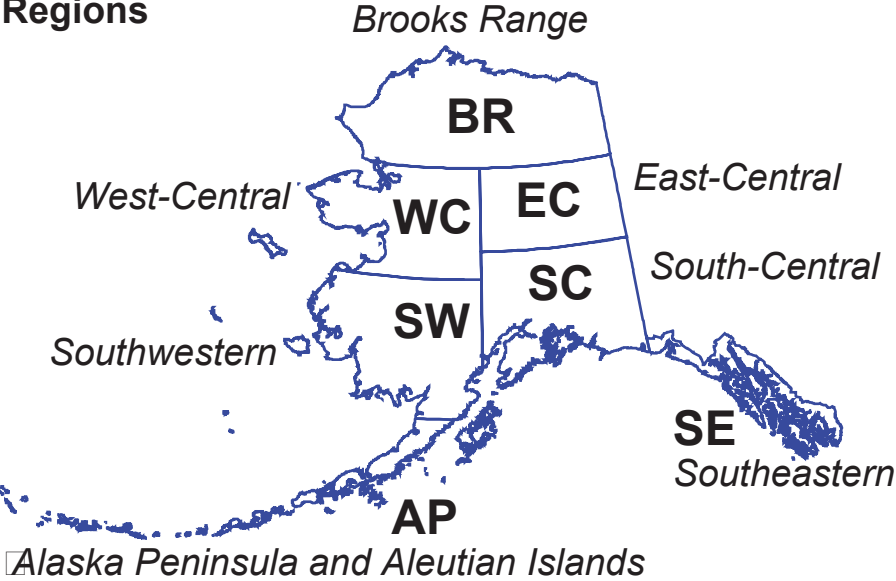
SC29



USGS National Mineral Resource Assessment

AKPZ: Zn-Pb-Ag Veins

Assessment Regions



Cumulative Distribution

Histogram

Table

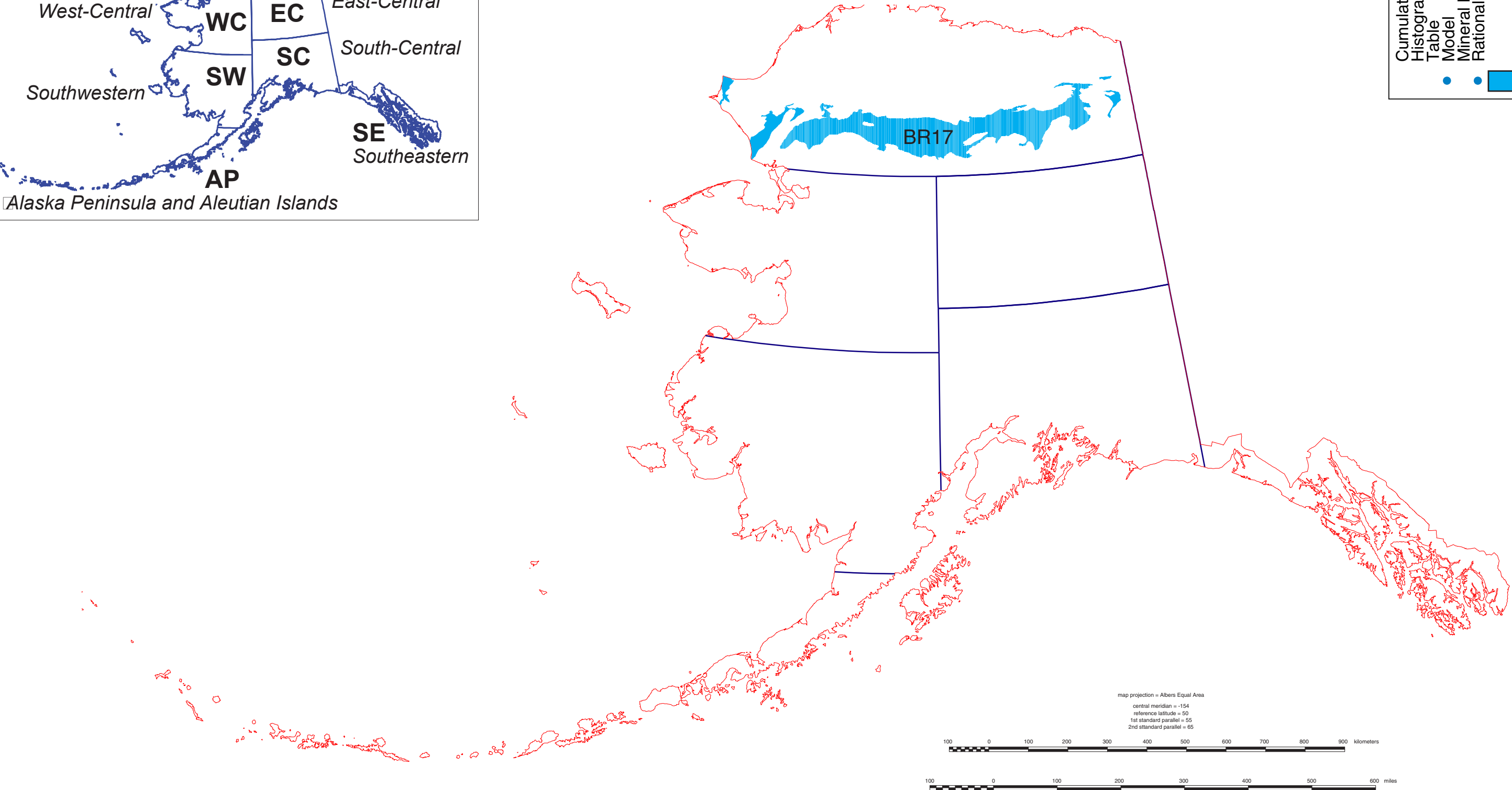
Model

Mineral Deposits

Rationale

AKPZ

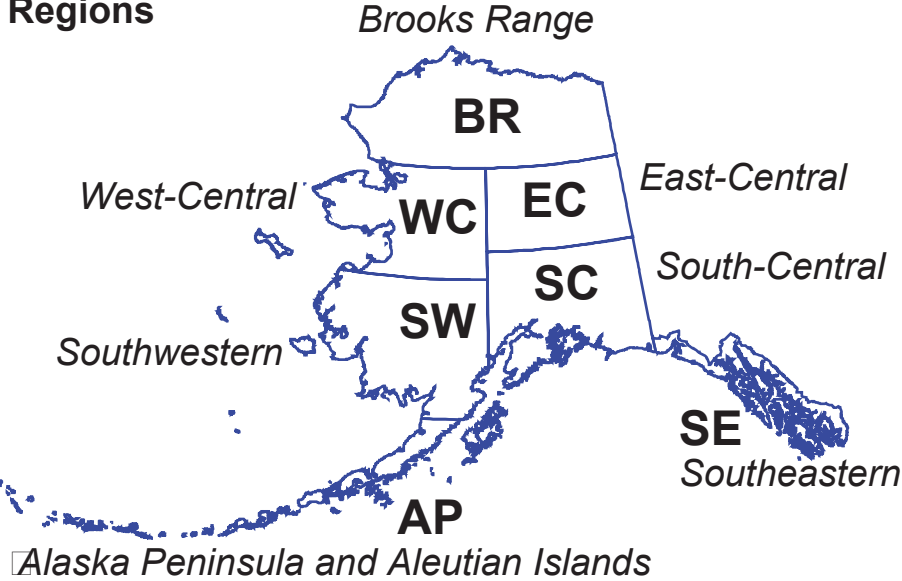
BR17



USGS National Mineral Resource Assessment

AKSD: Sediment Hosted Copper

Assessment Regions



Cumulative Distribution

Histogram

Table

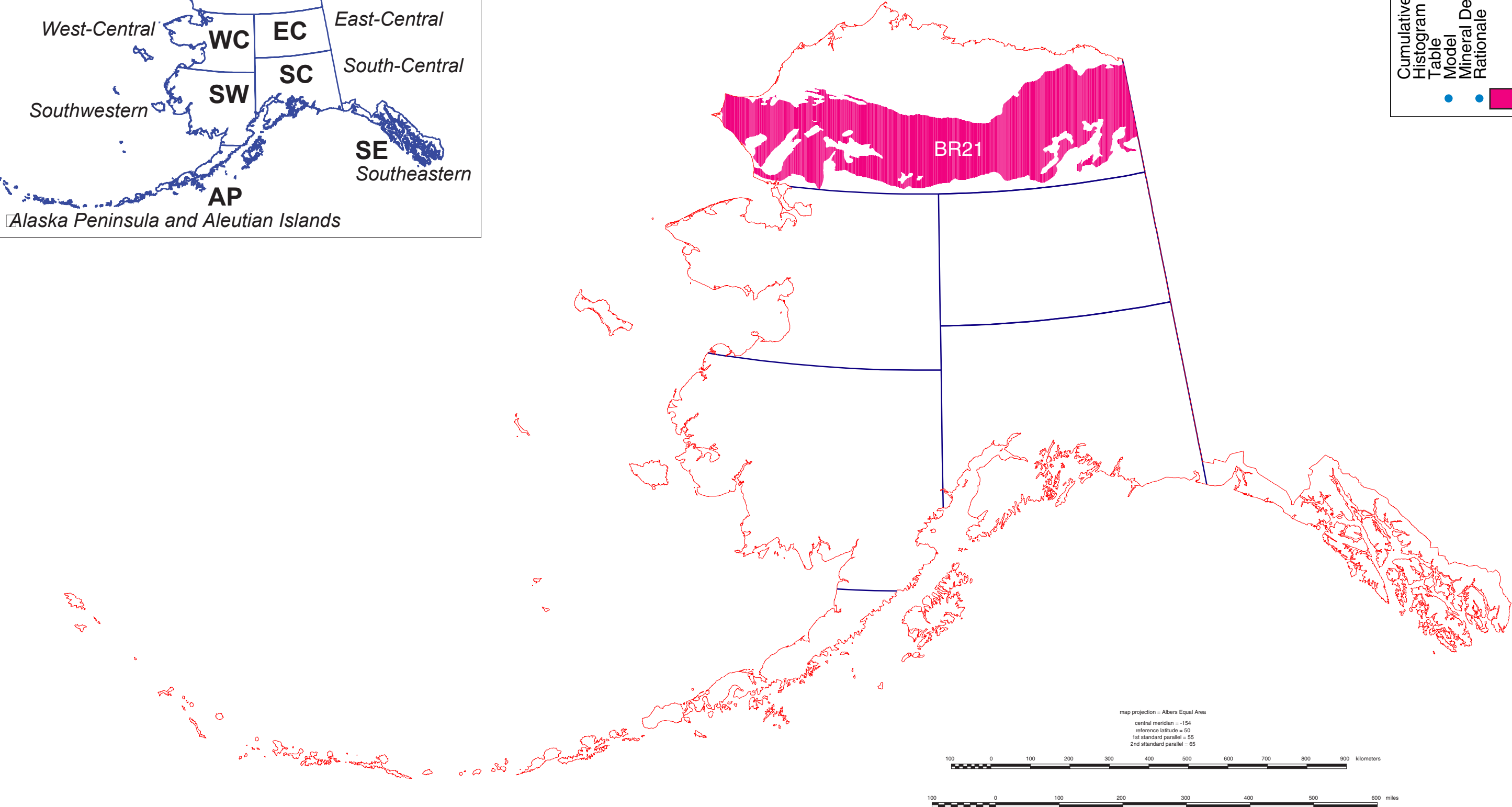
Model

Mineral Deposits

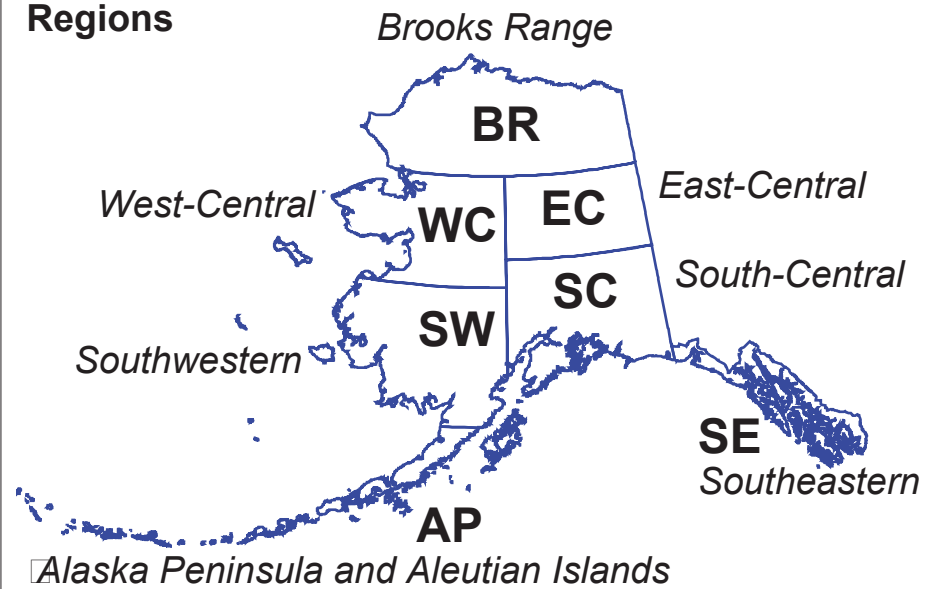
Rationale

AKSD

BR21

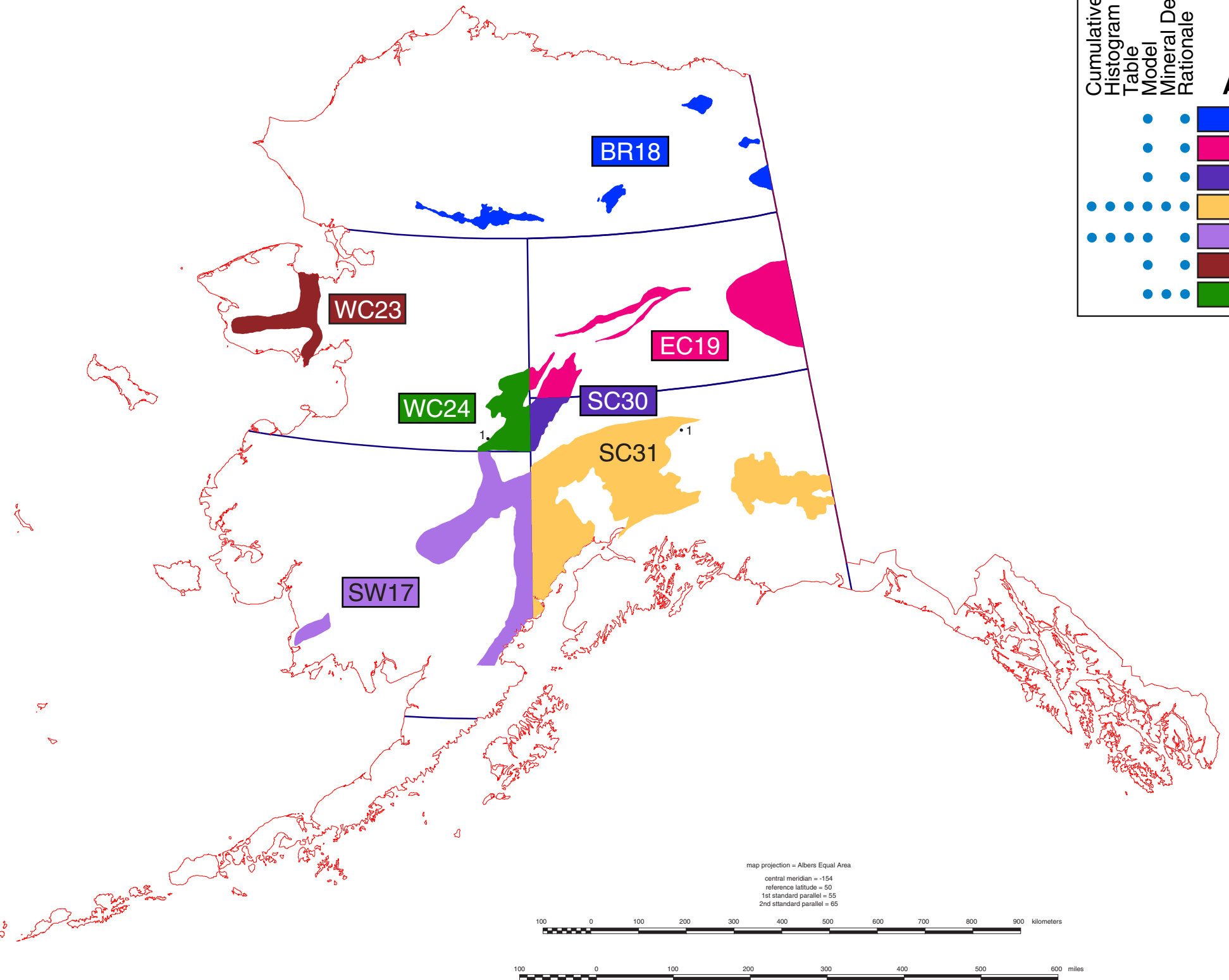


Assessment Regions



USGS National Mineral Resource Assessment

AKSK1: Cu-(Au) Skarn I

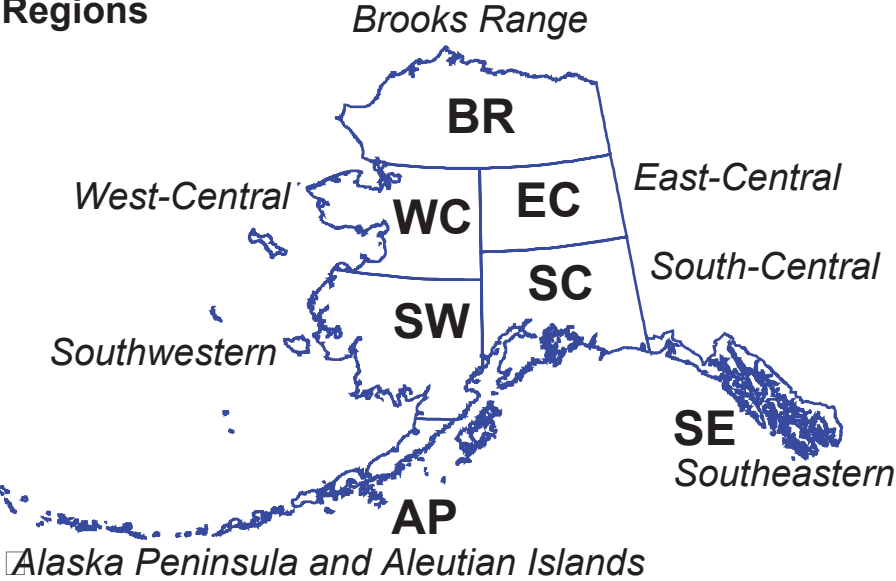


Cumulative Distribution Histogram	Table Model	Mineral Deposits Rationale		
				BR18
				EC19
				SC30
				SC31
				SW17
				WC23
				WC24

USGS National Mineral Resource Assessment

AKSK2: Cu-(Au) Skarn II

Assessment Regions



Cumulative Distribution

Histogram

Table

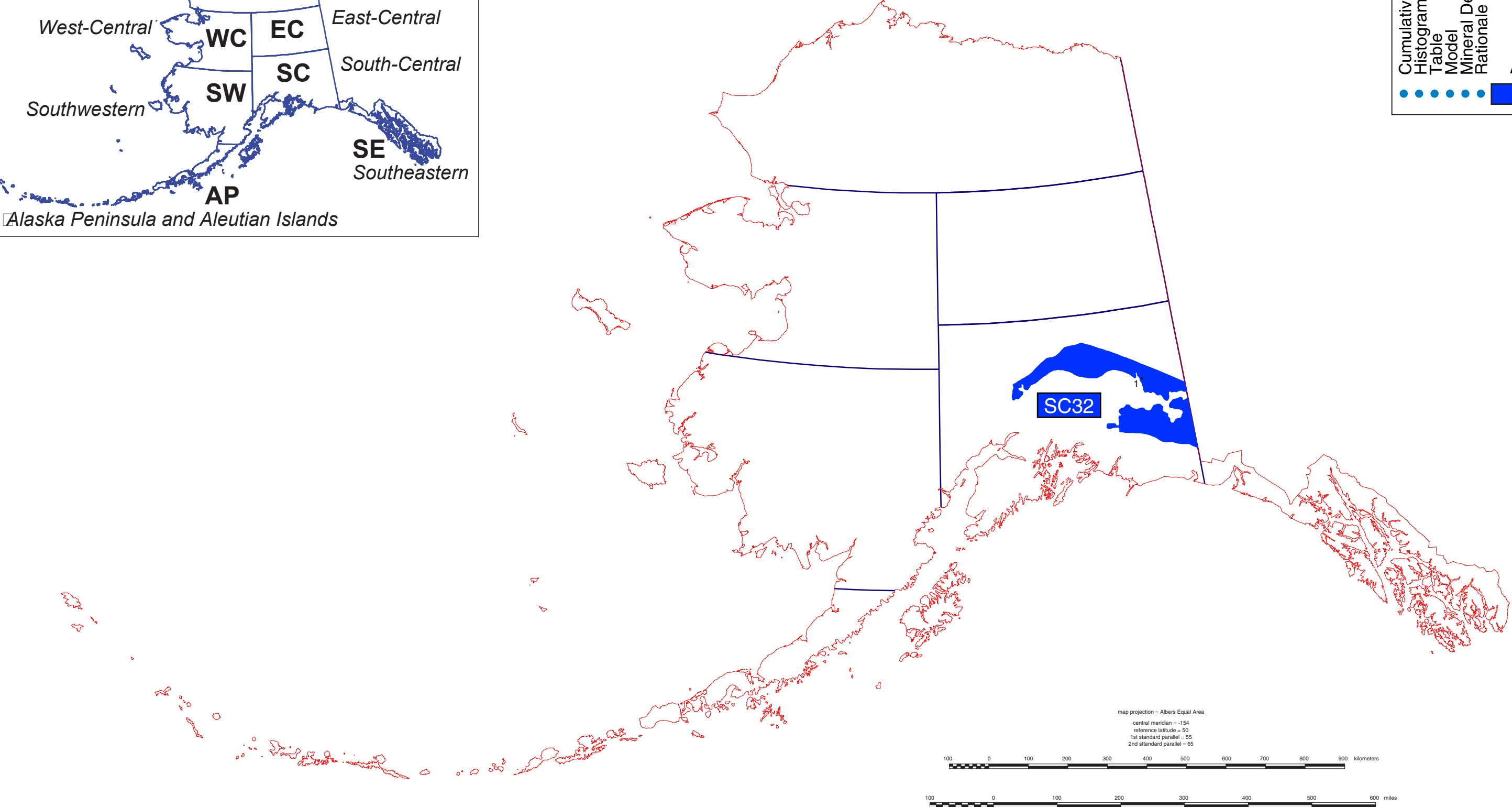
Model

Mineral Deposits

Rationale

AKSK2

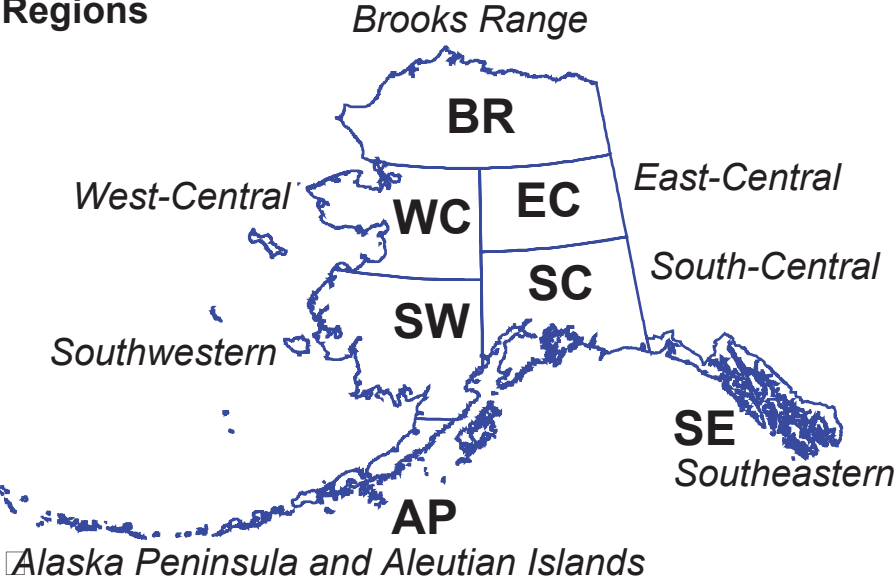
SC32



USGS National Mineral Resource Assessment

AKSK3: Cu-(Au) Skarn III

Assessment Regions



Cumulative Distribution

Histogram

Table

Model

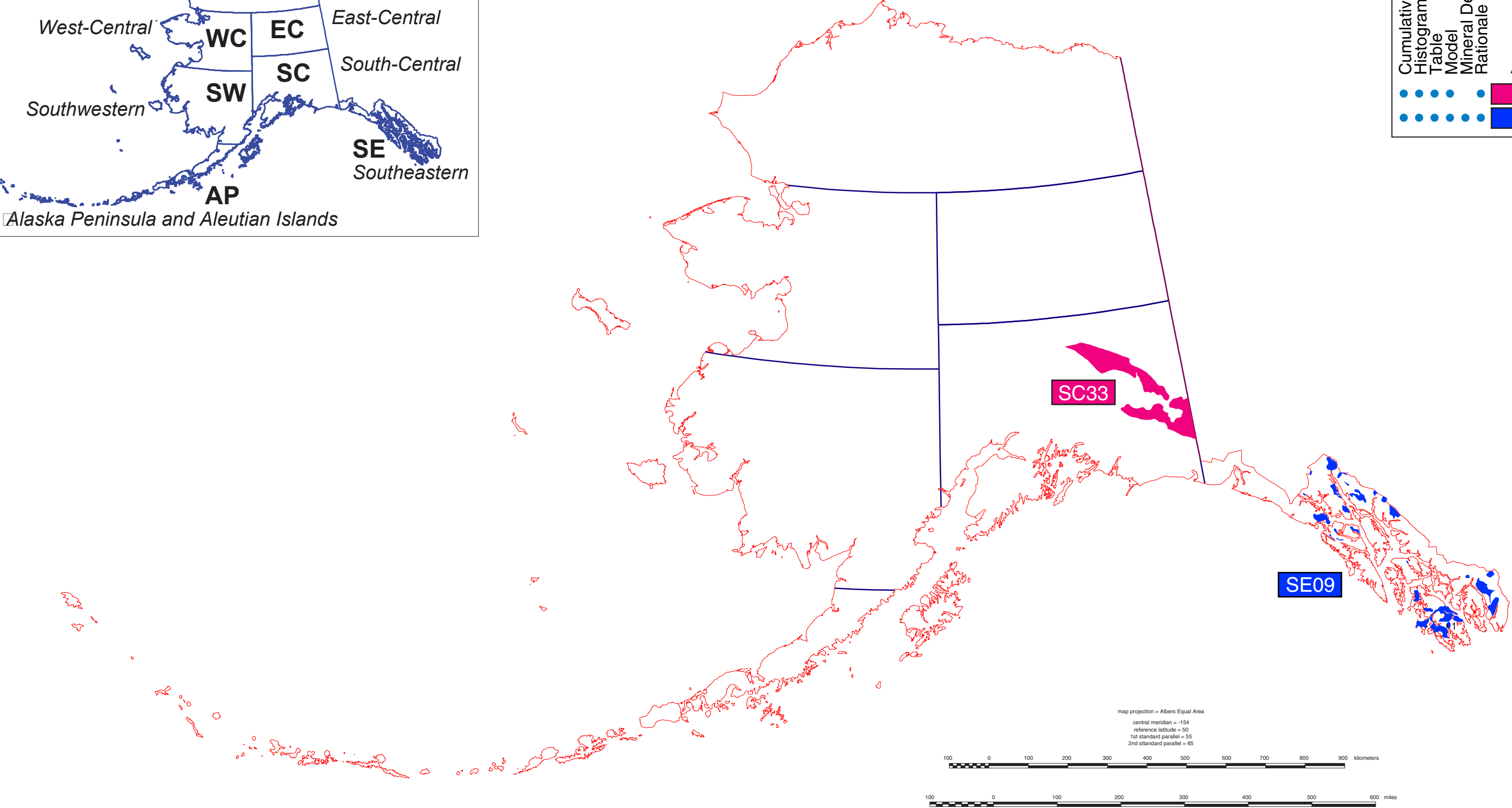
Mineral Deposits

Rationale

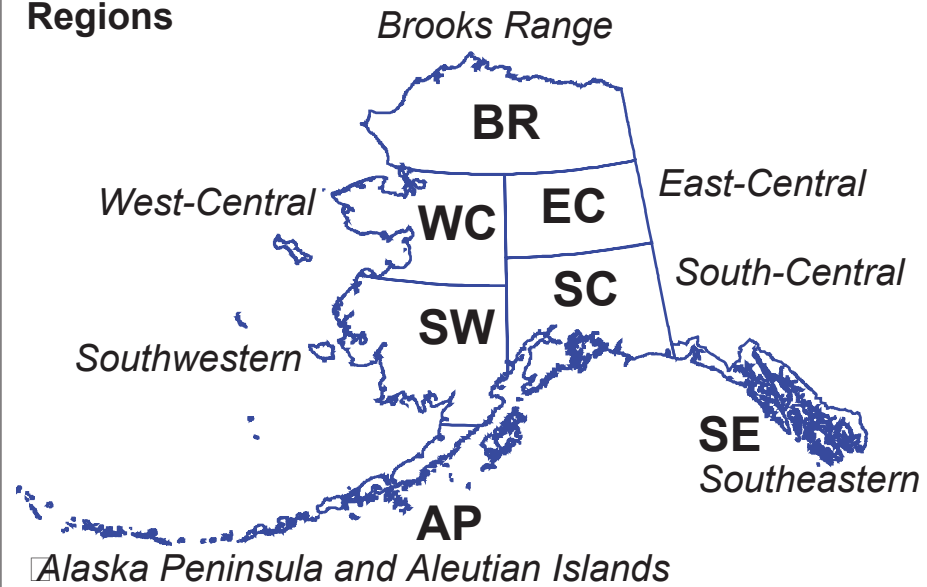
AKSK3

SC33

SE09

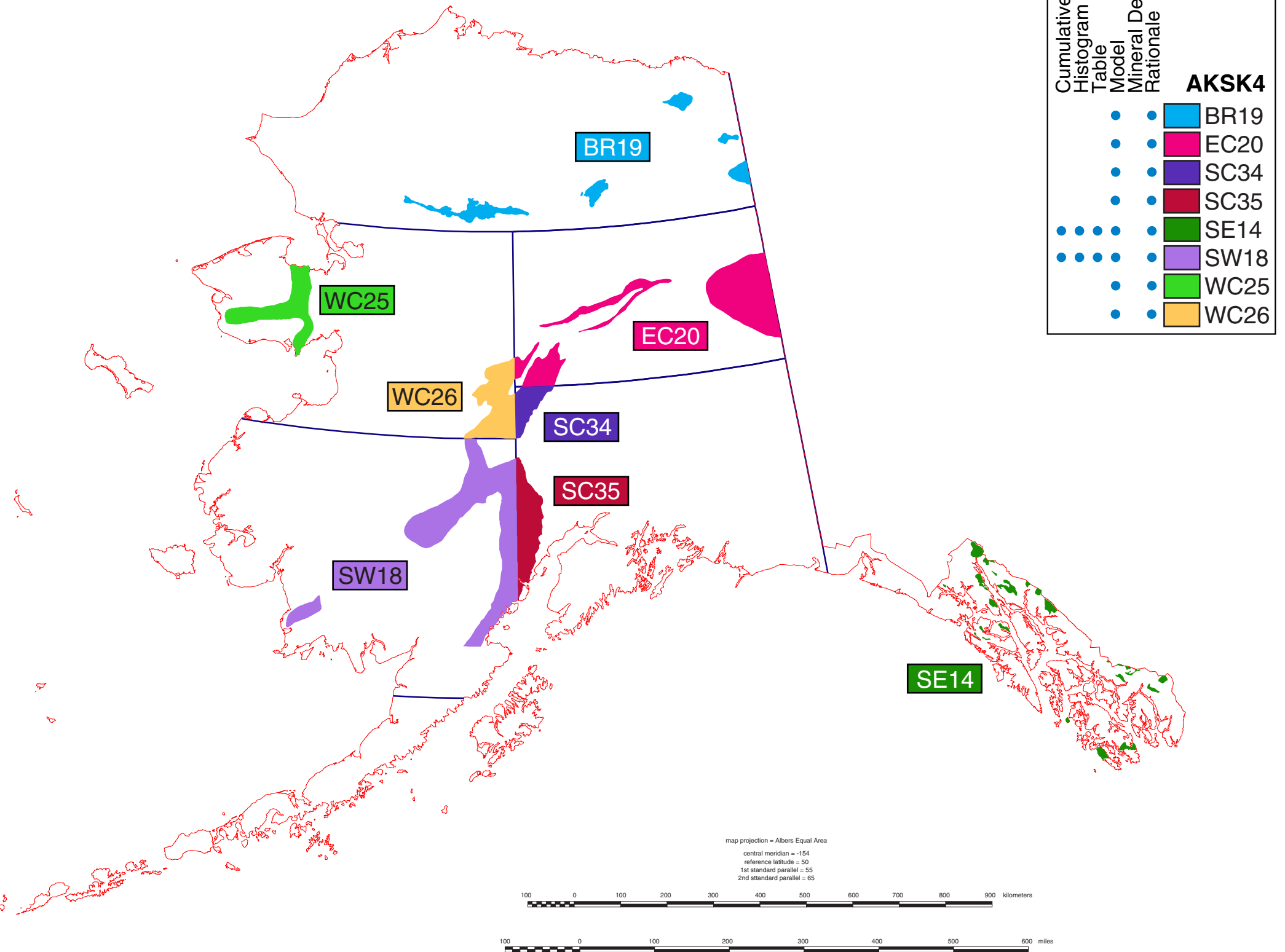


Assessment Regions



USGS National Mineral Resource Assessment

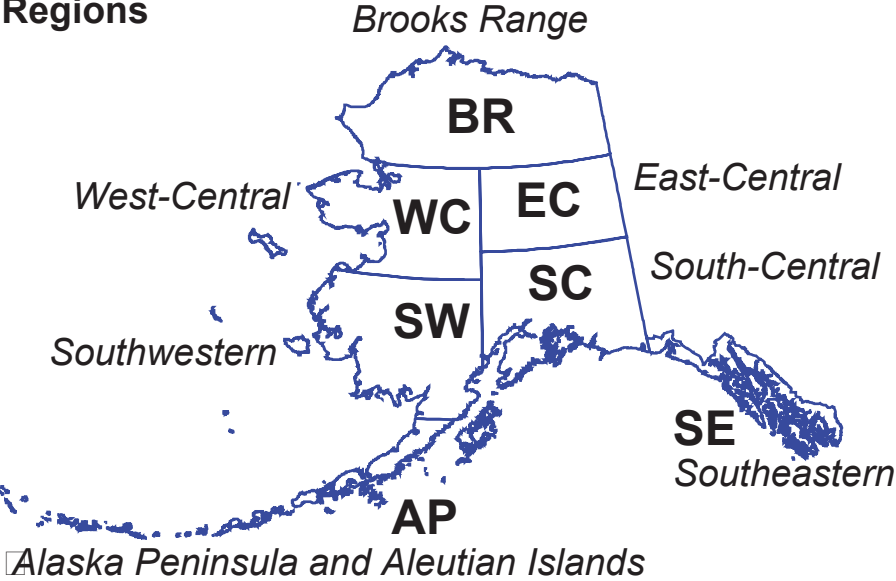
AKSK4: Cu-(Au) Skarn IV



USGS National Mineral Resource Assessment

AKSS: Sandstone Hosted Pb-Zn

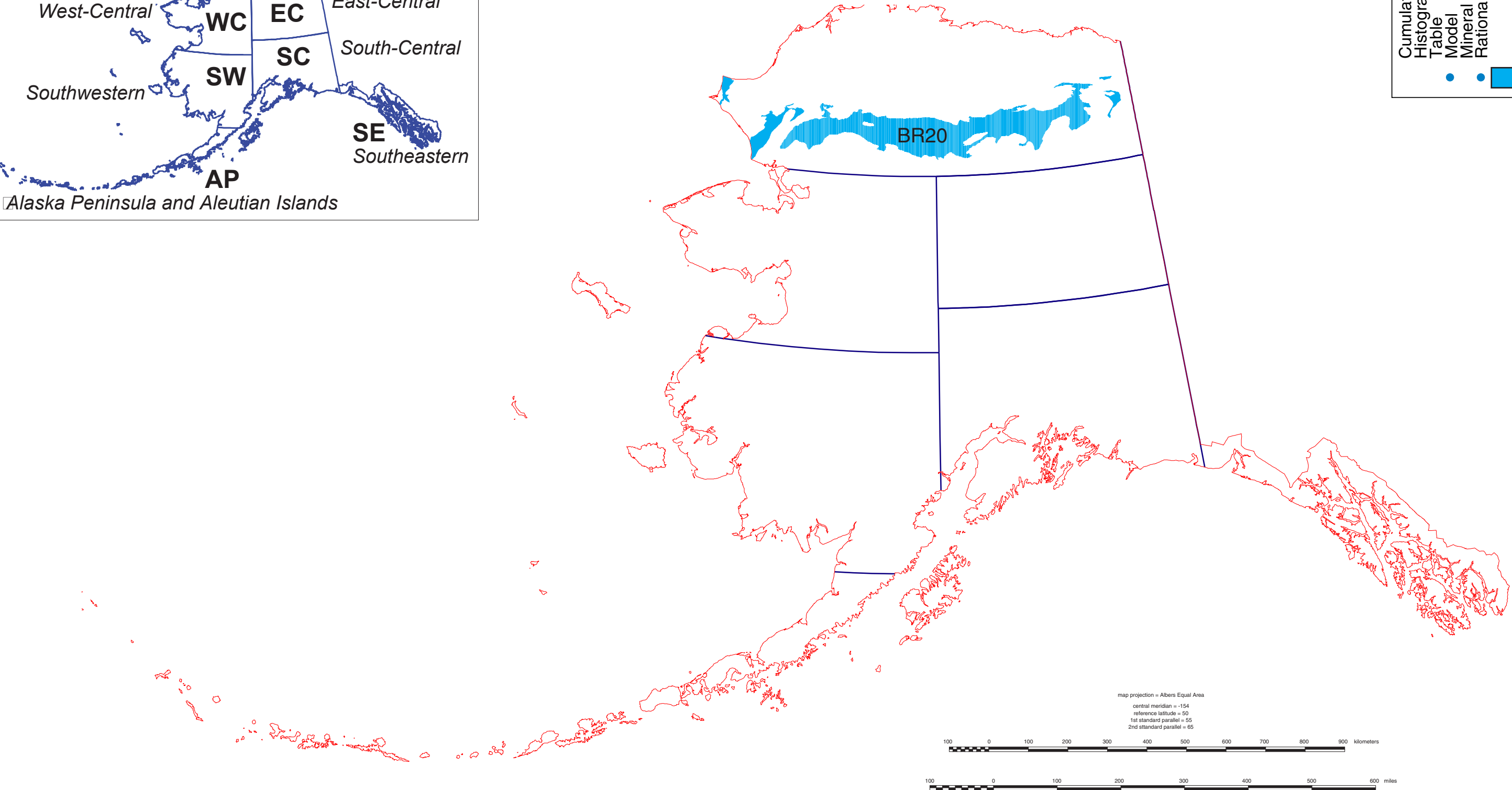
Assessment Regions



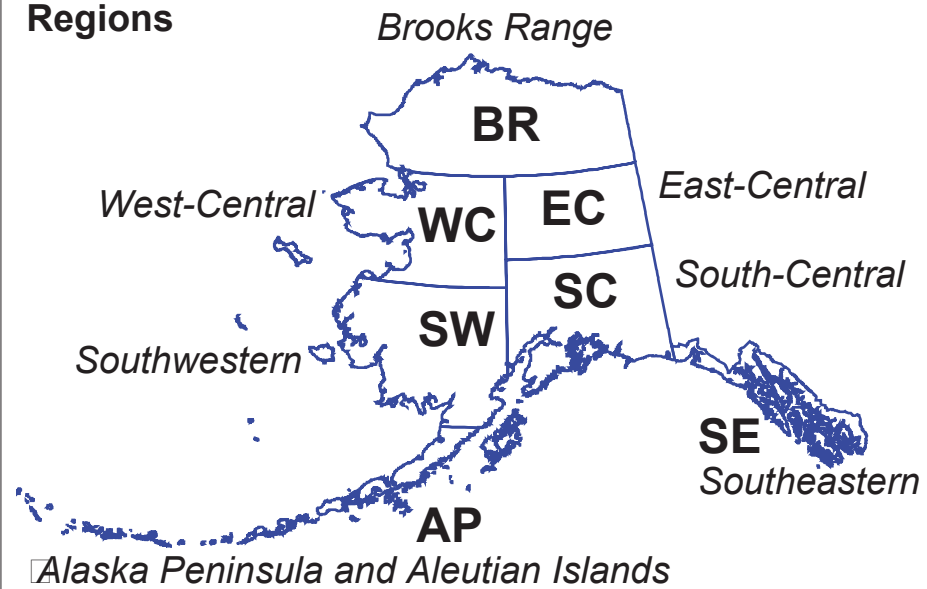
Cumulative Distribution
Histogram
Table
Model
Mineral Deposits
Rationale

AKSS

BR20

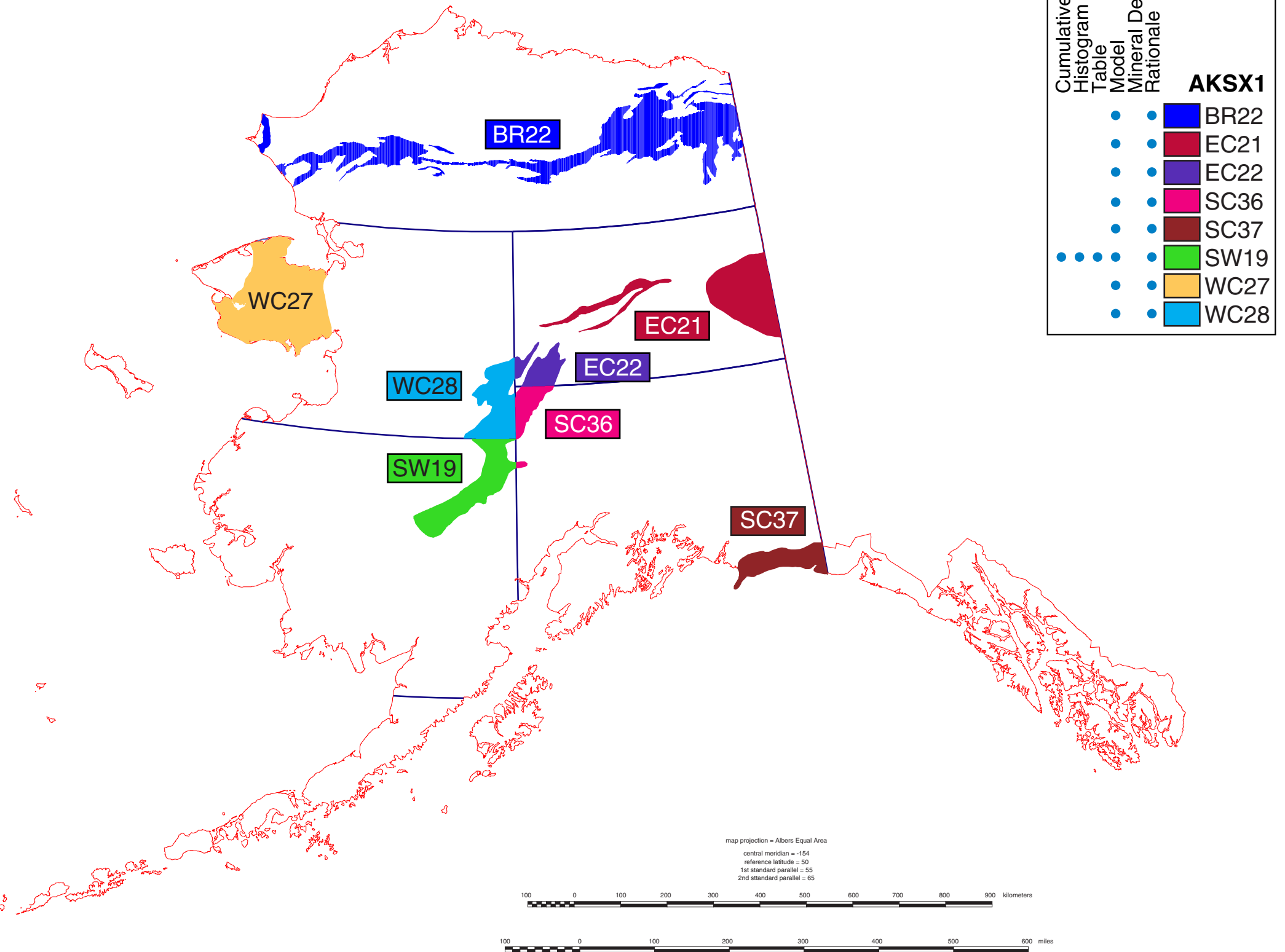


Assessment Regions



USGS National Mineral Resource Assessment

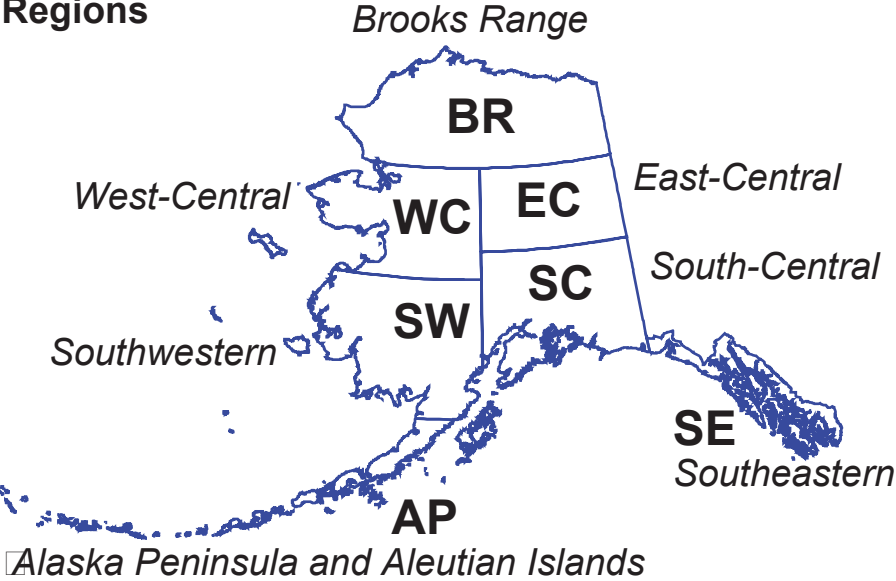
AKSX1: Sedimentary-Exhalative Zn-Pb I



USGS National Mineral Resource Assessment

AKSX2: Sedimentary-Exhalative Zn-Pb II

Assessment Regions



Cumulative Distribution

Histogram

Table

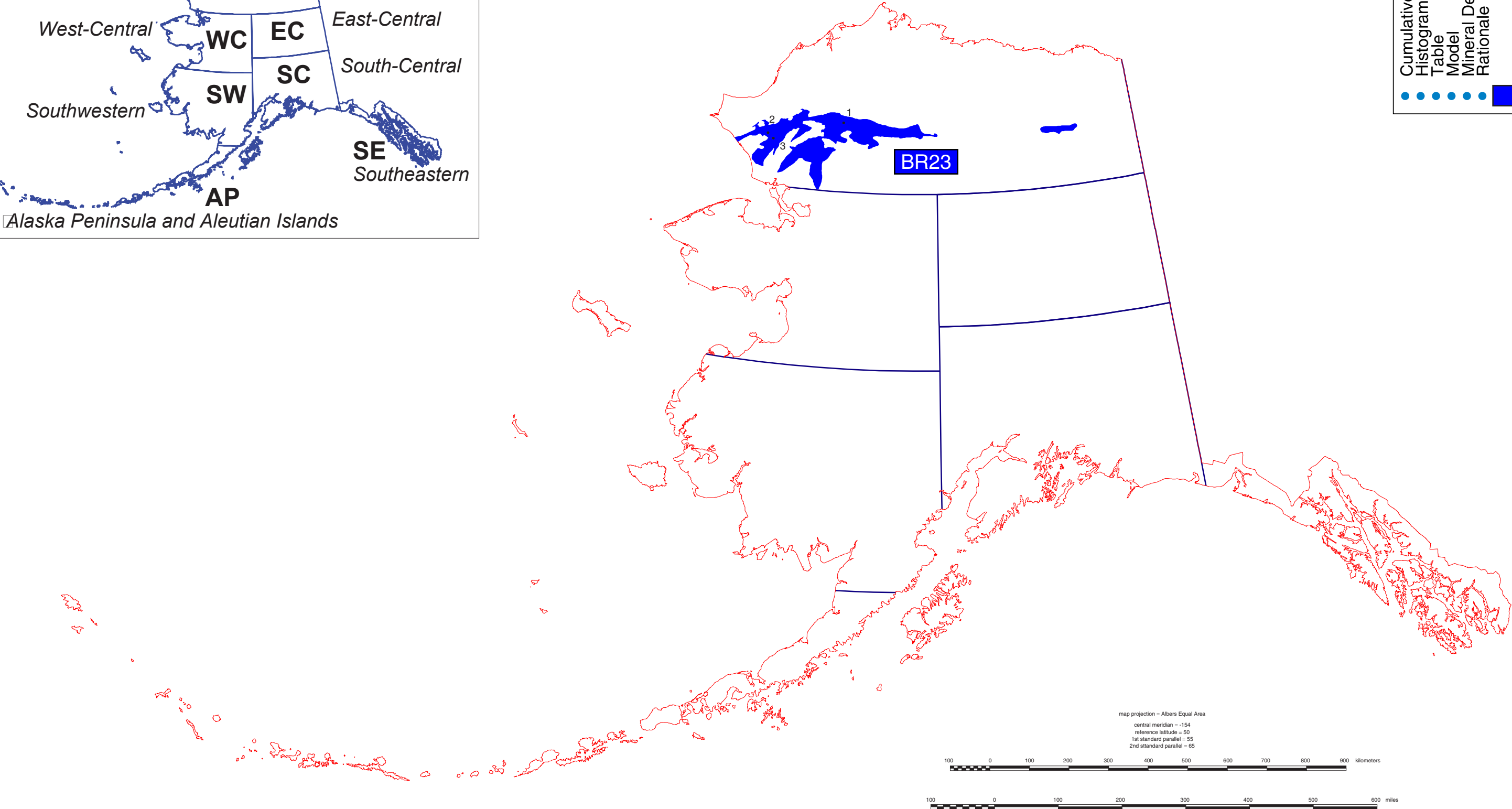
Model

Mineral Deposits

Rationale

AKSX2

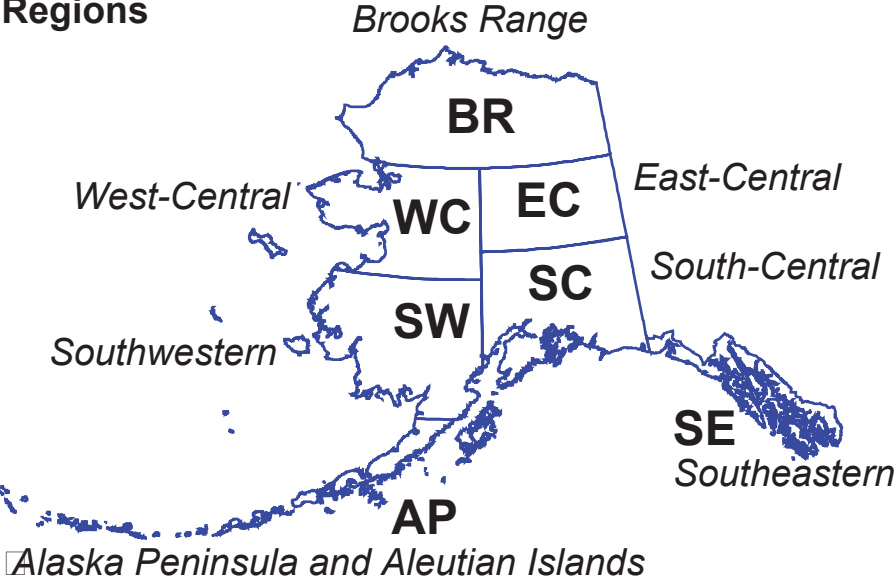
BR23



USGS National Mineral Resource Assessment

AKSX3: Sedimentary-Exhalative Zn-Pb III

Assessment Regions



Cumulative Distribution

Histogram

Table

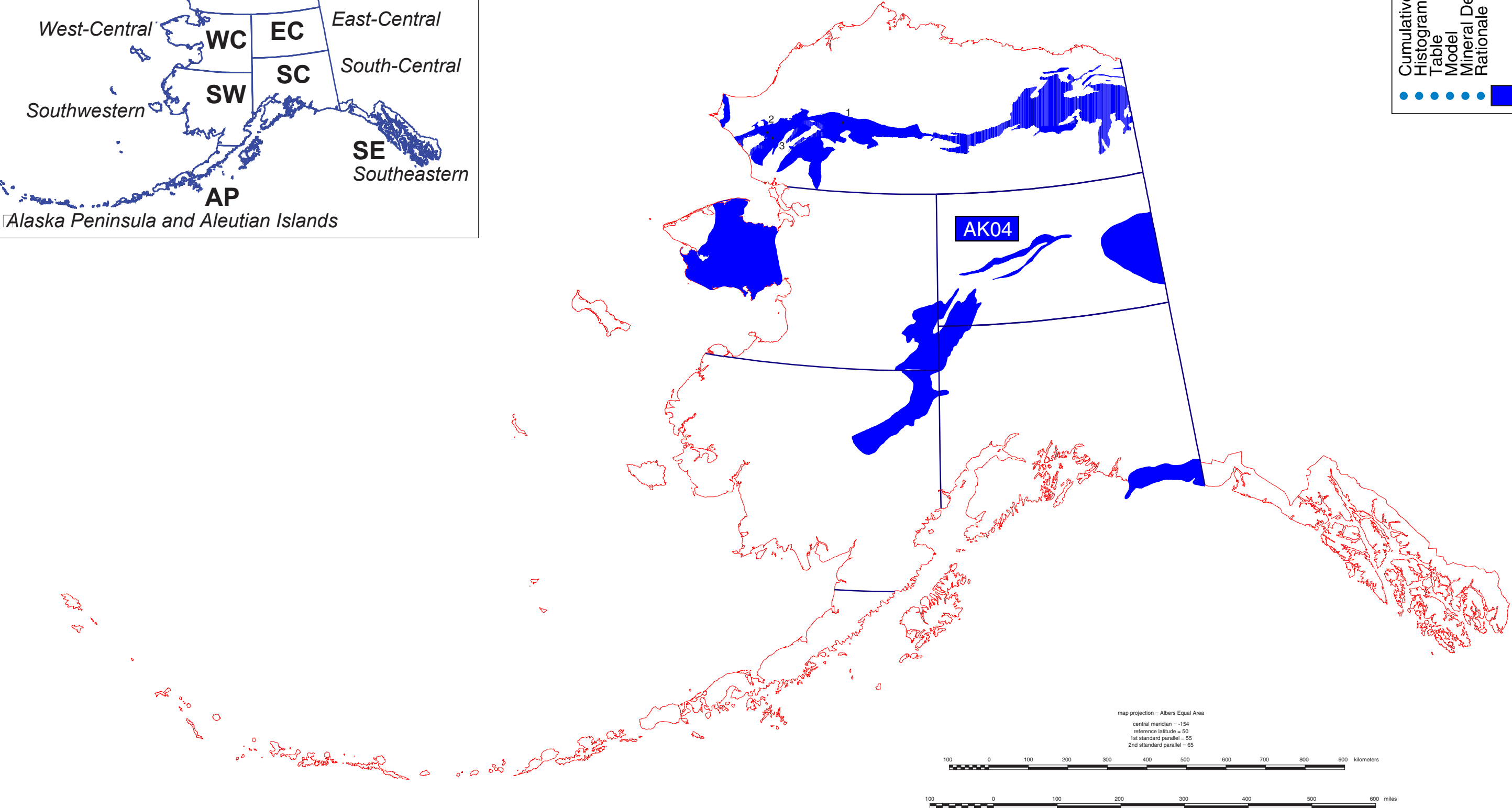
Model

Mineral Deposits

Rationale

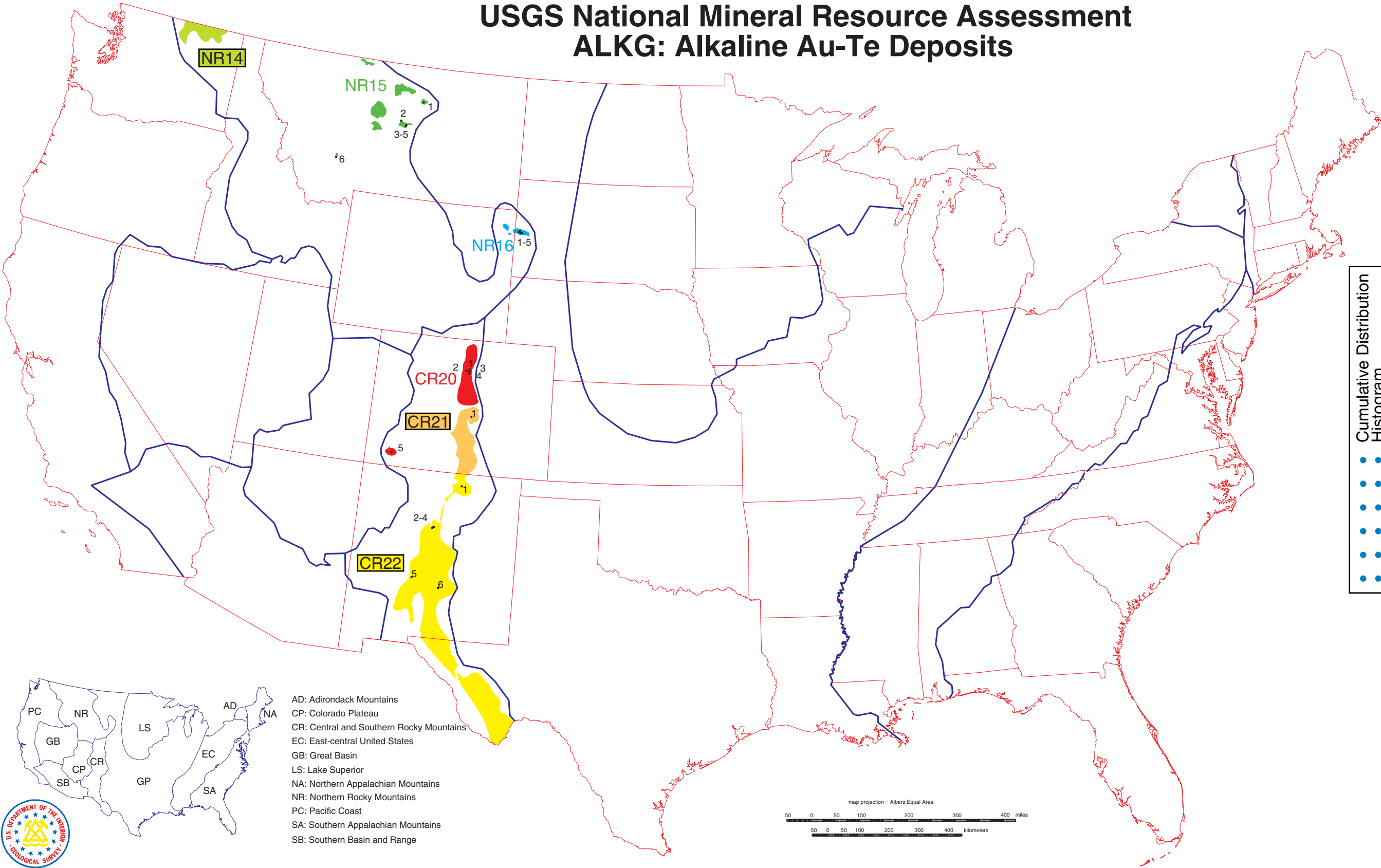
AKSX3

AK04

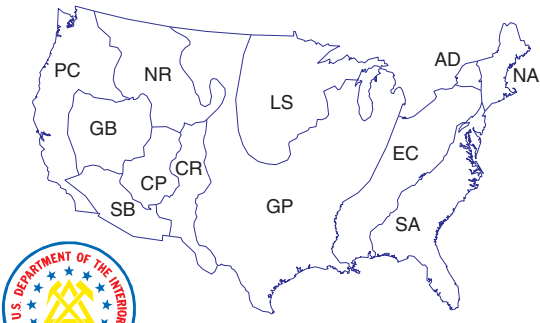


USGS National Mineral Resource Assessment

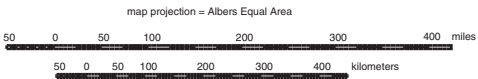
ALKG: Alkaline Au-Te Deposits



Cumulative Distribution	ALKG
Histogram	CR20
Table	CR21
Model	CR22
Mineral Deposits	NR14
Rationale	NR15
	NR16

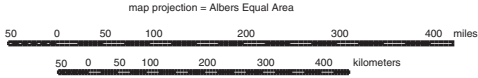
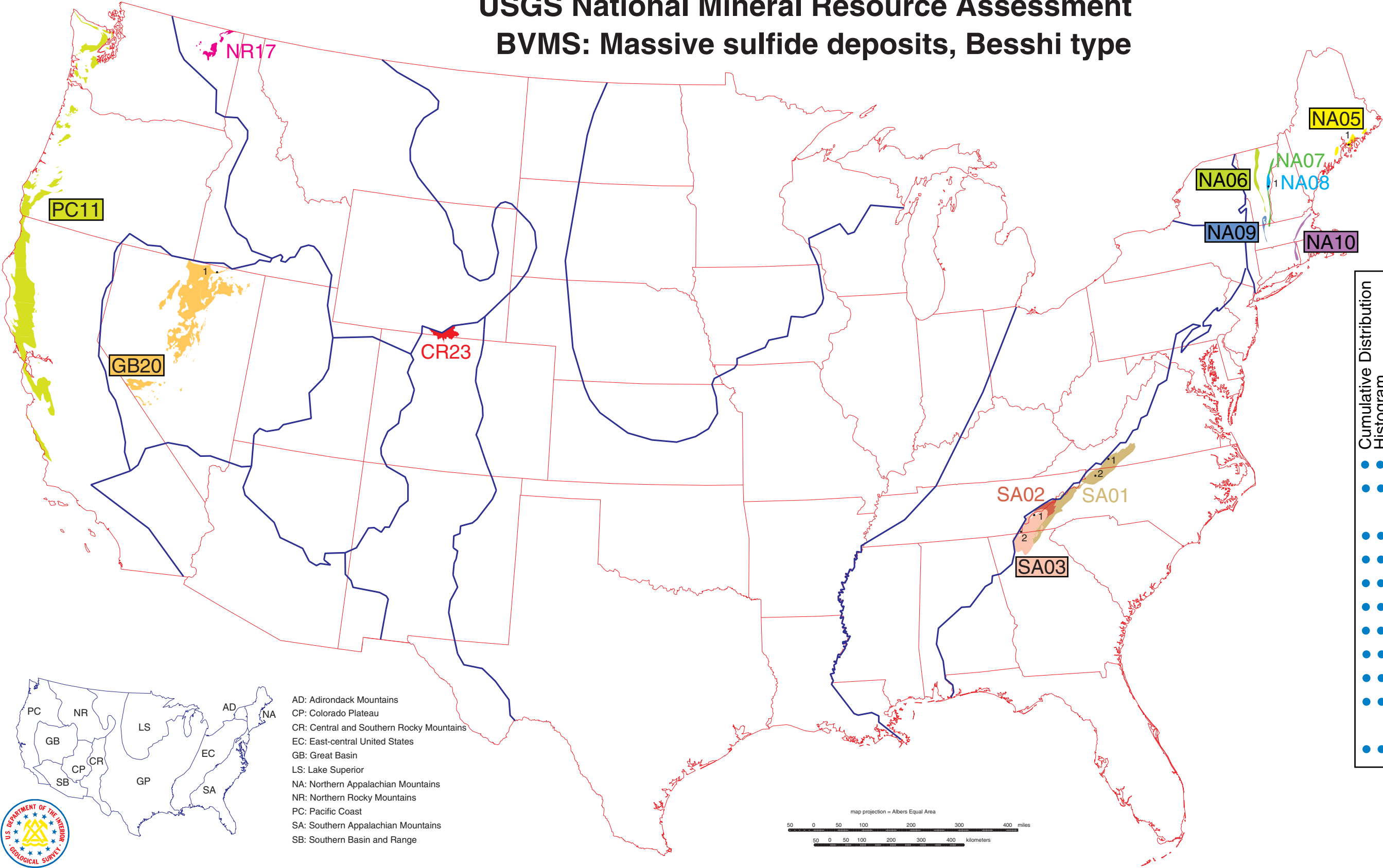


AD: Adirondack Mountains
CP: Colorado Plateau
CR: Central and Southern Rocky Mountains
EC: East-central United States
GB: Great Basin
LS: Lake Superior
NA: Northern Appalachian Mountains
NR: Northern Rocky Mountains
PC: Pacific Coast
SA: Southern Appalachian Mountains
SB: Southern Basin and Range



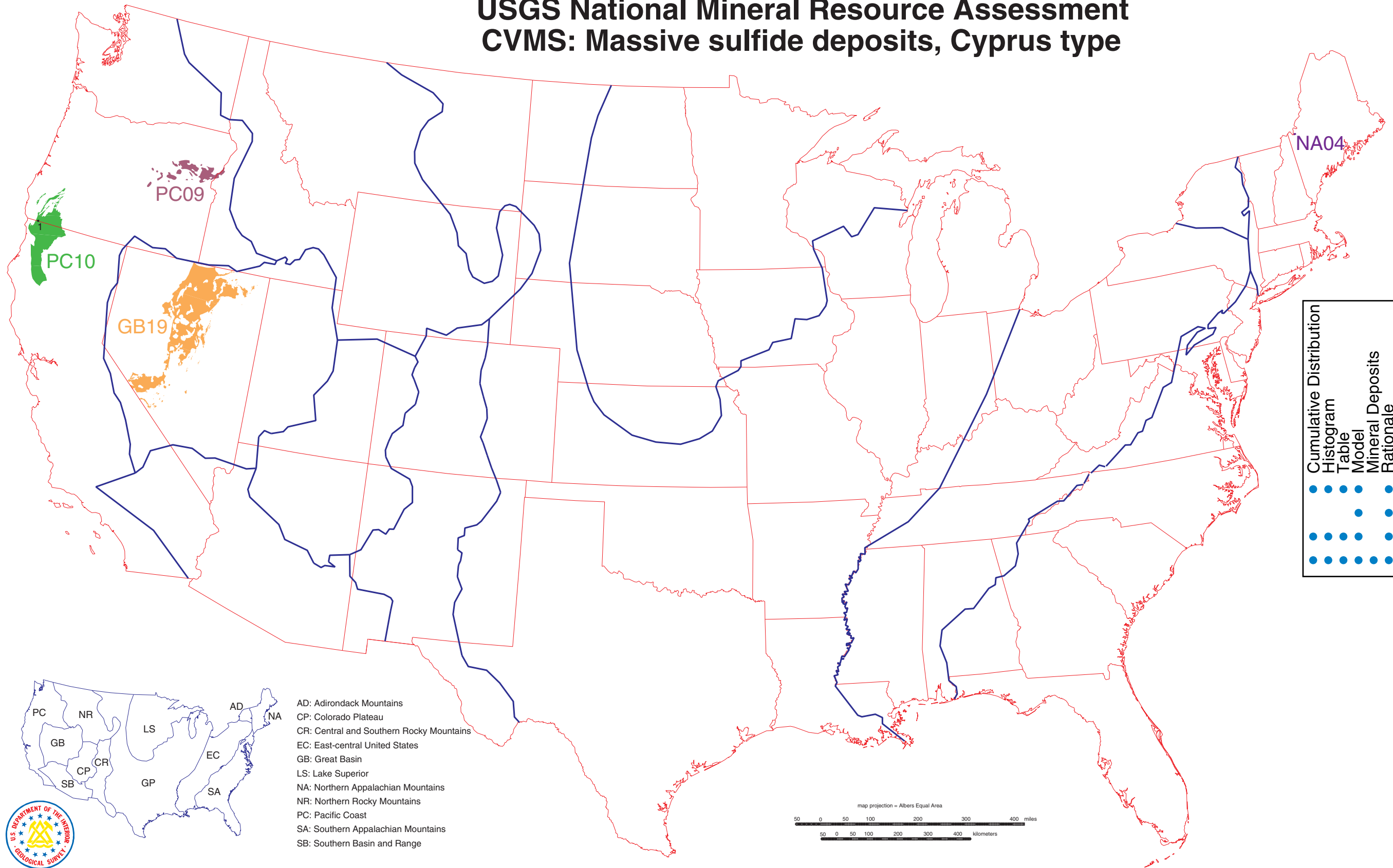
USGS National Mineral Resource Assessment

BVMS: Massive sulfide deposits, Besshi type



USGS National Mineral Resource Assessment

CVMS: Massive sulfide deposits, Cyprus type



Cumulative Distribution

Histogram

Table

Model

Mineral Deposits

Rationale

CVMS

GB19

NA04

PC09

PC10

PC

NR

LS

AD

NA

GB

CP

CR

EC

SB

GP

SA

AD: Adirondack Mountains

CP: Colorado Plateau

CR: Central and Southern Rocky Mountains

EC: East-central United States

GB: Great Basin

LS: Lake Superior

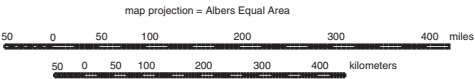
NA: Northern Appalachian Mountains

NR: Northern Rocky Mountains

PC: Pacific Coast

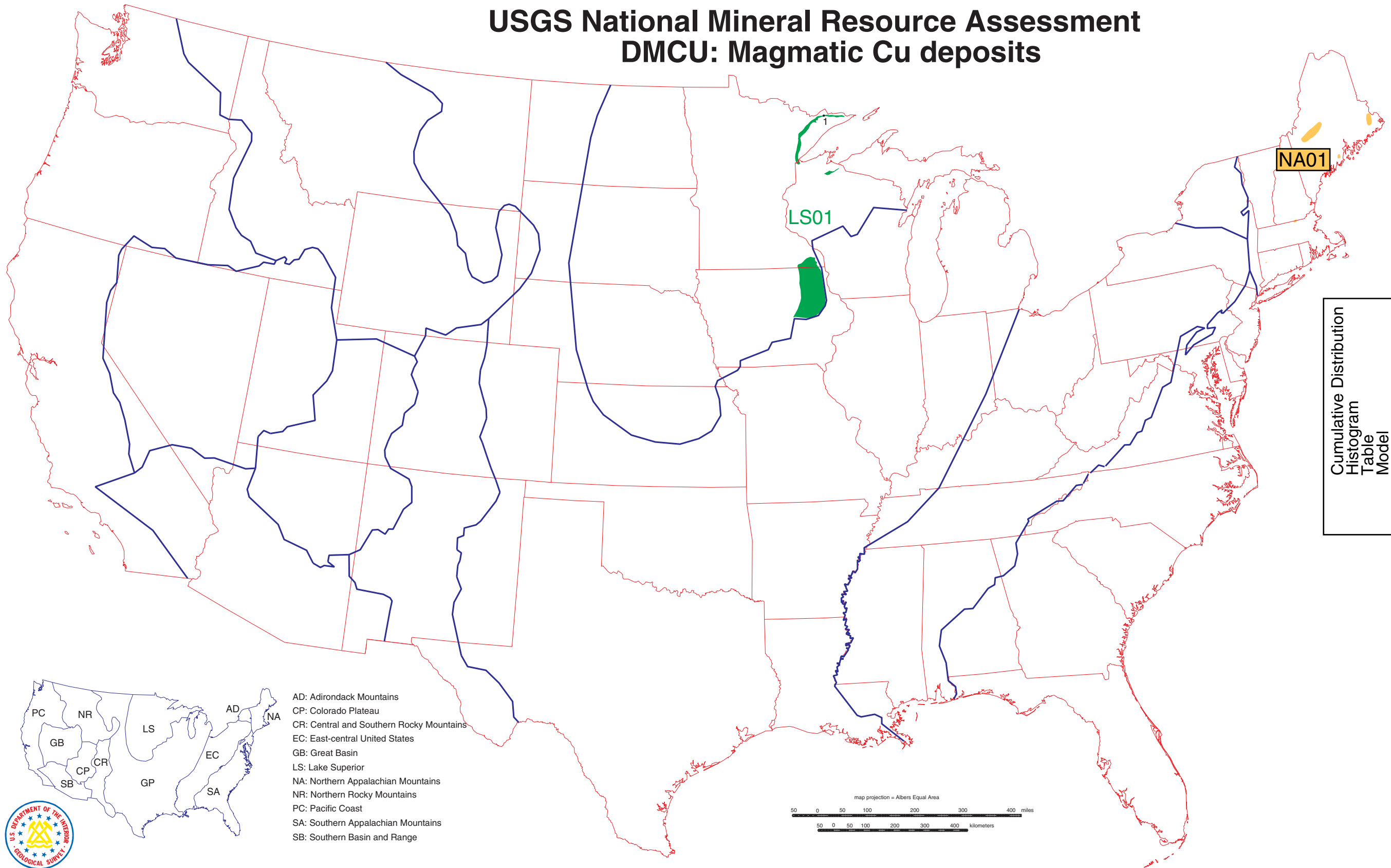
SA: Southern Appalachian Mountains

SB: Southern Basin and Range



USGS National Mineral Resource Assessment

DMCU: Magmatic Cu deposits

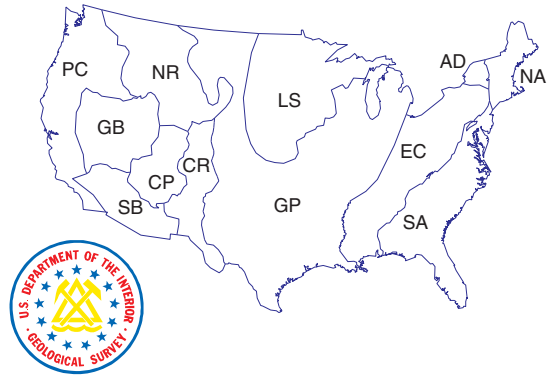


Cumulative Distribution
Histogram
Table
Model
Mineral Deposits
Rationale

DMCU

LS01

NA01

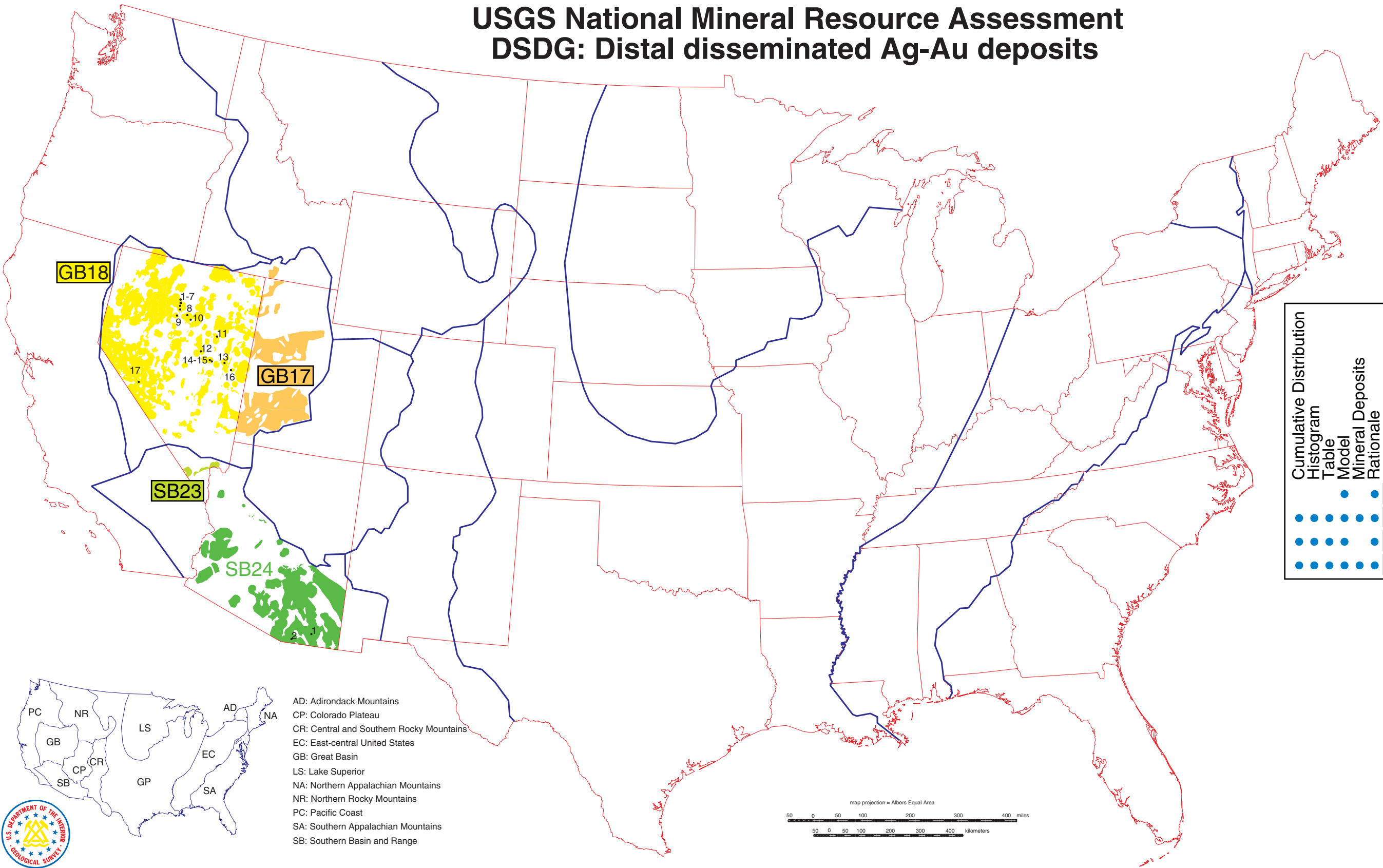


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USGS National Mineral Resource Assessment

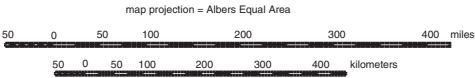
DSDG: Distal disseminated Ag-Au deposits



Cumulative Distribution	Histogram	Table	Model	Mineral Deposits	Rationale	DSDG
•	•	•	•	•	•	GB17
•	•	•	•	•	•	GB18
•	•	•	•	•	•	SB23
•	•	•	•	•	•	SB24

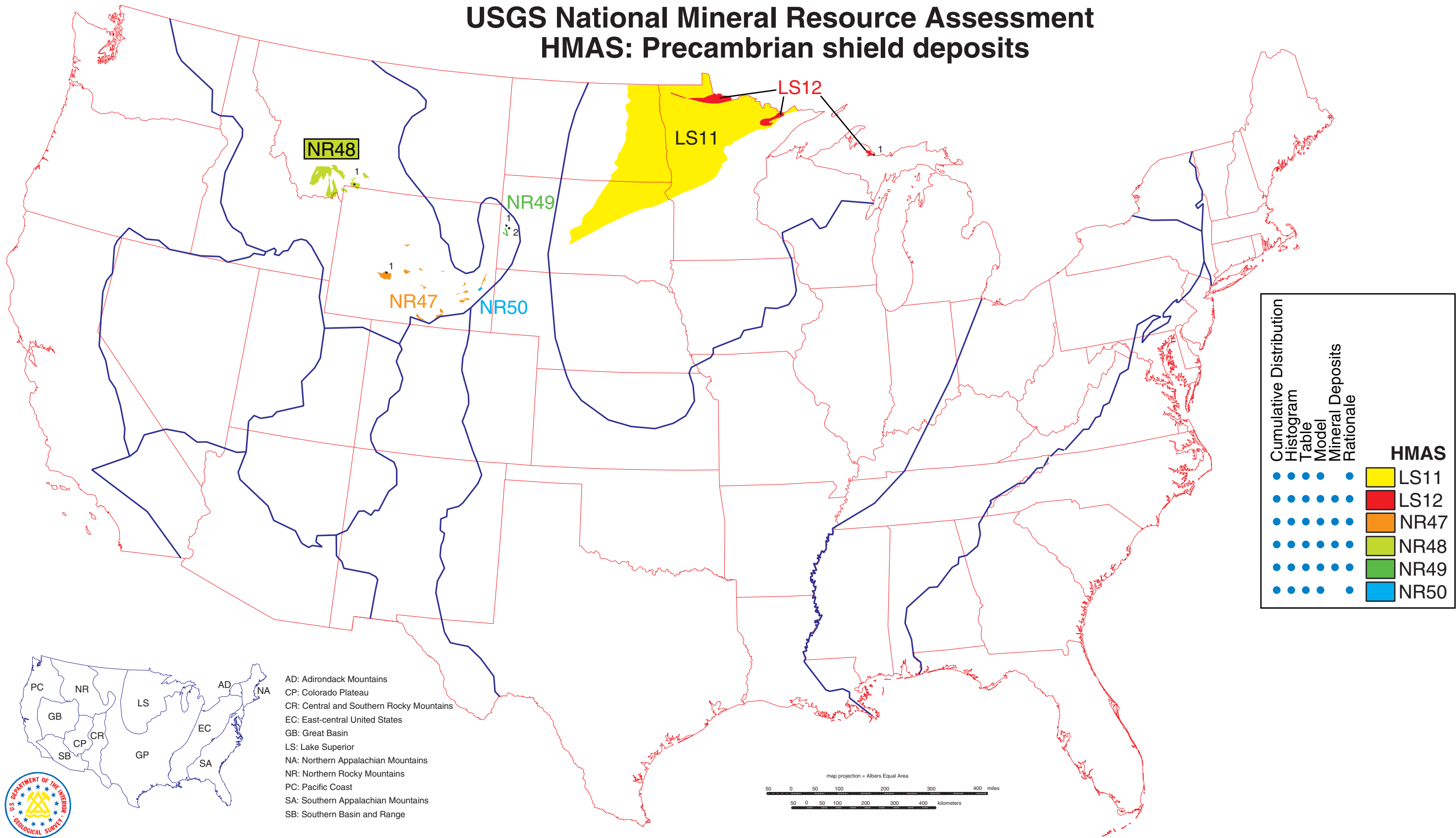
PC NR LS AD NA
GB CP CR EC
SB GP SA

AD: Adirondack Mountains
CP: Colorado Plateau
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EC: East-central United States
GB: Great Basin
LS: Lake Superior
NA: Northern Appalachian Mountains
NR: Northern Rocky Mountains
PC: Pacific Coast
SA: Southern Appalachian Mountains
SB: Southern Basin and Range



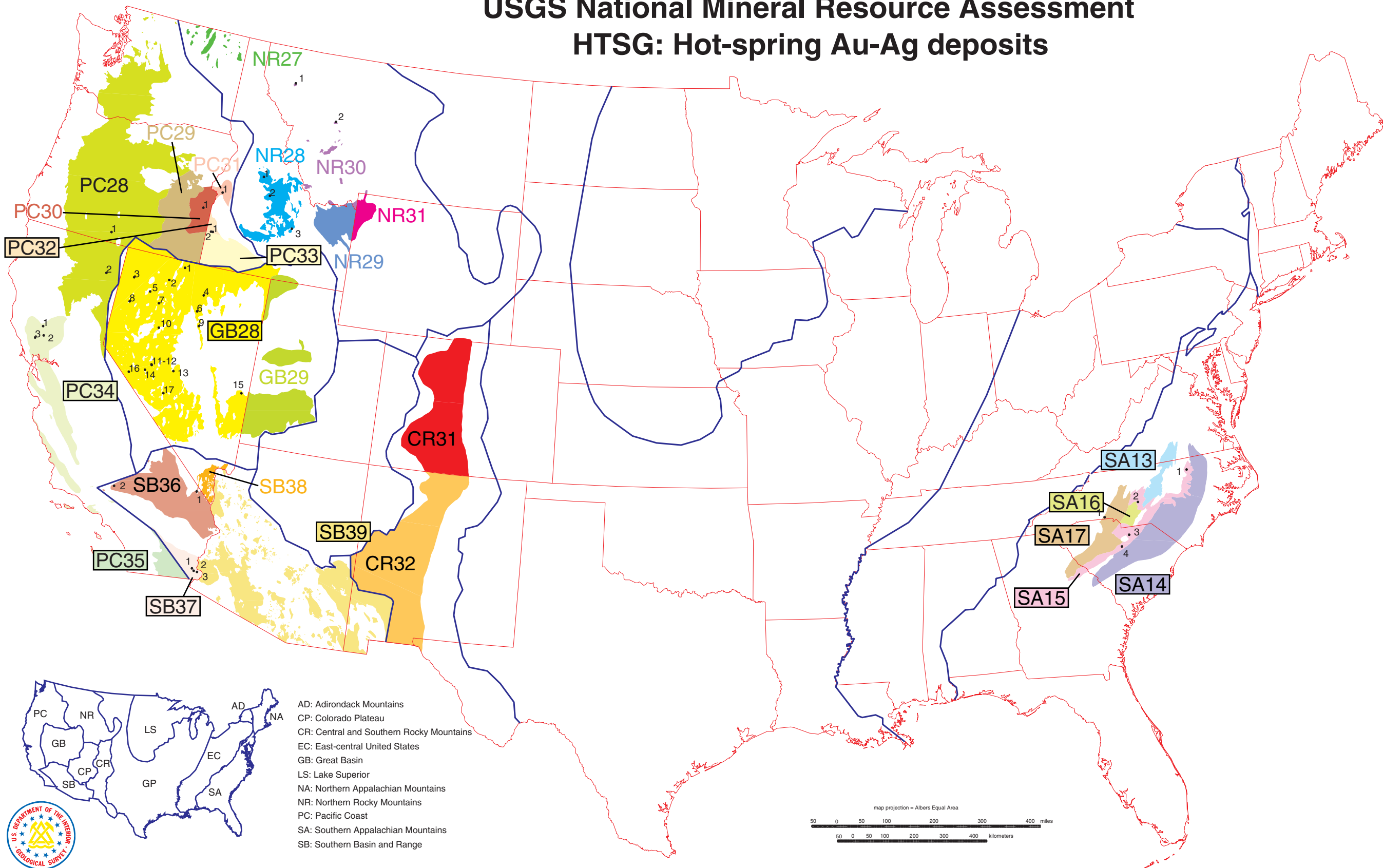
USGS National Mineral Resource Assessment

HMAS: Precambrian shield deposits



USGS National Mineral Resource Assessment

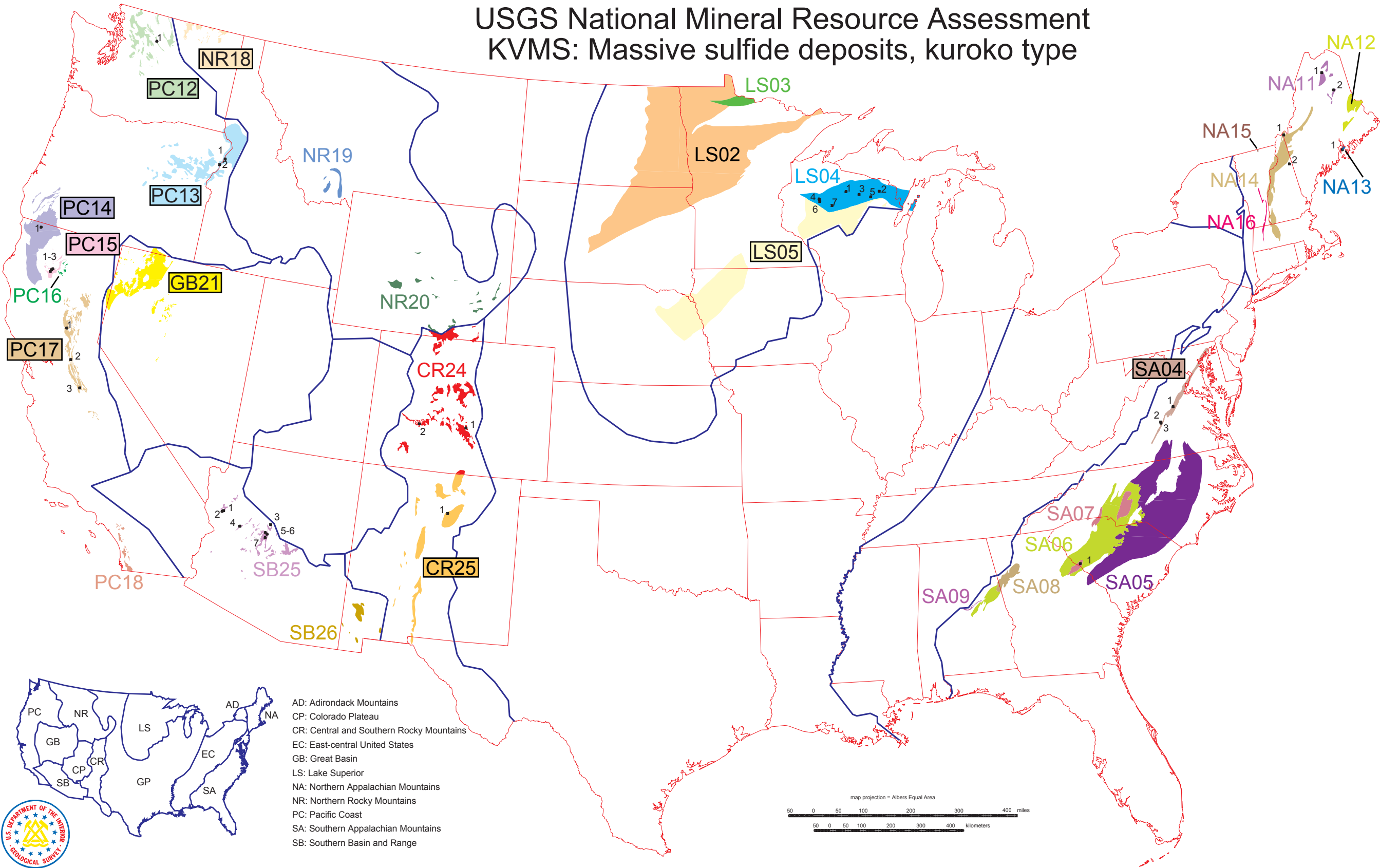
HTSG: Hot-spring Au-Ag deposits



Cumulative Distribution Histogram Table	Model	Mineral Deposits	Rationale	HTSG
•••••	•	•	•	CR31
•••••	•	•	•	CR32
•••••	•	•	•	GB28
•••••	•	•	•	GB29
•••••	•	•	•	NR27
•••••	•	•	•	NR28
•••••	•	•	•	NR29
•••••	•	•	•	NR30
•••••	•	•	•	NR31
•••••	•	•	•	PC28
•••••	•	•	•	PC29
•••••	•	•	•	PC30
•••••	•	•	•	PC31
•••••	•	•	•	PC32
•••••	•	•	•	PC33
•••••	•	•	•	PC34
•••••	•	•	•	PC35
•••••	•	•	•	SA13
•••••	•	•	•	SA14
•••••	•	•	•	SA15
•••••	•	•	•	SA16
•••••	•	•	•	SA17
•••••	•	•	•	SB36
•••••	•	•	•	SB37
•••••	•	•	•	SB38
•••••	•	•	•	SB39

USGS National Mineral Resource Assessment

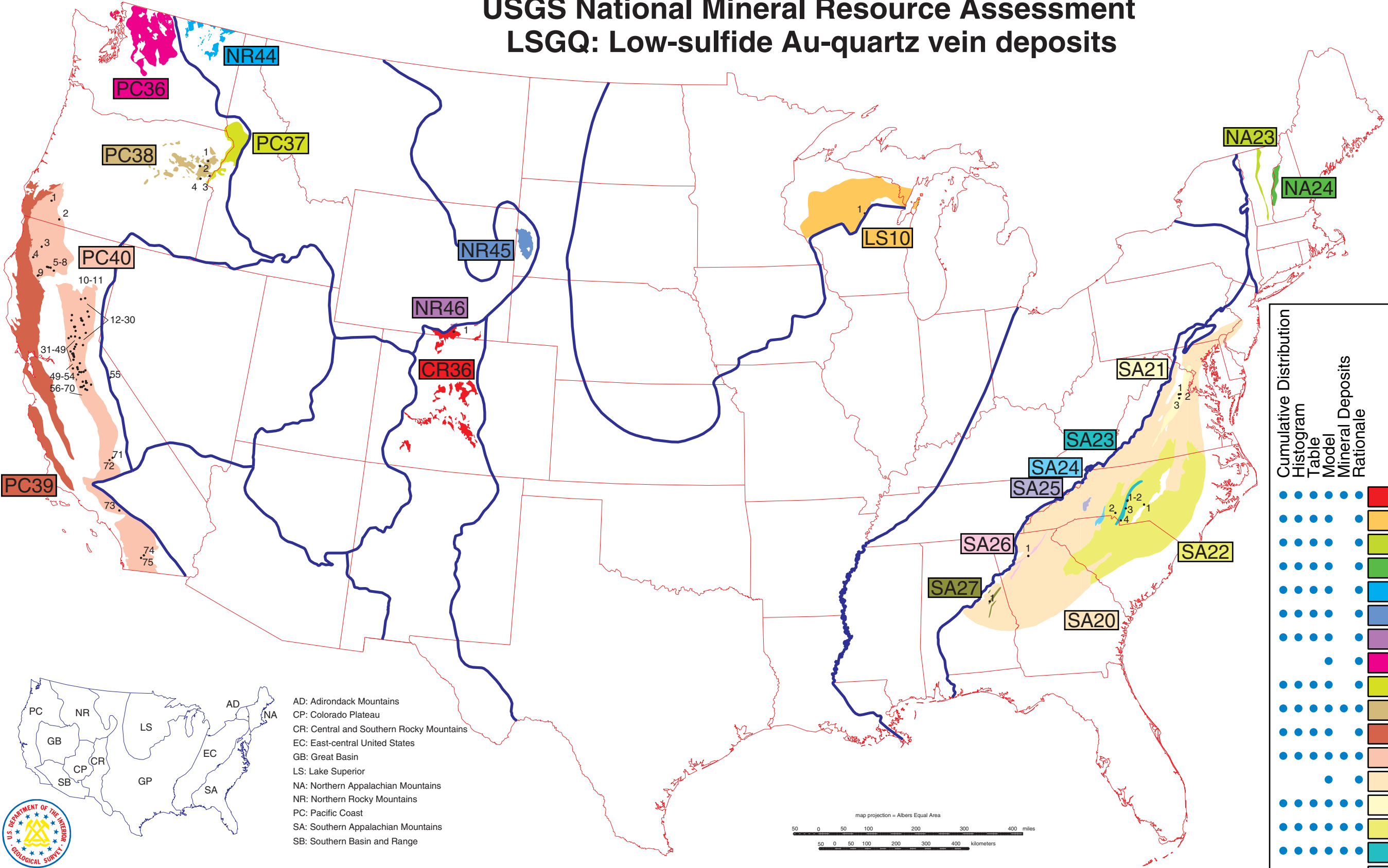
KVMS: Massive sulfide deposits, kuroko type



Cumulative Distribution	Histogram	Table	Model	Mineral Deposits	Rationale	KVMS
•••••	•••••	•••••	•••••	•••••	•••••	CR24
•••••	•••••	•••••	•••••	•••••	•••••	CR25
•••••	•••••	•••••	•••••	•••••	•••••	GB21
•••••	•••••	•••••	•••••	•••••	•••••	LS02
•••••	•••••	•••••	•••••	•••••	•••••	LS03
•••••	•••••	•••••	•••••	•••••	•••••	LS04
•••••	•••••	•••••	•••••	•••••	•••••	LS05
•••••	•••••	•••••	•••••	•••••	•••••	NA11
•••••	•••••	•••••	•••••	•••••	•••••	NA12
•••••	•••••	•••••	•••••	•••••	•••••	NA13
•••••	•••••	•••••	•••••	•••••	•••••	NA14
•••••	•••••	•••••	•••••	•••••	•••••	NA15
•••••	•••••	•••••	•••••	•••••	•••••	NA16
•••••	•••••	•••••	•••••	•••••	•••••	NR18
•••••	•••••	•••••	•••••	•••••	•••••	NR19
•••••	•••••	•••••	•••••	•••••	•••••	NR20
•••••	•••••	•••••	•••••	•••••	•••••	PC12
•••••	•••••	•••••	•••••	•••••	•••••	PC13
•••••	•••••	•••••	•••••	•••••	•••••	PC14
•••••	•••••	•••••	•••••	•••••	•••••	PC15
•••••	•••••	•••••	•••••	•••••	•••••	PC16
•••••	•••••	•••••	•••••	•••••	•••••	PC17
•••••	•••••	•••••	•••••	•••••	•••••	PC18
•••••	•••••	•••••	•••••	•••••	•••••	SA04
•••••	•••••	•••••	•••••	•••••	•••••	SA05
•••••	•••••	•••••	•••••	•••••	•••••	SA06
•••••	•••••	•••••	•••••	•••••	•••••	SA07
•••••	•••••	•••••	•••••	•••••	•••••	SA08
•••••	•••••	•••••	•••••	•••••	•••••	SA09
•••••	•••••	•••••	•••••	•••••	•••••	SB25
•••••	•••••	•••••	•••••	•••••	•••••	SB26

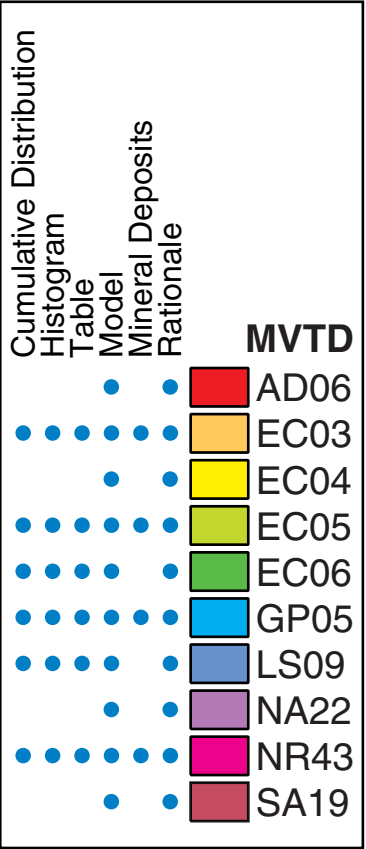
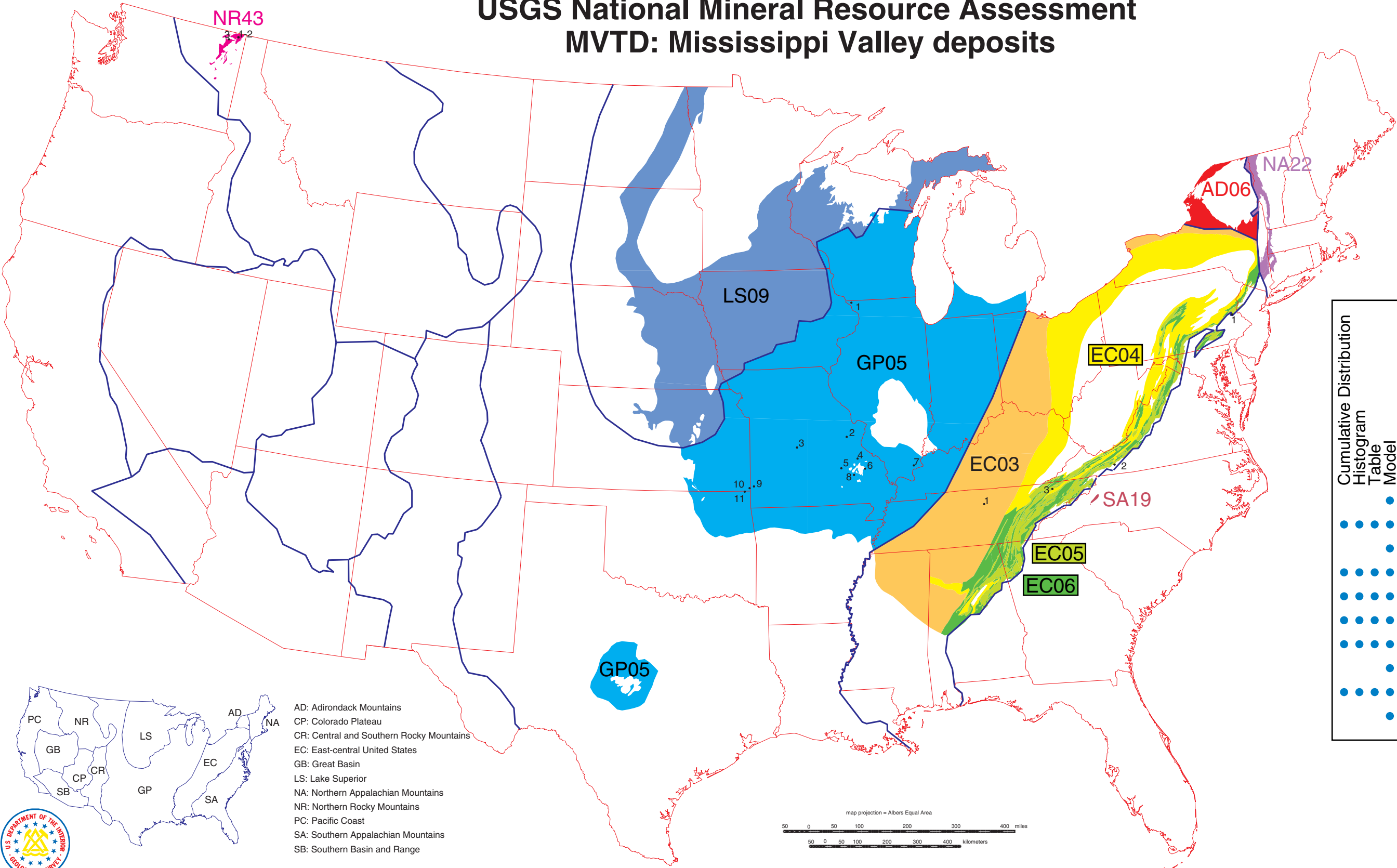
USGS National Mineral Resource Assessment

LSGQ: Low-sulfide Au-quartz vein deposits



USGS National Mineral Resource Assessment

MVTD: Mississippi Valley deposits

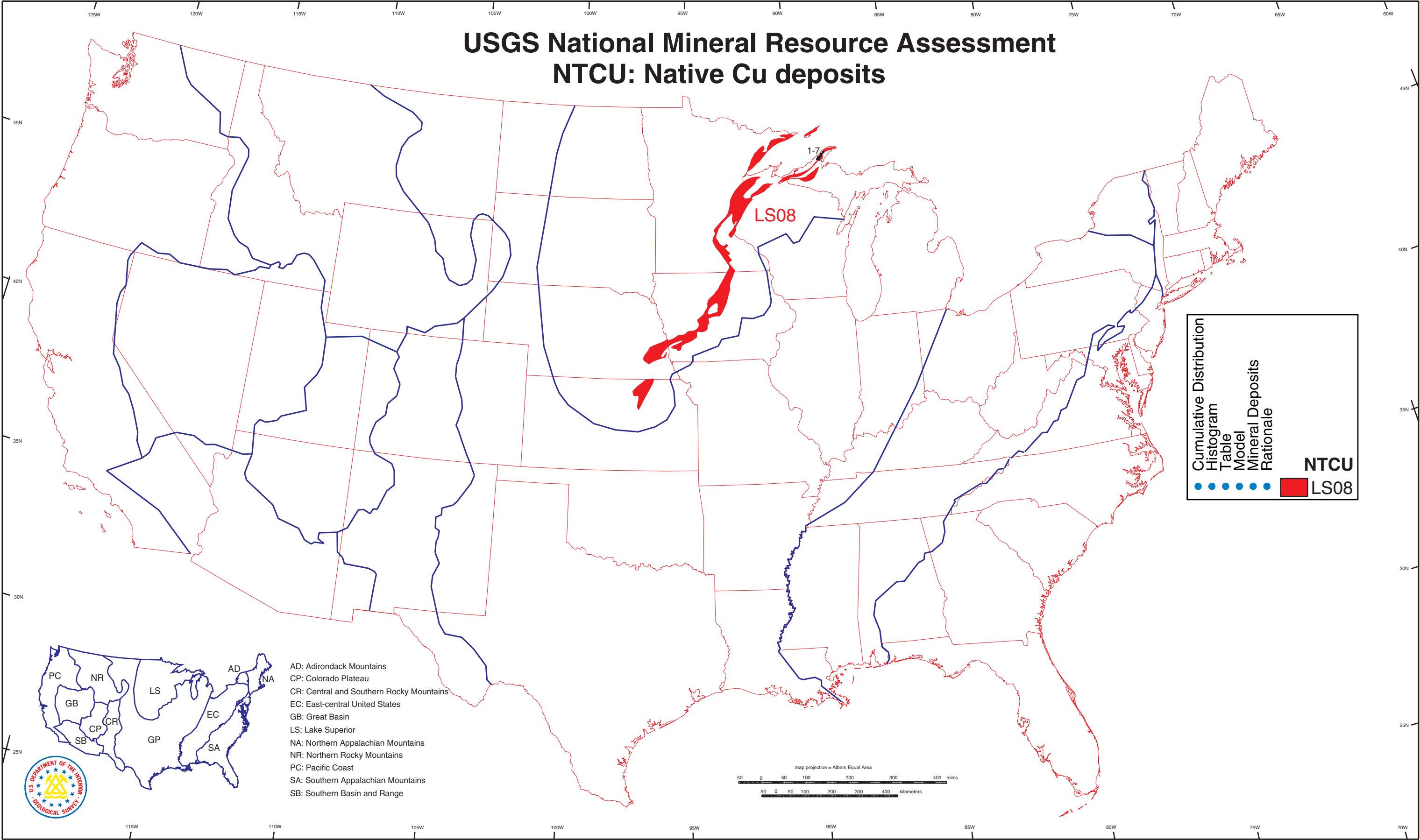


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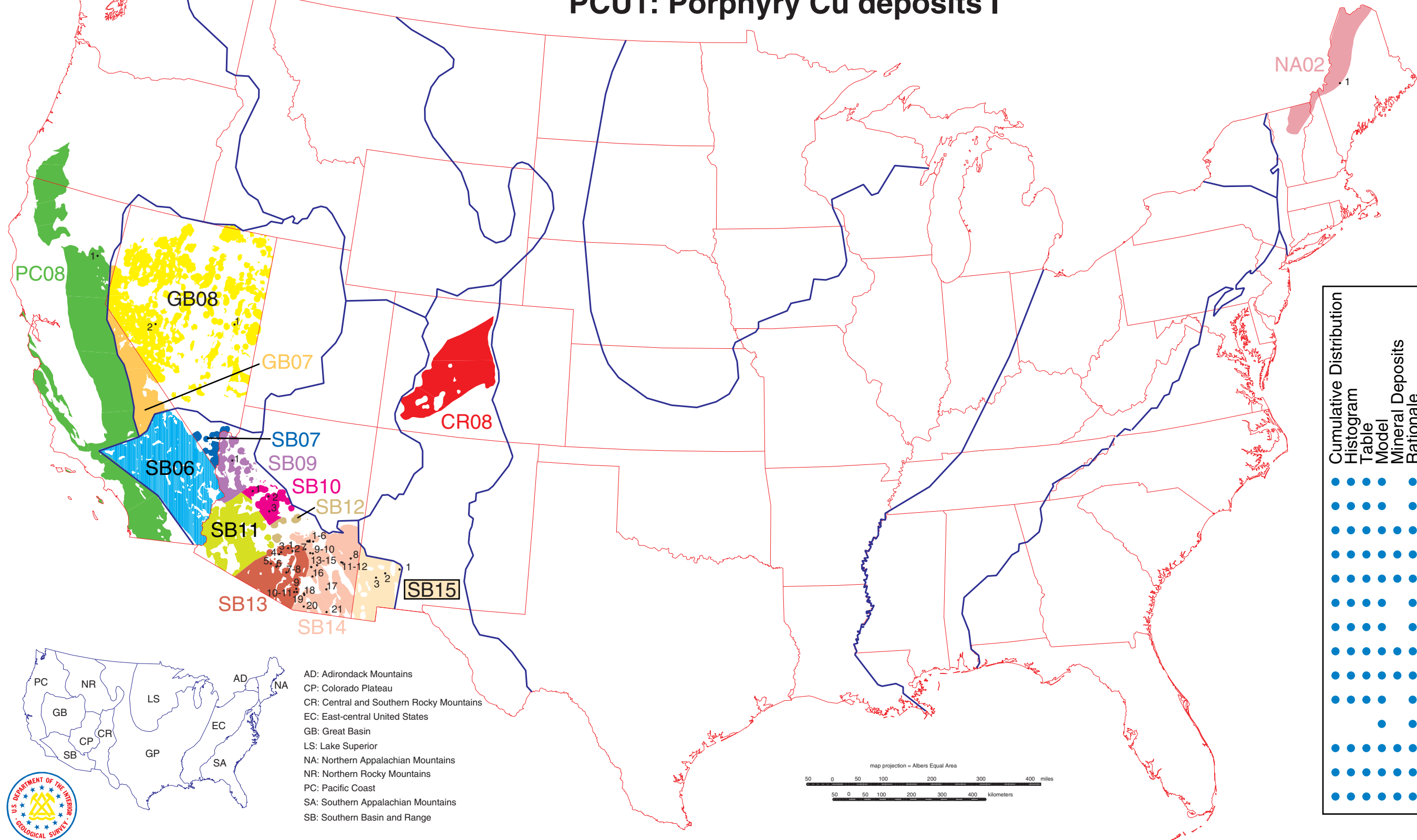
USGS National Mineral Resource Assessment

NTCU: Native Cu deposits



USGS National Mineral Resource Assessment

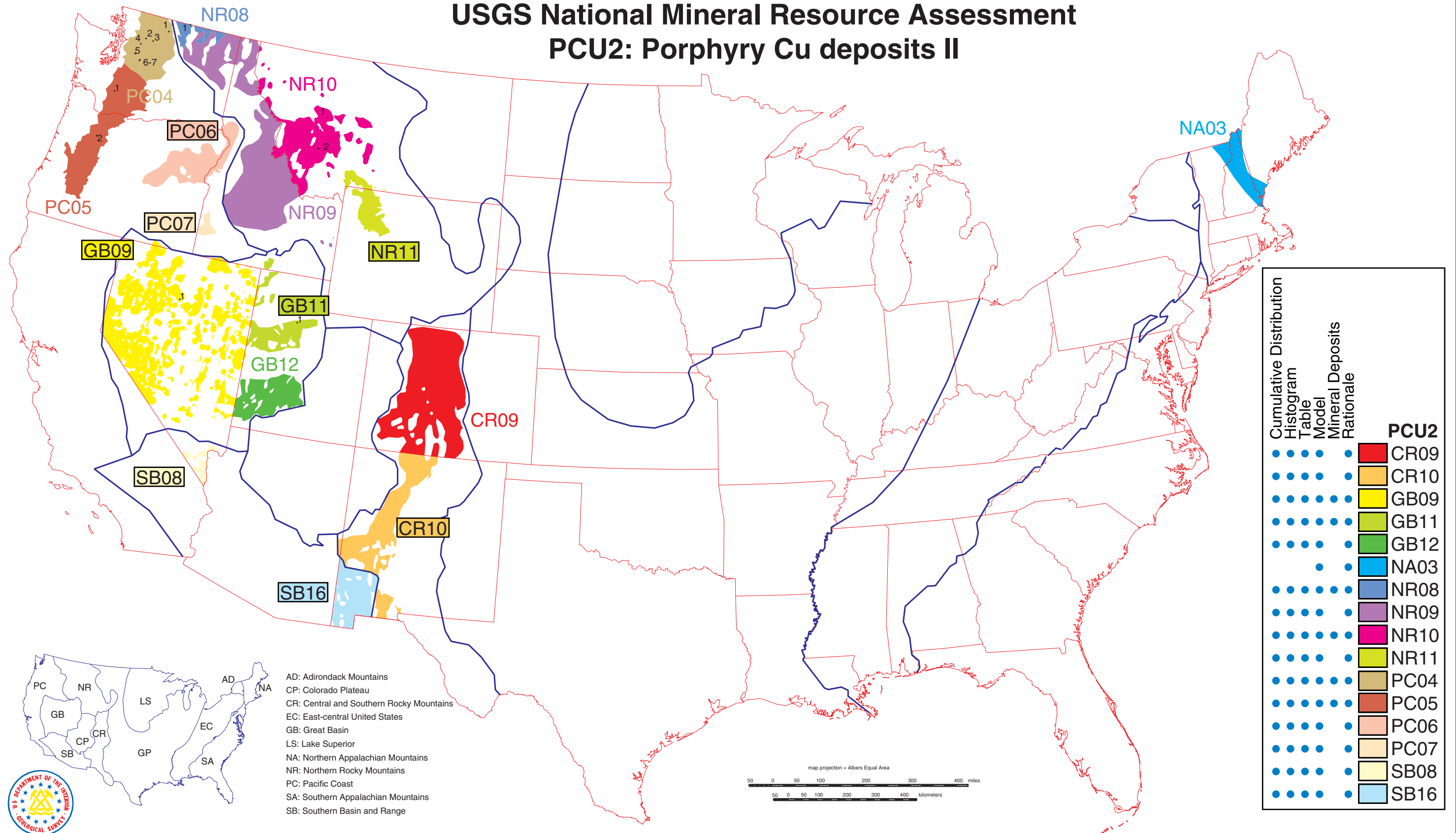
PCU1: Porphyry Cu deposits I



	Cumulative Distribution Histogram	Table Model	Mineral Deposits Rationale		PCU1
●	●	●	●	●	CR08
●	●	●	●	●	GB07
●	●	●	●	●	GB08
●	●	●	●	●	NA02
●	●	●	●	●	PC08
●	●	●	●	●	SB06
●	●	●	●	●	SB07
●	●	●	●	●	SB09
●	●	●	●	●	SB10
●	●	●	●	●	SB11
		●	●	●	SB12
●	●	●	●	●	SB13
●	●	●	●	●	SB14
●	●	●	●	●	SB15

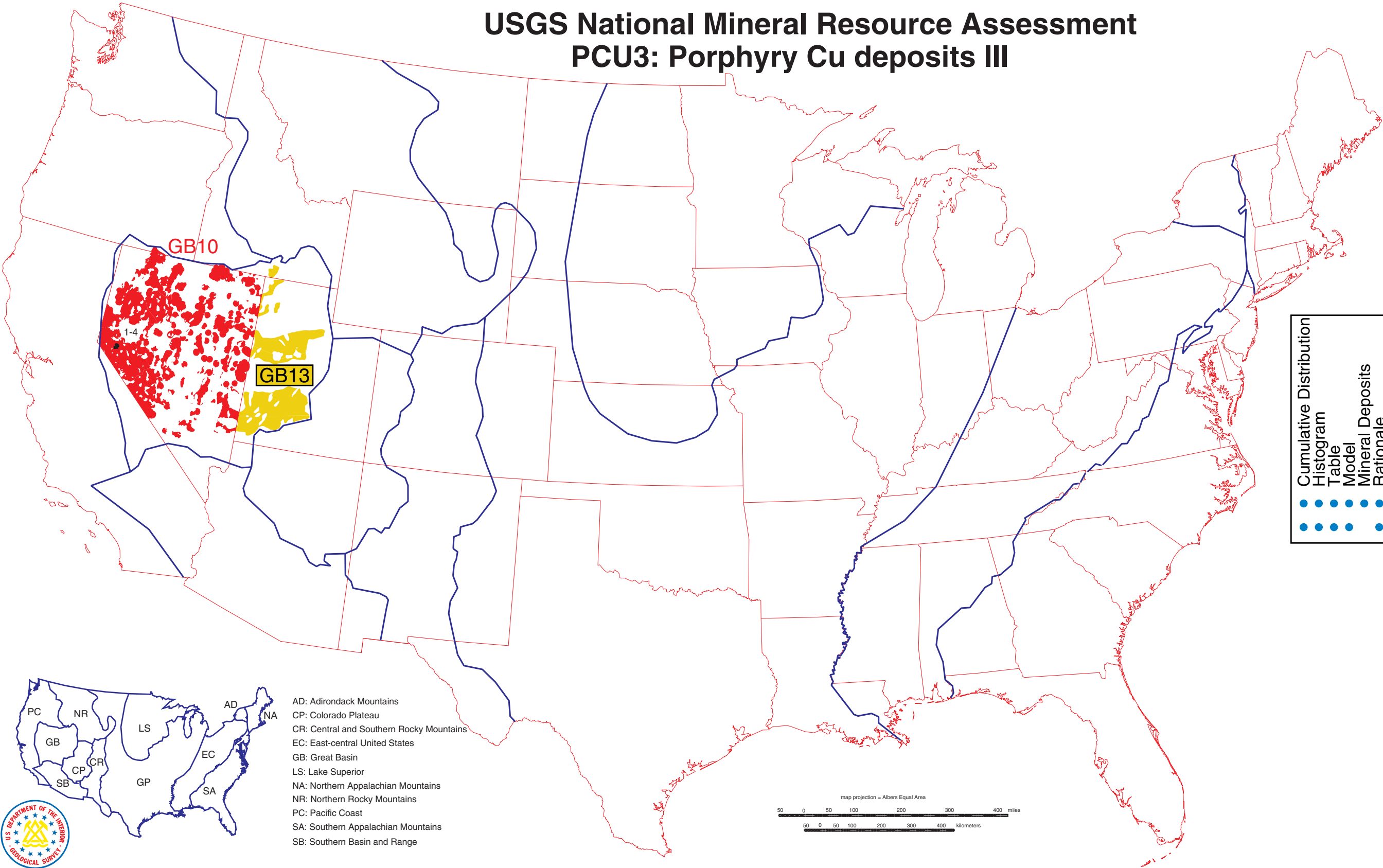
USGS National Mineral Resource Assessment

PCU2: Porphyry Cu deposits II



USGS National Mineral Resource Assessment

PCU3: Porphyry Cu deposits III



Cumulative Distribution

Histogram

Table

Model

Mineral Deposits

Rationale

●●●●●●●●●●

●●●●●●●●●●

●●●●●●●●●●

●●●●●●●●●●

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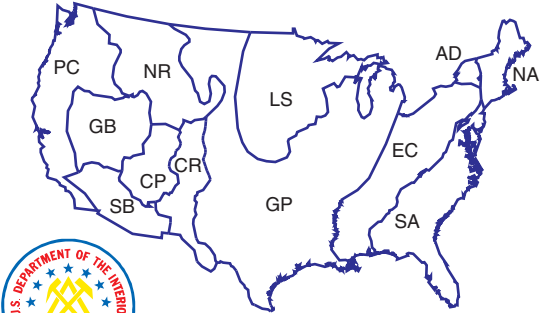
■

■

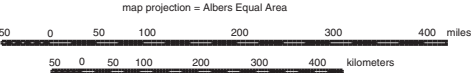
PCU3

GB10

GB13

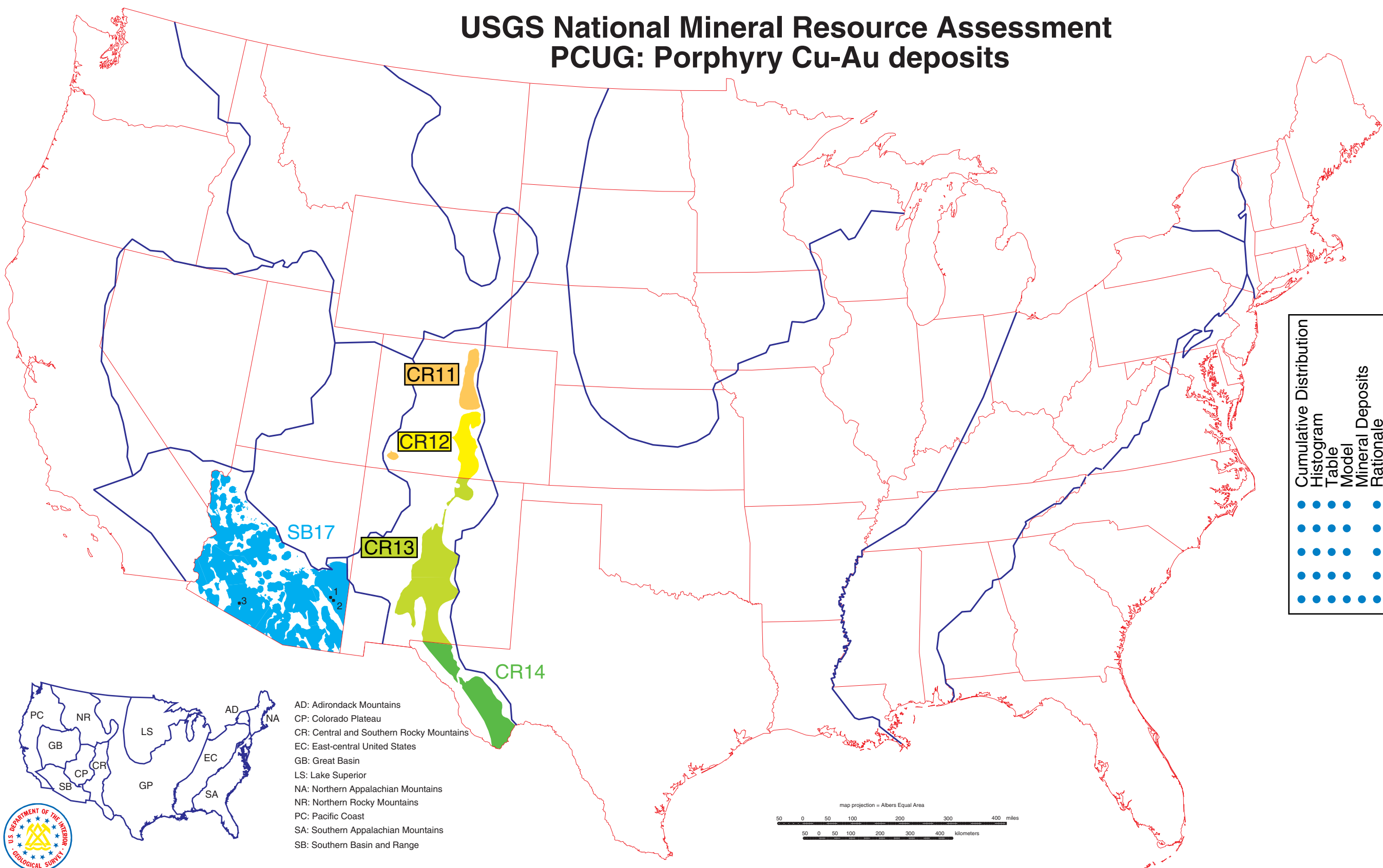


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GB: Great Basin
LS: Lake Superior
NA: Northern Appalachian Mountains
NR: Northern Rocky Mountains
PC: Pacific Coast
SA: Southern Appalachian Mountains
SB: Southern Basin and Range



USGS National Mineral Resource Assessment

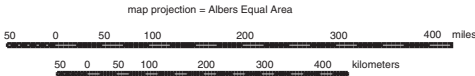
PCUG: Porphyry Cu-Au deposits



Cumulative Distribution	Histogram	Table	Model	Mineral Deposits	Rationale	PCUG
•	•	•	•	•	•	CR11
•	•	•	•	•	•	CR12
•	•	•	•	•	•	CR13
•	•	•	•	•	•	CR14
•	•	•	•	•	•	SB17

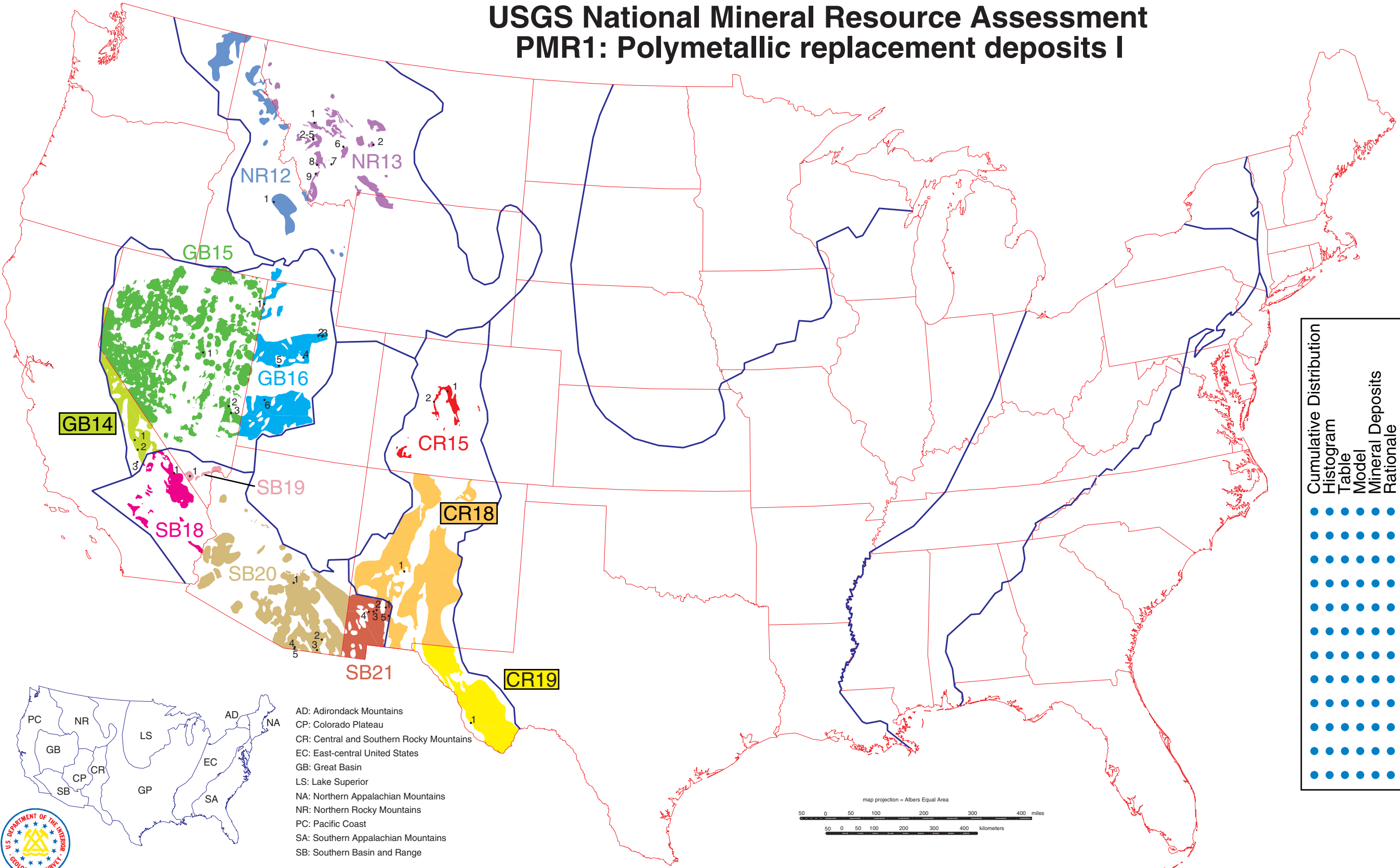


AD: Adirondack Mountains
CP: Colorado Plateau
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EC: East-central United States
GB: Great Basin
LS: Lake Superior
NA: Northern Appalachian Mountains
NR: Northern Rocky Mountains
PC: Pacific Coast
SA: Southern Appalachian Mountains
SB: Southern Basin and Range

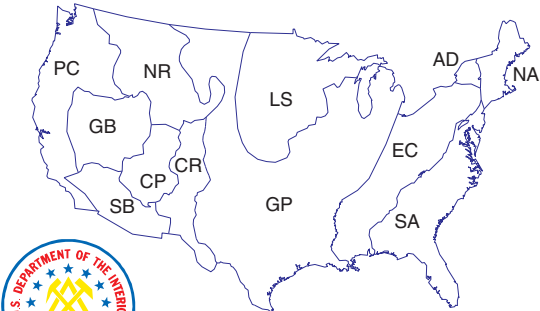


USGS National Mineral Resource Assessment

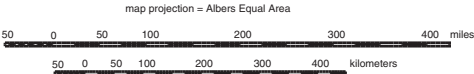
PMR1: Polymetallic replacement deposits I



Cumulative Distribution	PMR1
Histogram	CR15
Table	CR18
Model	CR19
Mineral Deposits	GB14
Rationale	GB15
	GB16
	NR12
	NR13
	SB18
	SB19
	SB20
	SB21

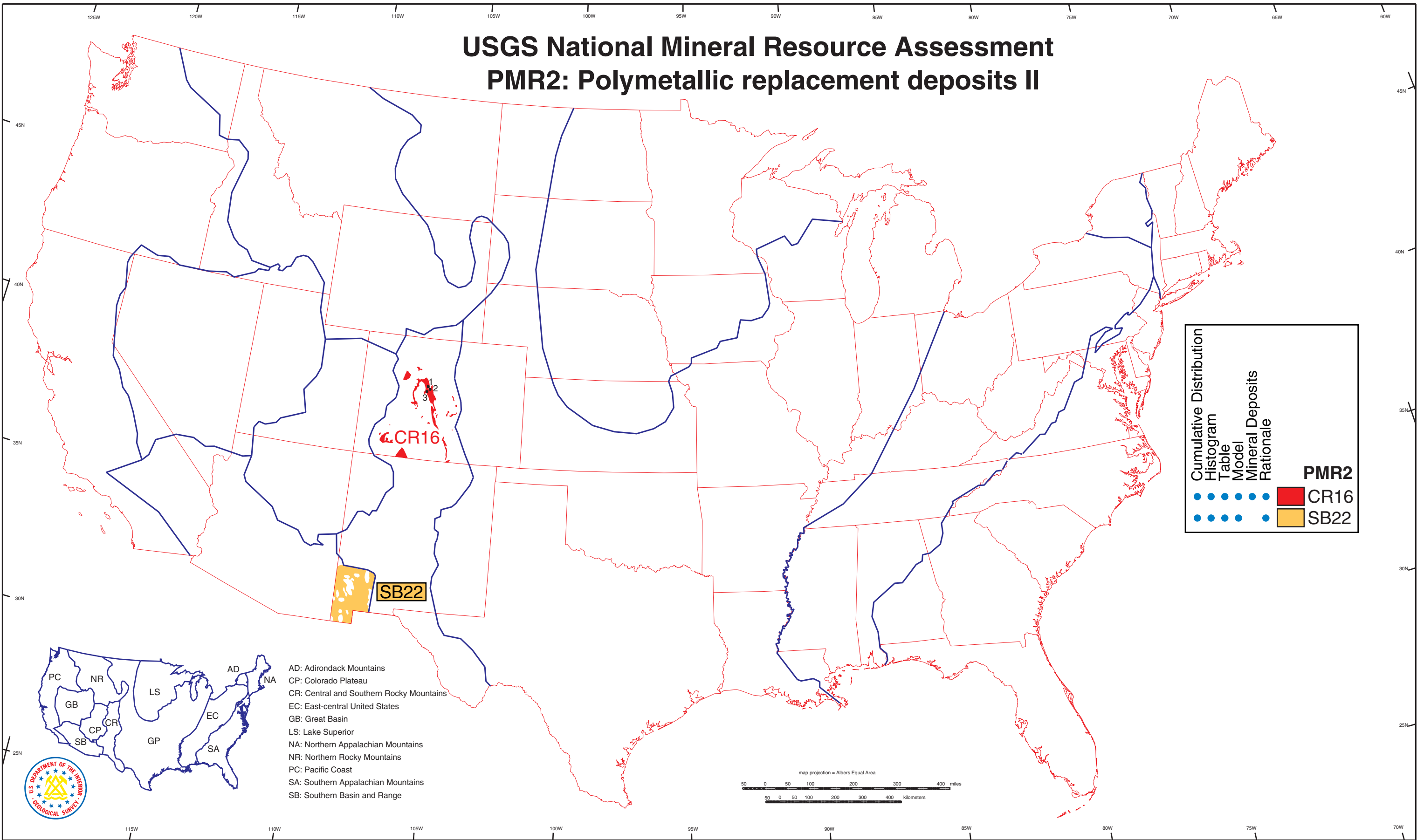


AD: Adirondack Mountains
CP: Colorado Plateau
CR: Central and Southern Rocky Mountains
EC: East-central United States
GB: Great Basin
LS: Lake Superior
NA: Northern Appalachian Mountains
NR: Northern Rocky Mountains
PC: Pacific Coast
SA: Southern Appalachian Mountains
SB: Southern Basin and Range



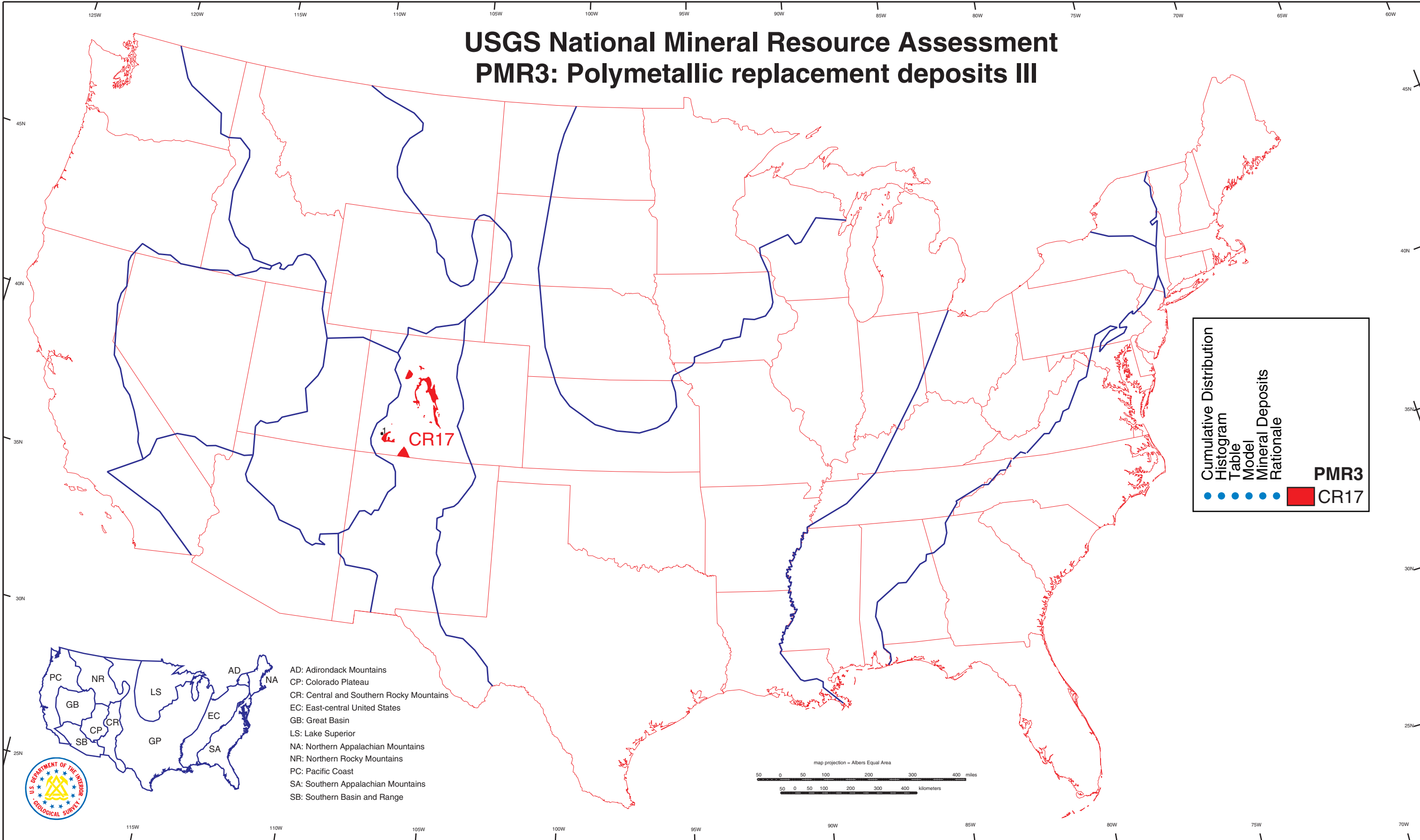
USGS National Mineral Resource Assessment

PMR2: Polymetallic replacement deposits II



USGS National Mineral Resource Assessment

PMR3: Polymetallic replacement deposits III



Cumulative Distribution

Histogram

Table

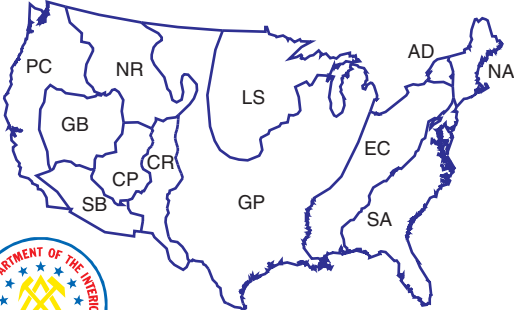
Model

Mineral Deposits

Rationale

PMR3

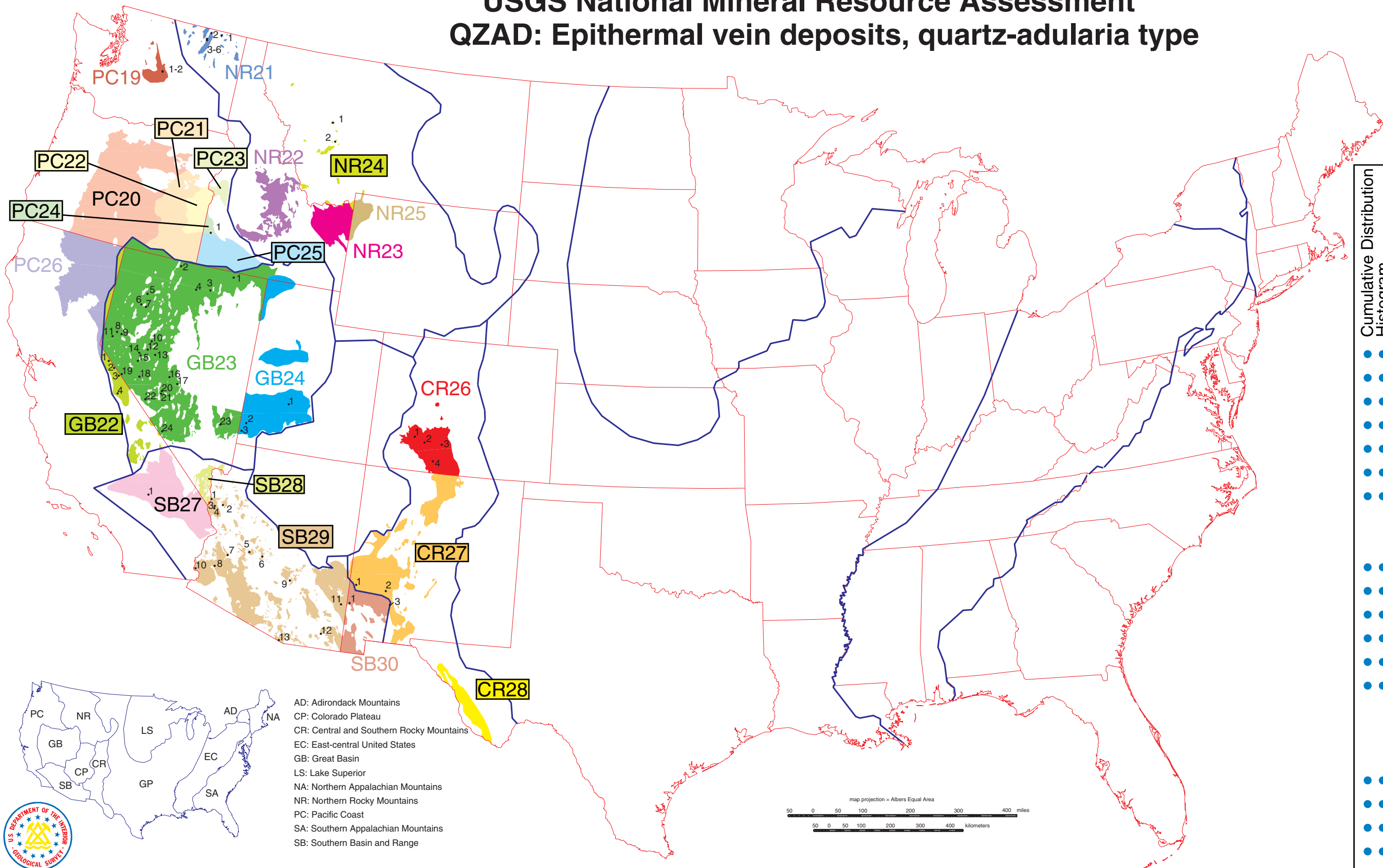
CR17



- AD: Adirondack Mountains
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- LS: Lake Superior
- NA: Northern Appalachian Mountains
- NR: Northern Rocky Mountains
- PC: Pacific Coast
- SA: Southern Appalachian Mountains
- SB: Southern Basin and Range

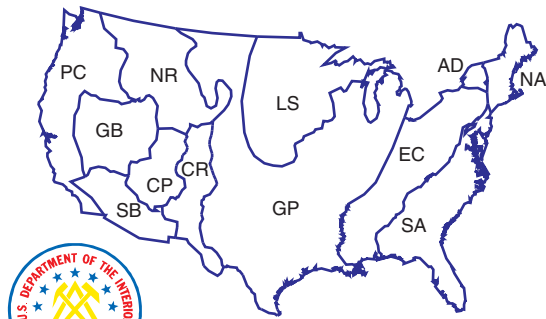
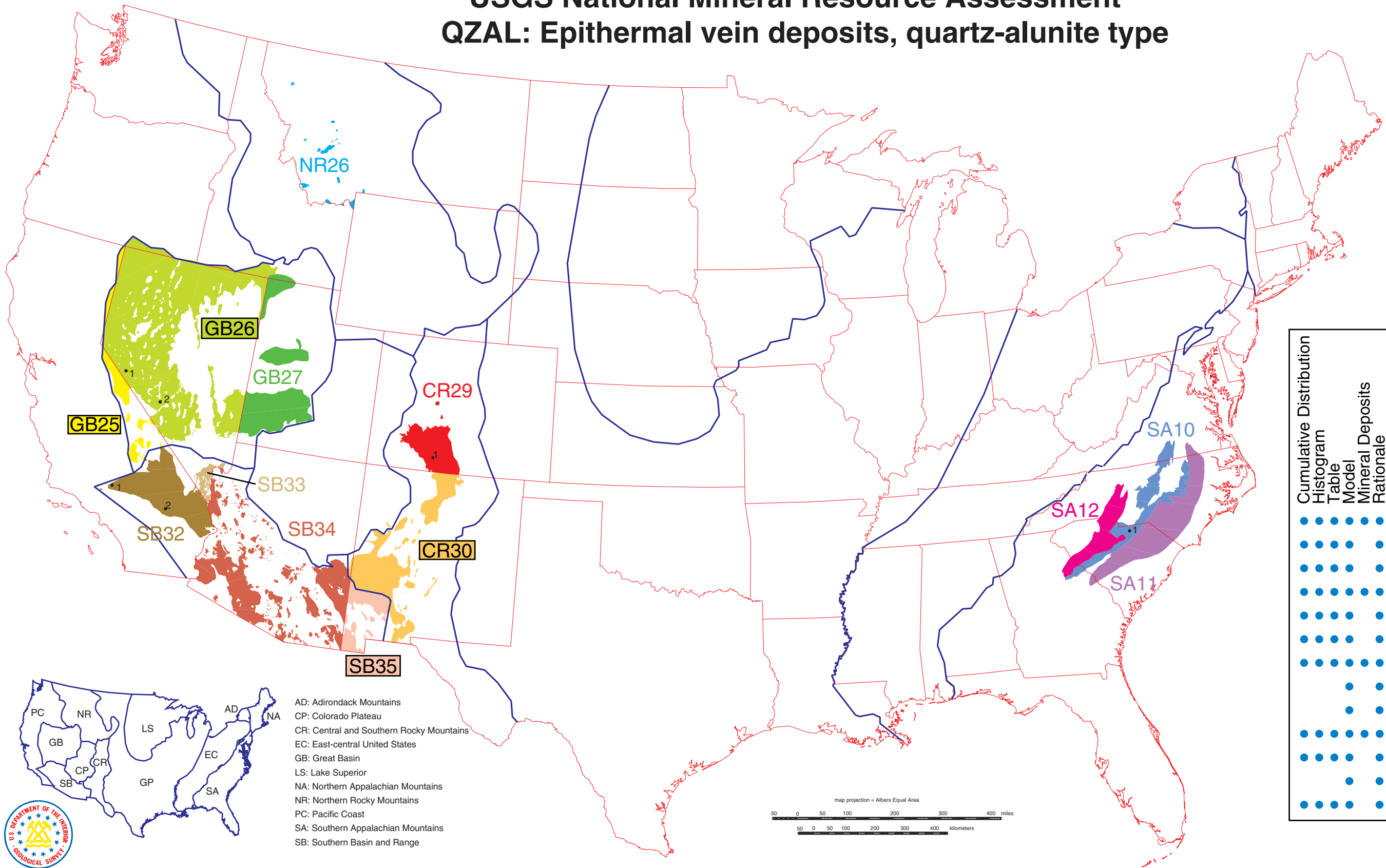


USGS National Mineral Resource Assessment
QZAD: Epithermal vein deposits, quartz-adularia type

[illegible]

USGS National Mineral Resource Assessment

QZAL: Epithermal vein deposits, quartz-alunite type



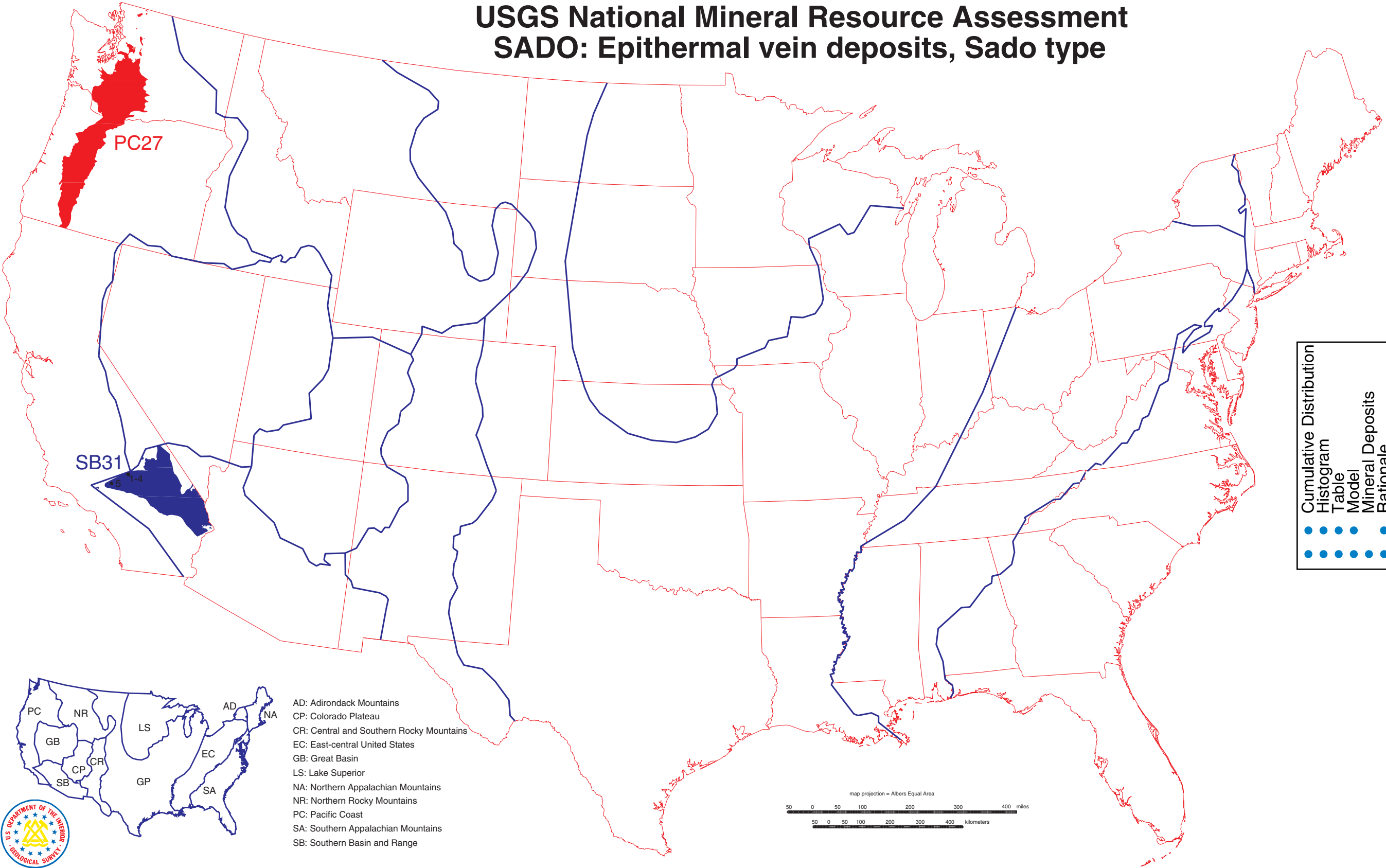
AD: Adirondack Mountains
CP: Colorado Plateau
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EC: East-central United States
GB: Great Basin
LS: Lake Superior
NA: Northern Appalachian Mountains
NR: Northern Rocky Mountains
PC: Pacific Coast
SA: Southern Appalachian Mountains
SB: Southern Basin and Range



Cumulative Distribution	Histogram	Table	Model	Mineral Deposits	Rationale	QZAL
•••••	•••••	•••••	•••••	•••••	•••••	CR29
•••••	•••••	•••••	•••••	•••••	•••••	CR30
•••••	•••••	•••••	•••••	•••••	•••••	GB25
•••••	•••••	•••••	•••••	•••••	•••••	GB26
•••••	•••••	•••••	•••••	•••••	•••••	GB27
•••••	•••••	•••••	•••••	•••••	•••••	NR26
•••••	•••••	•••••	•••••	•••••	•••••	SA10
•••••	•••••	•••••	•••••	•••••	•••••	SA11
•••••	•••••	•••••	•••••	•••••	•••••	SA12
•••••	•••••	•••••	•••••	•••••	•••••	SB32
•••••	•••••	•••••	•••••	•••••	•••••	SB33
•••••	•••••	•••••	•••••	•••••	•••••	SB34
•••••	•••••	•••••	•••••	•••••	•••••	SB35

USGS National Mineral Resource Assessment

SADO: Epithermal vein deposits, Sado type



Cumulative Distribution

Histogram

Table

Model

Mineral Deposits

Rationale

●●●●●

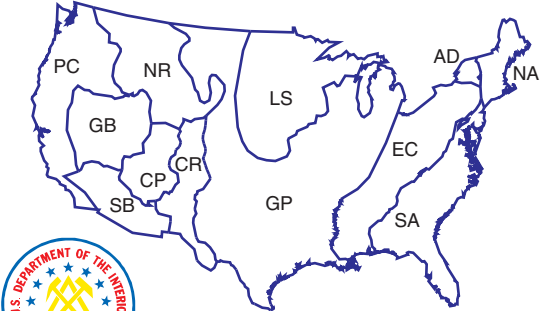
●●●●●

■

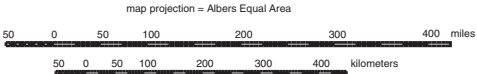
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PC27

SB31

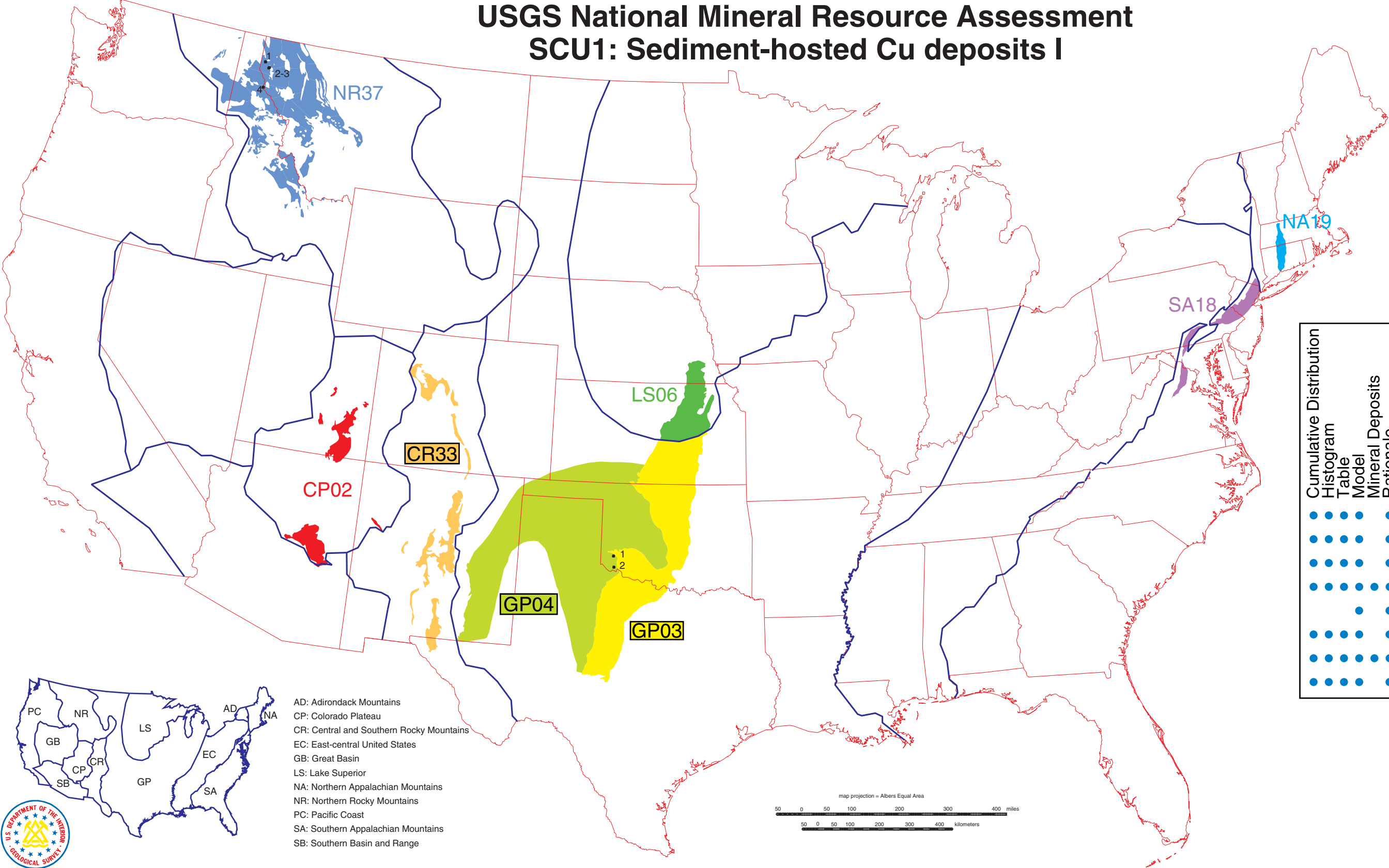


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- NA: Northern Appalachian Mountains
- NR: Northern Rocky Mountains
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- SA: Southern Appalachian Mountains
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USGS National Mineral Resource Assessment

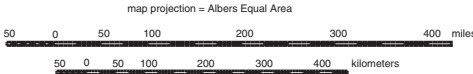
SCU1: Sediment-hosted Cu deposits I



AD: Adirondack Mountains
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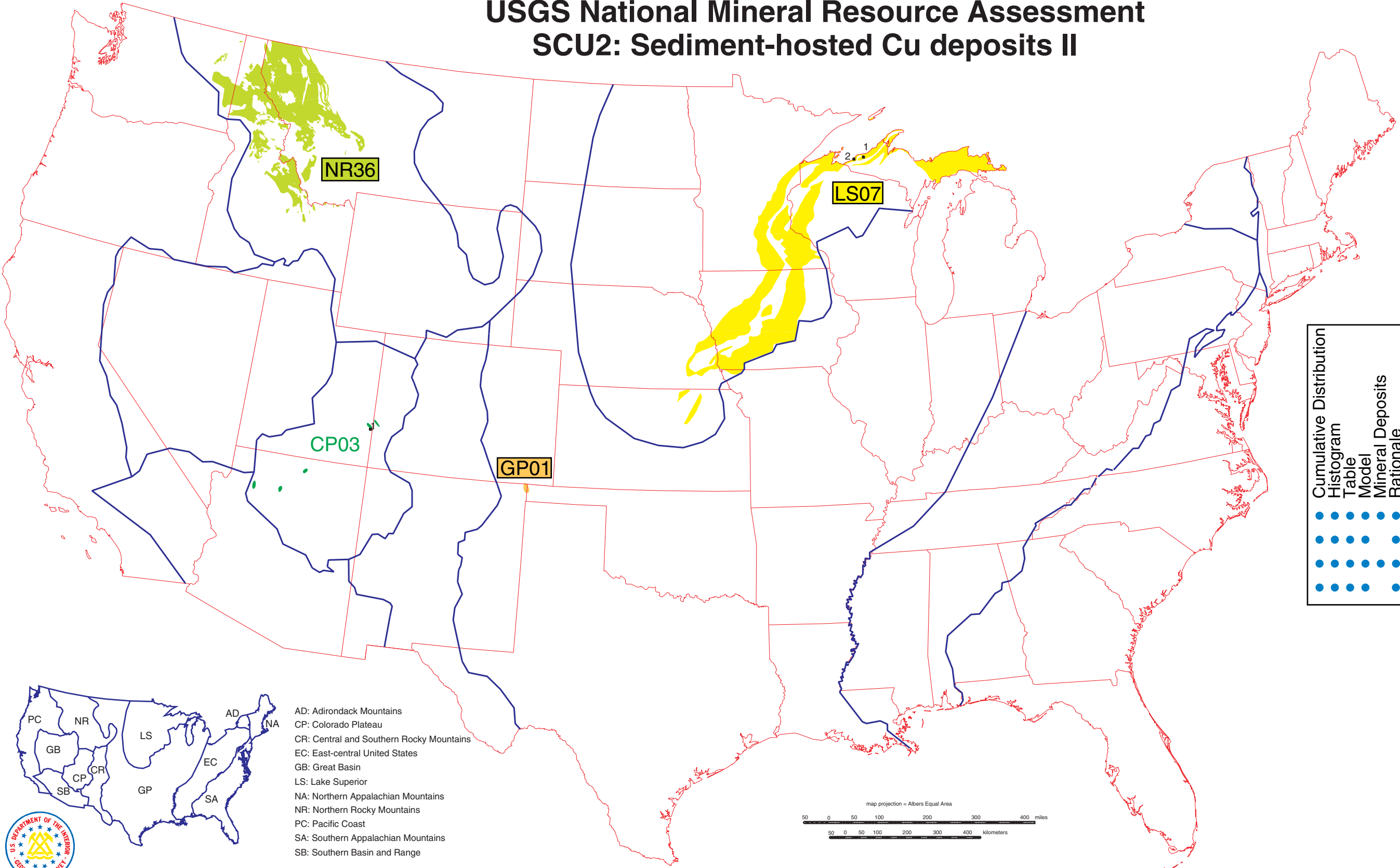


Cumulative Distribution	Histogram	Table	Model	Mineral Deposits	Rationale
•••••	•••••	•••••	•••••	•	CP02
•••••	•••••	•••••	•••••	•	CR33
•••••	•••••	•••••	•••••	•	GP03
•••••	•••••	•••••	•••••	•	GP04
•••••	•••••	•••••	•••••	•	LS06
•••••	•••••	•••••	•••••	•	NA19
•••••	•••••	•••••	•••••	•	NR37
•••••	•••••	•••••	•••••	•	SA18



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SCU2: Sediment-hosted Cu deposits II



Cumulative Distribution

Histogram

Table

Model

Mineral Deposits

Rationale

SCU2

CP03

GP01

LS07

NR36

PC

NR

AD

NA

GB

LS

EC

CR

CP

GP

SA

SB

AD: Adirondack Mountains

CP: Colorado Plateau

CR: Central and Southern Rocky Mountains

EC: East-central United States

GB: Great Basin

LS: Lake Superior

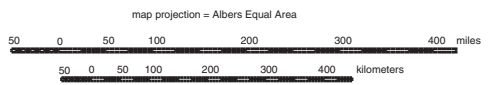
NA: Northern Appalachian Mountains

NR: Northern Rocky Mountains

PC: Pacific Coast

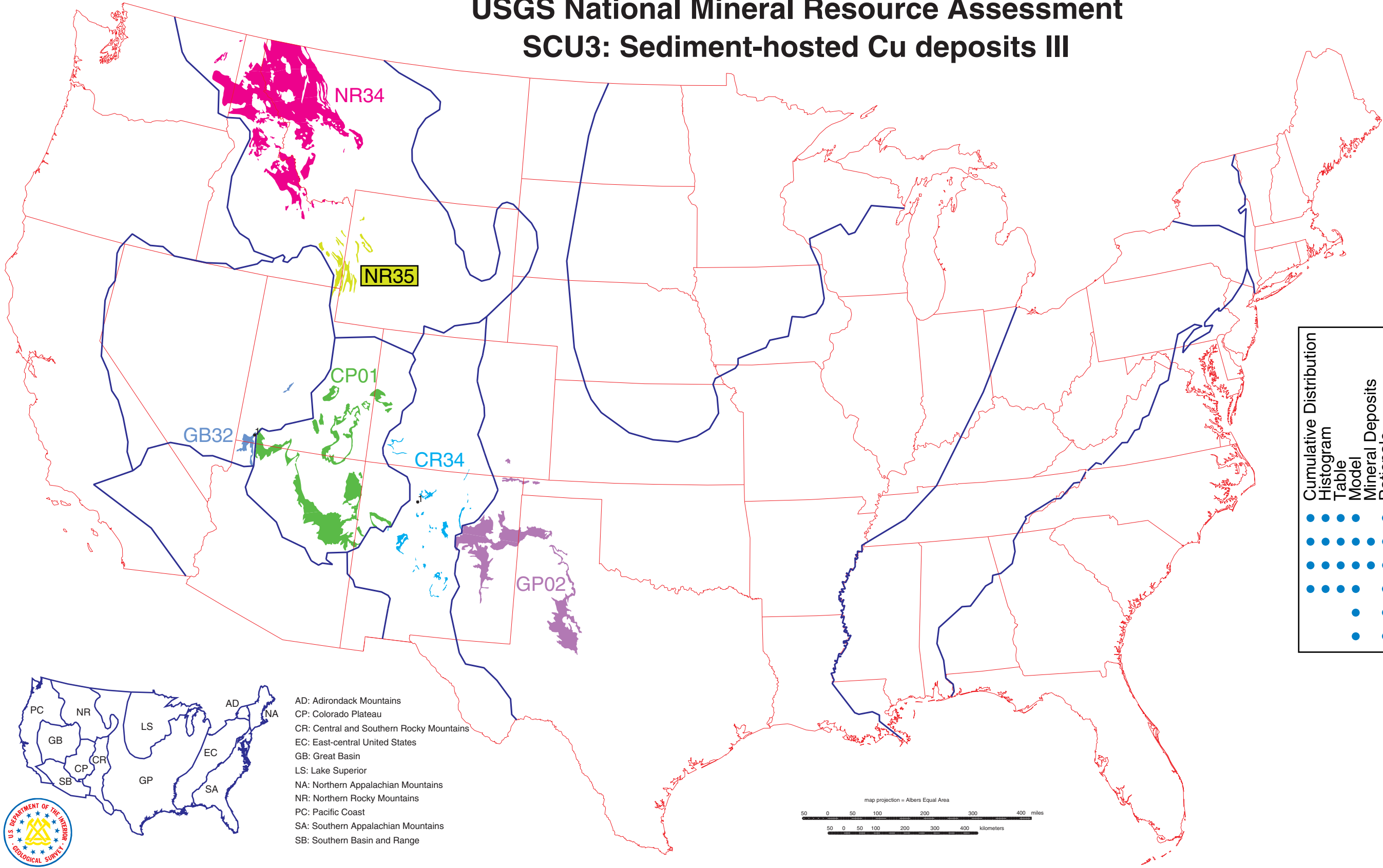
SA: Southern Appalachian Mountains

SB: Southern Basin and Range

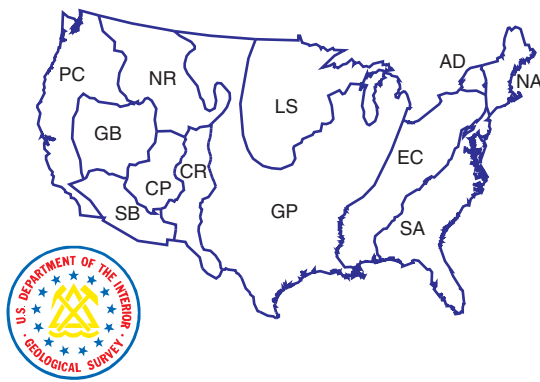


USGS National Mineral Resource Assessment

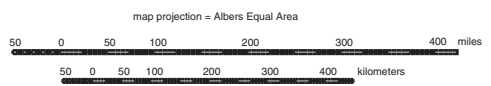
SCU3: Sediment-hosted Cu deposits III



SCU3	
Cumulative Distribution	● CP01
Histogram	● CR34
Table	● GB32
Model	● GP02
Mineral Deposits	● NR34
Rationale	● NR35

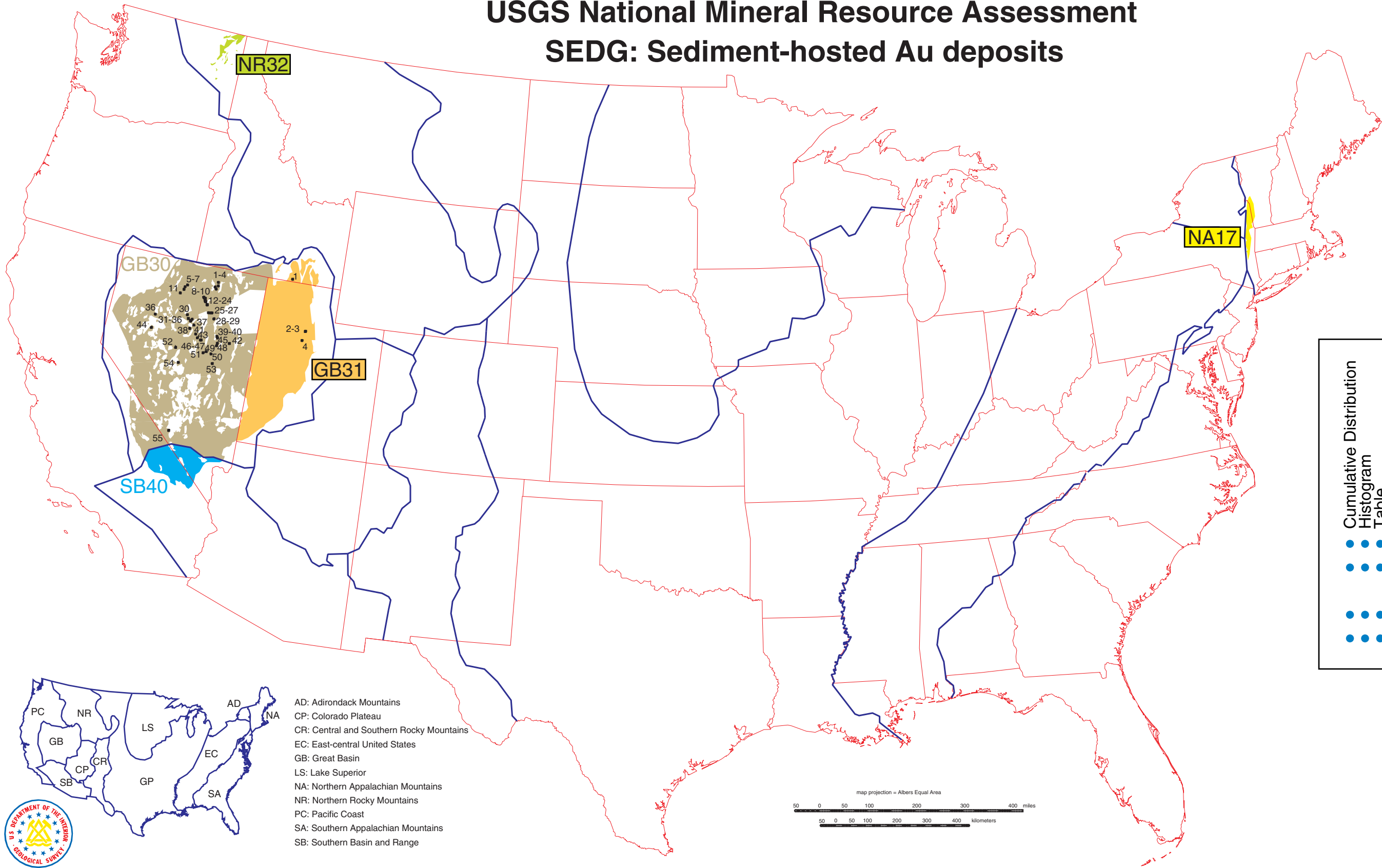


AD: Adirondack Mountains
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NR: Northern Rocky Mountains
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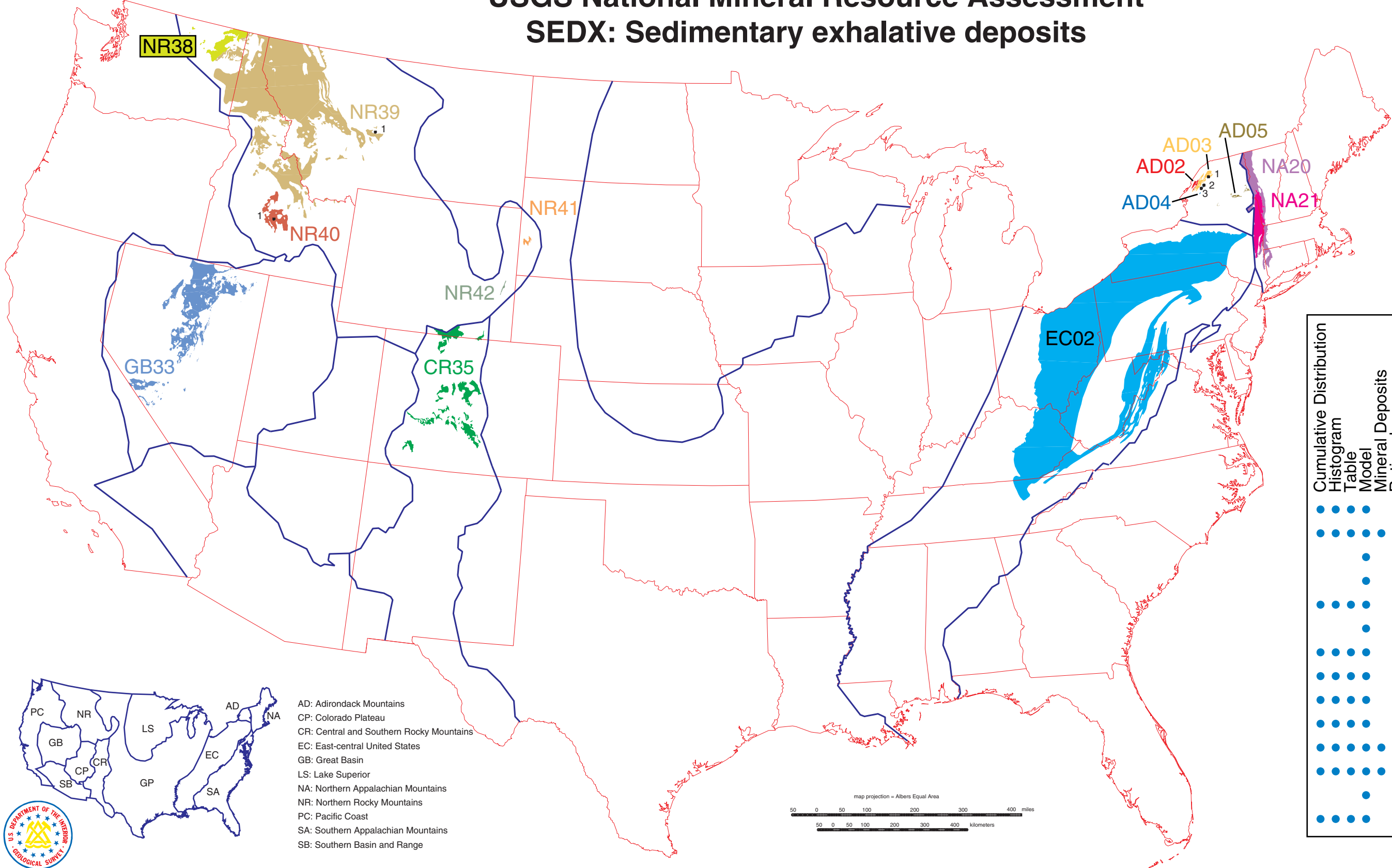
USGS National Mineral Resource Assessment

SEDG: Sediment-hosted Au deposits



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SEDX: Sedimentary exhalative deposits



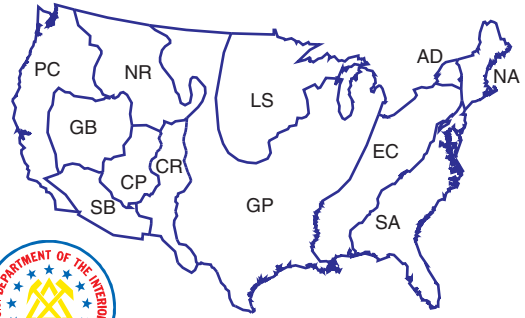
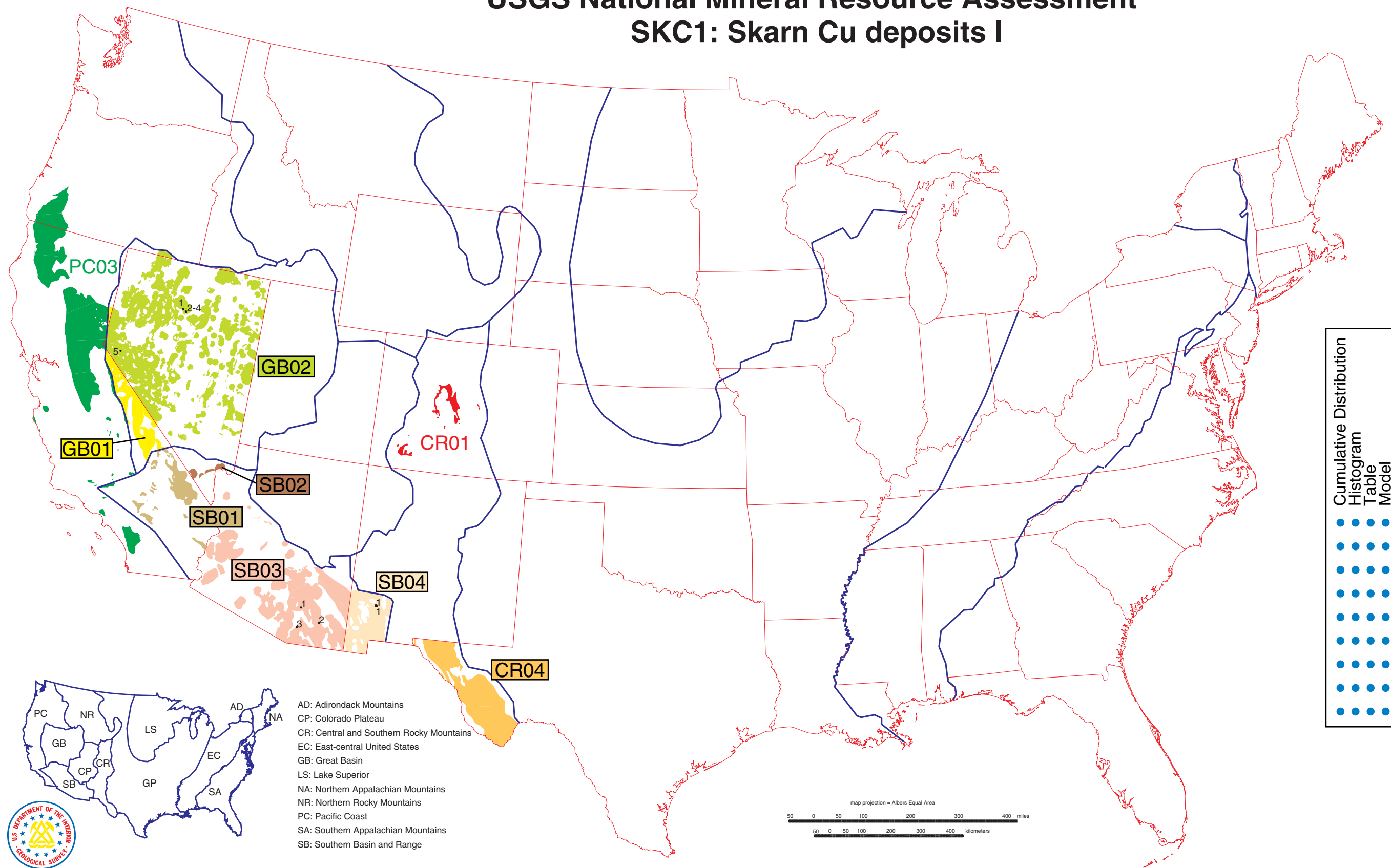
AD: Adirondack Mountains
CP: Colorado Plateau
CR: Central and Southern Rocky Mountains
EC: East-central United States
GB: Great Basin
LS: Lake Superior
NA: Northern Appalachian Mountains
NR: Northern Rocky Mountains
PC: Pacific Coast
SA: Southern Appalachian Mountains
SB: Southern Basin and Range

map projection = Albers Equal Area
50 0 50 100 200 300 400 miles
50 0 50 100 200 300 400 kilometers

Cumulative Distribution		
Histogram		
Table		
Model		
Mineral Deposits		
Rationale		
• • • • •	•	SEDX
• • • • •	•	AD02
• • • • •	•	AD03
• • • • •	•	AD04
• • • • •	•	AD05
• • • • •	•	CR35
• • • • •	•	EC02
• • • • •	•	GB33
• • • • •	•	NA20
• • • • •	•	NA21
• • • • •	•	NR38
• • • • •	•	NR39
• • • • •	•	NR40
• • • • •	•	NR41
• • • • •	•	NR42

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SKC1: Skarn Cu deposits I



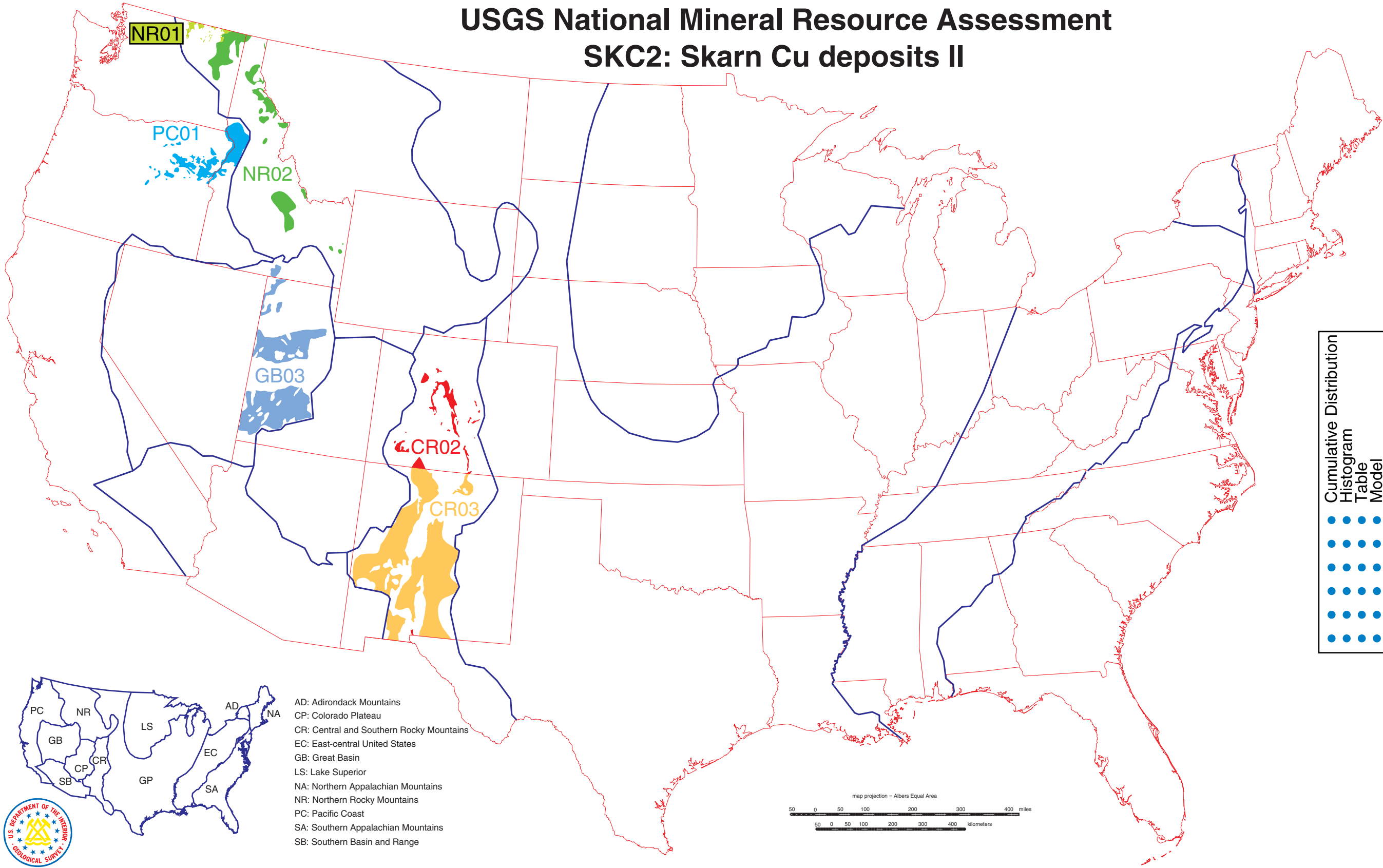
AD: Adirondack Mountains
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EC: East-central United States
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LS: Lake Superior
NA: Northern Appalachian Mountains
NR: Northern Rocky Mountains
PC: Pacific Coast
SA: Southern Appalachian Mountains
SB: Southern Basin and Range

Cumulative Distribution	Histogram	Table	Model	Mineral Deposits	Rationale
•••••	•••••	•••••	•••••	SKC1	
•••••	•••••	•••••	•••••	CR01	
•••••	•••••	•••••	•••••	CR04	
•••••	•••••	•••••	•••••	GB01	
•••••	•••••	•••••	•••••	GB02	
•••••	•••••	•••••	•••••	PC03	
•••••	•••••	•••••	•••••	SB01	
•••••	•••••	•••••	•••••	SB02	
•••••	•••••	•••••	•••••	SB03	
•••••	•••••	•••••	•••••	SB04	



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SKC2: Skarn Cu deposits II



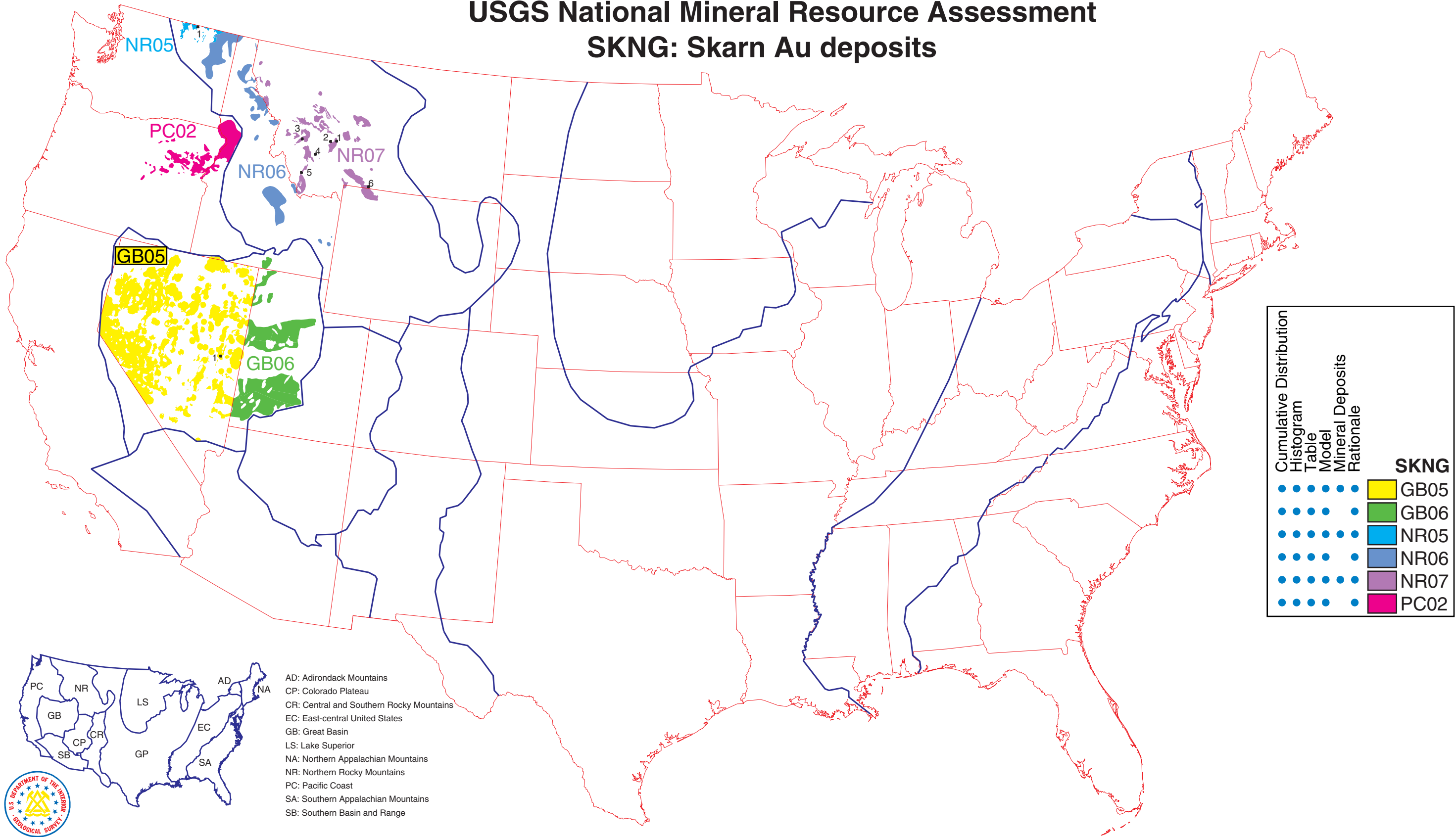
Cumulative Distribution	
Histogram	
Table	
Model	
Mineral Deposits	
Rationale	
• • • • •	SKC2
• • • • •	CR02
• • • • •	CR03
• • • • •	GB03
• • • • •	NR01
• • • • •	NR02
• • • • •	PC01

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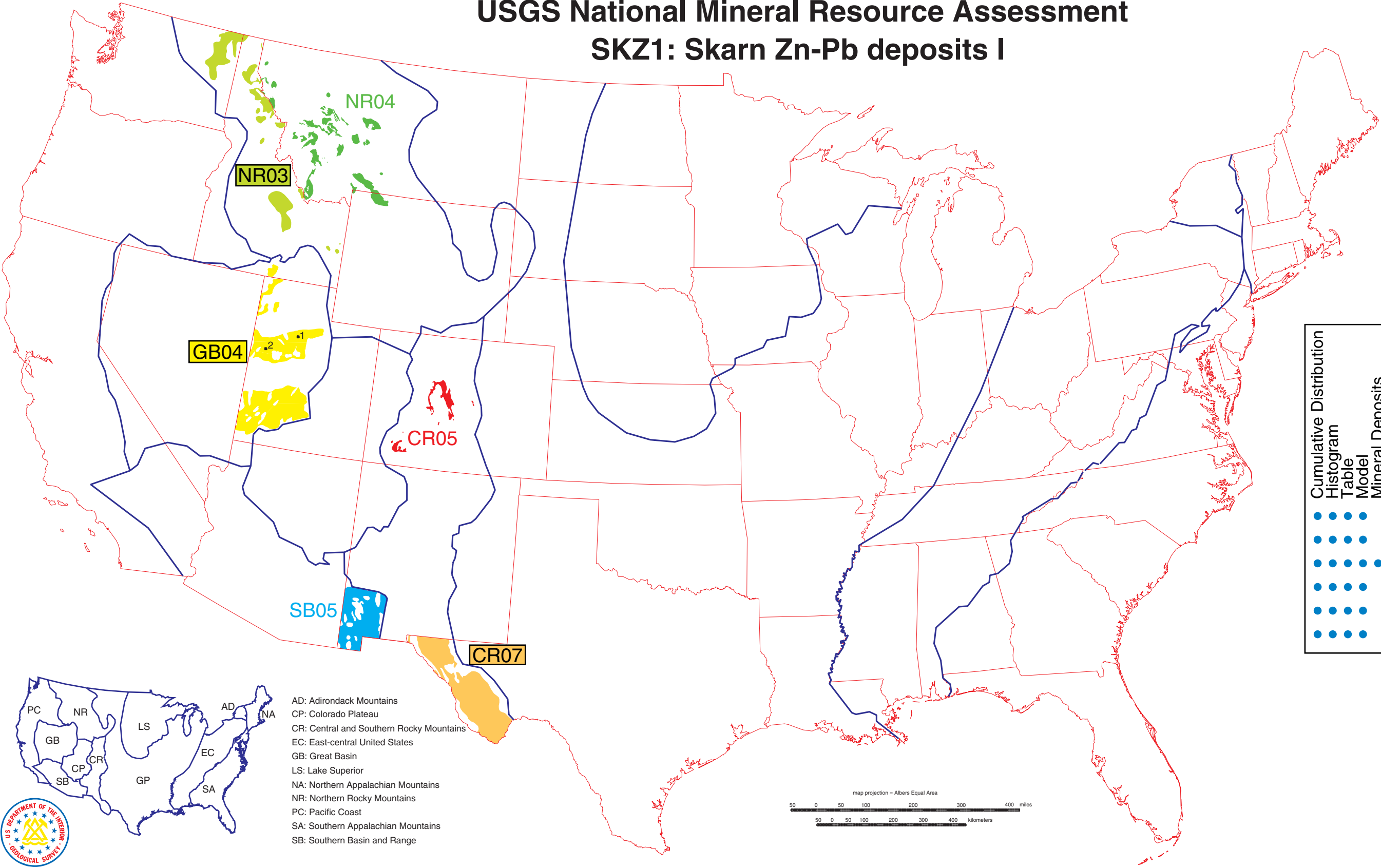
USGS National Mineral Resource Assessment

SKNG: Skarn Au deposits



USGS National Mineral Resource Assessment

SKZ1: Skarn Zn-Pb deposits I



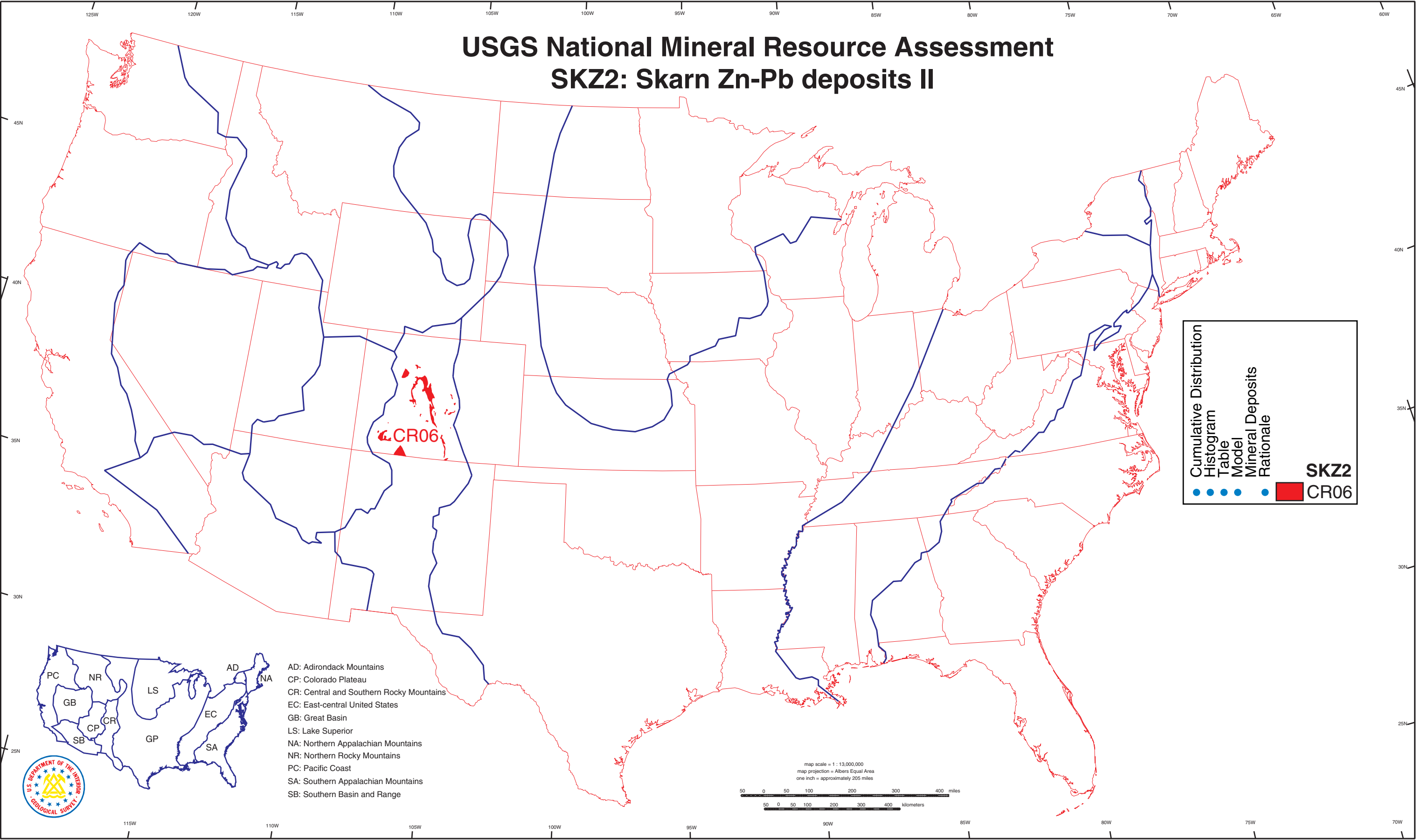
Cumulative Distribution	Histogram	Table	Model	Mineral Deposits	Rationale
•	•	•	•	•	•
•	•	•	•	•	•
•	•	•	•	•	•
•	•	•	•	•	•
•	•	•	•	•	•
•	•	•	•	•	•

SKZ1

- CR05
- CR07
- GB04
- NR03
- NR04
- SB05

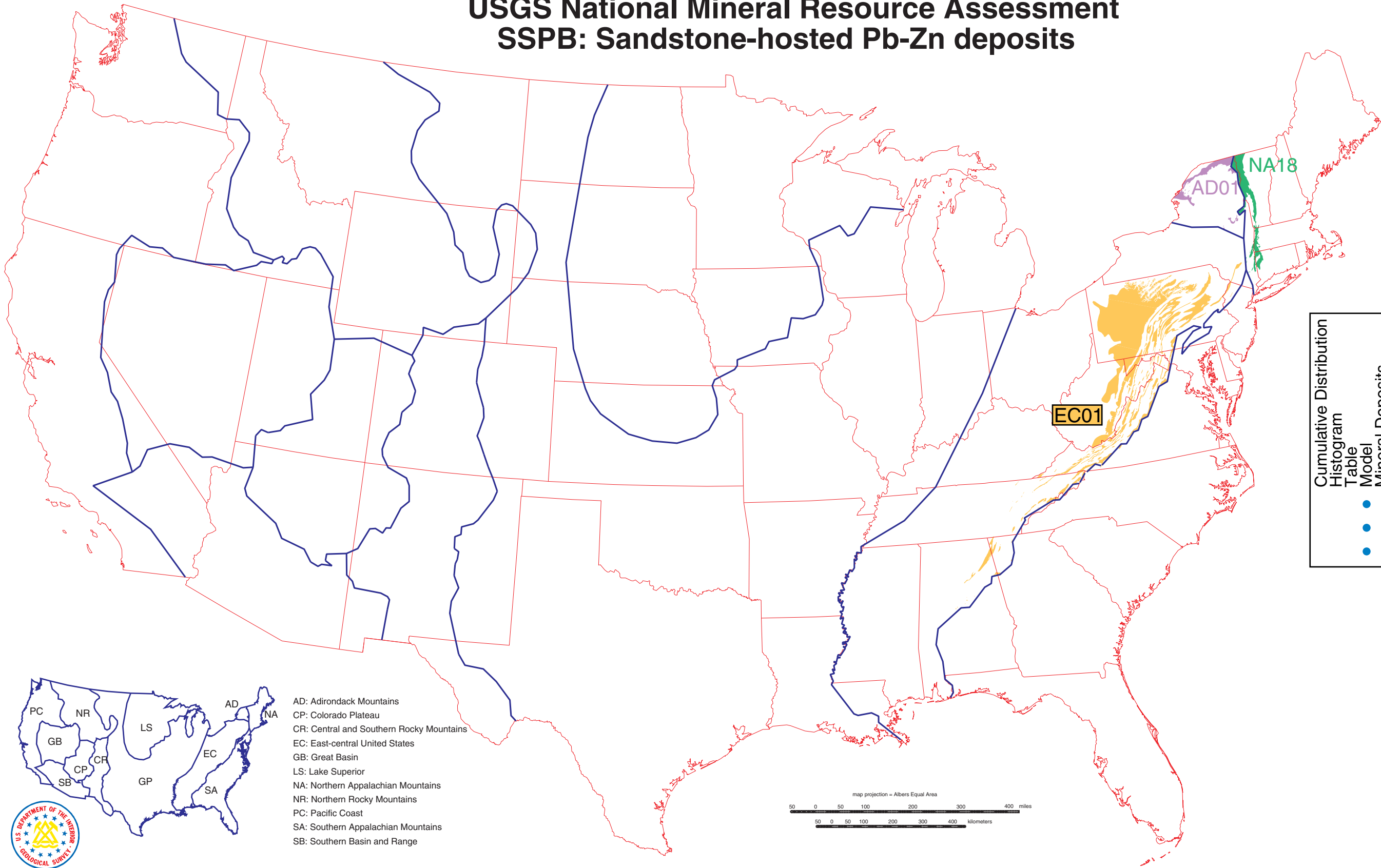
USGS National Mineral Resource Assessment

SKZ2: Skarn Zn-Pb deposits II



USGS National Mineral Resource Assessment

SSPB: Sandstone-hosted Pb-Zn deposits



Cumulative Distribution Histogram
Table
Model
Mineral Deposits
Rationale

SSPB

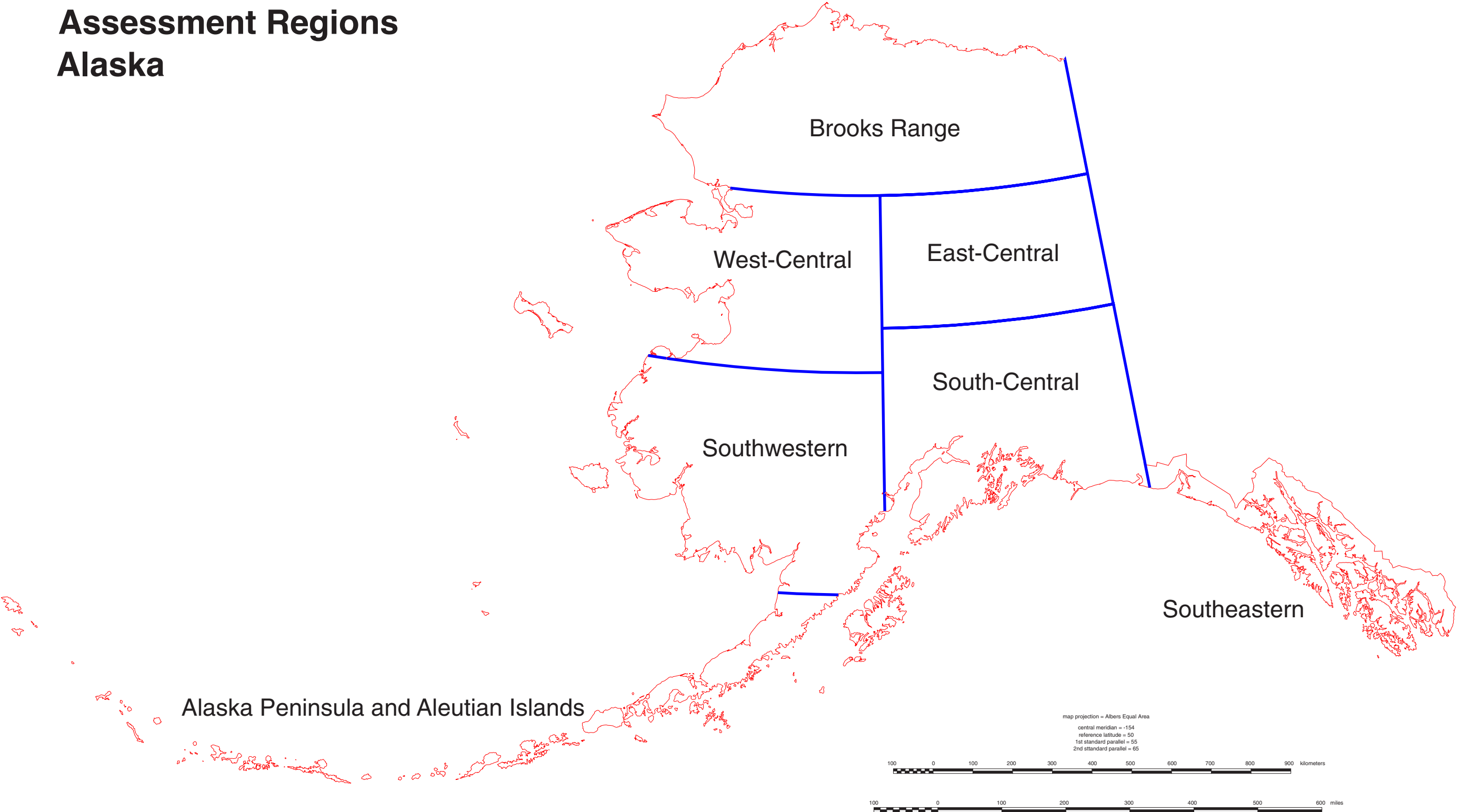
- AD01
- EC01
- NA18



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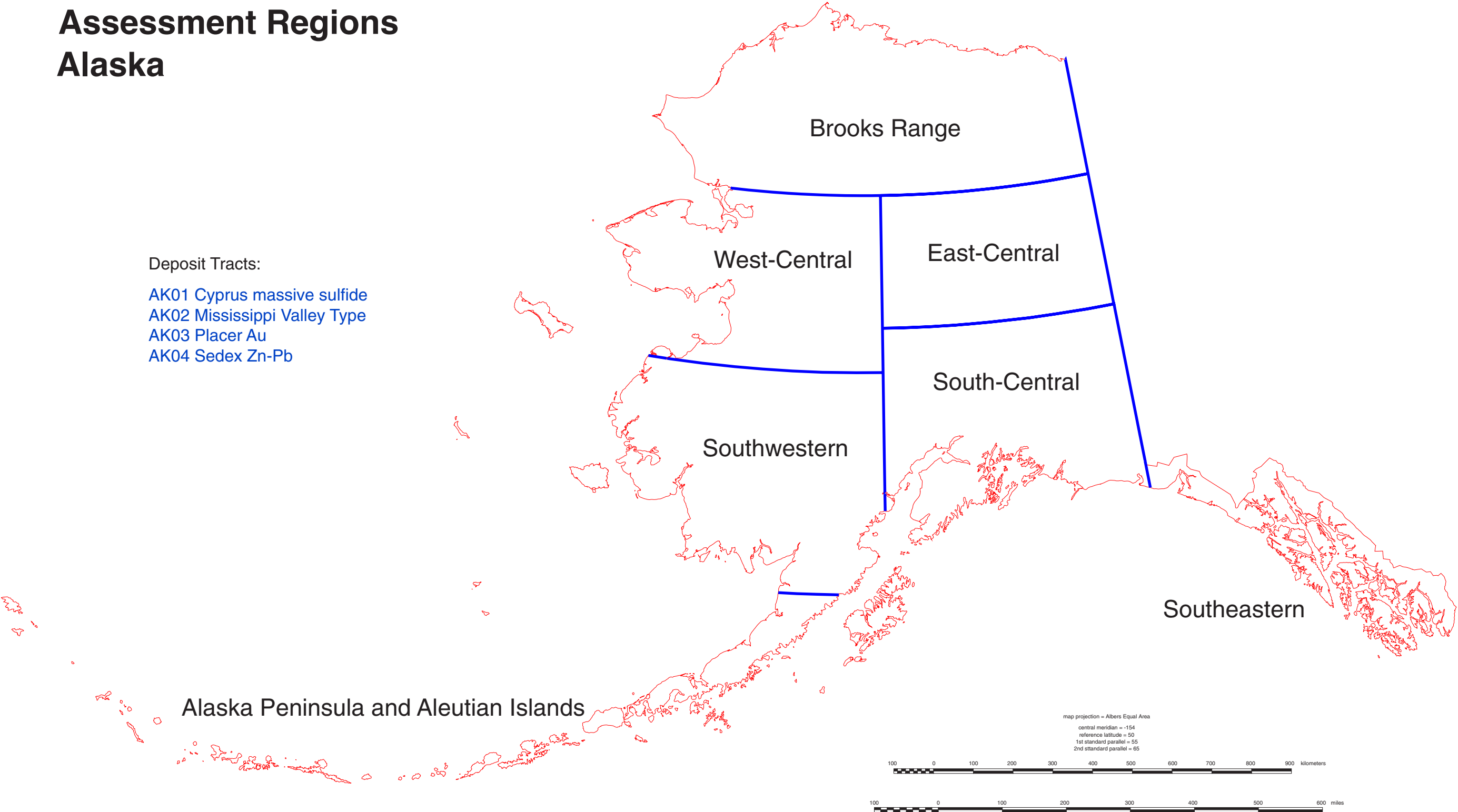
National Mineral Resource
Assessment Regions
Alaska



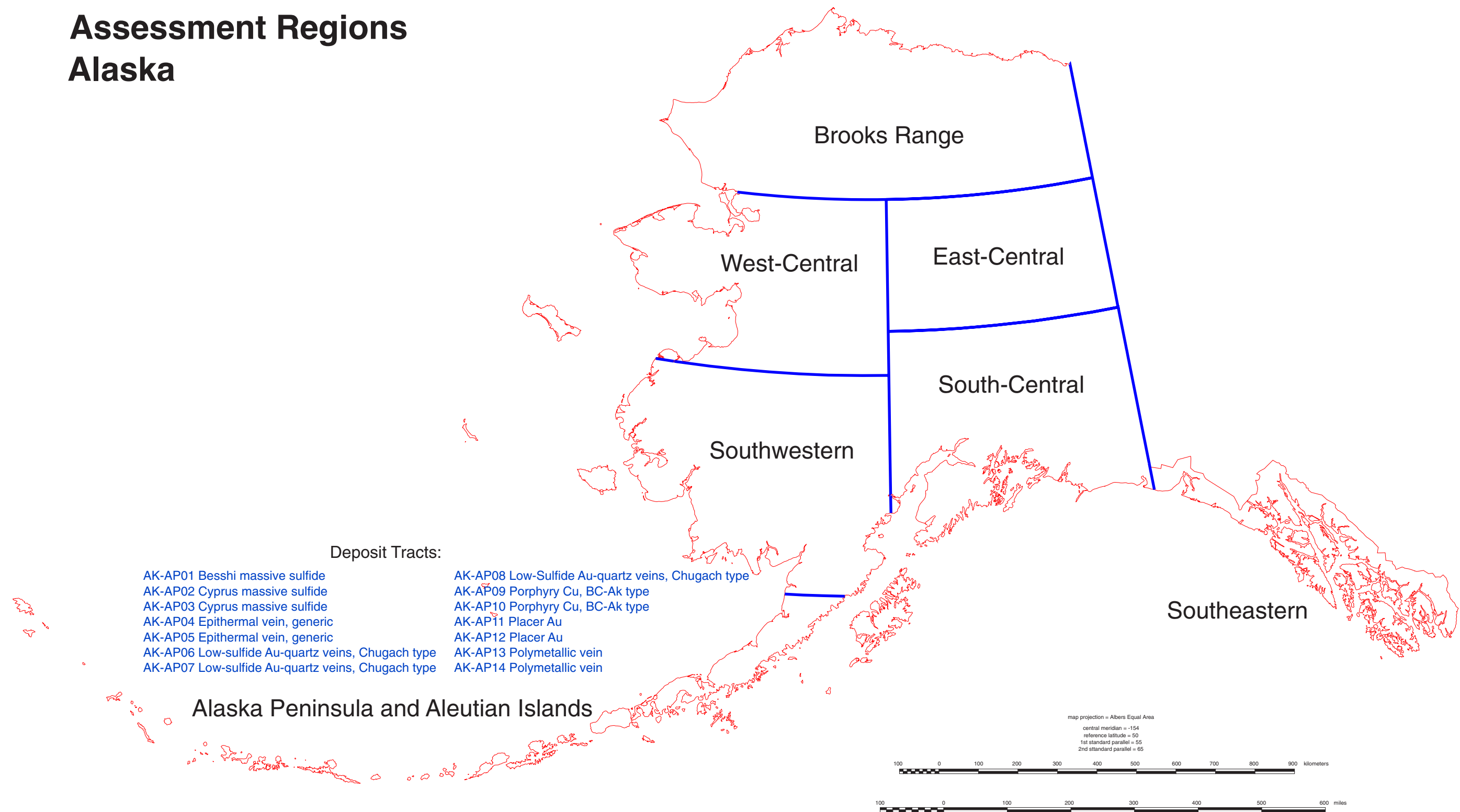
National Mineral Resource Assessment Regions Alaska

Deposit Tracts:

- AK01 Cyprus massive sulfide
- AK02 Mississippi Valley Type
- AK03 Placer Au
- AK04 Sedex Zn-Pb



National Mineral Resource Assessment Regions Alaska



National Mineral Resource Assessment Regions Alaska

- Deposit Tracts:
- | | |
|-------------------------------------|----------------------------------|
| AK-BR01 Beshi massive sulfide | AK-BR13 Placer Au |
| AK-BR02 Cyprus massive sulfide | AK-BR14 Placer Au |
| AK-BR03 Cyprus massive sulfide | AK-BR15 Polymetallic replacement |
| AK-BR04 Low-sulfide Au-quartz veins | AK-BR16 Polymetallic vein |
| AK-BR05 Kipushi Cu-Pb-Zn | AK-BR17 Zn-Pb-Ag veins |
| AK-BR06 Kipushi Cu-Pb-Zn | AK-BR18 Cu (Au) skarn |
| AK-BR07 Kuroko massive sulfide | AK-BR19 Zn-Pb skarn |
| AK-BR08 Mississippi Valley Type | AK-BR20 Sandstone hosted Pb-Zn |
| AK-BR09 Mississippi Valley Type | AK-BR21 Sediment-hosted Cu |
| AK-BR11 Porphyry Cu, BC-Ak type | AK-BR22 Sedex Zn-Pb |
| AK-BR12 Plutonic Porphyry Au | AK-BR23 Sedex Zn-Pb |

Brooks Range

West-Central

East-Central

South-Central

Southwestern

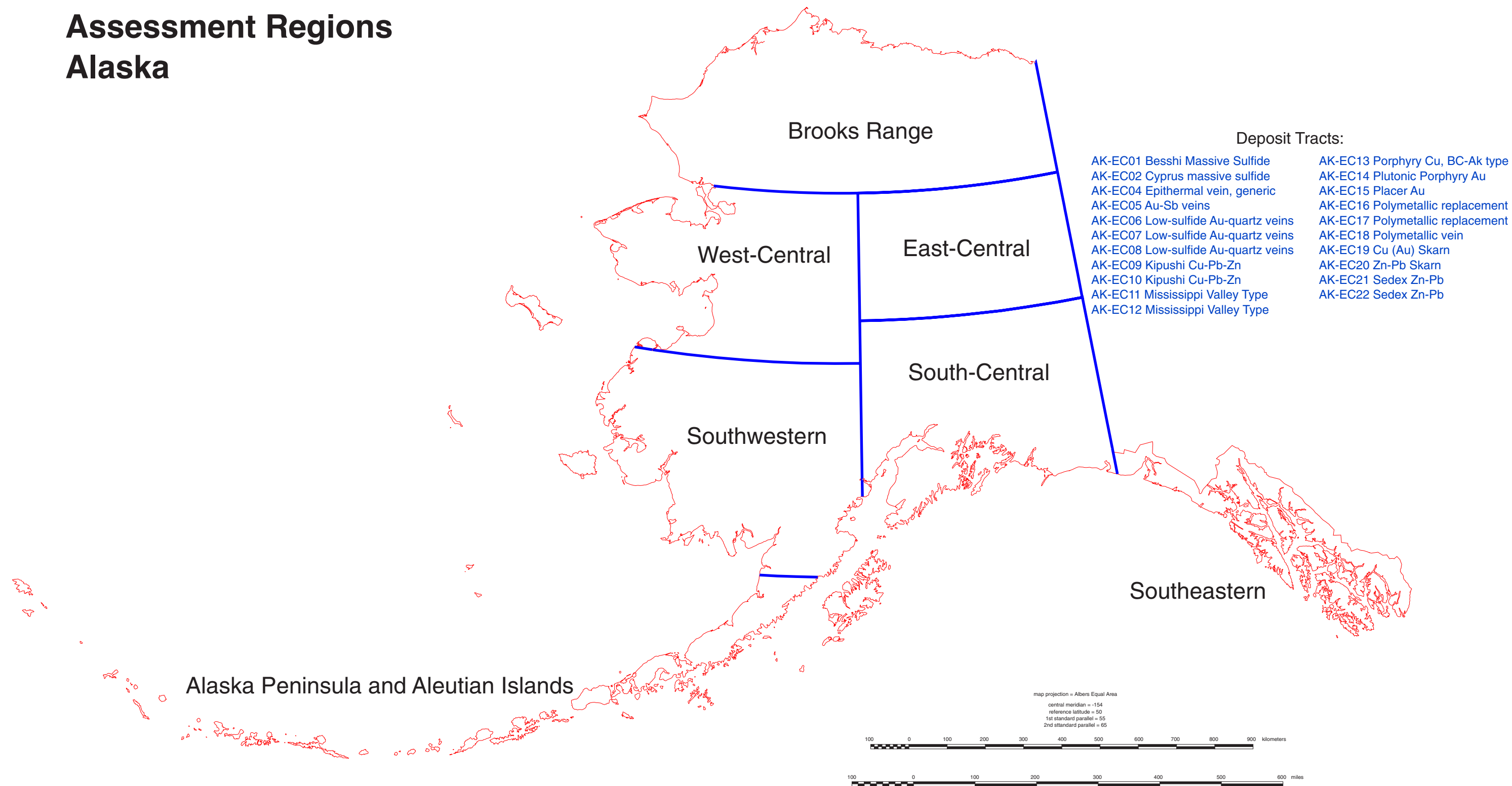
Southeastern

Alaska Peninsula and Aleutian Islands

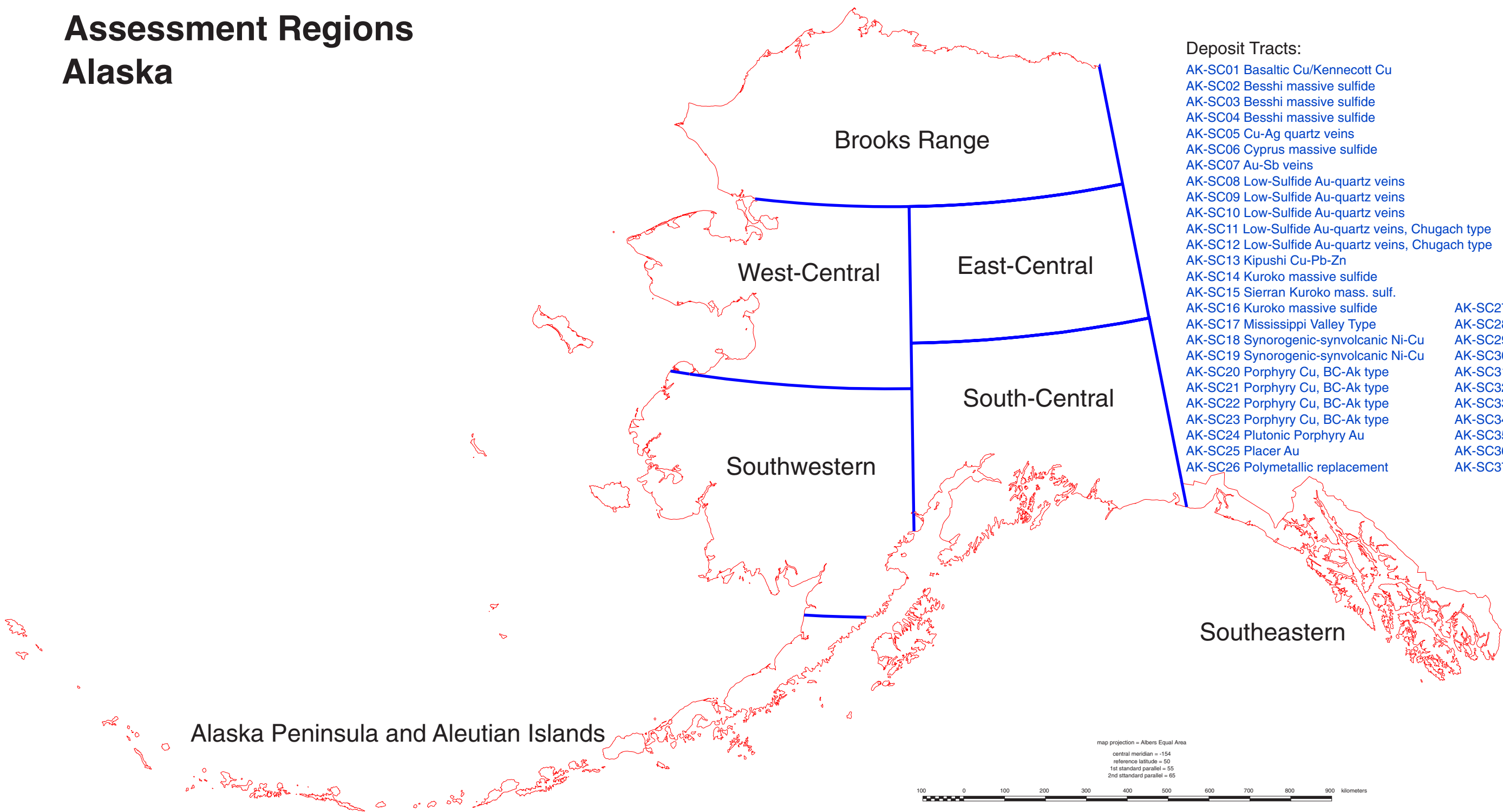
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central meridian = -154
reference latitude = 50
1st standard parallel = 55
2nd standard parallel = 65



National Mineral Resource Assessment Regions Alaska



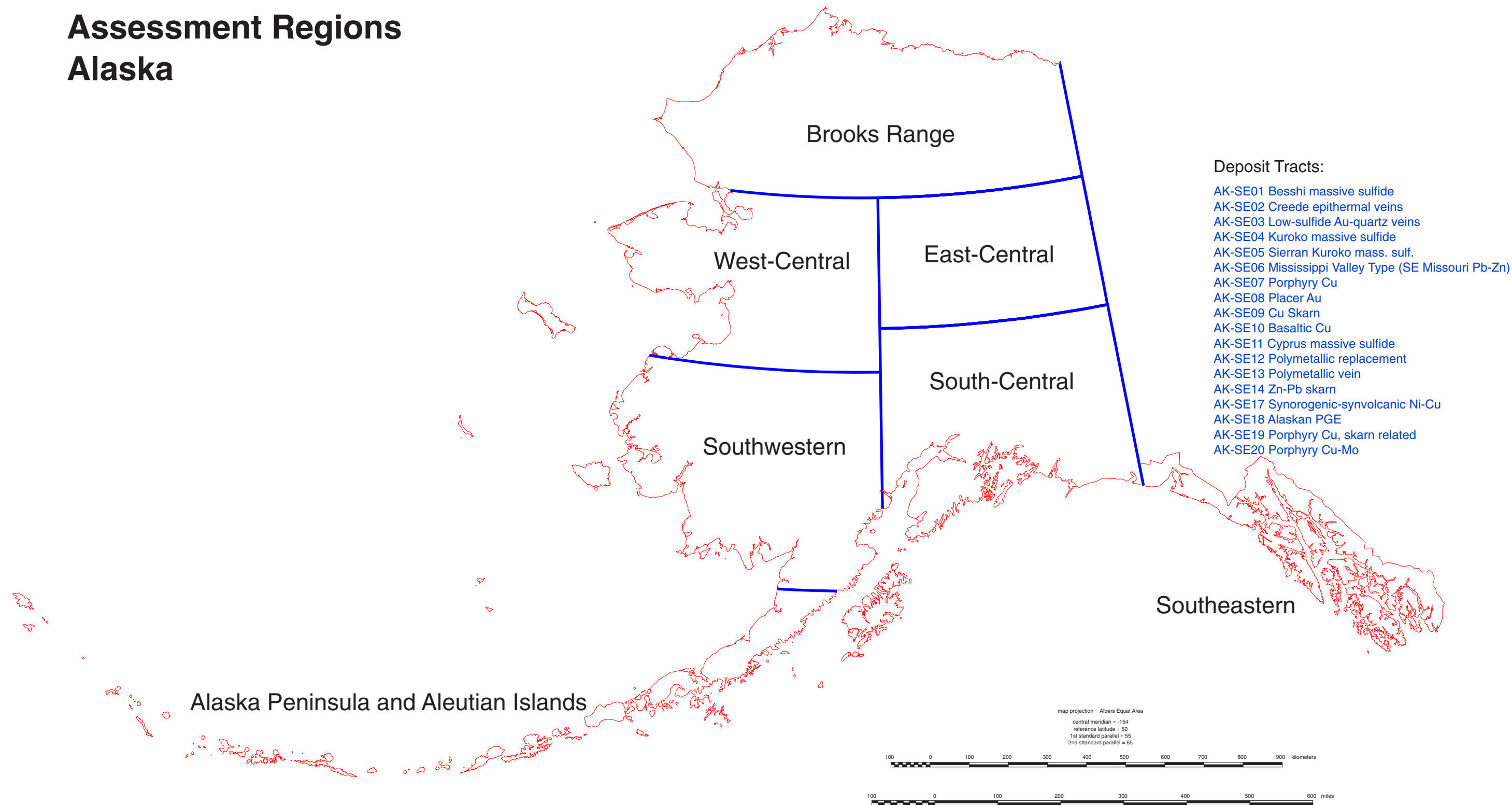
National Mineral Resource Assessment Regions Alaska



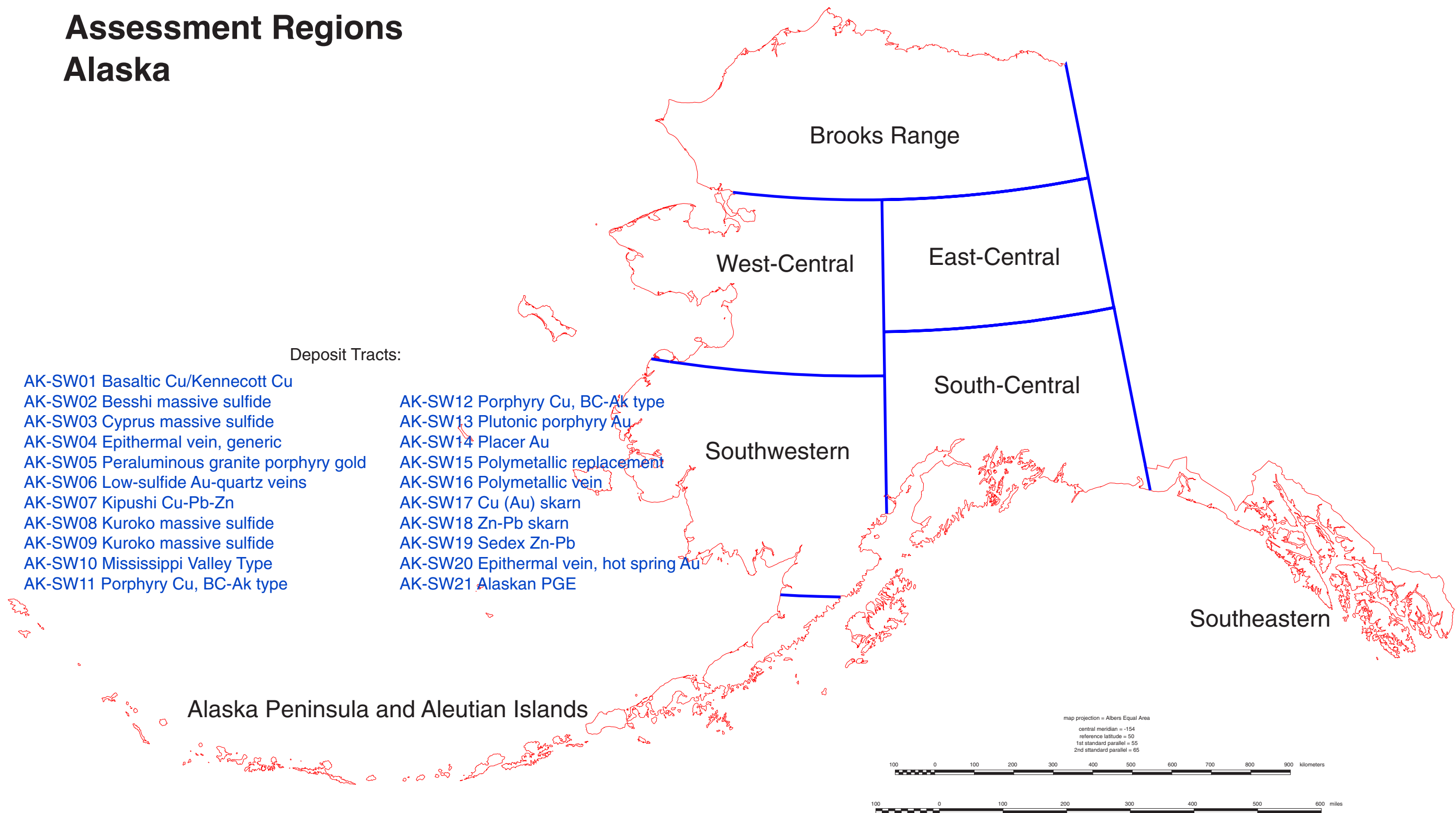
Deposit Tracts:

- AK-SC01 Basaltic Cu/Kennecott Cu
- AK-SC02 Besshi massive sulfide
- AK-SC03 Besshi massive sulfide
- AK-SC04 Besshi massive sulfide
- AK-SC05 Cu-Ag quartz veins
- AK-SC06 Cyprus massive sulfide
- AK-SC07 Au-Sb veins
- AK-SC08 Low-Sulfide Au-quartz veins
- AK-SC09 Low-Sulfide Au-quartz veins
- AK-SC10 Low-Sulfide Au-quartz veins
- AK-SC11 Low-Sulfide Au-quartz veins, Chugach type
- AK-SC12 Low-Sulfide Au-quartz veins, Chugach type
- AK-SC13 Kipushi Cu-Pb-Zn
- AK-SC14 Kuroko massive sulfide
- AK-SC15 Sierran Kuroko mass. sulf.
- AK-SC16 Kuroko massive sulfide
- AK-SC17 Mississippi Valley Type
- AK-SC18 Synorogenic-synvolcanic Ni-Cu
- AK-SC19 Synorogenic-synvolcanic Ni-Cu
- AK-SC20 Porphyry Cu, BC-Ak type
- AK-SC21 Porphyry Cu, BC-Ak type
- AK-SC22 Porphyry Cu, BC-Ak type
- AK-SC23 Porphyry Cu, BC-Ak type
- AK-SC24 Plutonic Porphyry Au
- AK-SC25 Placer Au
- AK-SC26 Polymetallic replacement
- AK-SC27 Polymetallic vein
- AK-SC28 Polymetallic vein
- AK-SC29 Polymetallic vein
- AK-SC30 Cu (Au) skarn
- AK-SC31 Cu (Au) skarn
- AK-SC32 Cu (Au) skarn
- AK-SC33 Cu (Au) skarn
- AK-SC34 Zn-Pb Skarn
- AK-SC35 Zn-Pb skarn
- AK-SC36 Sedex Zn-Pb
- AK-SC37 Sedex Zn-Pb

National Mineral Resource Assessment Regions Alaska



National Mineral Resource Assessment Regions Alaska

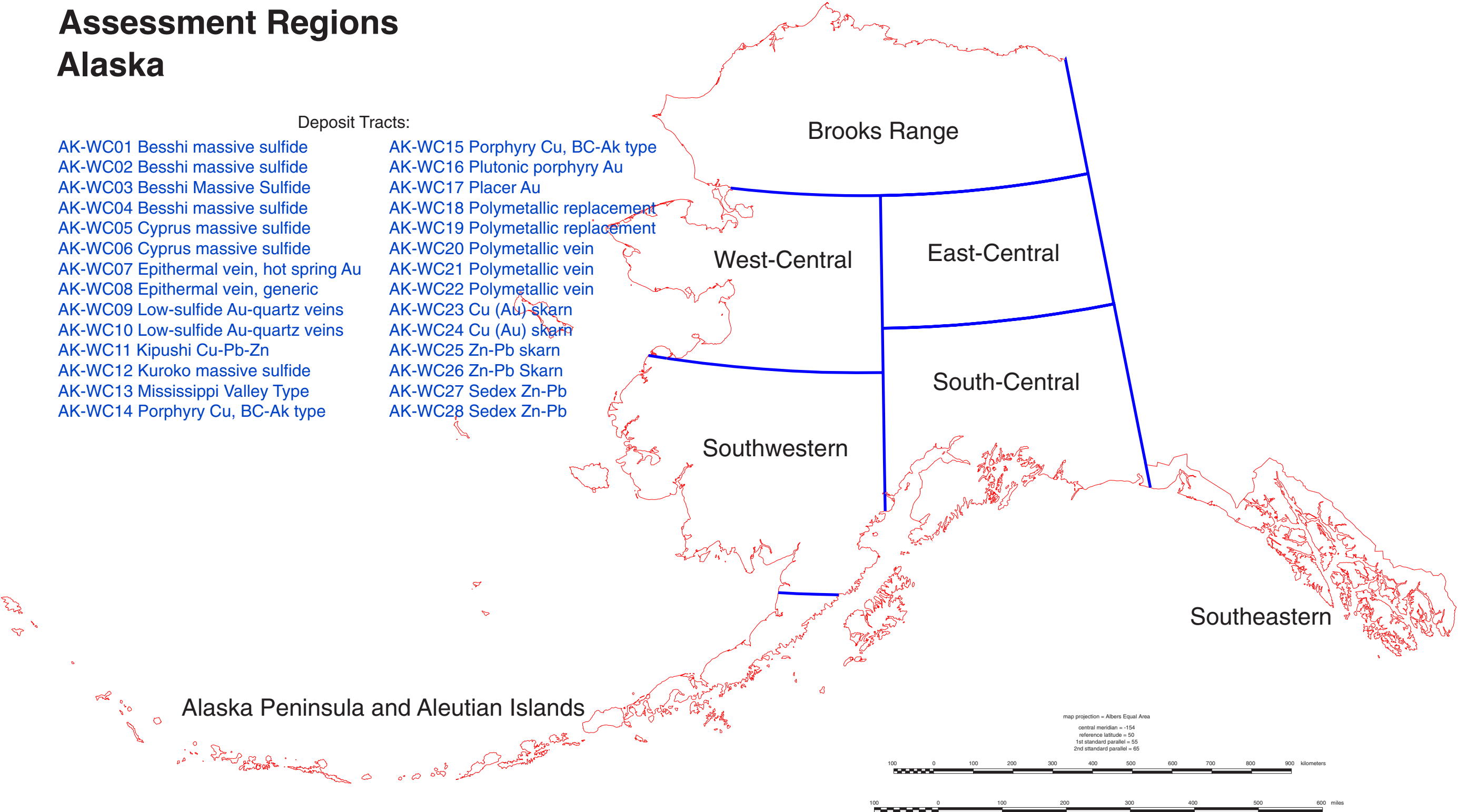


National Mineral Resource Assessment Regions Alaska

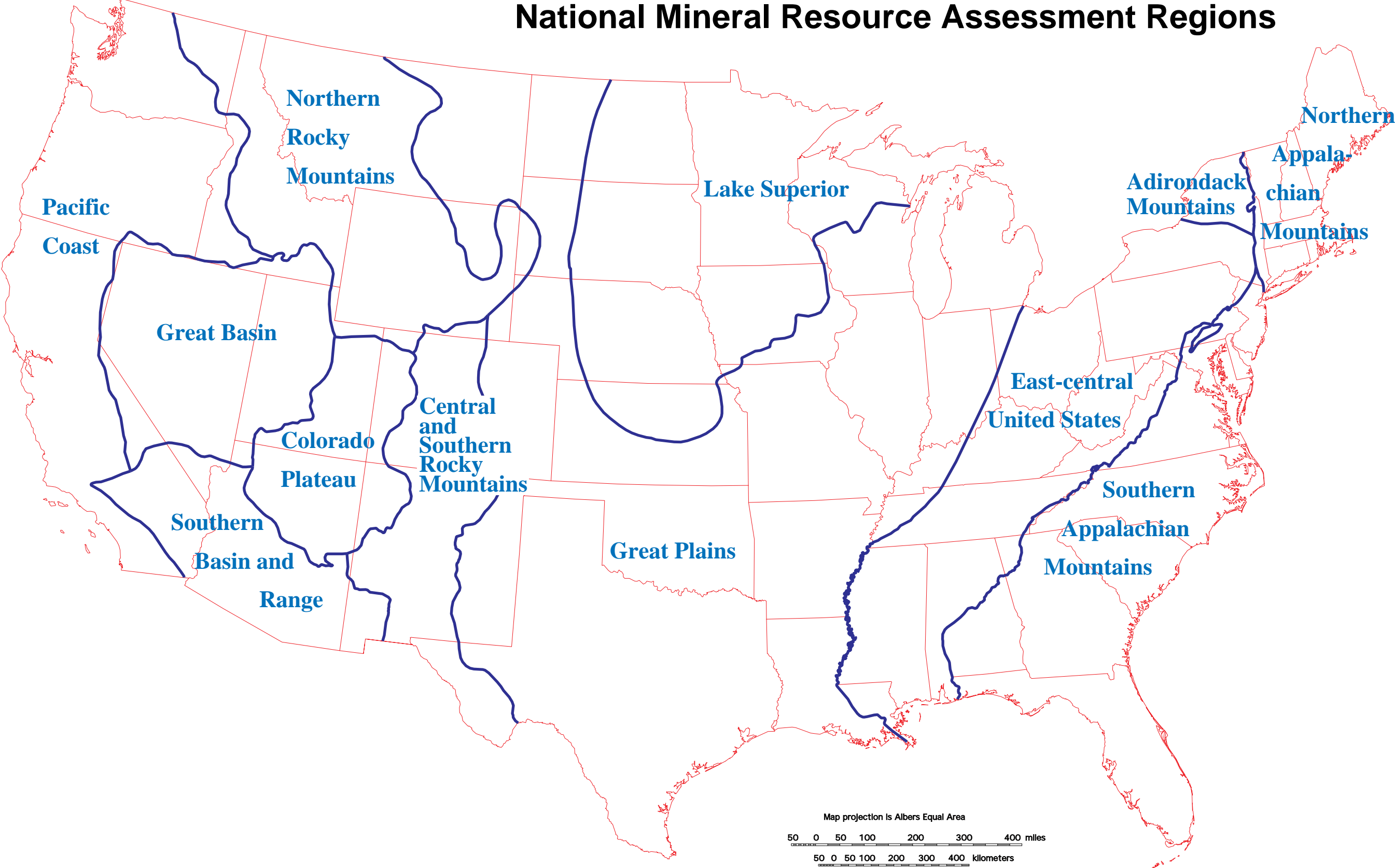
Deposit Tracts:

AK-WC01 Besshi massive sulfide
AK-WC02 Besshi massive sulfide
AK-WC03 Besshi Massive Sulfide
AK-WC04 Besshi massive sulfide
AK-WC05 Cyprus massive sulfide
AK-WC06 Cyprus massive sulfide
AK-WC07 Epithermal vein, hot spring Au
AK-WC08 Epithermal vein, generic
AK-WC09 Low-sulfide Au-quartz veins
AK-WC10 Low-sulfide Au-quartz veins
AK-WC11 Kipushi Cu-Pb-Zn
AK-WC12 Kuroko massive sulfide
AK-WC13 Mississippi Valley Type
AK-WC14 Porphyry Cu, BC-Ak type

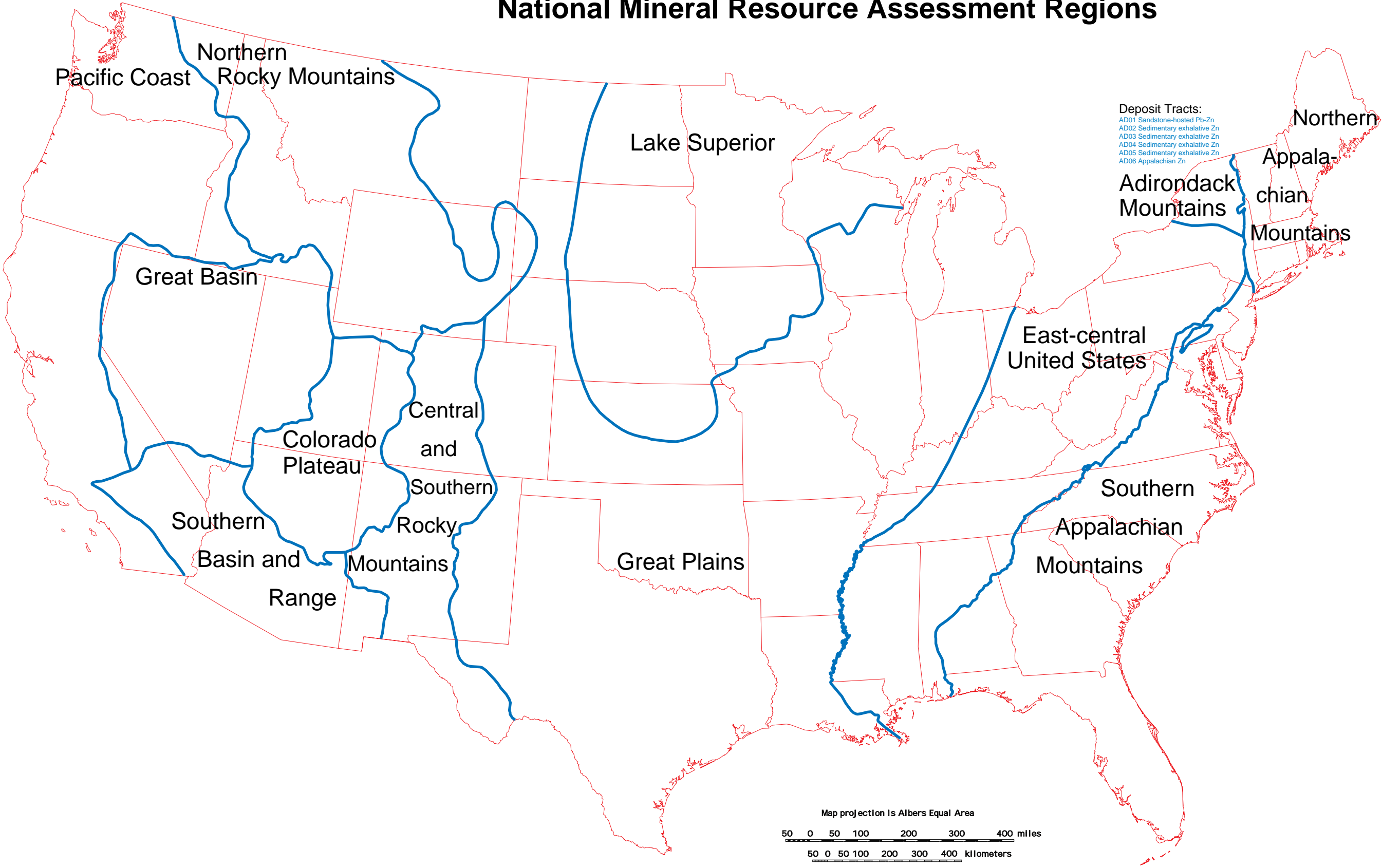
AK-WC15 Porphyry Cu, BC-Ak type
AK-WC16 Plutonic porphyry Au
AK-WC17 Placer Au
AK-WC18 Polymetallic replacement
AK-WC19 Polymetallic replacement
AK-WC20 Polymetallic vein
AK-WC21 Polymetallic vein
AK-WC22 Polymetallic vein
AK-WC23 Cu (Au) skarn
AK-WC24 Cu (Au) skarn
AK-WC25 Zn-Pb skarn
AK-WC26 Zn-Pb Skarn
AK-WC27 Sedex Zn-Pb
AK-WC28 Sedex Zn-Pb



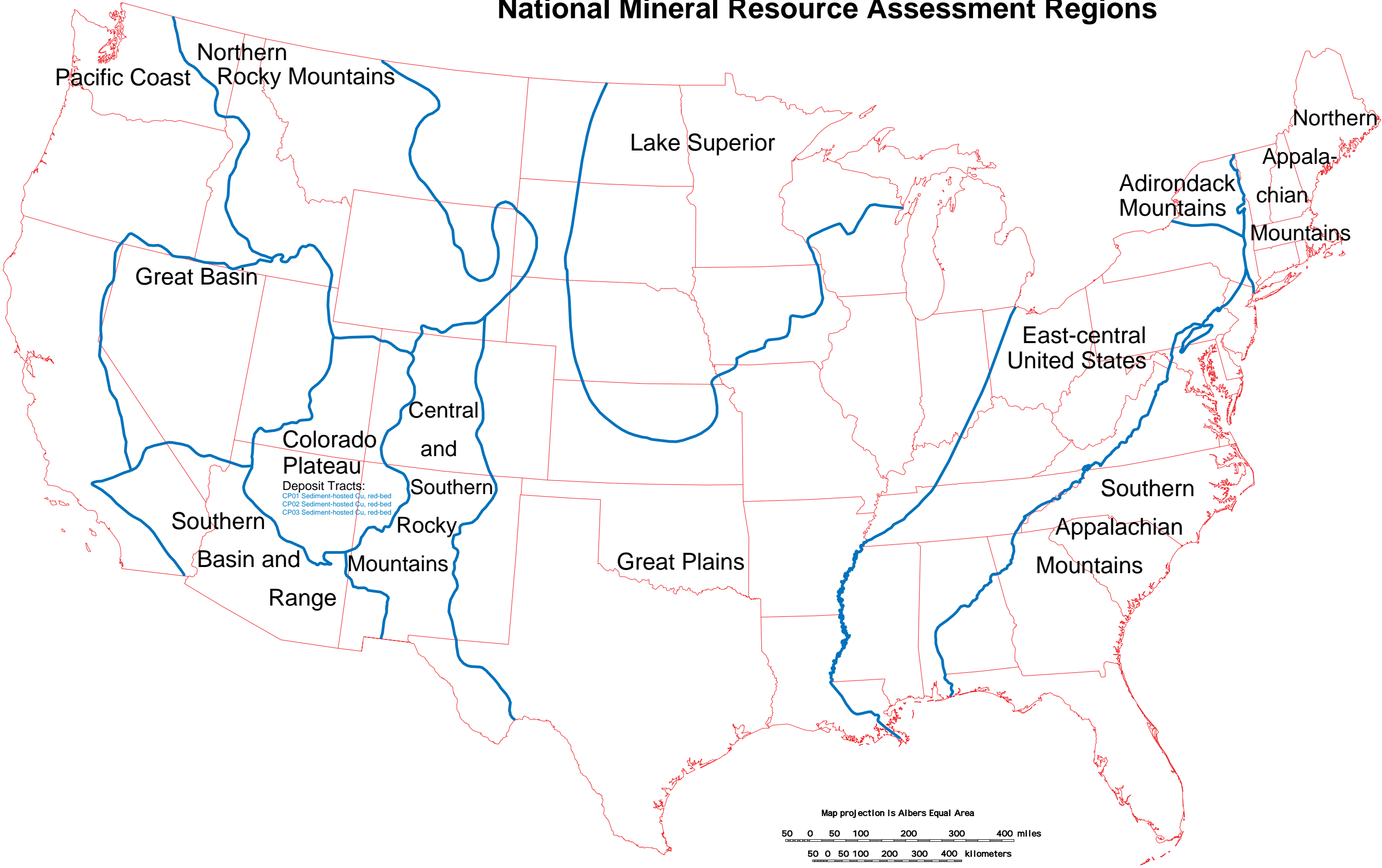
National Mineral Resource Assessment Regions



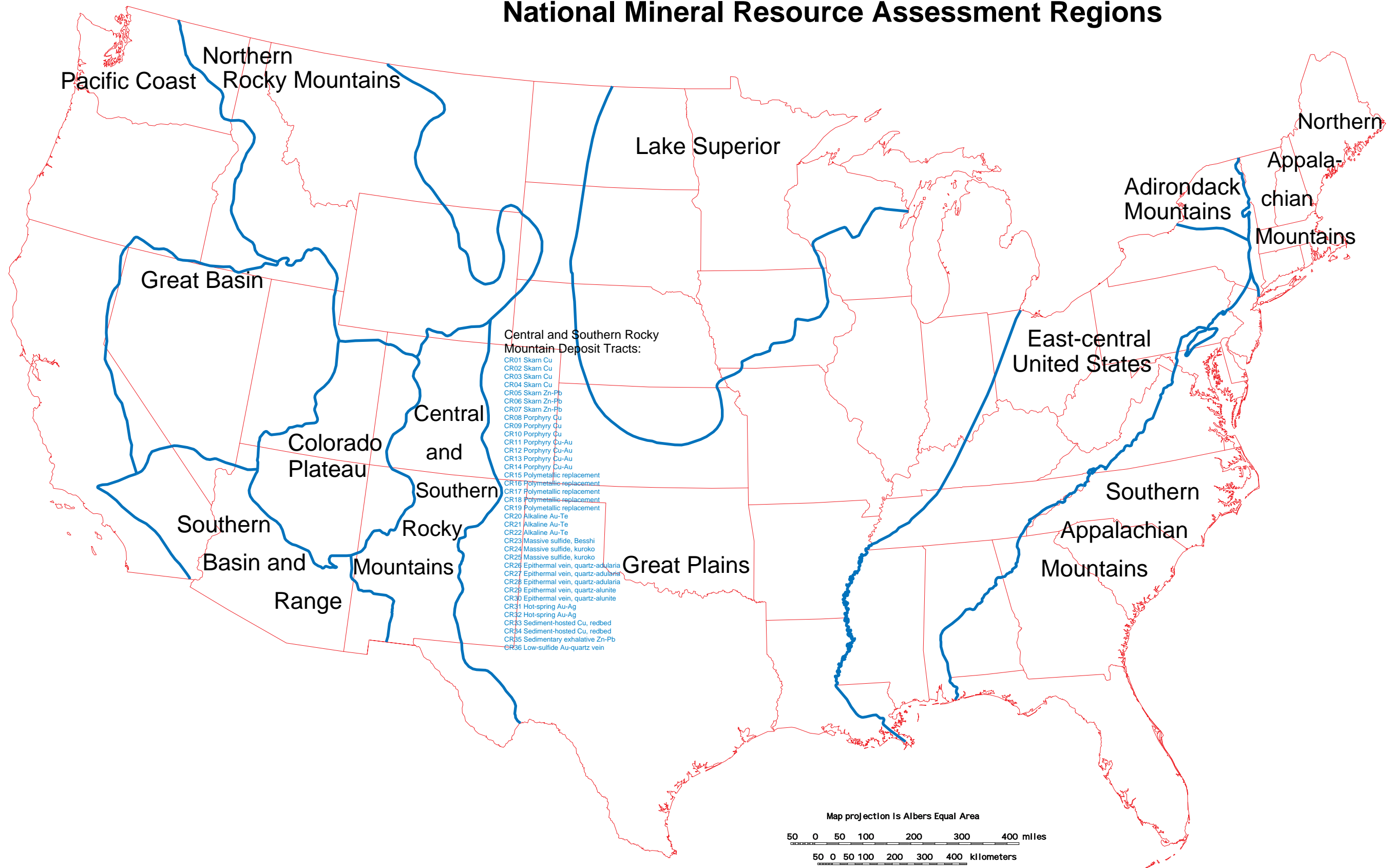
National Mineral Resource Assessment Regions



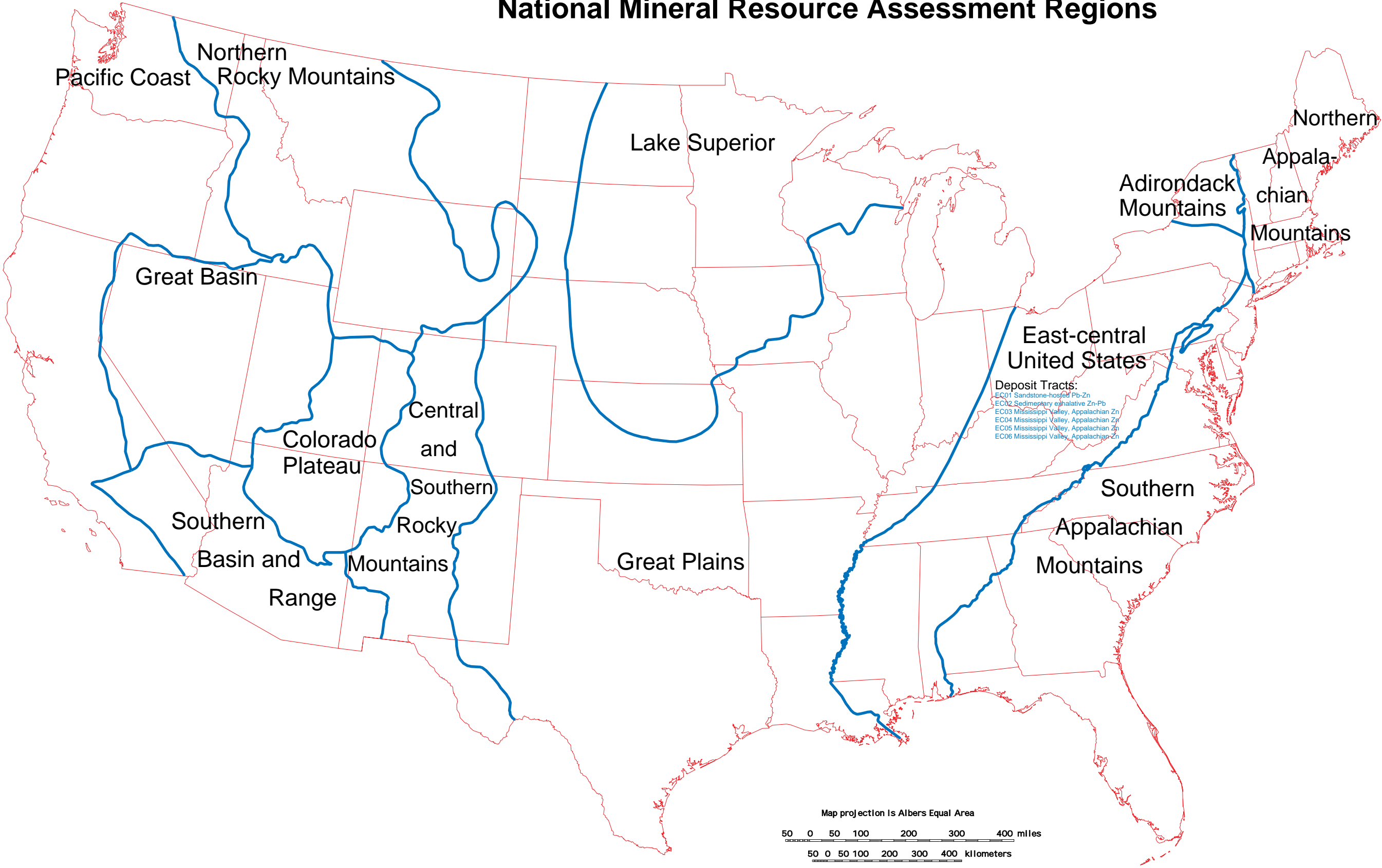
National Mineral Resource Assessment Regions



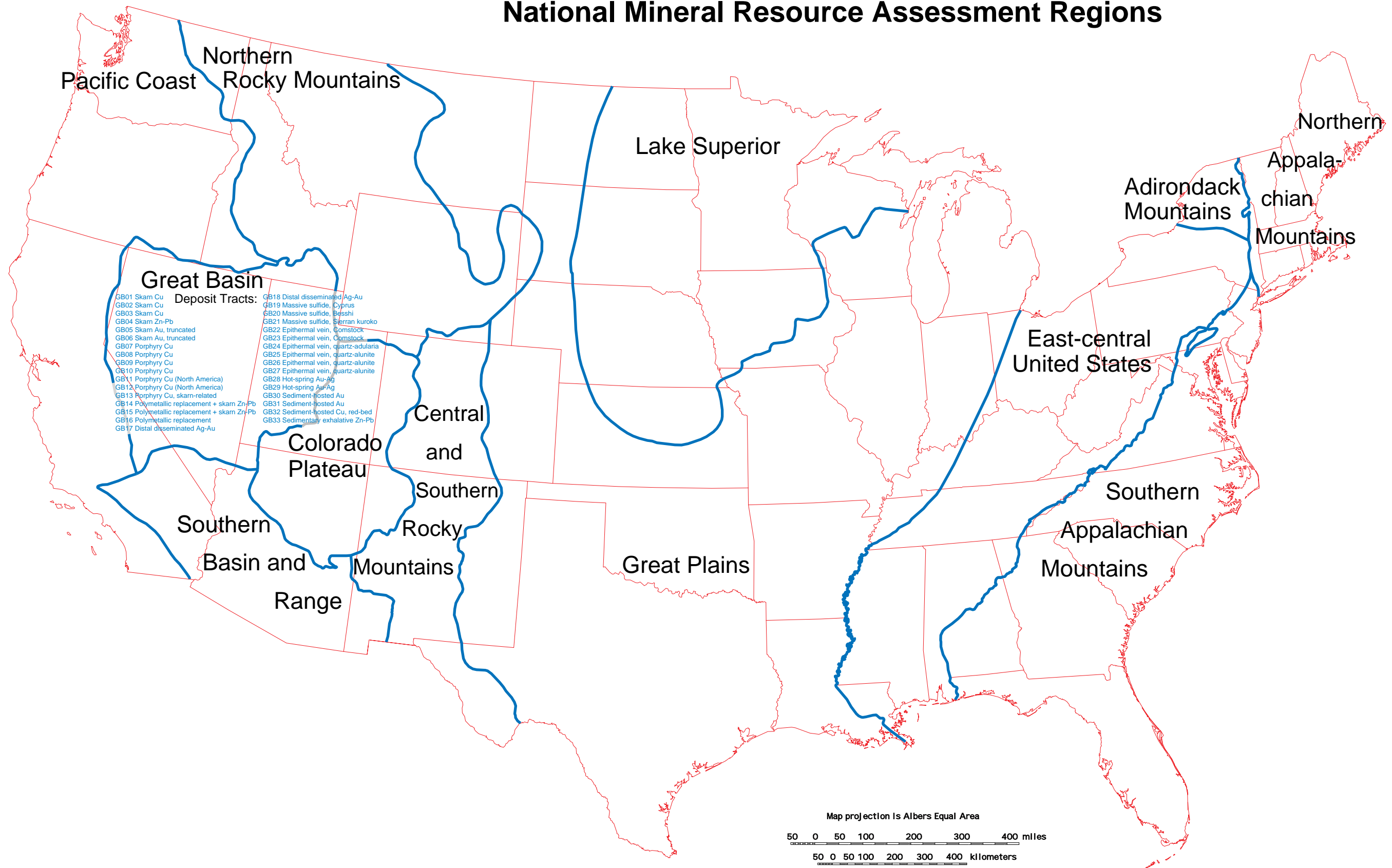
National Mineral Resource Assessment Regions



National Mineral Resource Assessment Regions



National Mineral Resource Assessment Regions

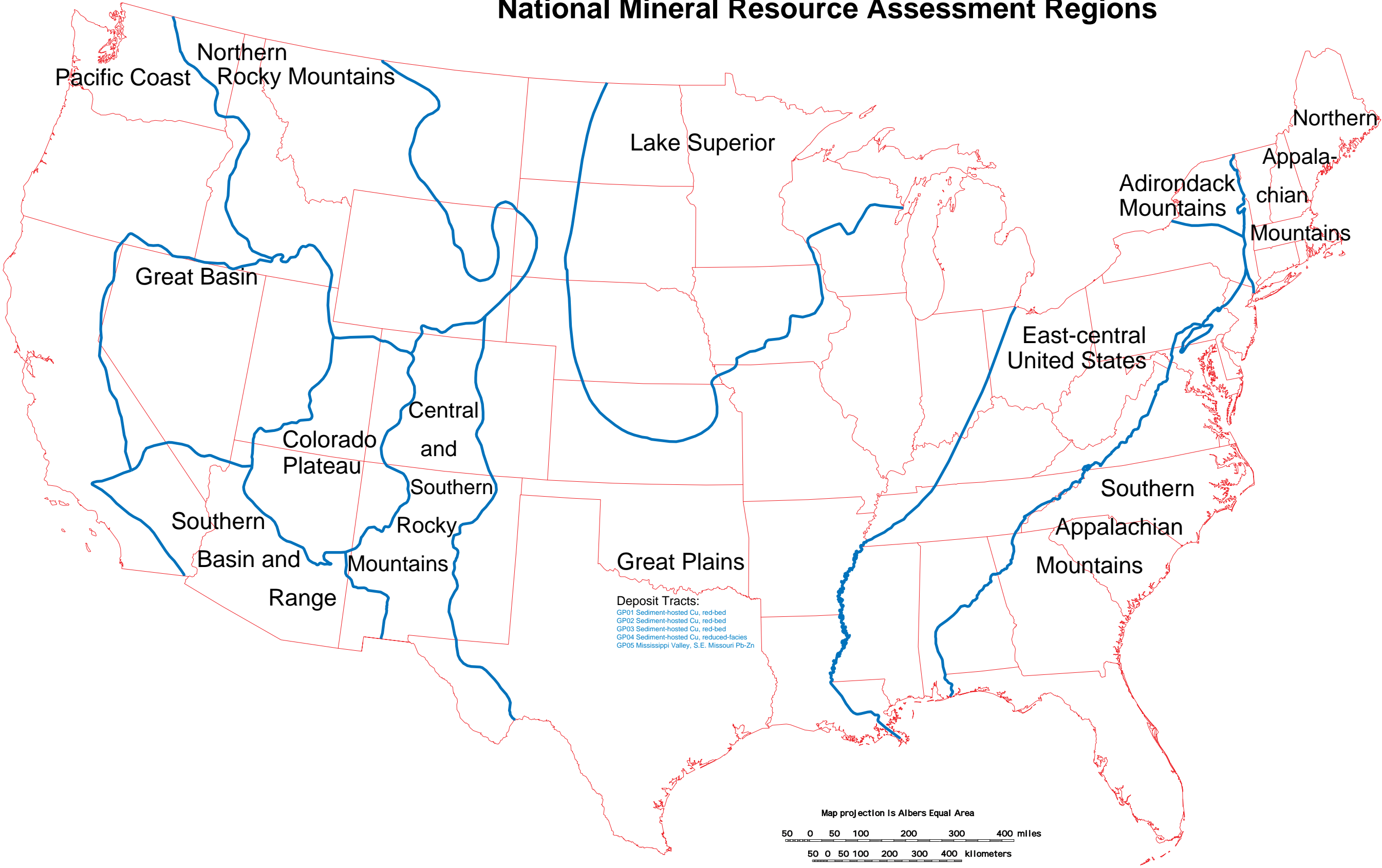


Map projection is Albers Equal Area

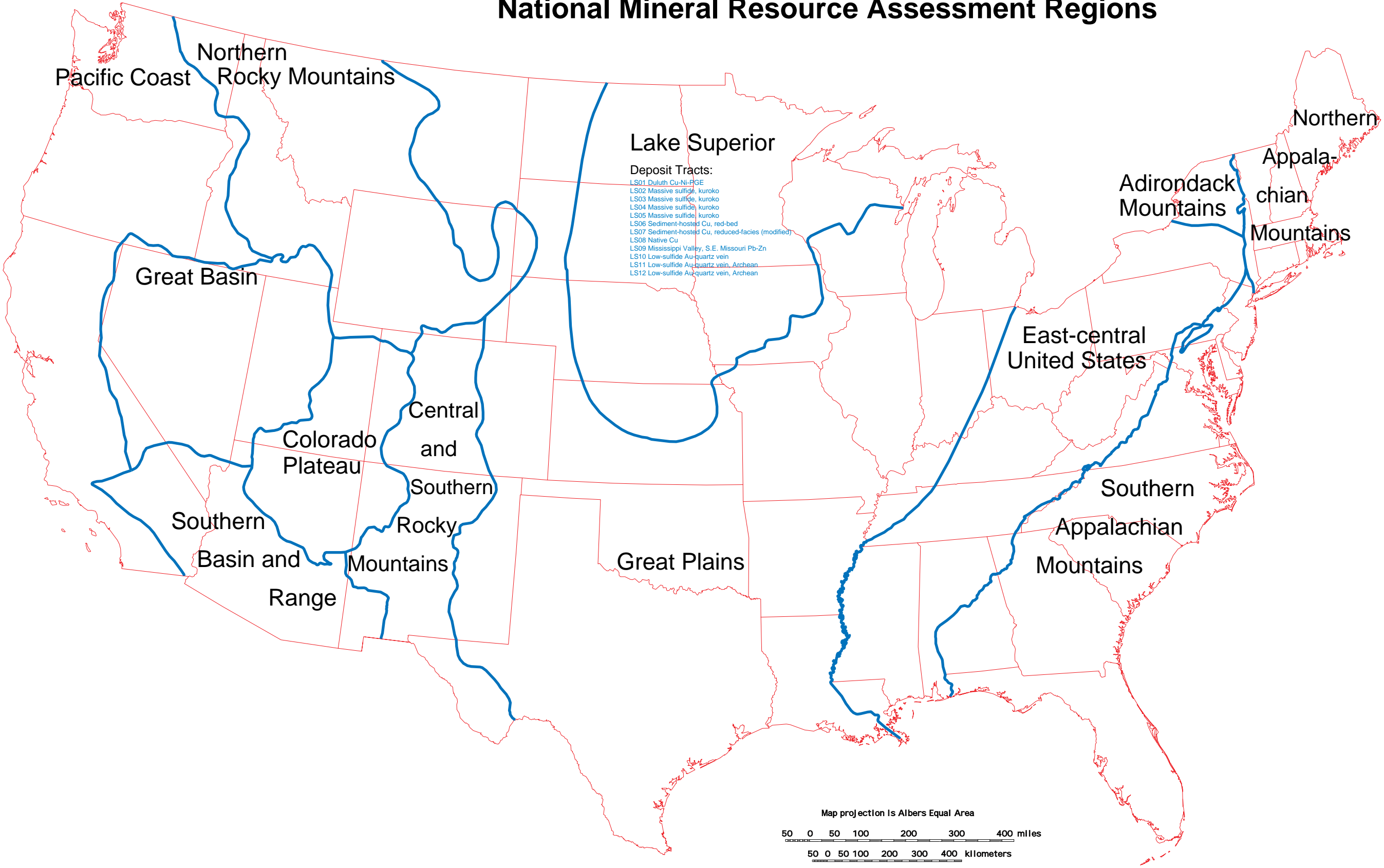
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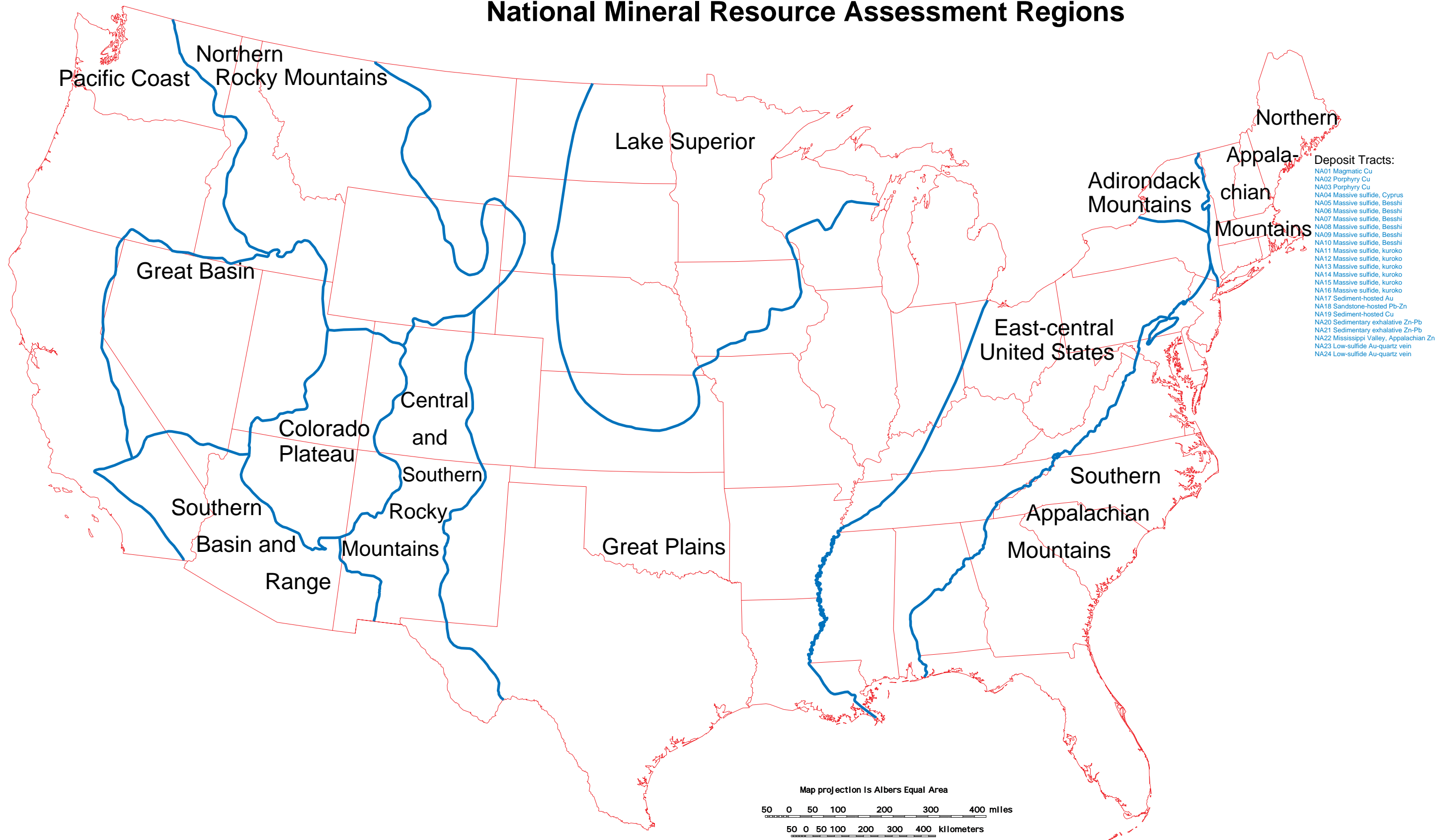
National Mineral Resource Assessment Regions



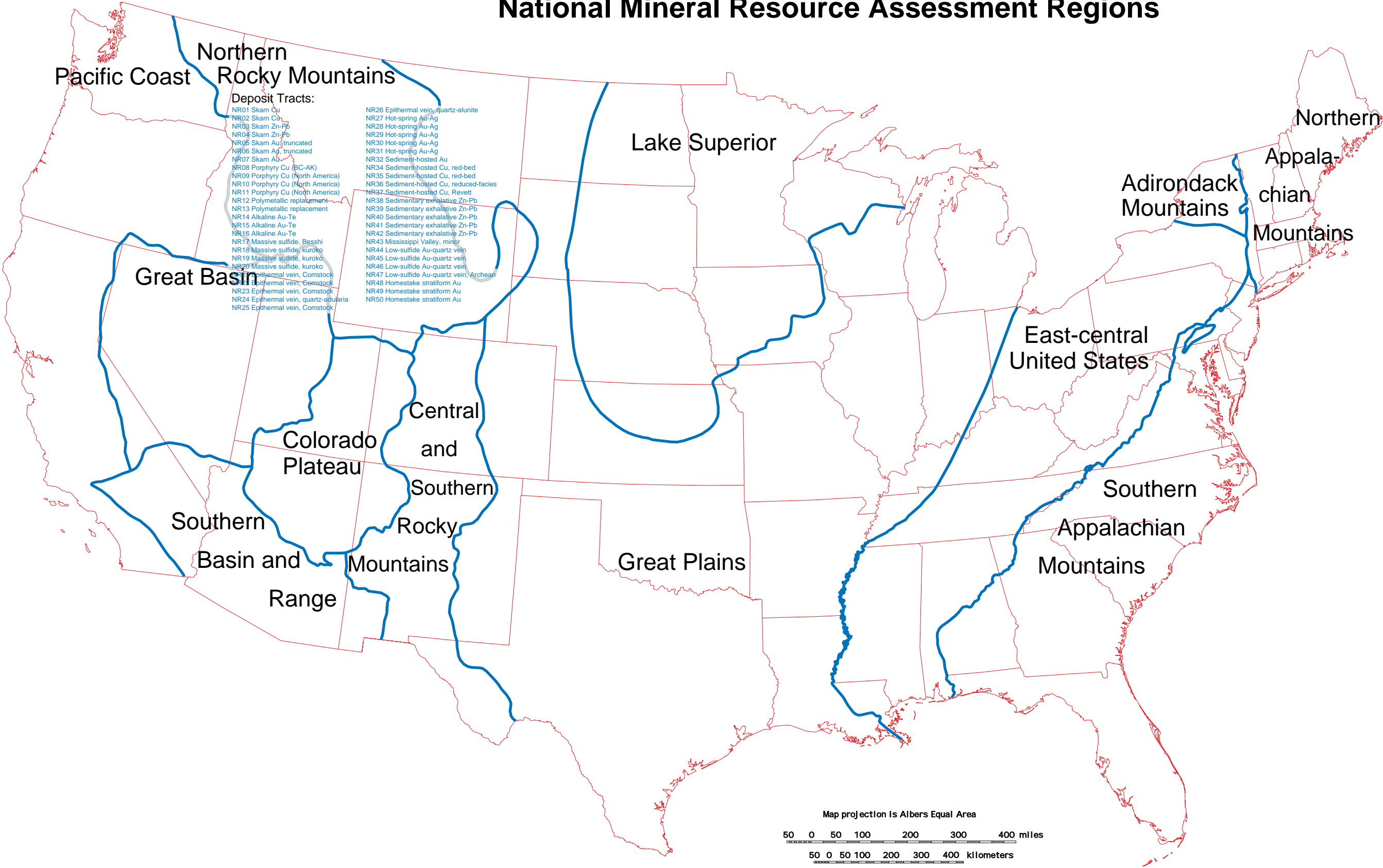
National Mineral Resource Assessment Regions



National Mineral Resource Assessment Regions

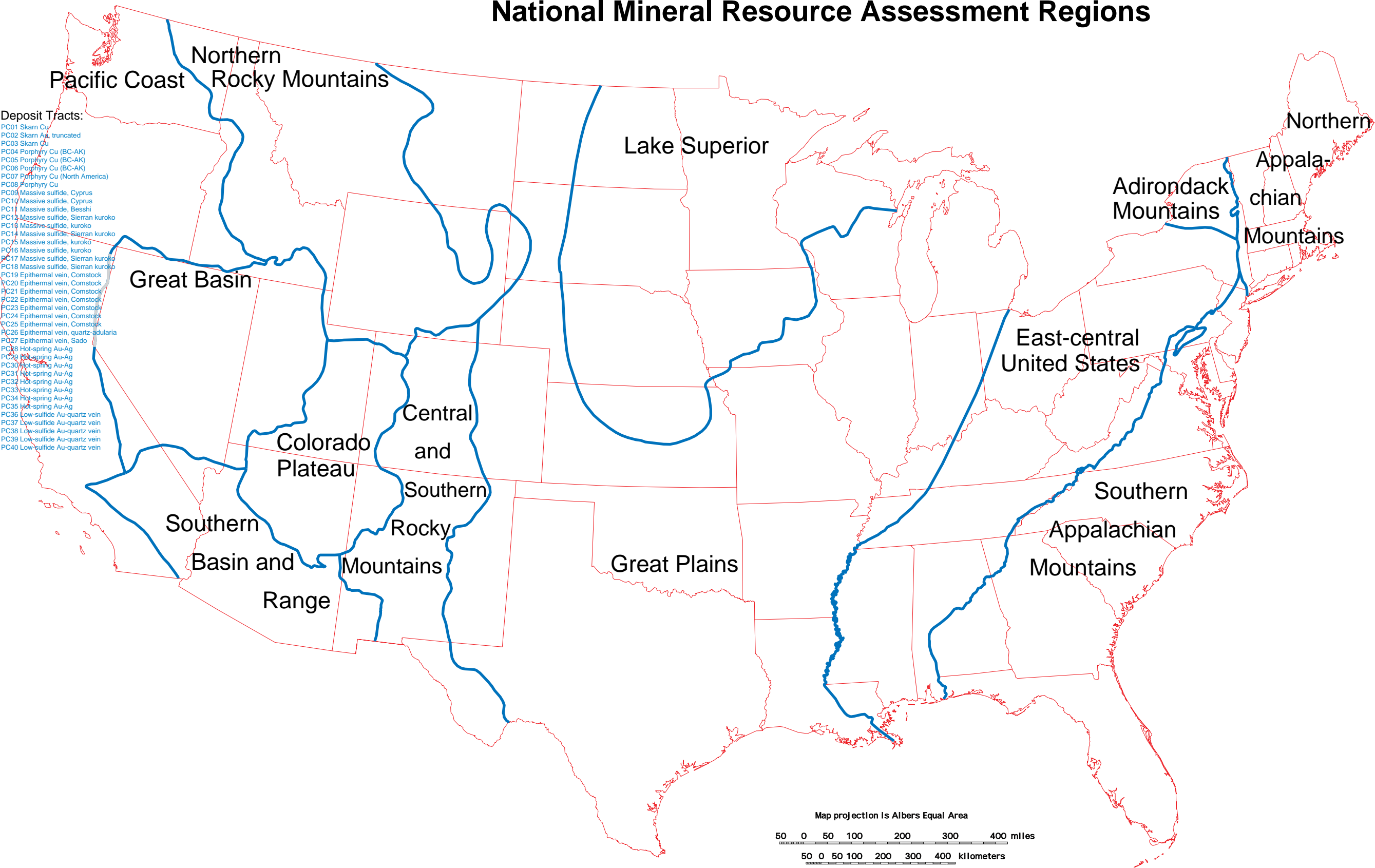


National Mineral Resource Assessment Regions

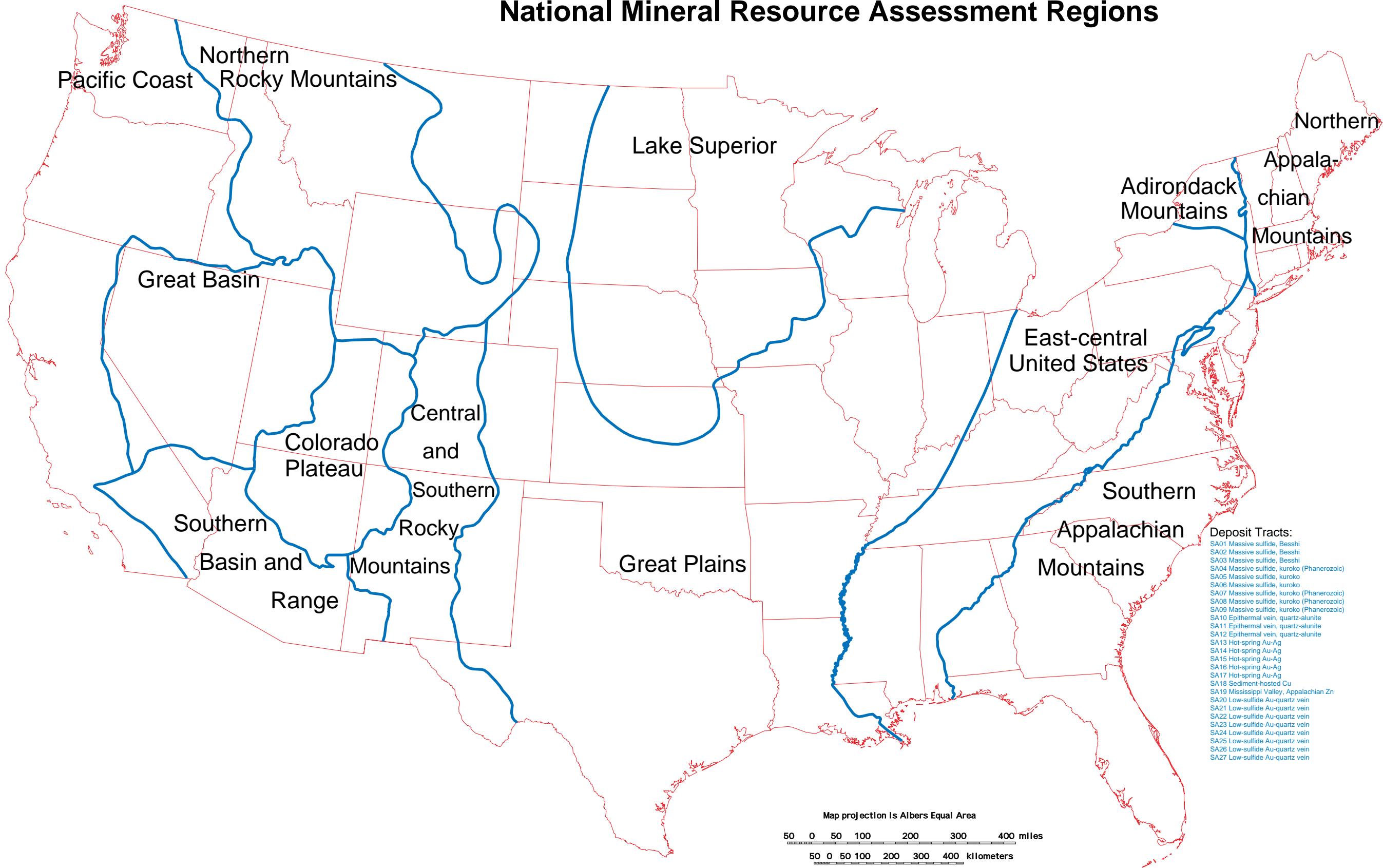


National Mineral Resource Assessment Regions

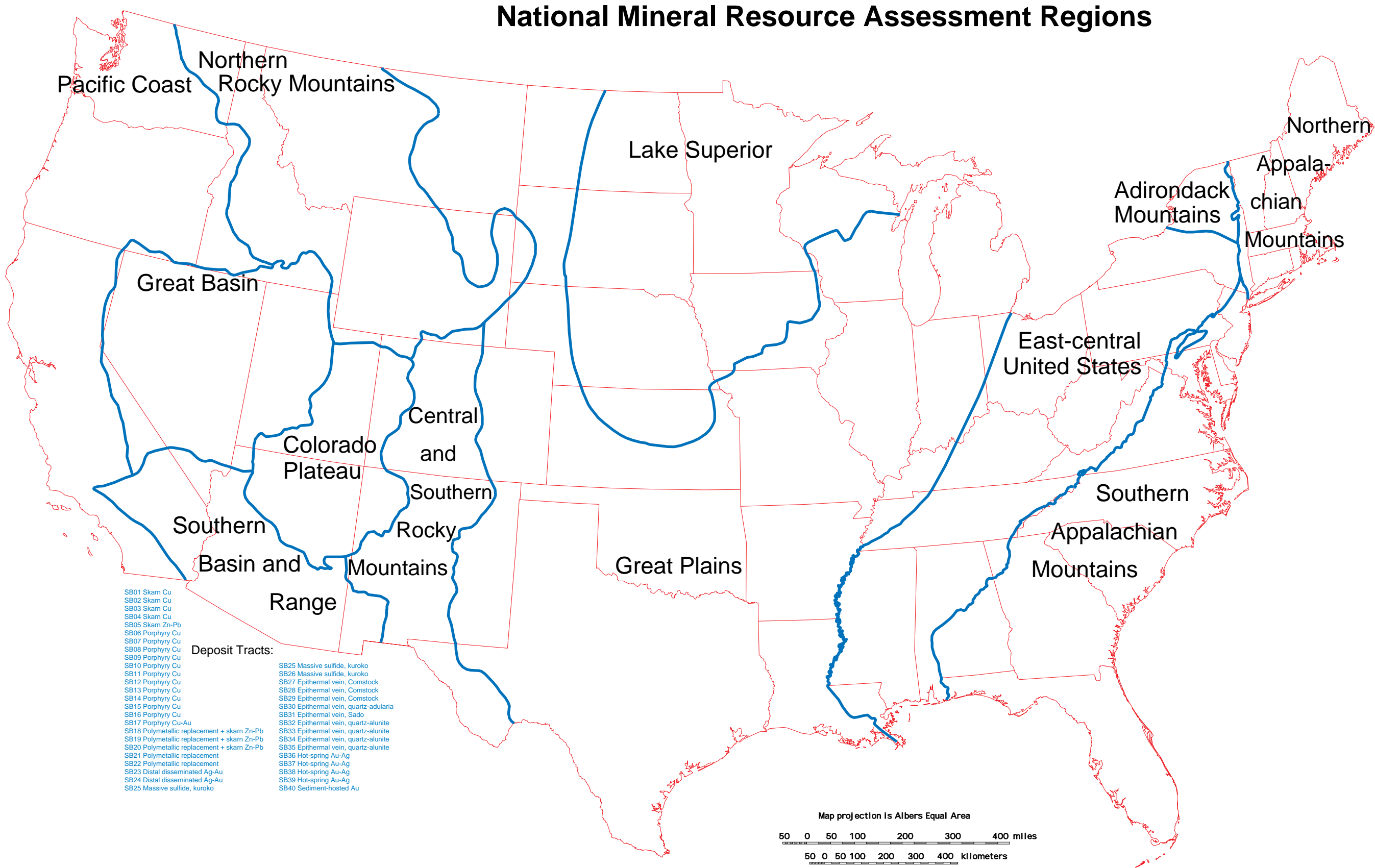
Deposit Tracts:
PC01 Skarn Cu
PC02 Skarn Ag, truncated
PC03 Skarn Cu
PC04 Porphyry Cu (BC-AK)
PC05 Porphyry Cu (BC-AK)
PC06 Porphyry Cu (BC-AK)
PC07 Porphyry Cu (North America)
PC08 Porphyry Cu
PC09 Massive sulfide, Cyprus
PC10 Massive sulfide, Cyprus
PC11 Massive sulfide, Besshi
PC12 Massive sulfide, Sierran kuroko
PC13 Massive sulfide, kuroko
PC14 Massive sulfide, Sierran kuroko
PC15 Massive sulfide, kuroko
PC16 Massive sulfide, kuroko
PC17 Massive sulfide, Sierran kuroko
PC18 Massive sulfide, Sierran kuroko
PC19 Epithermal vein, Comstock
PC20 Epithermal vein, Comstock
PC21 Epithermal vein, Comstock
PC22 Epithermal vein, Comstock
PC23 Epithermal vein, Comstock
PC24 Epithermal vein, Comstock
PC25 Epithermal vein, Comstock
PC26 Epithermal vein, quartz-adularia
PC27 Epithermal vein, Sado
PC28 Hot-spring Au-Ag
PC29 Hot-spring Au-Ag
PC30 Hot-spring Au-Ag
PC31 Hot-spring Au-Ag
PC32 Hot-spring Au-Ag
PC33 Hot-spring Au-Ag
PC34 Hot-spring Au-Ag
PC35 Hot-spring Au-Ag
PC36 Low-sulfide Au-quartz vein
PC37 Low-sulfide Au-quartz vein
PC38 Low-sulfide Au-quartz vein
PC39 Low-sulfide Au-quartz vein
PC40 Low-sulfide Au-quartz vein



National Mineral Resource Assessment Regions



National Mineral Resource Assessment Regions



[AK01](#)

Cyprus Massive Sulfide

Alaska

Descriptive Model: 24a

Mark3 Index: 11

Area: 124,223 km²

Mean undiscovered deposits: ????

[Cumulative Distribution](#)

[Histogram](#)

[Table](#)

[Model](#)

by: Thomas D. Light, Byron R. Berger, Larry J. Drew, Bruce M. Gamble, Donald Grybeck, Marti L. Miller, Jeanine M. Schmidt, and Frederick H. Wilson

Rationale for Model Choice

Many mafic and ultramafic complexes in Alaska are geologically permissive for the occurrence of Cyprus massive sulfide deposits as described by Singer (1986).

Rationale for Tract Delineation

This tract is a composite tract which comprises all areas permissive for Cyprus massive sulfide deposits throughout the state.

Important Examples of Deposit Type

There are several small deposits in south central and southeastern Alaska that are inferred to be Cyprus massive sulfide deposits.

Rationale for Numerical Estimates

The lack of estimates for undiscovered Cyprus massive sulfide deposits in half of the individual permissive tracts in Alaska reflects the lack of information upon which to classify a deposit estimate, rather than a lack of deposits. We considered that most of the known deposits outside either Cyprus or the former USSR do not exceed the mean deposit tonnage or grade shown on the distribution curve. We considered the estimates already made for some regions and the areal distribution of permissive areas. The number of undiscovered Cyprus massive sulfide deposits estimated for the composite permissive tracts for the state of Alaska, based on the grade and tonnage model of Singer and Mosier (1986) is:

Percentile	90	50	10	5	1
Estimated number of deposits	1	3	5	10	12

References

Singer, D.A., 1986, Descriptive model of Cyprus massive sulfide, *in*, Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 131.

Singer, D.A., and Mosier, D.L., 1986, Grade and tonnage model of Cyprus massive sulfide deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 131-135.

AK02

Mississippi Valley Type Pb-Zn

Alaska

Descriptive Model: 32a and 32b

Mark3 Index: 42

Area: 131,294 km²

Mean undiscovered deposits:

[Cumulative Distribution](#)

[Histogram](#)

[Table](#)

[Model](#)

[Mineral Deposits](#)

by: Thomas D. Light, Jeanine M. Schmidt, Byron R. Berger, Larry J. Drew, Bruce M. Gamble, Donald Grybeck, Marti L. Miller, and Frederick H. Wilson

Rationale for Model Choice

Two Mississippi Valley type (MVT) deposits are described in Cox and Singer (1986). The differences between Southeast Missouri Pb-Zn (model 32a; Briskey 1986b) and Appalachian Zn (model 32b; Briskey, 1986a) are subtle enough that the grade and tonnage models for the two deposit types are plotted together with no differentiation between types (Mosier and Briskey, 1986). In Alaska, the lack of detailed geologic information prevents distinguishing between the two deposit types, and a generic Mississippi Valley type model has been used.

Rationale for Tract Delineation

This tract comprises the combined areas of all the tracts throughout the state that are permissive for Mississippi Valley type deposits, and is defined predominately by the distribution of carbonate rocks. These are mainly platform carbonates, but also include slope and deeper-water lithologies.

Important Examples of Deposit Type

The Reef Ridge deposit in the Medfra quadrangle of west-central Alaska is an example of a Mississippi Valley type deposit (Andrews and Rishel, 1982). The Powdermilk deposit in the Brooks Range (Schmidt and Folger, 1986) and the Step deposit in East Central (Schmidt, 1997) may also be Mississippi Valley type deposits.

Rationale for Numerical Estimates

No basinal sources of fluids have been identified because of the difficulty of reconstructing the pre-Jurassic folding and thrusting paleogeography, and the timing of any possible Mississippi Valley type mineralizing episodes is totally unconstrained. In addition, the geology of most of the individual tracts is poorly known. Therefore, we have attempted to look at the state as a whole to project what little knowledge is available over a larger area. The estimated minimum number of undiscovered Mississippi Valley Type deposits in Alaska, based on the grade and tonnage model of Mosier and Briskey (1986) is:

Percentile	90	50	10	5	1
Estimated number of deposits	1	2	4	6	6

References

- Andrews, T., and Rishel, John, 1982, 1981 Annual Report-Reef Ridge I-XIII project areas, Kuskokwim Block, Volume 1 of 3: unpublished report, Patino Inc., Anchorage, Alaska, 49 p.
- Briskey, J.A., 1986a, Descriptive model of Appalachian Zn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 222-223.
- Briskey, J.A., 1986b, Descriptive model of southeast Missouri Pb-Zn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 220-221.
- Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, 379 p.
- Mosier, D.L., and Briskey, 1986, Grade and tonnage model of southeast Missouri Pb-Zn and Appalachian Zn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 224-226.

- Schmidt, J.M., 1997, Strata-bound carbonate-hosted Zn-Pb and Cu deposits of Alaska, *in* Goldfarb, R.J., and Miller, L.D., eds., Mineral Deposits of Alaska: Economic Geology Monograph 9, p. 90-119.
- Schmidt, J.M., and Folger, P.F., 1986, Pb-Zn-Ag mineralization in Paleozoic dolostones, Powdermilk prospect, Baird Mountains B-4 quadrangle, *in* Bartsch-Winkler, Susan, and Reed, K.M., eds., Geologic studies in Alaska by the U.S. Geological Survey during 1985: U.S. Geological Survey Circular 978, p. 19-21.

Descriptive Model: 39a

Mark3 Index: 54

Area: 942,218 km²

Mean undiscovered deposits: ????

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Thomas D. Light, Donald Grybeck, Jeanine M. Schmidt, Byron R. Berger, Marti L. Miller, Bruce M. Gamble, and Larry J. Drew.

Rationale for Model Choice

Placer gold has accounted about 24 million ounces, or more than 70%, of the gold production from Alaska (Bundtzen and others, 1996). Placer gold (Yeend, 1986) can be expected to occur in unconsolidated deposits downstream from any of the gold-bearing lode deposit types. Therefore the placer gold permissive area is quite broad.

Rationale for Tract Delineation

This composite tract comprises areas of unconsolidated deposits downstream from areas permissive for gold-bearing lode deposits.

Important Examples of Deposit Type

There are numerous important examples of placer gold deposits in Alaska, including deposits in the Fairbanks district, which produced more than 8 million ounces of gold, the Nome and Council districts, which together produced about 6 million ounces of gold, and the Iditarod and Circle districts, which each produced over a million ounces of gold.

Rationale for Numerical Estimates

Because of the long period of intense exploration and the geographically broad classification of placer districts, no new major districts are expected to be discovered. It is expected that by applying new technology and ideas, new deposits within the districts will be discovered, and that the districts will be extended. Berg and others (1964) assessed the placer gold resources of Alaska. They reported that 20 million ounces of gold had been produced from placer deposits in the state, and estimated that the remaining resources were "at least equal in quantity and grade to those that have been mined." We basically accepted their assessment and tried to express values for the different confidence levels. The undiscovered placer gold resources, in million ounces, at various confidence levels is estimated to be:

Percentile	90	50	10	5	1
Million ounces estimated	10	15	20	25	30

References

- Berg, H.C., Eberlein, G.D., and MacKevett, Jr., E.M., 1964, Metallic mineral resources, *in* Mineral and water resources of Alaska, Report prepared by the United States Geological Survey in cooperation with State of Alaska Department of Natural Resources at the request of Senator Ernest Gruening of Alaska of the Committee on Interior and Insular Affairs United States Senate, U.S. Government Printing Office, Washington, D.C., p. 95-125.
- Bundtzen, T.K., Swainbank, R.C., Clough, A.H., Henning, M.W., and Charlie, K.M., 1996, Alaska's Mineral Industry, 1995, Alaska Division of Geological and Geophysical Surveys Special Report 50, 72 p.
- Yeend, Warren, 1986, Descriptive model of placer Au-PGE, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 261.

Descriptive Model: 31a

Mark3 Index: 13

Area: 166,679 km²

Mean undiscovered deposits:

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Jeanine M. Schmidt, Byron R. Berger, Thomas D. Light, Larry J. Drew, Bruce M. Gamble, Donald Grybeck, Marti L. Miller, and Frederick H. Wilson

Rationale for Model Choice

Major deposits of shale-hosted Zn-Pb-Ag +/-Ba deposits (Briskey, 1986) occur in Alaska. The geologic setting, deep-water marine sedimentary host rocks and drainage geochemistry are permissive for additional deposits.

Rationale for Tract Delineation

This composite tract comprises all of the individual tracts permissive for sedex deposits in Alaska. Those tracts having estimates of the number of undiscovered deposits were used as guidelines to the potential for undiscovered deposits throughout the state.

Important Examples of Deposit Type

Known mineral occurrences of this type include the Red Dog mine (Lange and others, 1985; Moore and others, 1986; Schmidt and Zierenberg, 1988; Zierenberg and Schmidt, 1988) and the Lik (Forrest, 1983; Forrest and others, 1983; Forrest and Sawkins, 1987), Drenchwater (Nokleberg and Winkler, 1982), and Suds prospects (Schmidt, 1997).

Rationale for Numerical Estimates

Based on the wide extent of appropriate host rocks, several known and drilled prospects, and widespread geochemical anomalies, the number of undiscovered deposits, consistent with the median grade and tonnage for the model (Menzie and Mosier, 1986), estimated for Alaska is:

Percentile	90	50	10	5	1
Estimated number of deposits	3	8	12	17	30

References

- Briskey, J.A., 1986, Descriptive model of sedimentary exhalative Zn-Pb, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 211-212
- Forrest, Kimball, 1983, Geology and isotopic studies of the Lik deposit and the surrounding mineral district, DeLong Mountains, Western Brooks Range, Alaska: unpublished PhD thesis, Univ. of Minnesota, 161p.
- Forrest, Kimball, Rye, R., and Sawkins, F.J., 1983, Sulfur and oxygen isotope systematics of sedimentary exhalative Zn-Pb-Ag deposition in a fault-bounded basin, Lik deposit, Western Brooks Range, Alaska, (abs.): Geol. Assoc. of Canada, Abstracts with Program, Victoria, B.C., v. 8, p. A23.
- Forrest, Kimball, and Sawkins, F.J., 1987, Geologic setting and mineralization of the Lik deposit: Implications for the tectonic history of the western Brooks Range, *in* Tailleux, I.L., and Weimer, Paul, eds., Alaskan North Slope Geology: Soc. of Economic Paleontologists and Mineralogists Field Trip Guidebook 50, p. 295-305.
- Lange, I.M., Nokleberg, W.J., Plahuta, J.T., Krouse, H.R., and Doe, B.R., 1985, Geologic setting, petrology, and geochemistry of stratiform zinc-lead-barium deposits, Red Dog Creek and Drenchwater Creek areas, northwestern Brooks Range, Alaska: Economic Geology, v. 80, p. 1896-1926.

- Menzie, W.D., and Mosier, D.L., 1986, Grade and tonnage model of sedimentary exhalative Zn-Pb, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 212-215.
- Moore, D.W., Young, L.E., Modene, J.S., and Plahuta, J.T., 1986, Geologic setting and genesis of the Red Dog zinc-lead-silver deposit, western Brooks Range, Alaska: *Economic Geology*, v. 81, p. 1696 - 1727.
- Nokleberg, W.J., and Winkler, G.R., 1982, Stratiform zinc-lead deposits in the Drenchwater Creek area, Howard Pass quadrangle, northwestern Brooks Range, Alaska: U.S. Geological Survey Professional Paper 1209, 22 p, 2 sheets, scale 1:20,000.
- Schmidt, J.M., 1997, Shale-hosted Zn-Pb-Ag and barite deposits of Alaska, *in* Goldfarb, R.J., and Miller, L.D., eds., Mineral Deposits of Alaska: *Economic Geology Monograph* 9, p. 35-65.
- Schmidt, J.M., and Zierenberg, R.A., 1988, Lateral variations of ore, and reconstruction of the Red Dog Zn-Pb-Ag deposit, Noatak District, Alaska [abs.]: *Geol. Soc. of America Abstracts with Program*, v. 20, no. 7, p. A-37.
- Zierenberg, R.A., and Schmidt, J.M., 1988, Isotopic evidence for multiple sulfur sources at the Red Dog Zn-Pb-Ag deposit, Noatak District, Alaska [abs.]: *Geol. Soc. of America Abstracts with Program*, v. 20, no., 7, p. A-37.

Descriptive Model: 24b**Mark3 Index: 30****Area: 1,467 km²****Mean undiscovered deposits: (no estimate)****Model**

by Frederic H. Wilson, Stanley E. Church, Richard W. Saltus, Lawrence J. Drew, and W. David Menzie.

Rationale for Model Choice

The geology of the Kodiak Islands is permissive for Besshi massive sulfide deposits as described by Cox (1986) because the tectonic setting is that of a spreading ridge underlying terrigenous sediments at a continental slope.

Rationale for Tract Delineation

This tract comprises rocks of the Ghost Rocks, Sitkalidak, Sitkinak, and other Tertiary Formations on the southeast and east side of the Kodiak Islands. These formations have a variety of lithologies, including flysch and marine sandstone and siltstone and possibly ultramafic rocks. The rocks that are most favorable for this model are the Ghost Rocks Formation and nearby associated rocks, primarily of the slightly older Kodiak Formation. In south-central Alaska, Late Cretaceous metabasalt of the Valdez Group contain Besshi massive sulfide deposits. Metabasalts are not known in the equivalent units on Kodiak Island.

Important Examples of Deposit Type

No occurrences of Besshi-type deposits are known in the tract. However, the Old Harbor prospect on Sitkalidak Island (Berg and Cobb, 1967, p. 87) might be an example. For comparison, occurrences in the Orca Group (equivalent to the Ghost Rocks) include the Latouche and Beatson mines in the Seward quadrangle, the Ellamar mine in the Cordova quadrangle, and Fidalgo-Alaska mine in the Cordova quadrangle.

Rationale for Numerical Estimates

The lack of any geochemical or geophysical data, and of any known occurrences precludes making quantitative estimates of undiscovered Besshi massive sulfide deposits for this tract. The generally lower metamorphic grade of the rocks in this tract compared to those in south-central Alaska suggests a somewhat lower potential in this tract.

References

- Berg, H.C., and Cobb, E.H., 1967, Metalliferous lode deposits of Alaska: U.S. Geological Survey Bulletin 1246, 254 p.
- Cox, D.P., 1986, Descriptive model of Besshi massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 136.
- Moore, G.W., 1967, Preliminary geologic map of Kodiak Island and vicinity, Alaska: U.S. Geological Survey Open-file Map 271, scale 1:250,000.

AK-AP02

Cyprus Massive Sulfide

Alaska Alaska Peninsula and Aleutian Islands

Descriptive Model: 24a

Mark3 Index: 11

Area: 2,138 km²

Mean undiscovered deposits: (no estimate)

[Model](#)

by Frederic H. Wilson, Stanley E. Church, Richard W. Saltus, Lawrence J. Drew, and W. David Menzie.

Rationale for Model Choice

No Cyprus massive sulfide deposits been reported, but the area is considered permissive for this deposit type (Singer, 1986) because of the presence of ultramafic rocks, pillow basalt, black shale, and gray-red cherts of the Uyak Formation on Kodiak Island (Moore, 1969) in a structural setting characterized by steep faults.

Rationale for Tract Delineation

The tract is defined to include metamorphic, ultramafic, and plutonic rocks of Triassic and older ages west of the Border Ranges fault on Kodiak Island (Moore, 1967), especially the Uyak Formation (Moore, 1969).

Important Examples of Deposit Type

None are known.

Rationale for Numerical Estimates

There is inadequate information to estimate the number of undiscovered deposits.

References

- Moore, G.W., 1967, Preliminary geologic map of Kodiak Island and vicinity, Alaska: U.S. Geological Survey Open-file Map 271, scale 1:250,000.
- Moore, G.W., 1969, New formations on Kodiak and adjacent islands, Alaska, in Cohee, G.V, Bates, R.G., and Wright, W.B., Changes in stratigraphic nomenclature by the U.S. Geological Survey 1967: U.S. Geological Survey Bulletin 1274-A, p. A27-A35.
- Singer, D.A., 1986, Descriptive model of Cyprus massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 131.

AK-AP03

Cyprus Massive Sulfide

Alaska Alaska Peninsula and Aleutian Islands

Descriptive Model: 24a

Mark3 Index: 11

Area: 1,467 km²

Mean undiscovered deposits: 0.30

[Cumulative Distribution](#)

[Histogram](#)

[Table](#)

[Model](#)

by Frederic H. Wilson, Stanley E. Church, Richard W. Saltus, Lawrence J. Drew, and W. David Menzie.

Rationale for Model Choice

The area is geologically permissive for Cyprus massive sulfide deposits (Singer, 1986) based on the possible occurrence of ultramafic rocks.

Rationale for Tract Delineation

This tract comprises rocks of the Ghost Rocks, Sitkalidak, Sitkinak, and other Tertiary Formations on the southeast and east side of the Kodiak Islands (Moore, 1969). These formations contain a variety of lithologies, including flysch and marine sandstone and siltstone, and possibly ultramafic rocks. This tract is correlated with the Orca Group of Prince William Sound.

Important Examples of Deposit Type

The Old Harbor prospect (Berg and Cobb, 1967, p. 87) on Sitkalidak Island may be an example of this type of deposit in the tract.

Rationale for Numerical Estimates

The minimum number of undiscovered Cyprus massive sulfide deposits, consistent with the tonnage and grade model of Singer and Mosier (1986) has been estimated at:

Percentile	90	50	10	5	1
Estimated number of deposits	0	0	1	1	1

References

- Berg, H.C., and Cobb, E.H., 1967, Metalliferous lode deposits of Alaska: U.S. Geological Survey Bulletin 1246, 254 p.
- Moore, G.W., 1969, New formations on Kodiak and adjacent islands, Alaska: U.S. Geological Survey Bulletin 1274-A, p. A27-A35.
- Singer, D.A., 1986, Descriptive model of Cyprus massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 131.
- Singer, D.A., and Mosier, D.L., 1986, Grade and tonnage model of Cyprus massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 131-135.

Descriptive Models 25a-d

Mark3 Index : (none)

Area: 27,515 km²

Mean undiscovered deposits: 11.2

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Frederic H. Wilson, Stanley E. Church, Richard W. Saltus, Lawrence J. Drew, and W. David Menzie.

Rationale for Model Choice

Epithermal vein deposit models in the conterminous US have been divided into several types based largely on the underlying basement rocks (Cox and Singer, 1986). For the most part, information about Alaska is inadequate to classify individual epithermal gold vein types. Therefore, we have combined deposit models for Creede epithermal veins (Mosier and others, 1986b), Comstock epithermal veins (Mosier and others, 1986c), Sado epithermal veins (Mosier and others, 1986a), and epithermal quartz-alunite gold (Berger, 1986a) into a generic epithermal vein model. We evaluated the permissive area for undiscovered deposits of all types of epithermal veins based on this generic model, which includes gold and/or silver veins associated with intermediate to felsic volcanic rocks similar to those described by Panteleyev (1987).

Occurrences known on the Alaska Peninsula and in the Aleutian Islands may or may not display structural control, can occur in rocks ranging from basalt to dacite or in sedimentary rocks adjacent to felsic intrusive igneous rocks, and may contain variable, although typically small, amounts of base metal sulfides. Gold grade tends to be higher than is typical for Sado districts and individual deposits on the Alaska Peninsula tend to be the median size of districts under the Sado model.

Rationale for Tract Delineation

This tract is defined by occurrences of epithermal gold-veins in Cenozoic dacitic to basaltic volcanic rocks on the Alaska Peninsula and adjacent islands (Detterman and others, 1981, 1987; Wilson and others, 1992, in press). Most of these occurrences are in the southern part of the tract; however, similar volcanic rocks extend the length of the tract, northward into adjacent areas of southwestern Alaska, and southward to the Aleutian Islands. Areas adjacent to (within about 5 km) sub-volcanic felsic plutons intruding the volcanic and sedimentary rocks of the Chignik subterrane on the Alaska Peninsula (Wilson and others, 1985) are geologically and geochemically permissive for epithermal gold vein deposits.

Important Examples of Deposit Type

The Alaska-Apollo and Sitka mines and the Shumagin prospect in the Port Moller 1:250,000-scale quadrangle are examples of generic epithermal vein deposits (see Wilson and others, 1988).

Rationale for Numerical Estimates

There is no tonnage and grade model for generic epithermal vein deposits. Additional undiscovered epithermal vein deposits that are expected to occur in this tract would probably be about the same size as the known deposits (i.e., Apollo and Shumagin); that is, as much as 500,000 tons of ore containing 3-5 million grams of gold (90,000 to 160,000 ounces of gold). These estimates are for deposits, not districts.

The estimated minimum number of undiscovered deposits is:

Percentile	90	50	10	5	1
Estimated number of deposits	5	10	27	27	27

Descriptive Model 25a-d

Mark3 Index : (none)

Area: 20,011 km²

Mean undiscovered deposits: 11.9

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Frederic H. Wilson, Stanley E. Church, Richard W. Saltus, Lawrence J. Drew, and W. David Menzie.

Rationale for Model Choice

Epithermal vein deposit models in the conterminous US have been divided into several types based largely on the underlying basement rocks (Cox and Singer, 1986). For the most part, information about Alaska is inadequate to classify individual epithermal gold vein types. Therefore, we have combined deposit models for Creede epithermal veins (Mosier and others, 1986b), Comstock epithermal veins (Mosier and others, 1986c), Sado epithermal veins (Mosier and others, 1986a), and epithermal quartz-alunite gold (Berger, 1986a) into a generic epithermal vein model. We evaluated the permissive area for undiscovered deposits of all types of epithermal veins based on this generic model, which includes gold and/or silver veins associated with intermediate to felsic volcanic rocks similar to those described by Panteleyev (1987).

Occurrences known in the Aleutian Islands may or may not display structural control, can occur in rocks ranging from basalt to dacite or in volcanically-derived sedimentary rocks adjacent to felsic intrusive igneous rocks, and may contain variable, although typically small, amounts of base metal sulfides.

Rationale for Tract Delineation

The Aleutians Islands are a poorly mapped area of volcanic and volcanoclastic rocks of Tertiary and Quaternary age intruded by plutons of Oligocene, Late Miocene, and possibly other ages. The geologic setting is permissive for epithermal gold veins and there are several small occurrences, such as the one at Pyramid Peak on Unalaska Island.

Important Examples of Deposit Type

Pyramid Peak on Unalaska Island is an example of an epithermal vein deposit (Simpson, 1986).

Rationale for Numerical Estimates

Additional undiscovered epithermal vein deposits are expected to occur in this tract, and would be about the same size as the deposits known on the Alaska Peninsula (i.e., Apollo and Shumagin); that is, about 500,000 tons of ore containing 3-5 million grams of gold (90,000 to 160,000 ounces of gold). The minimum number of undiscovered deposits has been estimated as:

Percentile	90	50	10	5	1
Estimated number of deposits	5	10	30	30	30

Large tracts of volcanic rocks, for which existing records sporadically describe areas of alteration, suggest that there is a high probability that several additional deposits of this type exist within the tract. Although limited geochemical sampling has been published, unpublished data indicate a high potential in the region for epithermal vein deposits.

References

Berger, B.R., 1986a, Descriptive model of epithermal quartz-alunite Au, in Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 158.

- Berger, B.R., 1986b, Descriptive model of hot-spring Au-Ag, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 143.
- Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 130.
- Mosier, D.L., Berger, B.R., and Singer, D.A., 1986a, Descriptive model of Comstock epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 154.
- Mosier, D.L., Sato, Takeo, Page, N.J., Singer, D.A., and Berger, B.R., 1986b, Descriptive model of Creede epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 145.
- Mosier, D.L., Singer, D.A., and Berger, B.R., 1986c, Descriptive model of Comstock epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 150.
- Panteleyev, Andrejs, 1987, A Canadian cordilleran model for epithermal gold-silver deposits, *in* Roberts, R.G., and Sheahan, P.A., Ore Deposit Models: Geoscience Canada Reprint Series 3, p. 31-43.
- Simpson, D.F., 1986, Aleutian Islands project 1985 final report, Kennecott-Alaska Exploration: unpublished report available from The Aleut Corporation, 54 p.

AK-AP06

Low-Sulfide Au-Quartz Veins, Chugach Type Alaska
Alaska Peninsula and Aleutian Islands

Descriptive Model 36a

Mark3 Index: 26

Area: 2,138 km²

Mean undiscovered deposits: (no estimate)

Model

by Frederic H. Wilson, Stanley E. Church, Richard W. Saltus, Lawrence J. Drew, and W. David Menzie.

Rationale for Model Choice

Because it is adjacent to a tract containing several reported Chugach-type low-sulfide Au-quartz veins, this tract is considered permissive for Chugach-type low sulfide Au-quartz vein deposits.

Rationale for Tract Delineation.

This tract is defined by metamorphic, ultramafic, and plutonic rocks of Triassic and older ages west of the Border Ranges fault in the Kodiak Islands (Connelly and Moore, 1971).

Important Examples of Deposit Type

A Chugach-type low-sulfide Au-quartz vein occurs at Malina Bay (Capps, 1937), where a 4.2-m-wide quartz gold- and silver-bearing vein is at the contact of slate with granite and diorite plutons.

Rationale for Numerical Estimates

Information is not adequate to estimate the number of undiscovered deposits in this tract.

References

Capps, S.R., 1937, Kodiak and adjacent islands: U.S. Geological Survey Bulletin 880-C, p. 111-184.
Connelly, William, and Moore, J.C., 1979, Geologic map of the northwest side of Kodiak and adjacent islands, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1057, scale 1:250,000 and 1:63,360, 2 sheets.

Descriptive Model: 36a.1**Mark3 Index: 26****Area: 8,932 km²****Mean undiscovered deposits: 13.93**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Frederic H. Wilson, Stanley E. Church, Richard W. Saltus, Lawrence J. Drew, and W. David Menzie.

Rationale for Model Choice

Southeast of the Border Ranges Fault on Kodiak Island, the Chugach terrane, composed of the Kodiak and Shumagin Formations, is permissive for Chugach-type low-sulfide Au-quartz veins (Bliss, 1986, 1992), because such deposits are known in the tract, and because they also occur in the correlative Valdez Group of south-central Alaska.

Rationale for Tract Delineation

This tract consists of Upper Cretaceous graywacke and mudstone of the Kodiak and Shumagin Formations and lower Tertiary plutons on Kodiak, Semidi, Shumagin, and Sanak Islands. The rock units are correlative with the Valdez Group in Prince William Sound, although generally of lower metamorphic grade.

Important Examples of Deposit Type

Gold has been reported from several small occurrences, such as at the Amok Gold Mine (Capps, 1937), where a 1-m-thick gold-bearing quartz vein was mined in the early part of the 20th century.

Rationale for Numerical Estimates

Appropriate host rocks and a number of known occurrences suggest that additional deposits of this type occur within the tract. The low level of geologic knowledge of the region and the small size of these deposits, however, contributes to a high level of uncertainty in the estimates.

The minimum number of undiscovered low-sulfide Au-quartz vein deposits, consistent with the tonnage and grade model of Bliss (1992), estimated for this tract is:

Percentile	90	50	10	5	1
Estimated no. of deposits	4	10	30	30	30

References

- Bliss, J.D., 1986, Grade and tonnage model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239-243.
- Bliss, J.D., 1992, Grade and tonnage model of Chugach-type low-sulfide Au-quartz veins, *in*, Bliss, J.D., editor, Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, p. 44-46.
- Capps, S.R., 1937, Kodiak and adjacent islands: U.S. Geological Survey Bulletin 880-C, p. 111-184.

AK-AP08**Low-Sulfide Au-Quartz Veins, Chugach Type** **Alaska**
Alaska Peninsula and Aleutian Islands**Descriptive Model: 36a.1****Mark3 Index: 26****Area: 1,467 km²****Mean undiscovered deposits: (no estimate)**[Model](#)

by Frederic H. Wilson, Stanley E. Church, Richard W. Saltus, Lawrence J. Drew, and W. David Menzie.

Rationale for Model Choice

This tract is considered permissive for Chugach-type low-sulfide Au-quartz veins because it is adjacent to a geologically similar tract containing several occurrences of such veins. No gold occurrences are known in this tract.

Rationale for Tract Delineation

This tract comprises rocks of the Ghost Rocks, Sitkalidak, Sitkinak, and other Tertiary Formations on the southeast and east side of the Kodiak Islands (Moore, 1967, 1969). These formations consist of a variety of lithologies, including flysch and marine sandstone and siltstone, and possibly ultramafic rocks. Parts of this tract are tentatively correlated with the Orca Group of Prince William Sound.

Important Examples of Deposit Type

No gold occurrences are known in this tract.

Rationale for Numerical Estimates

No estimate of the number of undiscovered Chugach-type low-sulfide Au-quartz deposits has been attempted because of the lack of relevant geologic data.

References

- Moore, G.W., 1967, Preliminary geologic map of Kodiak Island and vicinity, Alaska: U.S. Geological Survey Open-file Map 271, scale 1:250,000.
- Moore, G.W., 1969, New formations on Kodiak and adjacent islands, Alaska: U.S. Geological Survey Bulletin 1274-A, p. A27-A35.

AK-AP09**Porphyry Cu (BC-Ak type)****Alaska
Alaska Peninsula and Aleutian Islands****Descriptive Model: 17.1****Mark3 Index: 89****Area: 27,515 km²****Mean undiscovered deposits: 13.87**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Frederic H. Wilson, Stanley E. Church, Richard W. Saltus, Lawrence J. Drew, and W. David Menzie.

Rationale for Model Choice

This model (Menzie and Singer, 1993), which is defined in part on the basis of deposits in this tract, is the definitive model for Alaskan porphyry copper deposits.

Rationale for Tract Delineation

The tract is defined as the area of the Alaska Peninsula that contains known or inferred intermediate to felsic plutons of Cenozoic age. Country rocks intruded by these plutons include Jurassic and Cretaceous clastic sedimentary rocks and Cenozoic volcanic and volcanoclastic rocks. Geochemical data support consideration of large areas of the Alaska Peninsula for porphyry copper deposits, and incomplete geophysical (largely aeromagnetic) data also suggest additional areas of inferred, buried intrusions.

Important Examples of Deposit Type

The Pyramid deposit near Balboa Bay has reserves of 126 million tons containing 0.413 percent Cu and 0.025 percent Mo (Christie, 1975). The Bee Creek (or Dry Creek) deposit near Chignik is reported to have an undetermined but small tonnage containing 0.25 percent Cu, 0.01 percent Mo, and 0.06 ppm Au (Fields, 1977).

Rationale for Numerical Estimates

The estimated minimum number of undiscovered porphyry Cu deposits, consistent with the grade and tonnage model of Menzie and Singer (1993), for this tract is:

Percentile	90	50	10	5	1
Estimated no. of deposits	5	13	25	25	25

References

- Christie, J.S., 1975, Pyramid project Aleut-Quintana-Duval joint venture report on 1975 drill programme: Unpublished Quintana Minerals Corporation report available from The Aleut Corporation, 17 p., 1 appendix, 5 maps and figures in pocket.
- Fields, E.D., 1977, 1976 Annual report, Alaska search: Chignik area-Bristol Bay region: Unpublished report available from the Bristol Bay Native Corp., 44 p.
- Menzie, W.D., and Singer, D.A., 1993, Grade and tonnage model of Porphyry Cu deposits in British Columbia, Canada, and Alaska, U.S.A.: U.S. Geological Survey Open-File Report 93-275, 7p.

AK-AP10

Porphyry Cu (BC-Ak type)

Alaska Alaska Peninsula and Aleutian Islands

Descriptive Model: 17.1

Mark3 Index: 89

Area: 20,010 km²

Mean undiscovered deposits: 1.60

[Cumulative Distribution](#)

[Histogram](#)

[Table](#)

[Model](#)

by Frederic H. Wilson, Stanley E. Church, Richard W. Saltus, Lawrence J. Drew, and W. David Menzie.

Rationale for Model Choice

The Aleutian Islands arc is a poorly mapped area containing volcanic and volcanoclastic rocks of Cenozoic age intruded by plutons of Oligocene, Late Miocene, and possibly other ages. The geologic setting is permissive for BC-Alaska type porphyry copper deposits as described by Menzie and Singer (1993).

Rationale for Tract Delineation

Large parts of the Aleutian Islands are considered permissive for porphyry copper-type deposits based chiefly on the well-known presence of porphyry-type deposits in other volcanic arcs throughout the world. The level of knowledge of the geology is very low and geophysical and geochemical data are virtually nonexistent. As more information becomes available, the tract can be restricted to areas near known or inferred intermediate to felsic plutons of Cenozoic age.

Important Examples of Deposit Type

In the eastern Aleutian Islands, Unalaska Island has a number of mineralized areas and Rootok Island has a small mineralized area, both of which have potential for porphyry copper deposits (Christie, 1974; 1976).

Rationale for Numerical Estimates

The minimum number of undiscovered porphyry Cu deposits for this tract, consistent with the tonnage and grade model of Menzie and Singer (1993), has been estimated as:

Percentile	90	50	10	5	1
Estimated no. of deposits	0	1	4	4	4

REFERENCES

- Christie, J.S., 1974, Aleut-Quintana-Duval 1974 joint venture final report: Unpublished Quintana Minerals Corporation report available from The Aleut Corporation, 24 p., 3 appendices, 2 maps in pocket.
- Christie, J.S., 1976, Aleut-Quintana-Duval joint venture 1975 report on drill programmes at the Tarasof and San Diego prospects and additional exploration on Rootok Island and Unalaska Island: Unpublished Quintana Minerals Corporation report available from The Aleut Corporation, 21 p., 1 appendix, 10 maps and figures in pocket.
- Menzie, W.D., and Singer, D.A., 1993, Grade and tonnage model of Porphyry Cu deposits in British Columbia, Canada, and Alaska, U.S.A.: U.S. Geological Survey Open-File Report 93-275, 7p.

Descriptive Model: 39a**Mark3 Index: 54****Area: 27,515 km²****Mean undiscovered deposits: (no estimate)**[Model](#)

by Frederic H. Wilson, Stanley E. Church, Richard W. Saltus, Lawrence J. Drew, and W. David Menzie.

Rationale for Model Choice

Placer gold can be expected to occur in unconsolidated deposits downstream from any of the gold-bearing lode deposit types. Therefore, the placer gold permissive area is quite broad. In addition, extensive glaciation over much of the tract area has mobilized unconsolidated deposits, possibly concentrating some into gold placers and eroding others.

This tract is permissive for porphyry copper deposits, and for polymetallic or epithermal gold veins. Erosion of any of these deposit types could result in a placer gold deposit.

Rationale for Tract Delineation

This tract, on the Alaska Peninsula, includes Permian to Quaternary age rocks of the Chignik subterranean and overlap sequences. Pre-Tertiary rocks are dominantly clastic and minor carbonate sedimentary rocks and very minor volcanic rocks. Tertiary and Quaternary rocks are largely volcanic and volcanoclastic, and small plutons and stocks are widely distributed in the tract.

Important Examples of Deposit Type

The Mary Lou mine on Popof Island beach at Sand Point (Wilson and others, 1988) is an example of the small placer deposits that can be expected in this tract. Additionally, shoreline placer occurrences on the Bering Sea coast, derived presumably from glacial deposits, are known but may be ephemeral.

Rationale for Numerical Estimates

Because of the relative ease of exploring for placer gold deposits, much of the state has been thoroughly explored. However, this part of the state is probably not as well explored as better known areas, and small deposits may yet be discovered. There is a low probability that any major new placer districts will be discovered, but it is likely that a few relatively small new deposits will be found in the known districts. A thorough understanding of Quaternary geologic history is necessary to a rational search for additional deposits in this tract. No estimate of the number of deposits was attempted.

References

Wilson, F.H., White, W.H., and DuBois, G.D., 1988, Brief descriptions of mines, prospects, and mineral occurrences in the Port Moller and Stepovak Bay quadrangles, Alaska Peninsula: U.S. Geological Survey Open-File Report 88-666, 128 p., scale 1:250,000, 1 map sheet.

Descriptive Model: 39a**Mark3 Index: 54****Area: 12,635 km²****Mean undiscovered deposits: (no estimate)**[Model](#)

by Frederic H. Wilson, Stanley E. Church, Richard W. Saltus, Lawrence J. Drew, and W. David Menzie.

Rationale for Model Choice

Placer gold can be expected to occur in unconsolidated deposits downstream from any of the gold-bearing lode deposit types. Therefore the placer gold permissive area is quite broad.

Rationale for Tract Delineation

On western Kodiak Island, west of the Border Ranges fault, the bedrock is metamorphic, ultramafic, and plutonic rocks of Triassic and older ages (Moore, 1967). The central portion of Kodiak Island, southeast of the Border Ranges fault, consists of Upper Cretaceous graywacke and mudstone of the Kodiak Formation and lower Tertiary plutons on the Kodiak Islands. The southeast portion of Kodiak Island comprises rocks of the Ghost Rocks, Sitkalidak, Sitkinak, and other Tertiary Formations, which consist of a variety of lithologies, including flysch and marine sandstone and siltstone, and possibly ultramafic rocks. This latter area is tentatively correlated with the Orca Group of Prince William Sound.

Several occurrences of bedrock gold mineralization and of shoreline placer gold have been reported in this tract, which is overlain by fluvial and glacial deposits that are largely of local derivation. Because of the glaciation and fluvial erosion and the known occurrence of shoreline placer gold, the area is considered permissive for placer gold deposits.

Important Examples of Deposit Type

Most of the placer occurrences northwest of the Border Ranges fault were in beach deposits, reworked from glacial deposits. As such, they tend to be ephemeral and typically were mined during periods of low tide (Martin, 1913). Gold has been mined in small-scale operations from several localities, including Cape Alitak, along 50 km of beaches between Cape Alitak and Old Red River, and in the vicinity of Olga Bay (see Capps, 1937). In the Orca Group-equivalent rocks, there are two reported placer occurrences: one each on Chirikof Island and Tugidak Island (see Smith, 1933); there also is an unsubstantiated report of PGE being dredged offshore of the tract at Cape Chiniak.

Rationale for Numerical Estimates

Because of the relative ease of exploring for placer gold deposits, much of the state has been thoroughly explored. There is a low probability that any major new placer districts will be discovered, but it is likely that a few relatively small new deposits will be found in the known districts.

There is inadequate information to estimate the number of undiscovered placer deposits.

References

- Capps, S.R., 1937, Kodiak and adjacent islands: U.S. Geological Survey Bulletin 880-C, p. 111-184.
Martin, G.C., 1913, Mineral deposits of Kodiak and the neighboring islands: U.S. Geological Survey Bulletin 542, p. 125-136.
Moore, G.W., 1967, Preliminary geologic map of Kodiak Island and vicinity, Alaska: U.S. Geological Survey Open-File Map 67-161, scale 1:250,000.
Smith, P.S., 1933, Mineral Industry of Alaska in 1930: U.S. Geological Survey Bulletin 836-A, p. 1-83.

Descriptive Model: 22c**Mark3 Index: 52****Area: 27,515 km²****Mean undiscovered deposits: 45.33**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Frederic H. Wilson, Stanley E. Church, Richard W. Saltus, Lawrence J. Drew, and W. David Menzie.

Rationale for Model Choice

Polymetallic vein deposits can be associated with intrusive rocks of any age and a wide range of compositions (Cox, 1986). Polymetallic veins may also be spatially related to a large number of other types of deposits, thus making their permissive area quite extensive. This model also serves as somewhat of a catch-all for deposits of unknown type that, given minimal information, do not appear to fit into other similar categories

Rationale for Tract Delineation

The tract is defined as all areas that lie within approximately 5 km of known or inferred volcanic and hypabyssal intrusions of Tertiary and Quaternary age in the Chignik subterrane of the Alaska Peninsula. Geochemical data support the permissive classification of large areas where no polymetallic vein deposits are known. Many areas of hydrothermally altered volcanic or sedimentary rocks occur within this tract and sparsely distributed geochemical sampling shows that a number of these are anomalous in multiple metals, including copper, lead, and or zinc. Polymetallic vein deposits are permissive around porphyry copper-type occurrences; the large number of potential porphyry copper-type occurrences in this tract suggest high potential for polymetallic veins. Areas that are not considered permissive are predominantly where there is sufficiently detailed geologic information to indicate that deposits do not exist.

Important Examples of Deposit Type

Of a total of 210 occurrences in this tract (Wilson and others, 1988), 52 of the occurrences are classified as possible polymetallic veins. Renshaw Point is an example of a possible polymetallic vein. Many other small occurrences of this type of deposit are known and additional deposits are expected.

Rationale for Numerical Estimates

The minimum number of undiscovered polymetallic vein deposits, consistent with the tonnage and grade model of Bliss and Cox (1986), expected to occur in this tract is estimated as:

Percentile	90	50	10	5	1
Estimated number of deposits	10	40	90	90	90

References

- Bliss, J.D., and Cox, D.P., 1986, Grade and tonnage model of polymetallic veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 125-129.
- Cox, D.P., 1986, Descriptive Model of polymetallic veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 125.
- Wilson, F.H., White, W.H., and DuBois, G.D., 1988, Brief descriptions of mines, prospects, and mineral occurrences in the Port Moller and Stepovak Bay quadrangles, Alaska Peninsula: U.S. Geological Survey Open-File Report 88-666, 128 p., scale 1:250,000, 1 map sheet.

Descriptive Model: 22c**Mark3 Index: 52****Area: 20,011 km²****Mean undiscovered deposits: 18.67**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Frederic H. Wilson, Stanley E. Church, Richard W. Saltus, Lawrence J. Drew, and W. David Menzie.

Rationale for Model Choice

Polymetallic vein deposits can be associated with intrusive rocks of any age and a wide range of compositions (Cox, 1986). Polymetallic veins may also be spatially related to a large number of other types of deposits, thus making their permissive area quite extensive. This model also serves as somewhat of a catch-all for deposits of unknown type that, given minimal information, do not appear to fit into other similar categories

Rationale for Tract Delineation

The Aleutian Islands are a poorly mapped area of volcanic and volcanoclastic rocks of Tertiary and Quaternary age intruded by plutons of Oligocene, Late Miocene, and possibly other ages. The geologic setting is permissive for polymetallic vein deposits and there are several small occurrences that possibly are polymetallic veins. In addition, polymetallic veins may be spatially related to other types of deposits, especially porphyry type systems, thus enlarging their permissive area. Very little geophysical and geochemical data are available to support or rule out the permissive classification of large areas where no polymetallic vein deposits are known. Areas not considered permissive are predominantly where there is sufficiently detailed geologic information to indicate that deposits do not exist.

Important Examples of Deposit Type

The Biorka prospect on Sedanka Island (Webber and others, 1946) and the Rootok Island prospect (Butherus and others, 1979) may both be polymetallic veins. In addition, a prospect reported by the Russians in the 18th or 19th century near Bornite Lake (Reinken or Bornite Lake prospect, Randolph, 1991) on Unalaska Island may also be a polymetallic vein.

Rationale for Numerical Estimates

The minimum number of undiscovered polymetallic vein deposits, consistent with the tonnage and grade model of Bliss and Cox (1986) has been estimated at:

Percentile	90	50	10	5	1
Estimated number of deposits	5	10	45	45	45

References

- Bliss, J.D., and Cox, D.P., 1986, Grade and tonnage model of polymetallic veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 125-129.
- Butherus, D.L., Gressitt, E.E., Pray, Jim, Corner, N.G., Lindberg, P.A., and Fankhauser, R.E., 1979, Exploration and evaluation of the Aleut Native Corporation Lands 1979: Unpublished Resource Associates of Alaska report prepared for Houston Oil and Minerals Corporation and available from The Aleut Corporation, 69 p., 1 appendix.
- Cox, D.P., 1986, Descriptive Model of polymetallic veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 125.
- Randolph, D.B., 1991, Unalaska project 1990 final report, Battle Mountain Exploration Company, Alaska District: unpublished report available from The Aleut Corporation, 62 p., 5 appendices, 15 plates, various scales.

Webber, B.S., Moss, J.M., and Rutledge, F.A., 1946, Exploration of Sedanka zinc deposit, Sedanka Island, Alaska: U.S. Bureau of Mines Report of Investigations 3967, 15 p.

Descriptive Model: 24b**Mark3 Index: 30****Area: 12,609 km²****Mean undiscovered deposits: (no estimate)****Model**

by Jeanine M. Schmidt, Karen D. Kelley, Richard I. Grauch, Byron R. Berger, John W. Cady, Gregory T. Spanski, James E. Kilburn.

Rationale for Model Choice

Parts of the Brooks Range are permissive for Besshi massive sulfide deposits as described by Cox (1986). Altered basalts, containing pyrite and locally high copper values, may suggest submarine hydrothermal activity.

Rationale for Tract Delineation

This tract contains all of the known mafic rocks of Proterozoic(?), Paleozoic, or Mesozoic age in the Brooks Range (Murchey and Harris, 1985; Pallister and others, 1989) outside of the mafic-ultramafic complexes.

Important Examples of Deposit Type

No Besshi massive sulfide deposits are known in this tract, although the Kivivik Creek prospect is possibly of this type (Schmidt and Allegro, 1988).

Rationale for Numerical Estimates

No deposits of this type are known in the area, and no estimates of the number of undiscovered deposits have been attempted.

REFERENCES

- Cox, D.P., 1986, Descriptive model of Besshi massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 136.
- Murchey, B.L., and Harris, A.G., 1985, Devonian to Jurassic sedimentary rocks in the Angayucham Mountains of Alaska: possible sea mount or oceanic plateau deposits [abs]: EOS, Transactions of the American Geophysical Union, v. 66, no. 46, p. 1102.
- Pallister, J.S., Budahn, J.R., and Murchey, B.L., 1989, Pillow basalts of the angayucham terrane: oceanic plateau and island crust accreted to the Brooks Range: Journal of Geophysical Research, v. 94, no. B11, p. 15,901-15,923.
- Schmidt, J.M., and Allegro, G.L., 1980, Mineral occurrences and indicators in the Baird Mountains quadrangle, Alaska: USGS Miscellaneous Field Studies Map MF1992, 1 plate, scale 1:250,000, 19 p.

[AK-BR02](#)

Cyprus Massive Sulfide

Alaska Brooks Range

Descriptive Model: 24a

Mark3 Index: 11

Area: 4,203 km²

Mean undiscovered deposits: (no estimate)

[Model](#)

by Jeanine M. Schmidt, Karen D. Kelley, Richard I. Grauch, Byron R. Berger, John W. Cady, Gregory T. Spanski, James E. Kilburn.

Rationale for Model Choice

Mafic and ultramafic complexes in the Brooks Range are geologically permissive for the occurrence of Cyprus massive sulfide deposits as described by Singer (1986). Altered basalts with pyrite and locally high copper values may suggest submarine hydrothermal activity.

Rationale for Tract Delineation

This tract comprises areas of known mafic and ultramafic rock complexes (i.e., the Brooks Range ophiolites) and includes dunite, layered peridotite, pyroxenite, gabbro, basalt, and minor plagiogranite. Boundaries of the permissive areas have been extended to indicate the possibility of buried ultramafic rocks where warranted by aeromagnetic data.

Important Examples of Deposit Type

No Cyprus massive sulfide deposits are known in this tract (Schmidt and Allegro, 1980).

Rationale for Numerical Estimates

There is not enough information available for this area to make estimates of the number of undiscovered deposits.

References

Schmidt, J.M., and Allegro, G.L., 1980, Mineral occurrences and indicators in the Baird Mountains quadrangle, Alaska: USGS Miscellaneous Field Studies Map MF1992, 1 plate, scale 1:250,000, 19 p.
Singer, D.A., 1986, Descriptive model of Cyprus massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 131.

AK-BR03

Cyprus Massive Sulfide

Alaska Brooks Range

Descriptive Model: 24a

Mark3 Index: 11

Area:

Mean undiscovered deposits: (no estimate)

[Model](#)

by Jeanine M. Schmidt, Karen D. Kelley, Richard I. Grauch, Byron R. Berger, John W. Cady, Gregory T. Spanski, James E. Kilburn.

Rationale for Model Choice

Altered basalts with pyrite and locally high copper values may suggest submarine hydrothermal activity, and the area is permissive for Cyprus massive sulfide deposits as defined by Singer (1986).

Rationale for Tract Delineation

This tract contains all the known mafic rocks of Proterozoic(?), Paleozoic, or Mesozoic age except the Brooks Range mafic-ultramafic complexes (Murchey and Harris, 1985; Pallister and others, 1989).

Important Examples of Deposit Type

No Cyprus-type deposits are known in the area, although the Kivivik Creek Cu prospect may be of this type (Schmidt and Allegro, 1980).

Rationale for Numerical Estimates

No estimates of the number of undiscovered deposits have been attempted.

References

- Murchey, B.L., and Harris, A.G., 1985, Devonian to Jurassic sedimentary rocks in the Angayucham Mountains of Alaska: possible sea mount or oceanic plateau deposits [abs]: EOS, Transactions of the American Geophysical Union, v. 66, no. 46, p. 1102.
- Pallister, J.S., Budahn, J.R., and Murchey, B.L., 1989, Pillow basalts of the Angayucham terrane: oceanic plateau and island crust accreted to the Brooks Range: Journal of Geophysical Research, v. 94, no. B11, p. 15,901-15,923.
- Singer, D.A., 1986, Descriptive model of Cyprus massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 131.
- Schmidt, J.M., and Allegro, G.L., 1980, Mineral occurrences and indicators in the Baird Mountains quadrangle, Alaska: USGS Miscellaneous Field Studies Map MF1992, 1 plate, scale 1:250,000, 19 p.

Descriptive Model: 36a

Mark3 Index: 27

Area: 35,958 km²

Mean undiscovered deposits: 3.06

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Jeanine M. Schmidt, Karen D. Kelley, Richard I. Grauch, Byron R. Berger, John W. Cady, Gregory T. Spanski, James E. Kilburn.

Rationale for Model Choice

Some low sulfide gold-quartz veins occur, especially in the Wiseman-Chandalar area; placer gold deposits are common, and the geologic setting and host rocks are permissive for additional deposits.

Rationale for Tract Delineation

This tract includes areas of Proterozoic(?) to Paleozoic mixed schists, including many predominately pelitic schists, and lesser quartzitic, mafic, calcareous, and carbonaceous schists.

Important Examples of Deposit Type

Low sulfide gold-quartz veins occur in the Wiseman and Chandalar districts (Dillon, 1982; Nokleberg and others, 1987). The Little Squaw (Ashworth, 1983) and Mikado are some of the larger examples of low-sulfide Au-quartz vein deposits.

Rationale for Numerical Estimates

Numerous placer gold deposits and some lode gold deposits in the tract suggest the presence of additional lode deposits. The minimum number of undiscovered low sulfide gold-quartz vein deposits of median grade and tonnage expected to occur in the tract is:

Percentile	90	50	10	5	1
Estimated number of deposits	1	2	5	10	15

References

- Ashworth, Kate, 1983, Genesis of gold deposits of Little Squaw Mine, Chandalar District, Alaska: Bellingham, Washington, Western Washington University M.S. Thesis, 64 p.
- Dillon, J.T., 1982, Source of lode- and placer-gold deposits of the Chandalar and upper Koyukuk districts, Alaska: Alaska Division of Geological and Geophysical Surveys Open-File Report 158, 22 p.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987. Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.

Descriptive Model 32c**Mark3 Index (none)****Area: 49,825 km²****Mean undiscovered deposits: (no estimate)****Model**

by Jeanine M. Schmidt, Karen D. Kelley, Richard I. Grauch, Byron R. Berger, John W. Cady, Gregory T. Spanski, James E. Kilburn.

Rationale for Model Choice

This Brooks Range tract is permissive for Kipushi-type deposits, as described by Cox and Bernstein (1986), because it has the appropriate geologic setting (a continental platform or shelf with continental or passive margin rifting) and host rocks (dolostone, shale and shallow-water or platform carbonate rocks) for the deposit model.

Rationale for Tract Delineation

This tract is defined by carbonate rocks of the Mississippian to Pennsylvanian Lisburne Group. These are mainly platform carbonates, with some slope and deeper-water lithologies. Rapid facies changes in the western part of the tract suggest an environment of extensional synsedimentary faulting. Where the environment of deposition is not known or indeterminate, carbonate rocks of possible shelf, slope, or deeper-water-facies are included.

Important Examples of Deposit Type

There are no known examples of Kipushi-type deposits in this tract, but there are several such deposits in pre-Mississippian rocks elsewhere in the Brooks Range.

Rationale for Numerical Estimates

No grade and tonnage curves are available for Kipushi-type deposits; no attempt was made to estimate the number of undiscovered deposits.

References

- Cox, D.P., and Bernstein, L.R., 1986, Descriptive model of Kipushi Cu-Pb-Zn, *in* Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 227.
- Schmidt, J.M., 1997b, Strata-bound carbonate-hosted Zn-Pb and Cu deposits of Alaska, *in* Goldfarb, R.J., and Miller, L.D., eds., Mineral Deposits of Alaska: Economic Geology Monograph 9, p. 90-119.

Descriptive Model 32c

Mark3 Index (none)

Area: 32,935 km²

Mean undiscovered deposits: (no estimate)

[Model](#)[Mineral Deposits](#)

by Jeanine M. Schmidt, Karen D. Kelley, Richard I. Grauch, Byron R. Berger, John W. Cady, Gregory T. Spanski, James E. Kilburn.

Rationale for Model Choice

Kipushi-type deposits (Cox and Bernstein, 1986) containing Cu, Co, and minor Zn, such as the Ruby Creek and Omar deposits, are known from two separate carbonate areas within this tract in the Brooks Range. The entire tract is permissive for Kipushi-type deposits because it has the appropriate geologic setting (a continental platform or shelf with continental or passive margin rifting) and host rocks (dolostone, shale and shallow-water or platform carbonate rocks) for the deposit model.

Rationale for Tract Delineation

This tract outlines all pre-Mississippian carbonate rocks in the Brooks Range, including very shallow water, platform, slope and deeper water facies of Late Proterozoic(?) through Devonian age. These rocks include the Katakturuk Dolostone, Nanook Limestone, Baird Group carbonates, Eli, Kougurourok, and Skajit Limestones, their metamorphosed equivalents, and various marbles of uncertain age and affinity. Where the environment of deposition is not known or indeterminate, thick carbonate rocks of possible shelf, slope, or deeper-water-facies are included. Minor mafic rocks and / or rapid facies changes into deeper-water sedimentary rocks suggest that extensional tectonism affected these host rocks during Proterozoic (?), Ordovician (?), late Devonian (?) and/or Mississippian time.

Important Examples of Deposit Type

The Ruby Creek (Hitzman, 1983, 1986; Bernstein and Cox, 1986), Omar (Folger and Schmidt, 1986; Folger, 1988), Pardners Hill and Aurora Mountain deposits, hosted by Ordovician (?) and Silurian to Devonian carbonate rocks, are examples of Kipushi type deposits.

Rationale for Numerical Estimates

There are no tonnage and grade curves for Kipushi-type deposits; no attempt was made to estimate the number of undiscovered deposits.

References

- Bernstein, L.R., and Cox, D.P., 1986, Geology and sulfide mineralogy of the Number One ore-body, Ruby Creek copper deposit, Alaska: *Economic Geology*, v. 81, p. 1675-1689.
- Cox, D.P., and Bernstein, L.R., 1986, Descriptive model of Kipushi Cu-Pb-Zn, *in* Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 227.
- Folger, P.F., 1988, The geology and mineralization at the Omar prospect, Baird Mountains Quadrangle, Alaska: unpublished MSc. thesis, Missoula, MT, University of Montana, 152p.
- Folger, P.F., and Schmidt, J.M., 1986, Geology of the carbonate-hosted Omar copper prospect, Baird Mountains, Alaska: *Economic Geology*, v. 81, no. 7, p. 1690-1695. Abstract reprinted in Tailleur, I.L., and Weimer, P, eds., 1987, v. 1, p. 286, *Alaskan North Slope Geology: SEPM Pacific Section*, Bakersfield, CA, Book 50, 2 volumes, 874 p..
- Hitzman, M.W., 1983, Geology of the Cosmos Hills and its relationship to the Ruby Creek copper-cobalt deposit: Stanford, California, Stanford University, PhD, dissertation, 266 p.
- Hitzman, M. W., 1986, Geology of the Ruby Creek copper deposit, southwestern Brooks Range, Alaska: *Economic Geology*, V. 81, p. 1644-1674.

Schmidt, J.M., 1997b, Strata-bound carbonate-hosted Zn-Pb and Cu deposits of Alaska, *in* Goldfarb, R.J., and Miller, L.D., eds., Mineral Deposits of Alaska: Economic Geology Monograph 9, p. 90-119.

Descriptive Model: 28a

Mark3 Index: 93

Area: 2,423 km²

Mean undiscovered deposits: 5.17

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Jeanine M. Schmidt, Karen D. Kelley, Richard I. Grauch, Byron R. Berger, John W. Cady, Gregory T. Spanski, James E. Kilburn.

Rationale for Model Choice

Felsic volcanic-hosted polymetallic massive sulfide deposits (Singer, 1986) occur within the tract, and the geologic setting and host rocks are favorable for additional deposits.

Rationale for Tract Delineation

This tract is defined by the distribution of the bimodal metabasalt-metarhyolite volcanic suite of the Devonian Ambler Group and correlative mafic and felsic rocks farther east in the Brooks Range. Geochemical data from stream sediment samples indicate a base metal-rich signature with a distinct lack of Sn. The aeromagnetic signature is low.

Important Examples of Deposit Type

This tract contains several kuroko-type volcanogenic massive sulfide deposits, including the Arctic deposit, with indicated reserves of 36.3 million tonnes of 4% Cu, 5.5% Zn, 0.8% Pb, 55 g/T Ag and 0.69 g/T Au (Schmidt, 1986; Swainbank and others, 1995). Other deposits include Sun, Smucker, and BT, as well as numerous other drilled prospects (Hitzman and others, 1986). The large number of sulfide deposits known to crop out within the Ambler Group *sensu stricto* (an area of less than 800 square kilometers), even with limited exploration, suggests a deposit density higher than that of many better known districts, and may indicate unusual metallogenetic conditions.

Rationale for Numerical Estimates

Based on the number of prospects known from industry mapping and drilling, and on the volume of the host volcanic suite, the estimated minimum number of undiscovered kuroko massive sulfide deposits, of median grade and tonnage consistent with the tonnage and grade model of Singer and Mosier (1986), is:

Percentile	90	50	10	5	1	
Estimated number of deposits		3	5	7	10	15

References

- Hitzman, M.W., Proffett, J.M., Schmidt, J.M., and Smith, T.E., 1986, Geology and mineralization of the Ambler district, northwestern Alaska: Economic Geology, v. 81, no. 7, p. 1592-1618. Reprinted in Tailleux, I.L., and Weimer, Paul, eds., 1987.
- Schmidt, J.M., 1986, Stratigraphic setting and mineralogy of the Arctic volcanogenic massive sulfide deposit, Ambler district, Alaska: Economic Geology, v. 81, no. 7, p. 1619-1643. Abstract reprinted in Tailleux, I.L., and Weimer, Paul, eds., 1987.
- Singer, D.A., 1986, Descriptive model of kuroko massive sulfide, in Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 189-190.
- Singer, D.A., and Mosier, D.L., 1986, Grade and tonnage model of kuroko massive sulfide, in Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 190-197.

Swainbank, R.C., Bundtzen, T.K., Clough, A.H., Henning, M.W., and Hansen, E.W., 1995, Alaska's Mineral Industry 1994: Alaska Division of Geological and Geophysical Surveys Special Report 49, Alaska Department of Natural Resources, Juneau Alaska, 77p.

Descriptive Model: 32a and 32b**Mark3 Index: 42****Area: 49,825 km²****Mean undiscovered deposits: (no estimate)****Model**

by Jeanine M. Schmidt, Karen D. Kelley, Richard I. Grauch, Byron R. Berger, John W. Cady, Gregory T. Spanski, James E. Kilburn

Rationale for Model Choice

Two Mississippi Valley type (MVT) deposits are described in Cox and Singer (1986). The differences between Southeast Missouri Pb-Zn (model 32a; Briskey 1986b) and Appalachian Zn (model 32b; Briskey, 1986a) are subtle enough that the grade and tonnage models for the two deposit types are plotted together with no differentiation between types (Mosier and Briskey, 1986). In Alaska, the lack of detailed geologic information prevents distinguishing between the two deposit types, and a generic Mississippi Valley type model has been used.

The geologic setting and host rocks, together with several known fluorite occurrences, suggest that this tract is permissive for Mississippi Valley type deposits,

Rationale for Tract Delineation

This tract is defined by the carbonate rocks of the Mississippian to Pennsylvanian Lisburne Group. These are mainly platform carbonates, with some slope and deeper-water lithologies.

Important Examples of Deposit Type

Several occurrences of fluorite within the Lisburne Group carbonates in the eastern Brooks Range (Porcupine River etc.) are unexplained but could indicate fluid movement associated with Mississippi Valley type mineralization.

Rationale for Numerical Estimates

Although grade and tonnage curves are available for Mississippi Valley type deposits, geologic knowledge about this tract inadequate to attempt an estimate of the number of undiscovered deposits. No basinal sources of fluids have been identified because of the difficulty of reconstructing the pre-Jurassic folding- and thrusting paleogeography, and the timing of any possible Mississippi Valley type mineralizing episodes is totally unconstrained.

References

- Briskey, J.A., 1986a, Descriptive model of Appalachian Zn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 222-223.
- Briskey, J.A., 1986b, Descriptive model of southeast Missouri Pb-Zn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 220-221.
- Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 130.
- Mosier, D.L., and Briskey, 1986, Grade and tonnage model of southeast Missouri Pb-Zn and Appalachian Zn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 224-226.

Descriptive Model: 32a and 32b**Mark3 Index: 42****Area: 32,935 km²****Mean undiscovered deposits: (no estimate)****Model**

by Jeanine M. Schmidt, Karen D. Kelley, Richard I. Grauch, Byron R. Berger, John W. Cady, Gregory T. Spanski, James E. Kilburn.

Rationale for Model Choice

Two Mississippi Valley type (MVT) deposits are described in Cox and Singer (1986). The differences between Southeast Missouri Pb-Zn (model 32a; Briskey 1986b) and Appalachian Zn (model 32b; Briskey, 1986a) are subtle enough that the grade and tonnage models for the two deposit types are plotted together with no differentiation between types (Mosier and Briskey, 1986). In Alaska, the lack of detailed geologic information prevents distinguishing between the two deposit types, and a generic Mississippi Valley type model has been used.

The geologic setting and host rocks in this tract are permissive for Mississippi Valley type deposits, and the Powdermilk Zn-Pb occurrence may be of this type.

Rationale for Tract Delineation

This tract outlines all pre-Mississippian carbonate rocks in the Brooks Range, including very shallow water, platform, slope and deeper water facies of late Proterozoic(?) through Devonian age. These units include the Katakturuk Dolostone, Nanook Limestone, Baird Group carbonates, Eli, Lougurourok, and Skajit Limestones, their metamorphosed equivalents, and various marbles of uncertain age and affinity.

Important Examples of Deposit Type

Classification of the Powdermilk Zn-Pb-Ag deposit in carbonate rocks as an MVT is uncertain (Schmidt and Folger, 1986).

Rationale for Numerical Estimates

Geologic knowledge of this area is inadequate to attempt an estimate of the number of undiscovered deposits.

References

- Briskey, J.A., 1986a, Descriptive model of Appalachian Zn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 222-223.
- Briskey, J.A., 1986b, Descriptive model of southeast Missouri Pb-Zn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 220-221.
- Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 130.
- Mosier, D.L., and Briskey, 1986, Grade and tonnage model of southeast Missouri Pb-Zn and Appalachian Zn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 224-226.
- Schmidt, J.M., and Folger, P.F., 1986, Pb-Zn-Ag mineralization in Paleozoic dolostones, Powdermilk prospect, Baird Mountains B-4 quadrangle, *in* Bartsch-Winkler, Susan, and Reed, K.M., eds., Geologic studies in Alaska by the U.S. Geological Survey during 1985: U.S. Geological Survey Circular 978, p. 19-21.

Descriptive Model: 17.1

Mark3 Index: 89

Area: 9,782 km²

Mean undiscovered deposits: (no estimate)

[Model](#)

by Jeanine M. Schmidt, Karen D. Kelley, Richard I. Grauch, Byron R. Berger, John W. Cady, Gregory T. Spanski, James E. Kilburn.

Rationale for Model Choice

Petrologic and geochemical information on Proterozoic, Devonian or Cretaceous granitic plutons in the Brooks Range is limited or absent, but numerous mineral deposit types are permissive, including porphyry Cu as described by Cox, (1986a), porphyry Cu-Au deposits (Cox, 1986b), or porphyry Cu-Mo deposits (Cox, 1986c). Numerous small occurrences of contact metasomatic skarns or disseminated and veinlet base metal mineralization are also known in the area.

Rationale for Tract Delineation

This tract comprises all the Proterozoic, Devonian or Cretaceous granitic plutons in the Brooks Range, and includes all potential host rocks within 5 km of the plutons. The geochemical data from stream sediment samples show anomalous levels of Sn, W, and/or Mo in addition to the base metals Cu, Pb, and Zn. There is very little, if any, gold associated with the intrusions.

Important Examples of Deposit Type

There are no known porphyry copper deposits in this tract, but there are numerous small occurrences of contact metasomatic skarns or disseminated and veinlet base metal mineralization. The Bear Mountain occurrence in the Table Mountain quadrangle, eastern Brooks Range, contains both Mo and W porphyry mineralization (Barker and Swainbank, 1986).

Rationale for Numerical Estimates

There is insufficient geologic or mineral deposit information to estimate the numbers of undiscovered mineral deposits for any of the permissive deposits in this tract.

References

- Barker, J.C., and Swainbank, R.C., 1986, A tungsten-rich porphyry molybdenum occurrence at Bear Mountain, Northeast Alaska: *Economic Geology* v. 81, p. 1753 - 1759.
- Cox, D.P., 1986a, Descriptive model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 76.
- Cox, D.P., 1986b, Descriptive model of porphyry Cu-Au, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 110.
- Cox, D.P., 1986c, Descriptive model of porphyry Cu-Mo, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 115.

Descriptive Model: 43**Mark3 Index: 43****Area: 9,782 km²****Mean undiscovered deposits: (no estimate)**[Model](#)

by Jeanine M. Schmidt, Karen D. Kelley, Richard I. Grauch, Byron R. Berger, John W. Cady, Gregory T. Spanski, James E. Kilburn.

Rationale for Model Choice

Proterozoic, Devonian or Cretaceous granitic plutons in the Brooks Range are permissive for plutonic porphyry Au as described by Hollister (1992). Although no deposits of this type are known, and petrologic and geochemical information on the plutons is limited or absent, the geologic setting and general rock types are appropriate for plutonic porphyry Au deposits. Numerous small occurrences of contact metasomatic skarns or disseminated and veinlet base metal mineralization are known in the area.

Rationale for Tract Delineation

This tract comprises all the Proterozoic, Devonian or Cretaceous granitic plutons in the Brooks Range, and includes all potential host rocks within 5 km of the plutons. The geochemical data from stream sediment samples show an anomalous Sn-W-Mo association in addition to the base metals Cu-Pb-Zn.

Important Examples of Deposit Type

There are no known plutonic porphyry Au deposits in this tract

Rationale for Numerical Estimates

There is insufficient geologic or mineral deposit information to estimate the numbers of undiscovered mineral deposits in this tract.

References

Hollister, V.F., 1992, On a proposed plutonic porphyry gold deposit model: Nonrenewable resources, v. 1, no. 4, p. 293-302.

Descriptive Model: 39a**Mark3 Index: 54****Area: 93,632 km²****Mean undiscovered deposits: (no estimate)**[Model](#)[Mineral Deposits](#)

by Jeanine M. Schmidt, Karen D. Kelley, Richard I. Grauch, Byron R. Berger, John W. Cady, Gregory T. Spanski, James E. Kilburn.

Rationale for Model Choice

The geologic setting and host rocks indicate that this tract is permissive for modern placer deposits as well as for preserved paleoplacer gold deposits as described by Yeend (1986). Several small- to moderate-sized placer deposits and districts (?Tertiary to Quaternary) occur, and several Au-bearing lode deposits are known.

Rationale for Tract Delineation

This tract comprises broad areas of Proterozoic(?) to Paleozoic mixed schists (predominately pelitic schists, and lesser quartzitic, mafic, calcareous, and carbonaceous schists), and sedimentary rocks of the Upper Devonian to Mississippian(?) Endicott Group (Brosge and others, 1988; TAILLEUR and others, 1967). The mixed schists are host to rare low-sulfide Au-quartz veins, and apparently form the bedrock upstream of most of the extensive Quaternary placer Au deposits. The Endicott group, including the nonmarine Kekituk and Kanayut Conglomerates, the marine Noatak Sandstone and the Kayak and Hunt Fork Shales, generally produces a broad distinct aeromagnetic low, and contains scattered geochemical anomalies of Zn and Pb. The sand-and conglomerate-dominant lithologies of the Endicott Group are consolidated, lithified equivalents of gravel and sand deposits. They may contain preserved paleoplacer Au deposits, because they include both beach and alluvial facies, and were shed from a continental source (Nilsen, 1981; Moore and Nilsen, 1984).

Important Examples of Deposit Type

This tract includes the Wiseman, Chandalar, Kiana, Shugnak, and Koyukuk placer gold districts. The Lucky Six Creek, Little Squaw Creek, Nolan Creek, and Hammond River deposits are a few of the noteworthy placer deposits (Cobb, 1973; Dillon, 1982).

Rationale for Numerical Estimates

Because the lode sources and geomorphic setting of the existing placers have not been well established, and because the timing and genesis of the lode gold deposits is not known, no estimate of the number of undiscovered placer or paleoplacer deposits has been attempted.

References

- Brosge, W.P., Nilsen, T.H., Moore, T.E., and Dutro, J.T., Jr., 1988, Geology of the Upper Devonian and Lower Mississippian (?) Kanayut Conglomerate in the central and eastern Brooks Range, in Gryc, George, ed., Geology and exploration of the National Petroleum Reserve in Alaska, 1974 to 1982, U.S. Geological Survey Professional Paper 1399, scale 1:500,000, p. 299-316.
- Cobb, E.H., 1973, Placer deposits of Alaska: U.S. Geological Survey Bulletin 1374, 213 p.
- Dillon, J.T., 1982, Source of lode- and placer-gold deposits of the Chandalar and upper Koyukuk districts, Alaska: Alaska Division of Geological and Geophysical Surveys Open-File Report 158, 22 p.
- Moore, T.E., and Nilsen, T.H., 1984, Regional sedimentological variations in the Upper Devonian and Lower Mississippian(?) Kanayut Conglomerate, Brooks Range, Alaska: Sedimentary Geology, v. 38, p. 464-498

Nilsen, T.H., 1984, Upper Devonian and Lower Mississippian redbeds, Brooks Range, Alaska, in Miall, A.D., ed., Sedimentation and tectonics in alluvial basins: Geological Association of Canada special Paper 23, p. 187-219.

Tailleux, I.L., Brosge, W.P., and Reiser, H.N., 1967, Palinspastic analysis of Devonian rocks in northwestern Alaska, in Oswald, D.H., ed., International Symposium on the Devonian System, v.2: Alberta Society of Petroleum Geologists, Calgary, Canada, p. 1345-1361.

Yeend, Warren, 1986, Descriptive model of placer Au-PGE, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 261.

Descriptive Model: 39a

Mark3 Index: 54

Area: 94,009 km²

Mean undiscovered deposits: (no estimate)

[Model](#)

by Jeanine M. Schmidt, Karen D. Kelley, Richard I. Grauch, Byron R. Berger, John W. Cady, Gregory T. Spanski, James E. Kilburn.

Rationale for Model Choice

Placer gold (Yeend, 1986) can be expected to occur in unconsolidated deposits downstream from any of the gold-bearing lode deposit types. Therefore the placer gold permissive area is quite broad.

Rationale for Tract Delineation

This tract is defined entirely by anomalously high Au values in lake sediments of the North Slope and Arctic coastal plain, as reported by the NURE program (Kelley and Sutley, 1993; Karen Kelley, USGS, written commun. 1994). These anomalous values suggest that the area is permissive for high-volume, low-grade, placer deposits containing very sparsely disseminated fine-grained gold in Quaternary and Tertiary(?) lake sediments.

Important Examples of Deposit Type

No deposits are known; the tract is defined by the anomalously high gold values.

Rationale for Numerical Estimates

No estimate of the number of undiscovered deposits has been attempted.

References

- Kelley, K.D., and Sutley, S.J., 1993, Maps showing the geochemistry of sediment samples from the northern part of the Chandler Lake quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2144D, scale 1:250,000
- Yeend, Warren, 1986, Descriptive model of placer Au-PGE, in Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 261.

Descriptive Model: 19a**Mark3 Index: 47****Area: 13,821 km²****Mean undiscovered deposits: (no estimate)****Model**

by Jeanine M. Schmidt, Karen D. Kelley, Richard I. Grauch, Byron R. Berger, John W. Cady, Gregory T. Spanski, James E. Kilburn.

Rationale for Model Choice

Numerous small occurrences of contact metasomatic skarns or disseminated and veinlet base metal mineralization associated with felsic plutons are known in the Brooks Range. Petrologic and geochemical information on the plutons is limited, but numerous mineral deposit types are permissive, including polymetallic replacement deposits as described by Morris (1986).

Rationale for Tract Delineation

This tract comprises all the Proterozoic, Devonian or Cretaceous granitic plutons in the Brooks Range, and includes all potential host rocks within 5 km of the plutons. These tracts contain variable amounts of carbonate rocks of ?Proterozoic to Paleozoic age which are likely hosts for replacement mineralization. The timing and grade of metamorphism of the carbonate rocks, and their lithologies are not known in enough detail to differentiate areas of higher or lower favorability. The geochemical data from stream sediment samples show anomalous levels of Sn, W, and/or Mo in addition to the base metals Cu-Pb-Zn. There is very little, if any, gold associated with the intrusions.

Important Examples of Deposit Type

There are no known examples of polymetallic replacement deposits in this tract.

Rationale for Numerical Estimates

There is insufficient geologic information to estimate the numbers of undiscovered mineral deposits for polymetallic replacement deposits in this tract.

References

Morris, H.T., 1986, Descriptive model of polymetallic replacement deposits, *in* Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 99.

Descriptive Model: 22c**Mark3 Index: 52****Area: 9,782 km²****Mean undiscovered deposits: (no estimate)****Model**

by Jeanine M. Schmidt, Karen D. Kelley, Richard I. Grauch, Byron R. Berger, John W. Cady, Gregory T. Spanski, James E. Kilburn.

Rationale for Model Choice

Polymetallic vein deposits (Cox, 1986) can be associated with intrusive rocks of any age and a wide range of compositions. Therefore, it is difficult to limit the permissive area of deposits without significantly more geologic control than exists in most of Alaska. This model also serves as somewhat of a catch-all for deposits of unknown type that, given minimal information, do not appear to fit into other categories. Areas that are not considered permissive are predominantly where there is sufficiently detailed geologic information to indicate that deposits do not exist.

Numerous small occurrences of contact metasomatic skarns or disseminated and veinlet base metal mineralization are known in the area (Grybeck and others, 1977; Grybeck and Nelson, 1981). Petrologic and geochemical information on the plutons is limited or absent but geologic factors are permissive for numerous mineral deposit types, including polymetallic vein deposits.

Rationale for Tract Delineation

This tract comprises all the Proterozoic, Devonian or Cretaceous granitic plutons in the Brooks Range, and includes all potential host rocks within 5 km of the plutons. The timing and grade of metamorphism of the host rocks, and their lithologies are not known in enough detail to differentiate areas of higher or lower favorability. The geochemical data from stream sediment samples show anomalous levels of Sn, W, and/or Mo in addition to the base metals Cu-Pb-Zn. There is very little, if any, gold associated with the intrusions.

Important Examples of Deposit Type

No polymetallic vein deposits are known in this tract.

Rationale for Numerical Estimates

There is insufficient geologic information to estimate the number of undiscovered polymetallic vein deposits in this tract.

References

- Cox, D.P., 1986, Descriptive Model of polymetallic veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 125.
- Grybeck, Donald, Beikman, H.M., Brosge, W.P., Tailleir, IL., Mull, C.G., 1977, Geologic map of the Brooks Range, Alaska: U.S. Geological Survey Open-File Report 77-166B, 2 sheets, scale 1:1,000,000.
- Grybeck, Donald, and Nelson, S.W., 1981, Mineral deposit map of the Survey Pass quadrangle, Brooks Range, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1176-F, 1 sheet, scale, 250,000.

AK-BR17**Zn-Pb-Ag veins (Brooks Range type)****Alaska
Brooks Range****Descriptive Model:** (none)**Mark3 Index:** (none)**Area:** 59,440 km²**Mean undiscovered deposits:** (no estimate)**Model**

by Jeanine M. Schmidt, Karen D. Kelley, Richard I. Grauch, Byron R. Berger, John W. Cady, Gregory T. Spanski, James E. Kilburn.

Rationale for Model Choice

Several dozen vein-breccia occurrences of this type help define this Brooks Range tract (Schmidt and Werdon, 1993). The deposits consist of color banded sphalerite growing in apparent open-space filling veins and surrounding wall rock clasts in simple breccias up to several meters in width. Quartz and argentiferous galena infill open space in both veins and breccias; in rare cases more than one generation of brecciation or veining are indicated. Alteration associated with the mineralization is limited to minor decarbonation of wall rocks (only in marine sandstones with calcareous cement), minor silicification rare muscovite formation within microns to millimeters of the vein walls. This deposit model is apparently unique to the Brooks Range, but has similarities to the Shawangunk deposits of New York and vein breccia deposits at Bad Grund, Germany. There is NO spatial or genetic association of these veins with either volcanic or plutonic igneous rocks, which distinguishes them from the igneous-related polymetallic vein model. The Pb-Zn-Ag veins are probably derived by dewatering of a large clastic sedimentary basin (such as the Late Devonian to Mississippian Endicott Group).

Rationale for Tract Delineation

This tract includes all known exposures of sedimentary rocks of the Upper Devonian to Mississippian(?) Endicott Group. These rocks include the nonmarine Kekituk and Kanayut Conglomerates, the marine Noatak Sandstone and the Kayak and Hunt Fork Shales. These units generally produce a broad distinct aeromagnetic low, and contain only scattered geochemical anomalies of Zn and Pb.

Important Examples of Deposit Type

Mineral occurrences such as Husky, Story Creek, Whoopee Creek, and Kady are examples of Brooks Range type Pb-Zn-Ag veins in quartzites and siltstones (Schmidt, 1997). No vein-breccia deposits cut rocks older than Late Devonian (Frasnian), or younger than Early Mississippian (Kinderhook Kayak Shale and Isikut Formation), suggesting that their age of formation is Early to Middle Mississippian.

Rationale for Numerical Estimates

Because no grade and tonnage data are available for any of the vein breccia occurrences, no local grade-tonnage distribution curve could be constructed. No attempt was made to estimate the number of undiscovered deposits.

References

- Schmidt, J.M., 1997, Shale-hosted Zn-Pb-Ag and barite deposits of Alaska, *in* Goldfarb, R.J., and Miller, L.D., eds., Mineral Deposits of Alaska: Economic Geology Monograph 9, p. 35-65.
- Schmidt, J.M., and Werdon, M.B., 1993, Clastic-hosted stratiform, vein-breccia, and disseminated Zn-Pb-Ag deposits of the northwestern Brooks Range, Alaska: Are they different expressions of dewatering of the same source basin? [abs], Geological Society of America Abstracts with Program, volume 25, no. 5, p. 143.

AK-BR18

Cu-(Au) Skarn

Alaska Brooks Range

Descriptive Model: 18b

Mark3 Index: 8

Area: 9,782 km²

Mean undiscovered deposits: (no estimate)

[Model](#)

by Jeanine M. Schmidt

Rationale for Model Choice

Numerous small occurrences of contact metasomatic skarns or disseminated and veinlet base metal mineralization are known in the area (Nokleberg and others, 1987). Petrologic and geochemical information about the plutons is limited or absent, but numerous mineral deposit types are possible, including Cu-(Au) skarn deposits.

Rationale for Tract Delineation

This multi-part tract comprises all the known and inferred Proterozoic, Devonian or Cretaceous granitic plutons in the Brooks Range, and all potential host rocks within a 5 km distance from the plutons. These tracts contain variable amounts of carbonate rocks of ?Proterozoic to Paleozoic age which are likely hosts for skarn mineralization. The timing and grade of metamorphism of the carbonate rocks, and their lithologies are not known in enough detail to differentiate areas of higher or lower favorability. The geochemical data from stream sediment samples show anomalous levels of Sn, W, and/or Mo in addition to the base metals Cu-Pb-Zn. There is very little, if any, gold associated with these intrusions.

Important Examples of Deposit Type

No Cu-(Au) skarn deposits are known in this tract.

Rationale for Numerical Estimates

There is insufficient geologic and mineral deposit information to estimate numbers of undiscovered Cu-(Au) skarn deposits in this tract.

REFERENCES

Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987, Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.

AK-BR19

Zn-Pb Skarn

Alaska Brooks Range

Descriptive Model: 18c

Mark3 Index: 22

Area: 9,782 km²

Mean undiscovered deposits: (no estimate)

Model

by Jeanine M. Schmidt, Karen D. Kelley, Richard I. Grauch, Byron R. Berger, John W. Cady, Gregory T. Spanski, James E. Kilburn.

Rationale for Model Choice

Numerous small occurrences of contact metasomatic skarns or disseminated and veinlet base metal mineralization near plutons are known in the Brooks Range (Newberry and others, 1986). Petrologic and geochemical information on the plutons is limited or absent, but numerous mineral deposit types may occur, including Zn-Pb skarn deposits (Cox, 1986).

Rationale for Tract Delineation

This tract comprises all the known or inferred Proterozoic, Devonian or Cretaceous granitic plutons in the Brooks Range, and includes all potential host rocks within 5 km of the plutons. These tracts contain variable amounts of carbonate rocks of ?Proterozoic to Paleozoic age which are likely hosts for skarn mineralization. The timing and grade of metamorphism of the carbonate rocks, and their lithologies are not known in enough detail to differentiate areas of higher or lower favorability. The geochemical data from stream sediment samples show anomalous levels of Sn, W, and/or Mo in addition to the base metals Cu-Pb-Zn. There is very little, if any, gold associated with the intrusions.

Important Examples of Deposit Type

No Zn-Pb skarn deposits are known in this tract.

Rationale for Numerical Estimates

There is insufficient information to estimate the numbers of undiscovered Zn-Pb skarn deposits in this tract.

References

- Cox, D.P., 1986, Descriptive model of Zn-Pb skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 90.
- Newberry, R.J., Dillon, J.T., and Adams, D.D., 1986, Regionally metamorphosed, calc-silicate-hosted deposits of the Brooks Range, Northern Alaska: *Economic Geology*, v. 81, p. 1728 - 1752.

Descriptive Model: 30a

Mark3 Index: 76

Area: 59,440 km²

Mean undiscovered deposits: (no estimate)

[Model](#)

by Jeanine M. Schmidt, Karen D. Kelley, Richard I. Grauch, Byron R. Berger, John W. Cady, Gregory T. Spanski, James E. Kilburn.

Rationale for Model Choice

The geologic setting, extensive sandstone and siltstone host rocks, and elevated Pb geochemistry indicate that this tract is permissive for sandstone-hosted Pb-Zn deposits (Briskey, 1986). Several small occurrences, such as Ginnie Creek (Mayfield and others, 1979), Ipnarik River, and Otuk Creek may be of this type.

Rationale for Tract Delineation

This tract includes all known exposures of sedimentary rocks of the Upper Devonian to Mississippian(?) Endicott Group. These rocks include the nonmarine Kekituk and Kanayut Conglomerates, the marine Noatak Sandstone and the Kayak and Hunt Fork Shales. These units generally produce a broad distinct aeromagnetic low, and contain scattered geochemical anomalies of Zn and Pb.

Important Examples of Deposit Type

No sandstone-hosted Pb-Zn deposits are known in this tract, but it includes several occurrences of disseminated sphalerite and galena in sandstones (Mayfield and others, 1979), and numerous vein-breccia Zn-Pb-Ag sulfide deposits (Schmidt and Weldon, 1993). Sphalerite and galena also occur infilling diagenetic concretions within the Kayak shale.

Rationale for Numerical Estimates

No attempt was made to estimate the number of undiscovered deposits.

REFERENCES

- Briskey, J.A., 1986b, Descriptive model of sandstone-hosted Pb-Zn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 201.
- Mayfield, C.F., Curtis, S.M., Eilersieck, I.F., and Tailleux, I.L., 1979, The Ginny Creek zinc-lead-silver and Nimiuktuk barite deposits, northwestern Brooks Range, Alaska, *in* Johnson, K.M., and Williams, J.R., eds., The U.S. Geological Survey in Alaska, Accomplishments during 1978: U.S. Geological Survey Circular 804B, p. B11-B13.
- Schmidt, J.M., and Weldon, M.B., 1993, Clastic-hosted stratiform, vein-breccia, and disseminated Zn-Pb-Ag deposits of the northwestern Brooks Range, Alaska: Are they different expressions of dewatering of the same source basin? [abs], Geological Society of America Abstracts with Program, volume 25, no. 5, p. 143.

Descriptive Model: 30b

Mark3 Index: 63

Area: 175,722 km²

Mean undiscovered deposits: (no estimate)

[Model](#)

by Jeanine M. Schmidt, Karen D. Kelley, Richard I. Grauch, Byron R. Berger, John W. Cady, Gregory T. Spanski, James E. Kilburn.

Rationale for Model Choice

There are numerous small chalcopyrite occurrences in this tract, often in quartz veinlets, and often associated with the Hunt Fork Shale or Noatak sandstone parts of the clastic Endicott Group (Schmidt and Allegro, 1980). The host rocks and geologic setting of this tract are permissive for Kupferschiefer type shale-hosted copper deposits (Cox, 1986) as well as for red-bed type sandstone-hosted deposits.

Rationale for Tract Delineation

This tract includes all outcrop areas of Proterozoic(?), Paleozoic, and Mesozoic sedimentary and metasedimentary rocks that are prospective for sedimentary or diagenetic Cu deposits. The lithologies included are shale, black shale, sandstone, siltstone, off-platform carbonate rocks, pelitic, quartzitic and carbonaceous schists, and marbles. No specific geochemical information was used to define this tract.

Important Examples of Deposit Type

No sediment-hosted Cu deposits are known in this tract, but numerous small Cu occurrences hosted in sedimentary rocks are known.

Rationale for Numerical Estimates

No estimate of the number of undiscovered deposits was attempted.

References

- Cox, D.P., 1986, Descriptive model of sediment-hosted Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 205.
- Schmidt, J.M., and Allegro, G.L., 1980, Mineral occurrences and indicators in the Baird Mountains quadrangle, Alaska: USGS Miscellaneous Field Studies Map MF1992, 1 plate, scale 1:250,000, 19 p.

Descriptive Model: 31a**Mark3 Index: 13****Area: 49,825 km²****Mean undiscovered deposits: (no estimate)****Model**

by Jeanine M. Schmidt, Karen D. Kelley, Richard I. Grauch, Byron R. Berger, John W. Cady, Gregory T. Spanski, James E. Kilburn

Rationale for Model Choice

The geologic setting and host rocks are permissive for sediment-hosted Zn-Pb-Ag deposits (Briskey, 1986), but no occurrences are known.

Rationale for Tract Delineation

This tract is defined by carbonate rocks of the Mississippian to Pennsylvanian Lisburne Group. These are mainly light-colored platform carbonates, but include some slope and deeper-water carbonate lithologies, and are permissive for Zn-Pb mineralization similar to the "Irish" type orebodies of Novan and Silvermines (Hitzman and Lange, 1986).

Important Examples of Deposit Type

No sediment-hosted deposits are known in this tract, although time-equivalent deeper-water rocks to the west host the Red Dog and Lik deposits (Schmidt, 1997).

Rationale for Numerical Estimates

Because of the lack of geologic information and mineral deposit data, no attempt was made to estimate the number of undiscovered deposits that may exist.

References

- Briskey, J.A., 1986b, Descriptive model of sedimentary exhalative Zn-Pb, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 211-212
- Hitzman, M.W., and Lange, Duncan, 1986, A review and classification of the Irish carbonate-hosted base metal deposits *in*, Andrew, C.J., Crowe, R.W.A., Finlay, S., Pennell, W.M., and Pyne, J.F., eds., Geology and genesis of mineral deposits in Ireland: Dublin, Ireland, Irish Association of Economic Geologists, p. 217-238.
- Schmidt, J.M., 1997, Shale-hosted Zn-Pb-Ag and barite deposits of Alaska, *in* Goldfarb, R.J., and Miller, L.D., eds., Mineral Deposits of Alaska: Economic Geology Monograph 9, p. 35-65.

Descriptive Model: 31a

Mark3 Index: 13

Area: 29,735 km²

Mean undiscovered deposits: 4.94

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Jeanine M. Schmidt, Karen D. Kelley, Richard I. Grauch, Byron R. Berger, John W. Cady, Gregory T. Spanski, James E. Kilburn

Rationale for Model Choice

Shale-hosted Zn-Pb-Ag +/-Ba deposits (Briskey, 1986) occur in this tract. The geologic setting, deep-water marine sedimentary host rocks and drainage geochemistry are permissive for additional deposits.

Rationale for Tract Delineation

This tract is defined by dark, fine-grained sedimentary rocks that may host base-metal and barite mineral deposits. The most favorable units included here are Mississippian to Pennsylvanian black shale, black mudstone, black chert and some dark limestones of the Kuna Formation, Akmalik Chert, and Kayak Shale, and time-equivalent unnamed units. However, this tract also includes permissive dark fine-grained lithologies of the Cretaceous Torok Shale, and the Triassic Shublik and Otuk Formations. Tract boundaries are delineated by the outcrop areas of these strata, and by anomalously high concentrations of base metals in stream sediment samples.

Important Examples of Deposit Type

Known mineral occurrences of this type include the Red Dog mine (Lange and others, 1985; Moore and others, 1986; Schmidt and Zierenberg, 1988; Zierenberg and Schmidt, 1988) and the Lik (Forrest, 1983; Forrest and others, 1983; Forrest and Sawkins, 1987), Drenchwater (Nokleberg and Winkler, 1982), and Suds prospects (Schmidt, 1997).

Rationale for Numerical Estimates

Based on the wide extent of appropriate host rocks, several known and drilled prospects, and widespread geochemical anomalies, the number of undiscovered deposits, consistent with the median grade and tonnage for the model (Menzie and Mosier, 1986), estimated for this tract is:

Percentile	90	50	10	5	1
Estimated number of deposits	2	5	7	10	15

References

- Briskey, J.A., 1986, Descriptive model of sedimentary exhalative Zn-Pb, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 211-212
- Forrest, Kimball, 1983, Geology and isotopic studies of the Lik deposit and the surrounding mineral district, DeLong Mountains, Western Brooks Range, Alaska: unpublished PhD thesis, Univ. of Minnesota, 161p.
- Forrest, Kimball, Rye, R., and Sawkins, F.J., 1983, Sulfur and oxygen isotope systematics of sedimentary exhalative Zn-Pb-Ag deposition in a fault-bounded basin, Lik deposit, Western Brooks Range, Alaska, (abs.): Geol. Assoc. of Canada, Abstracts with Program, Victoria, B.C., v. 8, p. A23.
- Forrest, Kimball, and Sawkins, F.J., 1987, Geologic setting and mineralization of the Lik deposit: Implications for the tectonic history of the western Brooks Range, in Tailleux, I.L., and Weimer, Paul,

- eds., *Alaskan North Slope Geology: Soc. of Economic Paleontologists and Mineralogists Field Trip Guidebook 50*, p. 295 -305.
- Lange, I.M., Nokleberg, W.J., Plahuta, J.T., Krouse, H.R., and Doe, B.R., 1985, Geologic setting, petrology, and geochemistry of stratiform zinc-lead-barium deposits, Red Dog Creek and Drenchwater Creek areas, northwestern Brooks Range, Alaska: *Economic Geology*, v. 80, p. 1896-1926.
- Moore, D.W., Young, L.E., Modene, J.S., and Plahuta, J.T., 1986, Geologic setting and genesis of the Red Dog zinc-lead-silver deposit, western Brooks Range, Alaska: *Economic Geology*, v. 81, p. 1696 - 1727.
- Menzie, W.D., and Mosier, D.L., 1986, Grade and tonnage model of sedimentary exhalative Zn-Pb, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models: U.S. Geological Survey Bulletin 1693*, p. 212-215
- Nokleberg, W.J., and Winkler, G.R., 1982, Stratiform zinc-lead deposits in the Drenchwater Creek area, Howard Pass quadrangle, northwestern Brooks Range, Alaska: *U.S. Geological Survey Professional Paper 1209*, 22p, 2 sheets, scale 1:20,000.
- Schmidt, J.M., 1997, Shale-hosted Zn-Pb-Ag and barite deposits of Alaska, *in* Goldfarb, R.J., and Miller, L.D., eds., *Mineral Deposits of Alaska: Economic Geology Monograph 9*, p. 35-65.
- Schmidt, J.M., and Zierenberg, R.A., 1988, Lateral variations of ore, and reconstruction of the Red Dog Zn-Pb-Ag deposit, Noatak District, Alaska [abs.]: *Geol. Soc. of America Abstracts with Program*, v. 20, no. 7, p. A-37.
- Zierenberg, R.A., and Schmidt, J.M., 1988, Isotopic evidence for multiple sulfur sources at the Red Dog Zn-Pb-Ag deposit, Noatak District, Alaska [abs.]: *Geol. Soc. of America Abstracts with Program*, v. 20, no., 7, p. A-37.

Descriptive Model: 24b

Mark3 Index: 30

Area: 44,937 km²

Mean undiscovered deposits: (no estimate)

[Model](#)

by Jeanine M. Schmidt, Bruce M. Gamble, and Thomas D. Light,

Rationale for Model Choice

No massive sulfide deposits are known in this tract. The presence of altered basalts containing pyrite and locally high copper values may suggest submarine hydrothermal activity, and suggest that the area is permissive for Besshi massive sulfide deposits as described by Cox (1986).

Rationale for Tract Delineation

This tract encompasses mafic rocks of Proterozoic(?), Paleozoic, or Mesozoic age (Murchey and Harris, 1985; Pallister and others, 1989).

Important Examples of Deposit Type

No Besshi massive sulfide deposits are known in this tract.

Rationale for Numerical Estimates

No deposits of this type are known in the area, and no estimates of the number of undiscovered deposits have been attempted.

References

- Cox, D.P., 1986, Descriptive model of Besshi massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 136.
- Murchey, B.L., and Harris, A.G., 1985, Devonian to Jurassic sedimentary rocks in the Angayucham Mountains of Alaska: possible sea mount or oceanic plateau deposits [abs]: EOS, Transactions of the American Geophysical Union, v. 66, no. 46, p. 1102.
- Pallister, J.S., Budahn, J.R., and Murchey, B.L., 1989, Pillow basalts of the Angayucham terrane: oceanic plateau and island crust accreted to the Brooks Range: Journal of Geophysical Research, v. 94, no. B11, p. 15,901-15,923.

Descriptive Model: 24a**Mark3 Index: 11****Area:****Mean undiscovered deposits: (no estimate)**[Model](#)*by* Jeanine M. Schmidt and Thomas D. Light**Rationale for Model Choice**

Altered basalts with pyrite and locally high copper values may suggest submarine hydrothermal activity, and the area is permissive for Cyprus massive sulfide deposits as defined by Singer (1986).

Rationale for Tract Delineation

This tract contains mafic rocks of Proterozoic(?), Paleozoic, or Mesozoic age similar to those rocks in the southern flank of the Brooks Range (Murchey and Harris, 1985; Pallister and others, 1989).

Important Examples of Deposit Type

No Cyprus-type deposits are known in the area.

Rationale for Numerical Estimates

No estimates of the number of undiscovered deposits have been attempted.

References

- Murchey, B.L., and Harris, A.G., 1985, Devonian to Jurassic sedimentary rocks in the Angayucham Mountains of Alaska: possible sea mount or oceanic plateau deposits [abs]: EOS, Transactions of the American Geophysical Union, v. 66, no. 46, p. 1102.
- Pallister, J.S., Budahn, J.R., and Murchey, B.L., 1989, Pillow basalts of the Angayucham terrane: oceanic plateau and island crust accreted to the Brooks Range: Journal of Geophysical Research, v. 94, no. B11, p. 15,901-15,923.
- Singer, D.A., 1986, Descriptive model of Cyprus massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 131.

Descriptive Model: 25a**Area: 103 km²**[Model](#)*by* Bruce M. Gamble and Marti L. Miller**Rationale for Model Choice**

This tract is underlain by Late Cretaceous subaerial volcanic rocks that are permissive for Hot Spring Au (+ Hg) epithermal deposits similar to those described by Berger (1986).

Rationale for Tract Delineation

This tract represents the extension of the adjacent tract in west-central Alaska, and is inferred to be underlain by Late Cretaceous subaerial volcanic rocks (Patton and others, 1994; Moll-Stalcup, 1994), consisting of andesites, rhyolites, and minor basalts.

Important Examples of Deposit Type

No epithermal vein deposits are known in the tract

Rationale for Numerical Estimates

Estimates of the number of undiscovered epithermal vein deposits for east-central Alaska were not attempted.

References

- Berger, B.R., 1986, Descriptive model of hot-spring Au-Ag, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 143.
- Moll-Stalcup, E.J., 1994, Latest Cretaceous and Cenozoic magmatism in mainland Alaska, *in* Plafker, George, and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G-1, p. 589-619.
- Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1994, Geology of west-central Alaska, *in* Plafker, George, and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G-1, p. 241-269.

Descriptive Model 25a-d**Mark3 Index : (none)****Area: 1,061 km²****Mean undiscovered deposits: (no estimate)**[Model](#)

by Donald Grybeck, Thomas D. Light, William J. Keith, Dennis P. Cox, Gregory K. Lee, and Jeffrey D. Phillips.

Rationale for Model Choice

Epithermal vein deposit models in the conterminous US have been divided into several types based largely on the underlying basement rocks (Cox and Singer, 1986). For the most part, information about Alaska is inadequate to classify individual epithermal gold vein types. Therefore, we have combined deposit models for Creede epithermal veins (Mosier and others, 1986b), Comstock epithermal veins (Mosier and others, 1986c), Sado epithermal veins (Mosier and others, 1986a), and epithermal quartz-alunite gold (Berger, 1986a) into a generic epithermal vein model. We evaluated the permissive area for undiscovered deposits of all types of epithermal veins based on this generic model, which includes gold and/or silver veins associated with intermediate to felsic volcanic rocks similar to those described by Panteleyev (1987).

This tract is permissive for the occurrence of epithermal Au veins based on the known occurrence at the Democrat deposit in the Big Delta quadrangle.

Rationale for Tract Delineation

The tract is defined as the part of the Yukon-Tanana terrane containing the epithermal Au-Ag Democrat deposit, gold placers in Tenderfoot and Banner Creeks, and nearby high-level residual gold placers. Until the discovery of the Democrat deposit, epithermal gold veins were not expected in this area. There is almost certainly potential for additional such deposits beyond the tract as defined, but it is difficult to establish the limits of this larger permissive area. Much of the Yukon-Tanana terrane to the north, east, and west is mantled by a thick cover of loess (up to several hundred feet thick) and surficial material that makes exploration difficult and could well hide additional such deposits. The small size of the epithermal deposits further reduces their likelihood of discovery. Probably the best regional guide to such deposits are placer gold deposits, especially those without a clear lode source. One such placer is at Caribou Creek, a tributary to the Salcha River about 15 miles northeast of the tract, which contains large nuggets of native bismuth. Small placer occurrences also are sprinkled throughout Yukon-Tanana terrane between the Yukon and Tanana Rivers which suggest that the permissive area may include most of the Yukon-Tanana Upland. However, epithermal vein deposits need not necessarily form placers and a better guide to the extent of such deposits may be the distribution of late Cretaceous plutons, which are widely distributed in the Yukon-Tanana Upland.

Important Examples of Deposit Type

The Democrat Au-Ag deposit is tentatively classified as an epithermal deposit. Native gold, acanthite, and a variety of silver sulfosalts typical of epithermal deposits are associated with a 86.9 Ma. felsic dike variously called a granite porphyry, porphyry, or rhyolite porphyry. The deposit is associated with a relatively small alluvial placer below the deposit. In addition, there are several high-level placers in the district, notable for their angular gold, that are associated with northwest-trending lineaments and/or extensions of the rhyolite porphyry dike at the Democrat deposit or with other similar dikes. These are probably residual placers (oral communication, Don May, 1993).

There was some production from the Democrat deposit in the late 1980's; a test shipment was made to a mill in Fairbanks and a small open pit was developed that recovered gold with a simple washing plant. There was also some drilling but more work is necessary to fully define the property; its extension at depth is particularly uncertain and some have speculated that it represents the top of a porphyry gold system (Thomas Bundtzen, Alaska Division of Geological and Geophysical Surveys, oral communication, 1992).

The placers in the area have been known since before World War I but most of the work on the Democrat lode deposit began in the mid-1970's. Regional exploration is greatly hindered by a thick loess cover that mantles the hillsides.

Rationale for Numerical Estimates

Insufficient data precludes estimation of the number of undiscovered epithermal gold veins in this tract.

References

- Berger, B.R., 1986a, Descriptive model of epithermal quartz-alunite Au, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 158.
- Bundtzen, T. K., and Reger, R. D., 1977, The Richardson lineament, a structural control for gold deposits in the Richardson mining district, Interior Alaska, *in* Short Notes on Alaskan Geology-1977: Alaska Division of Geological and Geophysical Surveys Geologic Report 55, p. 29-34.
- Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 130.
- Miller, T. P., 1994, Pre-Cenozoic plutonic rocks in mainland Alaska, *in* Plafker, George, and Berg, H. C., The Geology of Alaska: The Geology of North America, volume, G-1, Geological Society of America, p. 535-554.
- Mosier, D.L., Berger, B.R., and Singer, D.A., 1986a, Descriptive model of Comstock epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 154.
- Mosier, D.L., Sato, Takeo, Page, N.J., Singer, D.A., and Berger, B.R., 1986b, Descriptive model of Creede epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 145.
- Mosier, D.L., Singer, D.A., and Berger, B.R., 1986c, Descriptive model of Comstock epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 150.
- Nokleberg, et. al, 1993, Metallogenesis of mainland Alaska and the Russian Northeast: U. S. Geological Survey Open-File Report 93-339, 222 p.
- Panteleyev, Andrejs, 1987, A Canadian cordilleran model for epithermal gold-silver deposits, *in* Roberts, R.G., and Sheahan, P.A., Ore Deposit Models: Geoscience Canada Reprint Series 3, p. 31-43.

Descriptive Model: 36c

Mark3 Index : 95

Area: 1,721 km²

Mean undiscovered deposits: 3.28

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Donald Grybeck, Thomas D. Light, William J. Keith, Dennis P. Cox, Gregory K. Lee, and Jeffrey D. Phillips.

Rationale for Model Choice

The lode gold deposits in the Fairbanks district occur in a variety of host rocks that include felsic to intermediate plutonic stocks and various types of schist units. The deposits have some of the characteristics of low-sulfide Au-qtz veins (Berger, 1986), polymetallic veins (Cox, 1986), simple antimony veins (Bliss and Orris, 1986), and Au-Sb veins (Berger, 1992), but are much richer in Sb than most of the polymetallic veins in that model. Locally, the Fairbanks Au-quartz veins grade into simple Sb veins having a much higher gold content than is normal for the simple antimony model. Some of these veins could be classified as low-sulfide Au-quartz veins, but locally have a much higher sulfide and sulfosalt content than Berger's (1986) model.

Rationale for Tract Delineation

This tract was defined by the distribution of known deposits, and by the outcrop area of inferred permissive host rocks.

Important Examples of Deposit Type

The Cleary Hill, Hi-Yu, and Ryan Lode mines may be examples of gold-antimony veins in the Fairbanks area, although these mines have also been classified as low-sulfide gold-quartz veins (Berger, 1986).

Rationale for Numerical Estimates

The expected tonnage and grade of the majority of the gold-bearing veins in the Fairbanks area probably most closely fit the distribution curves for the low-sulfide Au-qtz model (Berger, 1986), and several deposits in the east-central Alaska area, such as the Cleary Hill, Hi-Yu, and Ryan Lode mines, have been included in the that model. We estimated that the number of undiscovered deposits that would fit the grade and tonnage curves for Au-Sb deposits (Berger, 1993) would be approximately one fourth of the number of low-sulfide Au-quartz veins for the same area (see tract AK-EC08). The minimum number of undiscovered deposits, consistent with the grade and tonnage curves of (Berger, 1993) is:

Percentile	90	50	10	5	1
Estimated number of deposits		1	3	5	8 12

References

- Berger, B.R., 1986c, Descriptive model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239.
- Berger, V.I., 1993, Descriptive, and grade-tonnage model for gold-antimony deposits: U.S. Geological Survey Open-File Report 93-194, 24 p.

Descriptive Model: 36a

Mark3 Index: 27

Area: 25,659 km²

Mean undiscovered deposits: (no estimate)

[Model](#)[Mineral Deposits](#)*by* Thomas D. Light, Bruce M. Gamble, and Donald Grybeck**Rationale for Model Choice**

The presence of placer Au deposits, greenschist facies rocks of the Ruby terrane, and local geochemical anomalies support definition of a permissive tract for low-sulfide Au-quartz veins.

Rationale for Tract Delineation

This tract is defined by Precambrian(?) and Paleozoic pelitic schists, metabasites, quartzites, orthogneiss, and marbles (Patton and others, 1989; Dover, 1994; Nokleberg and others, 1994). As, Zn, W, and Cu, are the most common stream sediment anomalies, and traces of Au, Ag and Bi are present locally.

Important Examples of Deposit Type

No low-sulfide Au-quartz veins are known in the tract, but the geologic environment suggests that low-sulfide Au-quartz veins may be present.

Rationale for Numerical Estimates

No estimate of the number of undiscovered low-sulfide Au-quartz vein deposits was attempted.

References

- Dover, J.A., 1994, Geology of part of east-central Alaska, Chapter 5 *in* Plafker, George, and Berg, H.C., eds., The Geology of Alaska, v. G-1 of Geology of North America: Boulder, Colorado, Geological Society of America, Decade of North American Geology series, p. 153-204.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 45 manuscript p., scale 1:2,500,000.
- Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1989, Geology of west-central Alaska: U.S. Geological Survey Open-File Report 89-554, 41 p.

Descriptive Model: 36a*Mark3 Index:* 27**Area:** 74,586 km²**Mean undiscovered deposits:** 8.84[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Donald Grybeck, Thomas D. Light, William J. Keith, Dennis P. Cox, Gregory K. Lee, and Jeffrey D. Phillips

Rationale for Model Choice

The metamorphic rocks of the Yukon-Tanana Upland outside the Fairbanks area are permissive for low-sulfide Au-quartz veins as described by Berger (1986), because the geology and tectonic setting are similar to the Fairbanks area, which hosts numerous low-sulfide Au-quartz veins.

Rationale for Tract Delineation

The major constraint as well as the main evidence for undiscovered low-sulfide Au-quartz vein deposits is the widespread occurrence of placer gold deposits and the presence of favorable host rocks.

Important Examples of Deposit Type

No good examples occur outside the Fairbanks area, but the Fairbanks deposits serve as excellent examples of what might be found elsewhere in similar rocks in east-central Alaska.

Rationale for Numerical Estimates

Additional deposits similar to those in the Fairbanks area are expected to occur outside the Fairbanks area. Using the mean size and grade projections of Bliss (1986), the estimated minimum number of undiscovered low-sulfide Au-quartz veins in the Yukon-Tanana Upland is:

Percentile	90	50	10	5	1
Estimated number of deposits	2	8	15	20	30

References

- Berger, B.R., 1986, Descriptive model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239.
- Bliss, J.D., 1986, Grade and tonnage model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239-243.

Descriptive Model: 36a

Mark3 Index: 27

Area: 1,721 km²

Mean undiscovered deposits: 13.32

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Donald Grybeck, Thomas D. Light, William J. Keith, Dennis P. Cox, Gregory K. Lee, and Jeffrey D. Phillips.

Rationale for Model Choice

The lode gold deposits in the Fairbanks district occur in a variety of host rocks that include felsic to intermediate plutonic stocks and various types of schist units. The deposits have some of the characteristics of low-sulfide Au-qtz veins (Berger, 1986), polymetallic veins (Cox, 1986), simple antimony veins (Bliss and Orris, 1986), and Au-Sb veins (Berger, 1992), but are much richer in Sb than most of the polymetallic veins in that model. Locally, the Fairbanks Au-quartz veins grade into simple Sb veins with a much higher gold content than is normal for the simple antimony model. Some of these veins could be classified as low-sulfide Au-quartz veins, but locally have a much higher sulfide and sulfosalt content than Berger's (1986) model.

Rationale for Tract Delineation

This tract was defined mainly by the distribution of known deposits.

Important Examples of Deposit Type

The most important deposits of this type in this tract are the Cleary Hill and Hi-Yu mines in the Cleary Hill area, and the numerous mines and deposits in the Ester Dome area.

Rationale for Numerical Estimates

The expected tonnage and grade of these gold-bearing veins in the Fairbanks area probably most closely fit the distribution curves for the low-sulfide Au-qtz model of Bliss (1986), with an average orebody size of 30,000 tonnes and an average grade of 16 grams of gold per ton. The estimated minimum number of undiscovered low-sulfide Au-quartz deposits is:

Percentile	90	50	10	5	1
Estimated number of deposits	5	12	20	30	50

References

- Berger, B.R., 1986, Descriptive model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239.
- Berger, V.I., 1993, Descriptive, and grade-tonnage model for gold-antimony deposits: U.S. Geological Survey Open-File Report 93-194, 24 p.
- Bliss, J.D., 1986, Grade and tonnage model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239-243.
- Bliss, J.D., and Orris, G.J., 1986, Descriptive model of simple Sb deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 183-184.
- Cox, D.P., 1986c, Descriptive Model of polymetallic veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 125.

Descriptive Model 32c**Mark3 Index (none)****Area: 23,291 km²****Mean undiscovered deposits: (no estimate)**[Model](#)

by Jeanine M. Schmidt, Thomas D. Light, and Bruce M. Gamble.

Rationale for Model Choice

This tract in east-central Alaska is permissive for Kipushi-type deposits, as described by Cox and Bernstein (1986), because it has the appropriate geologic setting (a continental platform or shelf with continental or passive margin rifting) and host rocks (dolostone, shale and shallow-water or platform carbonate rocks) for the deposit model.

Rationale for Tract Delineation

This tract is defined by Paleozoic platform carbonate rocks. Where the environment of deposition is not known or indeterminate, thick carbonate rocks of possible shelf, slope, or deeper-water-facies are included. Paleozoic metamorphic rocks that contain minor marble units of unknown origin, such as the biotite gneiss and amphibolite (PzpGb of Foster, 1976), have not been included in this tract. In the Eagle and Charley River quadrangles geologically favorable units include the limestones of the Tindir Group, the Funnel Creek Limestone, the Hillard Limestone, and the Calico Bluff Formation. The western portion of this tract includes the Paleozoic limestones of the Quail, Amy Creek, Schwatka, and minor other units.

Important Examples of Deposit Type

There are no Kipushi-type deposits known in this tract.

Rationale for Numerical Estimates

There are no tonnage and grade curves for Kipushi-type deposits. No quantitative estimates of the number of undiscovered deposits was attempted.

References

- Cox, D.P., and Bernstein, L.R., 1986, Descriptive model of Kipushi Cu-Pb-Zn, *in* Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 227.
- Foster, H.L., 1976, Geologic map of the Eagle quadrangle, Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map I-922, scale 1:250,000.

Descriptive Model 32c**Mark3 Index (none)****Area: 5,974 km²****Mean undiscovered deposits: (no estimate)**[Model](#)*by* Jeanine M. Schmidt and Bruce M. Gamble**Rationale for Model Choice**

Paleozoic platform carbonate rocks in east-central Alaska are permissive for Kipushi-type deposits as defined by Cox and Bernstein (1986), because they were formed in an appropriate geologic setting (a continental platform or shelf with continental or passive margin rifting) and because they contain appropriate host rocks (dolostone, shale, and shallow-water or platform carbonate rocks) for the deposit model. Although no occurrences are known in this tract, correlative rocks in west-central Alaska host numerous strata-bound Zn prospects (informally called the Reef Ridge district) in carbonate rocks.

Rationale for Tract Delineation

This tract consists of areas locally underlain by Cambrian to Devonian shallow-water facies platform carbonate rocks of the Nixon Fork and Minchumina terranes (Patton and others, 1994). Locally, Pb and Zn anomalies are in stream-sediment and panned-concentrate samples in west-central Alaska. Sphalerite, chalcopyrite, cinnabar, pyrite and malachite were identified in some stream-sediment concentrate samples.

Important Examples of Deposit Type

Examples of carbonate-hosted base-metal deposits occur in equivalent rocks in the Reef Ridge district in the Medfra quadrangle of west-central Alaska (Schmidt, 1997).

Rationale for Numerical Estimates

There are no tonnage and grade curves for Kipushi-type deposits; no quantitative estimates of the number of undiscovered deposits were attempted.

References

- Cox, D.P., and Bernstein, L.R., 1986, Descriptive model of Kipushi Cu-Pb-Zn, *in* Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 227.
- Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1994, Geology of west-central Alaska, *in* Plafker, George, and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G-1, p. 241-269.
- Schmidt, J.M., 1997, Strata-bound carbonate-hosted Zn-Pb and Cu deposits of Alaska, *in* Goldfarb, R.J., and Miller, L.D., eds., Mineral Deposits of Alaska: Economic Geology Monograph 9, p. 90-119.

Descriptive Model: 32a and 32b**Mark3 Index: 42****Area: 23,298 km²****Mean undiscovered deposits: (no estimate)**[Model](#)*by* Thomas D. Light and Jeanine M. Schmidt**Rationale for Model Choice**

Two Mississippi Valley type (MVT) deposits are described in Cox and Singer (1986). The differences between Southeast Missouri Pb-Zn (model 32a; Briskey 1986b) and Appalachian Zn (model 32b; Briskey, 1986a) are subtle enough that the grade and tonnage models for the two deposit types are plotted together with no differentiation between types (Mosier and Briskey, 1986). In Alaska, the lack of detailed geologic information prevents distinguishing between the two deposit types, and a generic Mississippi Valley type model has been used.

The carbonate units of east-central Alaska are permissive for Mississippi Valley type deposits, based on the geologic setting, appropriate host rocks, and known deposits that may fit the model.

Rationale for Tract Delineation

This tract is defined by Paleozoic platform carbonate rocks. Where the environment of deposition is not known or indeterminate, thick carbonate rocks of possible shelf, slope, or deeper-water-facies are included. Paleozoic metamorphic rocks that contain minor marble units of unknown origin, such as biotite gneiss and amphibolite (PzpGb of Foster, 1976), have not been included in this tract. In the Eagle and Charley River quadrangles geologically favorable units include the limestones of the Tindir Group, the Funnel Creek Limestone, the Hillard Limestone, and the Calico Bluff Formation. The western portion of this tract includes the Paleozoic limestones of the Quail, Amy Creek, Schwatka, and minor other units.

Important Examples of Deposit Type

Step Mountain may be an example of a Mississippi Valley type deposit in this tract (Schmidt, 1997).

Rationale for Numerical Estimates

Geological information is inadequate to estimate the number of undiscovered Mississippi Valley type deposits in this tract.

References

- Briskey, J.A., 1986a, Descriptive model of Appalachian Zn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 222-223.
- Briskey, J.A., 1986b, Descriptive model of southeast Missouri Pb-Zn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 220-221.
- Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 130.
- Foster, H.L., 1976, Geologic map of the Eagle quadrangle, Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map I-922, scale 1:250,000.
- Mosier, D.L., and Briskey, 1986, Grade and tonnage model of southeast Missouri Pb-Zn and Appalachian Zn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 224-226.
- Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1989, Geology of west-central Alaska: U.S. Geological Survey Open-File Report 89-554, 41 p.
- Schmidt, J.M., 1997, Strata-bound carbonate-hosted Zn-Pb and Cu deposits of Alaska, *in* Goldfarb, R.J., and Miller, L.D., eds., Mineral Deposits of Alaska: Economic Geology Monograph 9, p. 90-119.

Descriptive Model: 32a and 32b**Mark3 Index: 42****Area: 5,974 km²****Mean undiscovered deposits: (no estimate)**[Model](#)

by Jeanine M. Schmidt, Thomas D. Light, and Bruce M. Gamble

Rationale for Model Choice

Two Mississippi Valley type (MVT) deposits are described in Cox and Singer (1986). The differences between Southeast Missouri Pb-Zn (model 32a; Briskey 1986b) and Appalachian Zn (model 32b; Briskey, 1986a) are subtle enough that the grade and tonnage models for the two deposit types are plotted together with no differentiation between types (Mosier and Briskey, 1986). In Alaska, the lack of detailed geologic information prevents distinguishing between the two deposit types, and a generic Mississippi Valley type model has been used.

This tract is permissive for Mississippi Valley type deposits because it locally contains platform carbonate rocks, which in west-central Alaska, host deposits thought to be Mississippi Valley type.

Rationale for Tract Delineation

This tract includes the Nixon Fork and Minchumina terranes, both of which locally contain lower Paleozoic platform carbonate rocks (Patton and others, 1994), in the Kantishna River quadrangle.

Important Examples of Deposit Type

The Reef Ridge deposit in the Medfra quadrangle of west-central Alaska is an example of a Mississippi Valley type deposit (Andrews and Rishel, 1982).

Rationale for Numerical Estimates

No estimate of the number of undiscovered deposits was attempted.

References

- Andrews, T., and Rishel, John, 1982, 1981 Annual Report-Reef Ridge I-XIII project areas, Kuskokwim Block, Volume 1 of 3: unpublished report, Patino Inc., Anchorage, Alaska, 49 p.
- Briskey, J.A., 1986a, Descriptive model of Appalachian Zn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 222-223.
- Briskey, J.A., 1986b, Descriptive model of southeast Missouri Pb-Zn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 220-221.
- Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 130.
- Mosier, D.L., and Briskey, 1986, Grade and tonnage model of southeast Missouri Pb-Zn and Appalachian Zn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 224-226.
- Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1994, Geology of west-central Alaska, *in* Plafker, George, and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G-1, p. 241-269.

[AK-EC13](#)

Porphyry Cu (BC-Ak type)

Alaska East Central

Descriptive Model: 17.1

Mark3 Index: 89

Area: 115,029 km²

Mean undiscovered deposits: 2.59

[Cumulative Distribution](#)

[Histogram](#)

[Table](#)

[Model](#)

by Donald Grybeck, Thomas D. Light, William J. Keith, Dennis P. Cox, Gregory K. Lee, and Jeffrey D. Phillips.

Rationale for Model Choice

Several porphyry copper deposits are known in the eastern part of east-central Alaska, outside of this tract. Similar deposits may occur in Upper Cretaceous or Tertiary granitic plutons, in the western portion of the tract. These plutons, however, are consistently low in copper and have much lower potential for porphyry copper occurrences. A general porphyry copper model has been described by Hollister (1978), Beane and Titley (1981), Titley and Beane (1981), McMillan and Panteleyev (1980), and Titley (1982).

Rationale for Tract Delineation

This tract is defined by the distribution of Upper Cretaceous or Tertiary granitic plutons and adjacent areas that may contain granitic plutons of similar age. Cretaceous plutons farther to the west are consistently low in copper and have a much lower potential for porphyry Cu occurrences.

Important Examples of Deposit Type

There are no porphyry deposits known in this tract, but such deposits are known in similar rocks to the south (i.e., the Taurus deposit in the Tanacross quadrangle).

Rationale for Numerical Estimates

The tonnage curve for the BC-AK type porphyry copper model (Menzie and Singer, 1993), which has a lower mean expected tonnage than the standard porphyry copper model, has been used to estimate numbers of undiscovered deposits. The grade of the undiscovered deposits is expected to be about 0.25% copper, reflecting the lower grade of Alaskan porphyry copper deposits. The estimated minimum number of undiscovered porphyry Cu-Mo deposits expected to occur in this tract is:

Percentile	90	50	10	5	1
Estimated no. of deposits	1	2	4	8	10

References

- Beane, R.E., and Titley, S.R., 1981, Porphyry copper deposits, Part II; Hydrothermal alteration and mineralization, in Skinner, B.J., editor, Economic Geology 75th Anniversary Volume: Economic Geology Publishing Company, p. 235-269.
- Holister, V.F., 1978, Geology of the porphyry copper deposits of the western hemisphere: New York, American Institute of Mining, Metallurgical, and Petroleum Engineers, 219 p.
- McMillan, W.J., and Panteleyev, A., 1980, Ore deposit models-1. Porphyry copper deposits: Geoscience Canada, v. 7, p. 52-63.
- Titley, S.R., 1982, Advances in geology of the porphyry copper deposits, southwestern North America: Tucson, Arizona, University of Arizona Press, 560 p.
- Titley, S.R., and Beane, R.E., 1981, Porphyry copper deposits Part I; Geologic settings, petrology and tectogeneses, in Skinner, B.J., editor, Economic Geology 75th Anniversary Volume: Economic Geology Publishing Company, p. 214-234.

Descriptive Model: 43

Mark3 Index: 43

Area: 84,106 km²

Mean undiscovered deposits: 3.35

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Donald Grybeck, Thomas D. Light, William J. Keith, Dennis P. Cox, Gregory K. Lee, and Jeffrey D. Phillips.

Rationale for Model Choice

The Fort Knox deposit near Fairbanks is the potentially the largest lode gold deposit ever found in Alaska, and is the type example of this model.

Rationale for Tract Delineation

The plutonic porphyry Au deposit is a relatively new model (Hollister, 1992), and the composition, age, and other variables that constrain the permissive plutons are not well defined. The Fort Knox deposit is in a granitic to granodioritic stock having an age of about 93 Ma (Newberry and others, 1995). It is not clear, however, what the age range or composition of other possible host stocks may be. Therefore, this tract is defined by the distribution of known or inferred felsic to intermediate plutons in east-central Alaska. If undiscovered deposits of this type are near the surface, placer gold is probably the best indicator.

Important Examples of Deposit Type

The Fort Knox deposit in the Fairbanks occurs in a small zoned stock of granite to granodiorite composition. Native gold is disseminated along fractured zones associated with quartz veins. Sulfides are rare; trace amounts of bismuthinite and bismuth tellurides are common (Bauman, 1990). The deposit is being developed as a bulk-tonnage, low-grade mine with published reserves of 158 million tonnes containing 0.83 grams per tonne (Bundtzen and others, 1994). The True North deposit is in the Livengood quadrangle.

Rationale for Numerical Estimates

The Fort Knox deposit has reported reserves of more than 4 million ounces of gold (Bundtzen and others, 1994). The estimated minimum number of undiscovered plutonic porphyry Au deposits, consistent with the deposit data reported by Hollister (1992), is:

Percentile	90	50	10	5	1
Estimated Number of deposits	1	3	5	9	13

References

- Bauman, F.W., 1990, Geology of the Fort Knox gold deposit, Fairbanks, Alaska; *Alaska Miner*, January, p. 14-15.
- Bundtzen, T.K., Swainbank, R.C., Clough, A.H., Henning, M.W., and Hansen, E.W., 1994, Alaska's Mineral Industry: Alaska Division of Geological and Geophysical Surveys Special Report 48, 84 p.
- Hollister, V.F., 1992, On a proposed plutonic porphyry gold deposit model: *Nonrenewable resources*, v. 1, p. 293-302.
- Newberry, R.J., McCoy, D.T., and Brew, D.A., 1995, Plutonic-hosted gold ores in Alaska; *Igneous vs. metamorphic origins: Resource Geology Special Issue No. 18*, p. 57-100.

Descriptive Model: 39a**Mark3 Index: 54****Area: 93,722 km²****Mean undiscovered deposits: (no estimate)**[Model](#)[Mineral Deposits](#)

by Donald Grybeck, Thomas D. Light, William J. Keith, Dennis P. Cox, Gregory K. Lee, and Jeffrey D. Phillips.

Rationale for Model Choice

Placer gold can be expected to occur in unconsolidated deposits downstream from any of the gold-bearing lode deposits, and therefore the permissive area for placer gold is extensive.

Rationale for Tract Delineation

This tract, in east-central Alaska, is defined by the distribution of its known deposits (Cobb, 1973).

Important Examples of Deposit Type

The majority of placer gold production in east-central Alaska has been from the Fairbanks, Circle, Livengood (Tolovana), Fortymile, Rampart, and Hot Springs (Tofty) districts. Placer deposits in the Fairbanks district have produced 8 million ounces of gold, the Circle district produced more than 1 million ounces of gold, and the other districts each produced 1/2 million or less ounces of gold (Bundtzen and others, 1994).

Rationale for Numerical Estimates

Exploring for placer gold deposits is relatively easy, and because of the numerous gold rushes from the 1890's to the 1920's much of the state has been thoroughly explored. There is a low probability that major new placer districts will be discovered, but a few relatively small new deposits probably will be found. Such small placer gold deposits may be outside the known districts, and might be mined during periods of high gold prices. No attempt was made to estimate the number of undiscovered deposits.

References

Bundtzen, T.K., Swainbank, R.C., Clough, A.H., Henning, M.W., and Hansen, E.W., 1994, Alaska's Mineral Industry: Alaska Division of Geological and Geophysical Surveys Special Report 48, 84 p.
Cobb, E.H., 1973, Placer deposits of Alaska: U.S. Geological Survey Bulletin 1374, 213 p.

Descriptive Model: 19a

Mark3 Index: 47

Area: 23,291 km²

Mean undiscovered deposits: (no estimate)

[Model](#)

by Jeanine M. Schmidt and Thomas D. Light

Rationale for Model Choice

Numerous small occurrences of contact metasomatic skarns or disseminated and veinlet base metal mineralization associated with felsic plutons are known in east-central Alaska. Petrologic and geochemical information on the plutons is limited, but the geology is permissive for several types of mineral deposits, including polymetallic replacement deposits as described by Morris (1986).

Rationale for Tract Delineation

This tract is defined by Paleozoic carbonate rocks of the Yukon-Tanana terrane. Paleozoic metamorphic rocks that contain minor marble units of unknown origin, such as biotite gneiss and amphibolite (PzpGb of Foster, 1976), have not been included in this tract. In the Eagle and Charley River quadrangles geologically favorable units include the limestones of the Tindir Group, the Funnel Creek Limestone, the Hillard Limestone, and the Calico Bluff Formation. The western portion of this tract includes the Paleozoic limestones of the Quail, Amy Creek, Schwatka, and other minor units.

Important Examples of Deposit Type

There are no known examples of polymetallic replacement deposits in this tract.

Rationale for Numerical Estimates

There is insufficient geologic information to estimate the number of undiscovered polymetallic replacement deposits in this tract.

References

- Foster, H.L., 1976, Geologic map of the Eagle quadrangle, Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map I-922, scale 1:250,000.
- Morris, H.T., 1986, Descriptive model of polymetallic replacement deposits, *in* Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 99.

Descriptive Model: 19a**Mark3 Index: 47****Area: 5,974 km²****Mean undiscovered deposits: (no estimate)**[Model](#)

by Marti L. Miller, Bruce M. Gamble, and Thomas D. Light

Rationale for Model Choice

In east-central Alaska and nearby parts of southwestern, west-central, and south-central Alaska, carbonate rocks that are locally intruded by small felsic plutons may host polymetallic replacement deposits as described by Morris (1986).

Rationale for Tract Delineation

The areas permissive for polymetallic replacement deposits are defined by Paleozoic carbonate rocks, belonging to the Nixon Fork and Minchumina terranes (Patton and others, 1994), that are locally intruded by Late Cretaceous and Tertiary plutons. This tract is a continuation of adjacent tracts in southwestern, west-central, and south-central Alaska.

Important Examples of Deposit Type

No examples of polymetallic replacement deposits are known in this tract.

Rationale for Numerical Estimates

No estimate of undiscovered resources was attempted.

References

- Morris, H.T., 1986, Descriptive model of polymetallic replacement deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 99-100.
- Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1994, Geology of west-central Alaska, *in* Plafker, George, and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G-1, p. 241-269.

Descriptive Model: 22c**Mark3 Index: 52****Area: 124,544 km²****Mean undiscovered deposits: (no estimate)****Model**

by Donald Grybeck, Thomas D. Light, Warren J. Nokleberg, William J. Keith, Dennis P. Cox, Gregory K. Lee, and Jeffrey D. Phillips.

Rationale for Model Choice

Polymetallic vein deposits can be associated with intrusive rocks of any age and a wide range of compositions (Cox, 1986). Polymetallic veins may also be spatially related to a large number of other types of deposits, thus making their permissive area quite extensive. This model also serves as somewhat of a catch-all for deposits of unknown type that, given minimal information, do not appear to fit into other similar categories

Rationale for Tract Delineation

The permissive area for polymetallic veins is considered to be the entire extent of the Yukon-Tanana Upland and the Kohnen-Hodzana Highlands of Wahrhaftig (1965), which comprise the southern and western portions of east central Alaska and the northern portion of south-central Alaska. This area is predominately Paleozoic metamorphic and sedimentary units intruded by Late Cretaceous and early Tertiary granitic plutons, dikes, and sills of the Kluane arc. Geophysical and geochemical data may support the permissive classification of large areas where no polymetallic vein deposits are known. This tract is contiguous to the permissive tract in south-central Alaska.

Important Examples of Deposit Type

The Banjo and Quigley Ridge deposits in the Mount McKinley quadrangle (Nokleberg and others, 1987), as well as many of the veins in the Fairbanks area can be classified as polymetallic veins. Insufficient information precludes a more detailed classification in many cases.

Rationale for Numerical Estimates

No estimates of the undiscovered polymetallic veins in this tract was attempted because of the lack of detailed geologic information.

References

- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987. Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.
- Wahrhaftig, Clyde, 1965, Physiographic Divisions of Alaska: U.S. Geological Survey Professional Paper 482, 52 p.

AK-EC19

Cu-(Au) Skarn

Alaska East Central

Descriptive Model: 18b

Mark3 Index: 8

Area: 29,265 km²

Mean undiscovered deposits: (no estimate)

Model

by Thomas D. Light

Rationale for Model Choice

This tract is permissive for Cu-(Au) skarn deposits where Cretaceous or Tertiary plutons have intruded near carbonate rocks or calcareous clastic rocks (Cox and Theodore, 1986).

Rationale for Tract Delineation

This multi-part tract is defined by Paleozoic carbonate rocks. Where the environment of deposition is not known or indeterminate, thick carbonate rocks of possible shelf, slope, or deeper-water-facies are included. Paleozoic metamorphic rocks that contain minor marble units of unknown origin, such as biotite gneiss and amphibolite (PzpGb of Foster, 1976), have not been included in this tract. In the Eagle and Charley River quadrangles, geologically favorable units include the limestones of the Tindir Group, the Funnel Creek Limestone, the Hillard Limestone, and the Calico Bluff Formation. In the Livengood quadrangle favorable units include the Tolovana Limestone and the limestones of the Wickersham unit.

Important Examples of Deposit Type

No Cu (Au) skarn deposits are known in this tract.

Rationale for Numerical Estimates

Because of the lack of detailed geological information, and the absence of known deposits, no estimate of the number of undiscovered Cu (Au) skarn deposits was attempted.

REFERENCES

- Cox, D.P., and Theodore, T.G., 1986, Descriptive model of Cu skarn deposits, *in* Cox, D.P. and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 86.
- Foster, H.L., 1976, Geologic map of the Eagle quadrangle, Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map I-922, scale 1:250,000.

Descriptive Model: 18c

Mark3 Index: 22

Area: 29,265 km²

Mean undiscovered deposits: (no estimate)

[Model](#)*by* Bruce M. Gamble, Marti L. Miller, and Thomas D. Light**Rationale for Model Choice**

The presence of intermediate to felsic plutonic rocks that may intrude carbonate-bearing units suggests that this tract is permissive for Zn-Pb skarn deposits as described by Cox (1986).

Rationale for Tract Delineation

This tract is defined by the distribution of carbonate rocks and possible carbonate-bearing units and by the known or inferred presence of intermediate to felsic plutonic rocks (Patton and others, 1994; Nokleberg and others, 1994). Known mineral deposits in the adjacent tract in west-central Alaska include a Cu-Au skarn and a Fe-skarn.

Important Examples of Deposit Type

No Zn-Pb skarn deposits are known in this tract.

Rationale for Numerical Estimates

Because of the lack of detailed geologic information, no estimates of the number of undiscovered deposits have been attempted.

References

- Cox, D.P., 1986, Descriptive model of Zn-Pb skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 90.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 45 manuscript p., scale 1:2,500,000.
- Patton, W.W., Jr., Box, S.E., and Grybeck, D.J., 1994, Ophiolites and other mafic-ultramafic complexes in Alaska, *in* Plafker, George, and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North American, v. G-1, p. 671-686.

Descriptive Model: 31a**Mark3 Index: 13****Area: 23,298 km²****Mean undiscovered deposits: (no estimate)****Model**

by Jeanine M. Schmidt and Thomas D. Light

Rationale for Model Choice

This tract contains dark, fine-grained, restricted or deep water marine sedimentary rocks similar to Paleozoic rocks that host several large sediment-hosted Zn-Pb (Briskey, 1986) and barite deposits in the adjacent Yukon Territory of Canada (Schmidt, 1997).

Rationale for Tract Delineation

The tract delineates the occurrence of dark-gray to black Paleozoic marine shales and some metamorphic rocks (graphitic schists etc.) inferred to be the equivalent of fine-grained marine sedimentary rocks (Dover, 1994). Many metasedimentary rocks of the Yukon-Tanana upland are Paleozoic, inferred to have been deposited on continental crust (Dover, 1994), and contain phyllites and argillites that could contain shale-hosted massive sulfide deposits.

Important Examples of Deposit Type

Prospects include Derwent Creek, Hard Luck Creek, Lead Creek, and Grayling (Doyon Ltd., 1986).

Rationale for Numerical Estimates

Due to the lack of detailed geologic information and mineral deposit data, no attempt was made to estimate the number of undiscovered sedex deposits.

References

- Briskey, J.A., 1986c, Descriptive model of sedimentary exhalative Zn-Pb, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 211-212.
- Dover, J.A., 1994, Geology of part of east-central Alaska, *in* Plafker, George, and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America p. 153-204.
- Doyon, Ltd., 1986, Mines, prospects, and geochemical anomalies on Doyon, Ltd., regional overselection lands, Alaska, vol., 1, Blocks 1-8: Doyon Report 86-01A, Doyon, Ltd., Fairbanks, Alaska, 150 p.
- Schmidt, J.M., 1997, Shale-hosted Zn-Pb-Ag and barite deposits of Alaska, *in* Goldfarb, R.J., and Miller, L.D., eds., Mineral Deposits of Alaska: Economic Geology Monograph 9, p. 35-65.

Descriptive Model: 31a

Mark3 Index: 13

Area: 4,721 km²

Mean undiscovered deposits: (no estimate)

[Model](#)

by Jeanine M. Schmidt, Marti L. Miller, and Bruce M. Gamble

Rationale for Model Choice

Deposition in a deep-water environment suggests the possibility of sedex deposits as described by Briskey (1986). Bedded barite deposits may form distal to sedex occurrences. The presence of a bedded barite deposit in possibly correlative rocks in the continuation of this tract to the southwest supports the selection of this model type.

Rationale for Tract Delineation

This tract encompasses parts of the Nixon Fork and Minchumina terranes (Patton and others, 1994), both of which locally contain deep-water facies. The region is poorly known; reconnaissance geochemical data are not available.

Important Examples of Deposit Type

No examples of sedex deposits are known in this tract, but the Gagaryah barite deposit (Bundtzen and Gilbert, 1991), in similar rocks in the Lime Hills quadrangle of southwestern Alaska, may be related to sedex mineralization.

Rationale for Numerical Estimates

No attempt was made to estimate the number of undiscovered Sedex Zn-Pb deposits in this tract.

REFERENCES

- Briskey, J.A., 1986, Descriptive model of sedimentary exhalative Zn-Pb, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 211-212.
- Bundtzen, T.K., and Gilbert, W.G., 1991, Geology and geochemistry of the Gagaryah barite deposit, western Alaska Range, Alaska, *in*, Reger, R.D., ed., Short Notes on Alaskan Geology 1991: Alaska Division of Geological and Geophysical Surveys Professional Report 111, p. 9-20.
- Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1994, Geology of west-central Alaska, *in* Plafker, George, and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G-1, p. 241-269.

Descriptive Model 23**Mark3 Index: (none)****Area: 25,441 km²****Mean undiscovered deposits: (no estimate)**[Model](#)[Mineral Deposits](#)

by Warren J. Nokleberg, Dennis P. Cox, David L. Campbell, and Warren Yeend.

Rationale for Model Choice

This tract covers parts of the Alaska Range and Wrangell Mountains, and is permissive for Kennecott Cu deposits because of favorable bedrock geologic units, known major mines, geochemical anomalies (Cu, As, Au, Ag, Hg), and locally abundant chalcopyrite and bornite in stream-sediment samples.

Rationale for Tract Delineation

The geologic units that define this tract are the Upper Triassic Chitistone Limestone and correlative units where underlain by the Upper Triassic Nikolai Greenstone. The mafic volcanic rocks of the Nikolai Greenstone exhibit elevated copper concentrations. The major Kennecott Cu deposits are interpreted as having been derived by a combination of hydrothermal and (or) metamorphic processes in the mid-Cretaceous (Nokleberg and others, 1993) from the upper part of the Nikolai to form the large deposits in the Kennecott Cu district (Bateman and McLaughlin, 1920) that occur in the overlying Upper Triassic Chitistone Limestone. Because the Nikolai is interpreted as the source of copper, the distribution of the Nikolai defines the permissive extent of both basaltic copper and Kennecott Cu deposit types. On the aeromagnetic map of Alaska (Godson, 1994), the tract displays local birds-eye magnetic anomalies that are characteristic of (meta) basalt. The Kennecott Cu deposits in this tract may be genetically associated with formation of Cu-Ag quartz vein deposits (tract AK-SC05) in that both are interpreted to have formed during mid-Cretaceous low-grade regional metamorphism (Nokleberg and others, 1993).

The distribution of the geologic units defining the tract is adapted from Nokleberg and others (1994). The distribution of this belt of mineral deposits is adapted from MacKevett and others (1978) and Nokleberg and others (1987, 1993). Mineral resource assessments of 250,000-scale quadrangles within the tract were done by Richter and others (1975), MacKevett (1976), Singer and others (1977, 1980), Cox and others (1989), and Nokleberg and others (1990).

Important Examples of Deposit Type

The famous Cu mines of the Kennecott district (Bonzana, Erie, Green Butte, Jumbo, Mother Lode) (Bateman and McLaughlin, 1920; MacKevett, 1976) occur in this tract. These mines were included in the basaltic copper model described by Cox (1986). Considerable debate exists over the inclusion of the Kennecott Cu deposits in the basaltic copper model, because these deposits, although interpreted as derived from the basalts, are formed in carbonate rocks as much as 100 meters above the basalt (Bateman and McLaughlin, 1920). The associated Cu-Ag quartz vein deposits in the Kennecott district and elsewhere in the tract are classified into a metamorphic-related Cu-Ag quartz vein deposit model by Nokleberg and others (1993).

Rationale for Numerical Estimates

No tonnage and grade model exists for Kennecott Cu deposits. Therefore, no estimate of the number of undiscovered deposits was attempted.

References

Bateman, A.M., and McLaughlin, D.H., 1920, Geology of the ore deposits of Kennecott, Alaska: Economic Geology, v. 15, p. 1-80.

- Cox, D.P., 1986, Descriptive Model of Basaltic Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 130.
- Cox, D.P., Light, T.D., Csejtey, Béla, and Campbell, D.L., 1989, Mineral resource assessment map of the Healy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2058-A, scale 1:250,000.
- Godson, Richard H., 1994, Composite magnetic anomaly map of Alaska and adjacent offshore area, *in* Plafker, G. and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America: The Geology of North America, v. G1, plate 10, scale 1:2,500,000.
- MacKevett, E.M., Jr., 1976, Mineral deposits and occurrences in the McCarthy quadrangle, Alaska: U.S.G.S. Miscellaneous Field Studies Map MF-773-B, 2 sheets, scale 1:250,000.
- MacKevett, E.M., Jr., Singer, D.A., and Holloway, C.D., 1978, Maps and tables describing metalliferous mineral resource potential of southern Alaska: U.S. Geological Survey Open-File Report 78-1E, 2 sheets, scale 1:1,000,000, 45 p.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, MS., Smith, T.E., and Yeend, Warren, 1987, Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, p. 104.
- Nokleberg, W.J., Bundtzen, T.K., Grybeck, Donald, Koch, R.D., Eremin, R.A., Rozenblum, I.S., Sidorov, A.A., Byalobzhesky, S.G., Sosunov, G.M., Shpikerman, V.I., and Gorodinsky, M.E., 1993, Metallogenesis of mainland Alaska and the Russian Northeast: Mineral deposit maps, models, and tables, metallogenic belt maps and interpretation, and references cited: U.S. Geological Survey Open-File Report 93-339, 222 pages, 1 map, scale 1:4,000,000; 5 maps, scale 1:10,000,000.
- Nokleberg, W.J., Lange, I.M., Singer, D.A., Curtin, G.C., Tripp, R.B., Campbell, D.L., and Yeend, Warren, 1990, Mineral resource assessment maps of the Mount Hayes quadrangle, eastern Alaska Range, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1996-A, 4 sheets, scale 1:250,000, 22 p.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 53 p., scale 1:2,500,000.
- Richter, D.H., Singer, D.A., and Cox, D.P., 1975, Mineral resources map of the Nabesna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-655-K, 1 sheet, scale 1:250,000.
- Singer, D. A., Csejtey, Béla, Jr., and Miller, R.J., 1980, Map and discussion of the metalliferous and selected non-metalliferous mineral resources of Talkeetna Mountains quadrangle, Alaska: U.S. Geological Survey Open-File Report 78-558-Q, 34 p., 1 sheet, scale 1:250,000.
- Singer, D.A., and MacKevett, E.M., Jr., 1977, Mineral resources map of the McCarthy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-773-C, 1 sheet, scale 1:250,000.

Descriptive Model: 24b

Mark3 Index: 30

Area: 1,660 km²

Mean undiscovered deposits: (no estimate)

[Model](#)[Mineral Deposits](#)

by Warren J. Nokleberg, Dennis P. Cox, Richard J. Goldfarb, and David L. Campbell.

Rationale for Model Choice

Parts of the western Alaska Range are permissive for Triassic and Jurassic Besshi massive sulfide deposits because of geologically favorable bedrock units, a known occurrence, geochemical anomalies of Cu, Pb, Zn, As, Ag, and Co in stream sediment samples, and local aeromagnetic anomalies.

Rationale for Tract Delineation

The favorable geologic units in the tract are the marine pillow basalts that are interlayered with Triassic through Jurassic marine sedimentary rocks of the Mystic terrane. A subdued aeromagnetic birds-eye pattern might be expected over the pillow basalts, but is not seen on the aeromagnetic map of Alaska (Godson, 1994). The distribution of the geologic units defining the tract is adapted from Nokleberg and others (1994). The distribution of this belt of mineral deposits is adapted from MacKevett and others (1978) and Nokleberg and others (1987, 1993). A mineral resource assessment of the 250,000-scale Talkeetna quadrangle (Reed and others, 1979) covers part of the tract.

Important Examples of Deposit Type

The best known deposit of this type is the Shellebarger Pass occurrence in the Talkeetna quadrangle (Reed and Eberlein, 1972; Bundtzen and Gilbert, 1983).

Rationale for Numerical Estimates

The tract is locally covered by extensive ice fields and glaciers. Because only one occurrence is known, no attempt was made to estimate the number of undiscovered Besshi massive sulfide deposits in this tract.

References

- Bundtzen, T.K., and Gilbert, W.G., 1983, Outline of geology and mineral resources of upper Kuskokwim region, Alaska: Alaska Geological Society 1982 Symposium on Western Alaska, v. 3, p. 101-117.
- Godson, Richard H., 1994, Composite magnetic anomaly map of Alaska and adjacent offshore area, *in* Plafker, G. and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America: The Geology of North America, v. G1, plate 10, scale 1:2,500,000.
- MacKevett, E.M., Jr., Singer, D.A., and Holloway, C.D., 1978, Maps and tables describing metalliferous mineral resource potential of southern Alaska: U.S. Geological Survey Open-File Report 78-1E, 2 sheets, scale 1:1,000,000, 45 p.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987, Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.
- Nokleberg, W.J., Bundtzen, T.K., Grybeck, Donald, Koch, R.D., Eremin, R.A., Rozenblum, I.S., Sidorov, A.A., Byalobzhesky, S.G., Sosunov, G.M., Shpikerman, V.I., and Gorodinsky, M.E., 1993, Metallogenesis of mainland Alaska and the Russian Northeast: Mineral deposit maps, models, and tables, metallogenic belt maps and interpretation, and references cited: U.S. Geological Survey Open-File Report 93-339, 222 pages, 1 map, scale 1:4,000,000; 5 maps, scale 1:10,000,000.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and

overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 53 p., scale 1:2,500,000.

Reed, B.L., and Eberlein, G.D., 1972, Massive sulfide deposits near Shellebarger Pass, southern Alaska Range, Alaska: U.S. Geological Survey Bulletin 1342, 45 p.

Reed, B.L., Nelson, S.W., Curtin, G.C., and Singer, D.A., 1979, Mineral resources map of the Talkeetna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-870-D, 1 sheet, scale 1:250,000.

Descriptive Model: 24b

Mark3 Index: 30

Area: 9,684 km²

Mean undiscovered deposits: 2.23

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Warren J. Nokleberg

Rationale for Model Choice

Parts of the eastern Alaska Range and Wrangell Mountains are permissive for Late Triassic Besshi massive sulfide deposits (Cox, 1986), based on favorable bedrock units and the presence of known deposits.

Rationale for Tract Delineation

The favorable geologic units for the tract are the lower, marine, (meta)basalt member of the Upper Triassic Nikolai Greenstone of the Wrangellia terrane, and the Cottonwood Bay greenstone of the Peninsular terrane.

Important Examples of Deposit Type

The Denali deposit (Seraphim, 1975) was classified as basaltic copper by Cox (1986), and alternately as a Besshi massive sulfide by Nokleberg and others (1987).

Rationale for Numerical Estimates

The estimated minimum number of undiscovered Besshi massive sulfide deposits, consistent with the grade and tonnage model of Singer (1986), is:

Percentile	90	50	10	5	1
Estimated number of deposits	1	2	4	4	4

References

- Cox, D.P., 1986, Descriptive model of Besshi massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 136.
- Cox, D.P., Light, T.D., Csejtei, Béla, and Campbell, D.L., 1989, Mineral resource assessment map of the Healy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2058-A, scale 1:250,000.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987. Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.
- Seraphim, R.H., 1975, Denali—A nonmetamorphosed stratiform sulfide deposit: *Economic Geology*, v. 70, p. 949-959.
- Singer, D.A., 1986, Grade and tonnage model of Besshi massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 136-138.

Descriptive Model: 24b

Mark3 Index: 30

Area: 21,717 km²

Mean undiscovered deposits: 14.17

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Warren J. Nokleberg, Dennis P. Cox, Richard J. Goldfarb, and David L. Campbell.

Rationale for Model Choice

The northern Prince William Sound area is permissive for Late Cretaceous and early Tertiary Besshi massive sulfide deposits (Cox, 1986; Singer, 1986) because of favorable bedrock geologic units, known mines and abundant occurrences, anomalous concentrations of Fe, Co, Cu, Ni, and Zn in stream sediment samples (Goldfarb and others, 1992), abundant sulfide minerals in heavy mineral concentrates, and favorable aeromagnetic anomalies.

Rationale for Tract Delineation

Two geologic units are favorable in this tract: (1) an extensive unit of Late Cretaceous marine metabasalt and associated metamorphosed flysch along the southern margin of the Valdez Group in the southern part of the Chugach terrane; and (2) the abundant early Tertiary marine basalts and associated marine sedimentary rocks of the Orca Group in the Prince William terrane. On the aeromagnetic map of Alaska (Godson, 1994), the tract displays broad aeromagnetic highs that coincide with areas of basalt at the surface or areas where basalt is interpreted to occur near the surface.

The distribution of the geologic units defining the tract is adapted from Nokleberg and others (1994). The distribution of this belt of mineral deposits is adapted from MacKevett and others (1978) and Nokleberg and others (1987, 1993). Mineral resource assessments of 250,000-scale quadrangles within the tract were done by MacKevett (1976), Tysdal and Case (1982), Nelson and others (1984), Goldfarb and others (1992), and Madden-McGuire and Winkler (1993).

Important Examples of Deposit Type

The Midas mine in the Valdez quadrangle (Johnson, 1915; Moffit and Fellows, 1950) is an example in the Valdez Group. Examples in the Orca Group are the Blackbird, Beatson, and LaTouche mines on LaTouche Island in the Seward quadrangle (Johnson, 1915), and the Ellamar, Fidalgo-Alaska, and Schlosser mines in the Cordova quadrangle (Capps and Johnson, 1915). An estimated 200 small stratiform sulfide (chalcopyrite, sphalerite, and galena) occurrences are known in the tract and are interpreted as Besshi massive sulfide deposits (Crowe and others, 1992).

Rationale for Numerical Estimates

The tract is partly covered by extensive ice fields, glaciers, and forests, and is truncated by the southern Alaska coastline. The tract contains several large mines (listed above) and many small occurrences, some of which are Cyprus-type deposits (AK-SC06). Assuming a general ratio of Besshi to Cyprus massive sulfide deposits of 10:1 (Cox and Singer, 1986), about five undiscovered Besshi massive sulfide deposits are estimated to occur in this tract. The mineral resource team estimated the minimum number of undiscovered Besshi massive sulfide deposits, consistent with the grade and tonnage model of Singer (1986), to be:

Percentile	90	50	10	5	1
Estimated number of deposits	5	10	30	30	30

References

- Capps, S.R., and Johnson, B.L., 1915, The Ellamar district, Alaska: U.S. Geological Survey Bulletin 605, 125 p.
- Cox, D.P., 1986, Descriptive model of Besshi massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 136.
- Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, 379 p.
- Crowe, D.E., Nelson, S.W., Brown, P.E., Shanks, W.C., III, and Valley, J.W., 1992, Geology and geochemistry of volcanogenic massive sulfide deposits and related igneous rocks, Prince William Sound, south-central Alaska: Economic Geology, v. 87, p. 1722-1746.
- Godson, Richard H., 1994, Composite magnetic anomaly map of Alaska and adjacent offshore area, *in* Plafker, G. and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America: The Geology of North America, v. G1, plate 10, scale 1:2,500,000.
- Goldfarb, R.J., Carter Borden, J., and Winkler, G.R., 1995, Geochemical survey of the Valdez 1°x3° quadrangle, south-central Alaska: U.S. Geological Survey Bulletin 2084, 77 p., 1 sheet, scale 1:250,000.
- Goldfarb, R.J., Case, J.E., Plafker, George, and Winkler, G.R., 1992, Maps showing areas of potential for mineral resources in the Cordova and Middleton Island 1° x 3° quadrangles, southern Alaska: U.S. Geological Survey Miscellaneous Field Investigations Map MF-2190. 1 sheet, scale 1:250,000.
- Heran, W.D., 1992, Geophysical model of massive sulfide deposits, *in* Heran, W.D., ed., Codocil to The geophysical expression of selected mineral deposit models: U.S. Geological Survey Open-file Report 94-174, p.4-15.
- Johnson, B.L., 1915, The gold and copper deposits of the Port Valdez district: U.S. Geological Survey Bulletin 622, p. 140-148.
- MacKevett, E.M., 1976, Mineral deposits and occurrences in the McCarthy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-773B, scale 1:250,000, 2 sheets.
- MacKevett, E.M., Jr., Singer, D.A., and Holloway, C.D., 1978, Maps and tables describing metalliferous mineral resource potential of southern Alaska: U.S. Geological Survey Open-File Report 78-1E, 2 sheets, scale 1:1,000,000, 45 p.
- Madden-McGuire, D.J., and Winkler, G.R., 1993, Mineral resource maps of the Anchorage quadrangle, southern Alaska: U.S. Geological Survey Miscellaneous Investigations Map MI-2393, scale 1:250,000, 3 sheets.
- Moffit, F.H., and Fellows, R.E., 1950, Copper deposits of the Prince William Sound district, Alaska: U.S. Geological Survey Bulletin 963-B, p. 47-80.
- Nelson, S.W., Miller, M.L., Barnes, D.F., Dumoulin J.A., Goldfarb, R.J., Koski, R.A., Mull, G.C., Pickthorn, W.J., Jansons, Uldis, Hoekzema, R.B., Kurtak, J.M., Fechner, S.A., 1984, Mineral resource potential of the Chugach National Forest, Alaska: US Geological Survey Miscellaneous Field Studies Map MF-1645-A, scale 1:250,000, 23 p.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987. Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.
- Nokleberg, W.J., Bundtzen, T.K., Grybeck, Donald, Koch, R.D., Eremin, R.A., Rozenblum, I.S., Sidorov, A.A., Byalobzhesky, S.G., Sosunov, G.M., Shpikerman, V.I., and Gorodinsky, M.E., 1993, Metallogenesis of mainland Alaska and the Russian Northeast: Mineral deposit maps, models, and tables, metallogenic belt maps and interpretation, and references cited: U.S. Geological Survey Open-File Report 93-339, 222 pages, 1 map, scale 1:4,000,000; 5 maps, scale 1:10,000,000.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 53 p., scale 1:2,500,000.
- Singer, D.A., 1986, Grade and tonnage model of Besshi massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 136-138.
- Tysdal, R.G., and Case, J.E., 1982, Metalliferous mineral resource potential of the Seward and Blying Sound quadrangles, southern Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-880H, 2 sheets, scale 1:250,000, 23 p.

Descriptive Model [no number]**Mark3 Index: (none)****Area: 25,441 km²****Mean undiscovered deposits: (no estimate)**[Model](#)

by Warren J. Nokleberg, Dennis P. Cox, David L. Campbell, and Warren Yeend.

Rationale for Model Choice

Tract AK-SC05 in the Alaska Range and Wrangell Mountains is permissive for Cu-Ag quartz vein deposits because of favorable bedrock geology, known mines and occurrences, geochemical anomalies (Cu, As, Au, Ag, Hg), and locally abundant chalcopyrite and bornite in stream-sediment samples. The Cu-Ag quartz vein deposit type (Nokleberg and others, 1993) consists of Cu sulfides and accessory silver in quartz veins and disseminations in weakly regionally metamorphosed mafic igneous rocks, mainly basalt and gabbro, and in lesser andesite and dacite. The depositional environment is low-grade metamorphic belts. The veins are generally late-stage metamorphic. The deposit minerals include chalcopyrite, bornite, lesser chalcocite, and rare native copper. Alteration minerals include epidote, chlorite, actinolite, albite, quartz, and zeolites.

Rationale for Tract Delineation

This tract is delineated by the distribution of deposits and by the outcrop areas of Upper Triassic sedimentary and mafic volcanic rocks, and of older sedimentary and volcanic rocks of Wrangellia terrane that show pervasive, lower greenschist facies metamorphism of probable mid-Cretaceous age. This deposit type was established for this tract (Nokleberg and others, 1987, 1993); the deposits may be associated with formation of Kennecott Cu deposits (Tract AK-SC01) (Nokleberg and others, 1993).

The distribution of the geologic units defining the tract is adapted from Nokleberg and others (1994). The distribution of this belt of mineral deposits is adapted from MacKevett and others (1978) and Nokleberg and others (1987, 1993). Mineral resource assessments of 250,000-scale quadrangles within the tract were done by Richter and others (1975), MacKevett (1976), Singer and others (1977, 1980), Cox and others (1989), and Nokleberg and others (1990).

Important Examples of Deposit Type

The Nugget Creek and Nikolai occurrences (Moffit and Capps, 1911; Miller, 1946; MacKevett, 1976) in the McCarthy quadrangle, and the Kathleen-Margaret mine in the Mount Hayes quadrangle (MacKevett, 1965) are examples of Cu-Ag quartz vein deposits in the tract. Many other smaller occurrences and prospects of this deposit type occur in the tract.

Rationale for Numerical Estimates

No tonnage and grade model exists for the Cu-Ag quartz vein deposit type, and no estimate of the number of undiscovered deposits was attempted.

References

- Cox, D.P., Light, T.D., Csejtei, Béla, and Campbell, D.L., 1989, Mineral resource assessment map of the Healy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2058-A, scale 1:250,000.
- MacKevett, E.M., Jr., 1965, Ore controls at the Kathleen-Margaret (Maclaren River) copper deposit, Alaska: U.S. Geological Survey Professional Paper 501c, p. C116-C120.
- MacKevett, E.M., Jr., 1976, Mineral deposits and occurrences in the McCarthy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-773B, 2 sheets, scale 1:250,000.

- MacKevett, E.M., Jr., Singer, D.A., and Holloway, C.D., 1978, Maps and tables describing metalliferous mineral resource potential of southern Alaska: U.S. Geological Survey Open-File Report 78-1E, 2 sheets, scale 1:1,000,000, 45 p.
- Miller, D.J., 1946, Copper deposits of the Nizina district, Alaska: U.S. Geological Survey Bulletin 947-F, p. 93-140.
- Moffit, F.H., and Capps, S.R., 1911, Geology and mineral resources of the Nizina district, Alaska: U.S. Geological Survey Bulletin 448, 111 p.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987. Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.
- Nokleberg, W.J., Bundtzen, T.K., Grybeck, Donald, Koch, R.D., Eremin, R.A., Rozenblum, I.S., Sidorov, A.A., Byalobzhesky, S.G., Sosunov, G.M., Shpikerman, V.I., and Gorodinsky, M.E., 1993, Metallogenesis of mainland Alaska and the Russian Northeast: Mineral deposit maps, models, and tables, metallogenic belt maps and interpretation, and references cited: U.S. Geological Survey Open-File Report 93-339, 222 pages, 1 map, scale 1:4,000,000; 5 maps, scale 1:10,000,000.
- Nokleberg, W.J., Lange, I.M., Singer, D.A., Curtin, G.C., Tripp, R.B., Campbell, D.L., and Yeend, Warren, 1990, Mineral resource assessment maps of the Mount Hayes quadrangle, eastern Alaska Range, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1996-A, 4 sheets, scale 1:250,000, 22 p.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 53 p., scale 1:2,500,000.
- Richter, D.H., Singer, D.A., and Cox, D.P., 1975, Mineral resources map of the Nabesna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-655-K, 1 sheet, scale 1:250,000.
- Singer, D. A., Csejtey, Bèla, Jr., and Miller, R.J., 1980, Map and discussion of the metalliferous and selected non-metalliferous mineral resources of Talkeetna Mountains quadrangle, Alaska: U.S. Geological Survey Open-File Report 78-558-Q, 34 p., 1 sheet, scale 1:250,000.
- Singer, D.A., and MacKevett, E.M., Jr., 1977, Mineral resources map of the McCarthy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-773-C, 1 sheet, scale 1:250,000.

Descriptive Model: 24a

Mark3 Index: 11

Area: 19,811 km²

Mean undiscovered deposits: 3.43

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Warren J. Nokleberg, Dennis P. Cox, Richard J. Goldfarb, and David L. Campbell.

Rationale for Model Choice

Part of the northern Prince William Sound area is permissive for early Tertiary Cyprus massive sulfide deposits as described by Singer (1986), because of favorable bedrock geologic units, several known Cyprus massive sulfide deposits, anomalous concentration of Fe, Co, Cu, Ni, and Zn in stream sediment samples, abundant sulfide minerals in heavy mineral concentrates, and favorable aeromagnetic anomalies.

Rationale for Tract Delineation

The favorable geologic units for the tract are the mafic and minor ultramafic rocks that are interpreted as dismembered parts of an oceanic ophiolite basal unit in the early Tertiary Orca Group of the Prince William terrane (Nelson and Nelson, 1993). The tract contains abundant pyrite and chalcopyrite in heavy mineral stream-sediment concentrates. The tract displays broad aeromagnetic highs that coincide with areas of basalt at the surface or areas where basalt is interpreted to occur near the surface.

The distribution of the geologic units defining the tract is adapted from Nokleberg and others (1994). The distribution of this belt of mineral deposits is adapted from MacKevett and others (1978) and Nokleberg and others (1987, 1993). Mineral resource assessments of 250,000-scale quadrangles within the tract were done by MacKevett (1976), Tysdal and Case (1982), Nelson and others (1984), Goldfarb and others (1992), and Madden-McGuire and Winkler (1993).

Important Examples of Deposit Type

The Knight Island, Twentieth Century, Pandora, Copper Bullion, Rua Cove, and Jonsy mines in the Seward quadrangle (Johnson, 1915, 1918; Moffit and Fellows, 1950), and the Threeman and Standard Copper mines in the Cordova quadrangle (Capps and Johnson, 1915) are examples of the Cyprus massive sulfides in this region (Crowe and others, 1992). About 40 small stratiform sulfide (chalcopyrite, sphalerite, and galena) occurrences are known in the tract and are interpreted as Cyprus massive sulfide deposits.

Rationale for Numerical Estimates

The tract is locally covered by extensive ice fields, glaciers, and forests. Several mines and many small occurrences are known in the tract. The mineral resource team estimated the minimum number of undiscovered deposits, consistent with the grade and tonnage model of Singer and Mosier (1986), to be:

Percentile	90	50	10	5	1
Estimated number of deposits	1	2	8	8	8

References

- Capps, S.R., and Johnson, B.L., 1915, The Ellamar district, Alaska: U.S. Geological Survey Bulletin 605, 125 p.
- Crowe, D.E., Nelson, S.W., Brown, P.E., Shanks, W.C., III, and Valley, J.W., 1992, Geology and geochemistry of volcanogenic massive sulfide deposits and related igneous rocks, Prince William Sound, south-central Alaska: Economic Geology, v. 87, p. 1722-1746.

- Goldfarb, R.J., Case, J.E., Plafker, George, and Winkler, G.R., 1992, Maps showing areas of potential for mineral resources in the Cordova and Middleton Island 1° x 3° quadrangles, southern Alaska: U.S. Geological Survey Miscellaneous Field Investigations Map MF-2190. 1 sheet, scale 1:250,000.
- Johnson, B.L., 1915, The gold and copper deposits of the Port Valdez district: U.S. Geological Survey Bulletin 622, p. 140-148.
- Johnson, B.L., 1918, Mining on Prince William Sound: U.S. Geological Survey Bulletin 662, p. 183-192.
- MacKevett, E.M., 1976, Mineral deposits and occurrences in the McCarthy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-773B, scale 1:250,000, 2 sheets.
- MacKevett, E.M., Jr., Singer, D.A., and Holloway, C.D., 1978, Maps and tables describing metalliferous mineral resource potential of southern Alaska: U.S. Geological Survey Open-File Report 78-1E, 2 sheets, scale 1:1,000,000, 45 p.
- Madden-McGuire, D.J., and Winkler, G.R., 1993, Mineral resource maps of the Anchorage quadrangle, southern Alaska: U.S. Geological Survey Miscellaneous Investigations Map MI-2393, scale 1:250,000, 3 sheets.
- Moffit, F.H., and Fellows, R.E., 1950, Copper deposits of the Prince William Sound district, Alaska: U.S. Geological Survey Bulletin 963-B, p. 47-80.
- Nelson, S.W., Miller, M.L., Barnes, D.F., Dumoulin J.A., Goldfarb, R.J., Koski, R.A., Mull, G.C., Pickthorn, W.J., Jansons, Uldis, Hoekzema, R.B., Kurtak, J.M., Fechner, S.A., 1984, Mineral resource potential of the Chugach National Forest, Alaska: US Geological Survey Miscellaneous Field Studies Map MF-1645-A, scale 1:250,000, 23 p.
- Nelson, S.J., and Nelson, M.S., 1993, Geochemistry of ophiolitic rocks from Knight Island, Prince William Sound, Alaska, in Dusel-Bacon, Cynthia, and Till, A.B., eds., *Geologic Studies in Alaska by the U.S. Geological Survey, 1992: U.S. Geological Survey Bulletin 2068*, p. 130-142.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987, Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.
- Nokleberg, W.J., Bundtzen, T.K., Grybeck, Donald, Koch, R.D., Eremin, R.A., Rozenblum, I.S., Sidorov, A.A., Byalobzhesky, S.G., Sosunov, G.M., Shpikerman, V.I., and Gorodinsky, M.E., 1993, Metallogenesis of mainland Alaska and the Russian Northeast: Mineral deposit maps, models, and tables, metallogenic belt maps and interpretation, and references cited: U.S. Geological Survey Open-File Report 93-339, 222 pages, 1 map, scale 1:4,000,000; 5 maps, scale 1:10,000,000.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 53 p., scale 1:2,500,000.
- Singer, D.A., 1986, Descriptive model of Cyprus massive sulfide, in Cox, D.P., and Singer, D.A., eds., *Mineral deposit models: U.S. Geological Survey Bulletin 1693*, p. 131.
- Singer, D.A., and Mosier, D.L., 1986, Grade and tonnage model of Cyprus massive sulfide, in Cox, D.P., and Singer, D.A., eds., *Mineral deposit models: U.S. Geological Survey Bulletin 1693*, p. 131-135.
- Tysdal, R.G., and Case, J.E., 1982, Metalliferous mineral resource potential of the Seward and Blying Sound quadrangles, southern Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-880H, 2 sheets, scale 1:250,000, 23 p.

Descriptive Model: 36c

Mark3 Index : 95

Area: 46,929 km²

Mean undiscovered deposits: 5.07

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Warren J. Nokleberg, Richard J. Goldfarb, and Warren Yeend.**Rationale for Model Choice**

This tract, in the southern Yukon-Tanana Upland, is permissive for Late Cretaceous and early Tertiary Au-Sb vein deposits (Berger, 1993) because of favorable bedrock geologic units, known deposits, and stream-sediment geochemical anomalies (Sb, Pb, Au, As, Ag, Bi, W). The features of known deposits are typical of the gold-antimony deposit model of Berger (1993).

Rationale for Tract Delineation

The favorable geologic units for Au-Sb veins in this tract are the Devonian and Mississippian metasedimentary and lesser metavolcanic rocks of southern Yukon-Tanana terrane where metamorphosed to greenschist facies during major regional metamorphic event(s) ending in the mid-Cretaceous, and intruded by Upper Cretaceous and lower Tertiary granitic plutonic rocks of the Kluane arc. Two K-Ar ages suggest that granitic plutonism and associated Au-Sb vein mineralization occurred between 48.3 (Bundtzen, 1981) and 81 Ma. The metasedimentary rocks in the region were mainly quartz-rich shale and siltstone, quartz sandstone, minor limestone, and marl. The metavolcanic rocks in the region were mainly andesite, but ranged in composition from rhyolite to basalt.

The distribution of the geologic units defining the tract is adapted from Nokleberg and others (1994). The distribution of this belt of mineral deposits is adapted from MacKevett and others (1978) and Nokleberg and others (1987, 1993). This tract is the same area as for tract SC35 for plutonic porphyry Au deposits and tract SC-52 for porphyry Cu deposits. Mineral resource assessments of 250,000-scale quadrangles within the tract were done by Richter and others (1975), Singer and others (1977), Cox and others, 1989, and Nokleberg and others (1990).

Important Examples of Deposit Type

Au-Sb veins occur at Kansas Creek in the Healy quadrangle (Cox and others, 1989), and at Slate Creek, Eagles Den, Caribou Creek, and Stampede in the Kantishna district in the McKinley quadrangle (Capps, 1919; White, 1942; Barker, 1963; Bundtzen, 1981, 1983a). Local gold placer deposits in the Kantishna district in the tract may be derived in part from veins of this deposit type (Capps, 1919; Cobb, 1973; Bundtzen, 1981).

Rationale for Numerical Estimates

The tract is a large area that is partly covered by extensive glacial loess and dense vegetation. The existence of Au-Sb veins in the Healy and McKinley quadrangles in the northwestern part of the tract suggests that at least two undiscovered deposits probably occur in this tract. The mineral resource team estimated the minimum number of undiscovered Au-Sb vein deposits, consistent with the grade and tonnage model of Berger (1993), to be:

Percentile	90	50	10	5	1
Estimated number of deposits	2	4	10	10	10

References

Barker, Fred, 1963, Exploration for antimony deposits at the Stampede mine, Kantishna district, Alaska: U.S. Geological Survey Bulletin 1155, p. 10-17.

- Berger, V.I., 1993, Descriptive, and grade-tonnage model for gold-antimony deposits: U.S. Geological Survey Open-File Report 93-194, 24 p.
- Bundtzen, T.K., 1981, Geology and mineral deposits of the Kantishna Hills, Mount McKinley quadrangle, Alaska: Fairbanks, Alaska, University of Alaska, M.S. thesis, 237 p, 4 sheets, scale 1:63,360.
- Bundtzen, T.K., 1983a, Mineral resource modeling Kantishna-Dunkle Mine Study, Alaska: Alaska Division of Geological and Geophysical Surveys Report of Investigations 83-12, 51 p.
- Capps, S.R., 1919, The Kantishna region, Alaska: U.S. Geological Survey Bulletin 687, 118 p.
- Cobb, E.H., 1973, Placer deposits of Alaska: U.S. Geological Survey Bulletin 1324, 213 p.
- Cox, D.P., Light, T.D., Csejtey, Béla, and Campbell, D.L., 1989, Mineral resource assessment map of the Healy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2058-A, scale 1:250,000.
- MacKevett, E.M., Jr., Singer, D.A., and Holloway, C.D., 1978, Maps and tables describing metalliferous mineral resource potential of southern Alaska: U.S. Geological Survey Open-File Report 78-1E, 2 sheets, scale 1:1,000,000, 45 p.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987. Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.
- Nokleberg, W.J., Bundtzen, T.K., Grybeck, Donald, Koch, R.D., Eremin, R.A., Rozenblum, I.S., Sidorov, A.A., Byalobzhesky, S.G., Sosunov, G.M., Shpikerman, V.I., and Gorodinsky, M.E., 1993, Metallogenesis of mainland Alaska and the Russian Northeast: Mineral deposit maps, models, and tables, metallogenic belt maps and interpretation, and references cited: U.S. Geological Survey Open-File Report 93-339, 222 pages, 1 map, scale 1:4,000,000; 5 maps, scale 1:10,000,000.
- Nokleberg, W.J., Lange, I.M., Singer, D.A., Curtin, G.C., Tripp, R.B., Campbell, D.L., and Yeend, Warren, 1990, Mineral resource assessment maps of the Mount Hayes quadrangle, eastern Alaska Range, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1996-A, 4 sheets, scale 1:250,000, 22 p.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 45 manuscript p., scale 1:2,500,000.
- Richter, D.H., Singer, D.A., and Cox, D.P., 1975, Mineral resources map of the Nabesna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-655-K, 1 sheet, scale 1:250,000.
- Singer, D.A., Curtin, G.C., and Foster, H.L., 1977, Mineral resources map of the Tanacross quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-767-E, 1 sheet, scale 1:250,000.
- White, D.E., 1942, Antimony deposits of the Stampede Creek area, Kantishna district, Alaska: U.S. Geological Survey Bulletin 936-N, p. 331-348.

Descriptive Model: 36a

Mark3 Index: 27

Area : 48,045 km²

Mean undiscovered deposits: 20.17

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Warren J. Nokleberg, Dennis P. Cox, Richard J. Goldfarb, and Warren Yeend.

Rationale for Model Choice

This tract covers part of the Yukon-Tanana terrane. It is permissive for low-sulfide Au-quartz veins (Berger, 1986) because it contains sedimentary and intermediate volcanic rocks that are metamorphosed to greenschist facies, known occurrences and prospects, and stream-sediment geochemical anomalies (Au, As, Ag).

Rationale for Tract Delineation

The favorable geologic units defining this tract are the Devonian and Mississippian metasedimentary and lesser metavolcanic rocks of southern Yukon-Tanana terrane where metamorphosed in the mid-Cretaceous to greenschist facies. The metasedimentary rocks were mainly quartz-rich shale and siltstone, quartz sandstone, minor limestone, and marl. The metavolcanic rocks were mainly andesite, but ranged in composition from rhyolite to basalt.

The distribution of the geologic units defining the tract is adapted from Nokleberg and others (1994). The distribution of this belt of mineral deposits is adapted from MacKevett and others (1978) and Nokleberg and others (1987, 1993). Mineral resource assessments of 250,000-scale quadrangles within the tract were done by Richter and others (1975), Singer and others (1977), Cox and others, 1989, and Nokleberg and others (1990).

Important Examples of Deposit Type

There are no significant examples of low-sulfide Au-quartz veins in the tract. However, this deposit type is commonly associated with Au-Sb veins (Berger, 1993) that occur mainly along the southern margin of the Yukon-Tanana terrane. Minor occurrences and prospects are in the northeastern part of the tract. Local gold placer deposits in the Kantishna, Bonnifield, and Delta River districts may be derived in part from undiscovered lode deposits, or from gold-antimony deposits in this tract (Capps, 1912, 1919; Smith, 1941; Gilbert and Bundtzen, 1979; Cobb, 1973; Rose, 1965; Nokleberg and others, 1991).

Rationale for Numerical Estimates

The tract is a large area that locally is covered by thick glacial loess, and dense vegetation. The existence of favorable rock units, and of numerous occurrences of low-sulfide Au-quartz veins suggest that there are undiscovered deposits in this tract. The estimated minimum number of undiscovered deposits that are consistent with the grade and tonnage model of Bliss (1986) is:

Percentile	90	50	10	5	1
Estimated number of deposits	5	10	50	50	50

References

- Berger, B.R., 1986, Descriptive model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239.
- Berger, V.I., 1993, Descriptive, and grade-tonnage model for gold-antimony deposits: U.S. Geological Survey Open-File Report 93-194, 24 p.
- Bliss, J.D., 1986, Grade and tonnage model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239-243.

- Capps, S.R., 1912, The Bonifield region, Alaska: U.S. Geological Survey Bulletin 501, 64 p.
- Capps, S.R., 1919, The Kantishna region, Alaska: U.S. Geological Survey Bulletin 687, 116 p.
- Cobb, E.H., 1973, Placer deposits of Alaska: U.S. Geological Survey Bulletin 1324, 213 p.
- Cox, D.P., Light, T.D., Csejtei, Béla, and Campbell, D.L., 1989, Mineral resource assessment map of the Healy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2058-A, scale 1:250,000.
- Gilbert, W.G., and Bundtzen, T.K., 1979, Mid-Paleozoic tectonics, volcanism, and mineralization in north-central Alaska Range, *in* Sisson, A., ed., The relationship of plate tectonics to Alaskan geology and resources: Alaska Geological Society, Symposium, 1977, p. F1-F21.
- MacKevett, E.M., Jr., Singer, D.A., and Holloway, C.D., 1978, Maps and tables describing metalliferous mineral resource potential of southern Alaska: U.S. Geological Survey Open-File Report 78-1E, 2 sheets, scale 1:1,000,000, 45 p.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987, Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.
- Nokleberg, W.J., Bundtzen, T.K., Grybeck, Donald, Koch, R.D., Eremin, R.A., Rozenblum, I.S., Sidorov, A.A., Byalobzhesky, S.G., Sosunov, G.M., Shpikerman, V.I., and Gorodinsky, M.E., 1993, Metallogenesis of mainland Alaska and the Russian Northeast: Mineral deposit maps, models, and tables, metallogenic belt maps and interpretation, and references cited: U.S. Geological Survey Open-File Report 93-339, 222 pages, 1 map, scale 1:4,000,000; 5 maps, scale 1:10,000,000.
- Nokleberg, W.J., Lange, I.M., Roback, R.C., Yeend, Warren, and Silva S.R., 1991, Map showing locations of metalliferous lode and placer mineral occurrences, deposits, prospects, and mines, Mount Hayes quadrangle, eastern Alaska Range, Alaska: U.S. Geological Survey Map MF-1996-C, 42 p., 1 sheet, scale 1:250,000.
- Nokleberg, W.J., Lange, I.M., Singer, D.A., Curtin, G.C., Tripp, R.B., Campbell, D.L., and Yeend, Warren, 1990, Mineral resource assessment maps of the Mount Hayes quadrangle, eastern Alaska Range, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1996-A, 4 sheets, scale 1:250,000, 22 p.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 53 p., scale 1:2,500,000.
- Richter, D.H., Singer, D.A., and Cox, D.P., 1975, Mineral resources map of the Nabesna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-655-K, 1 sheet, scale 1:250,000.
- Rose, A.W., 1965, Geology and mineral deposits of the Rainy Creek area, Mt. Hayes quadrangle, Alaska: Alaska Division of Mines and Minerals Geologic Report 14, 51 p.
- Singer, D.A., Curtin, G.C., and Foster, H.L., 1977, Mineral resources map of the Tanacross quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-767-E, 1 sheet, scale 1:250,000.
- Smith, P.S., 1941, Mineral industry of Alaska in 1939: U.S. Geological Survey Bulletin 926-A, p. 1-106.

Descriptive Model: 36a**Mark3 Index: 27****Area: 25,441 km²****Mean undiscovered deposits: (no estimate)****Model**

by Warren J. Nokleberg, Dennis P. Cox, Richard J. Goldfarb, and Warren Yeend.

Rationale for Model Choice

Parts of the Alaska Range and the Wrangell Mountains are permissive for Cretaceous low-sulfide Au-quartz vein deposits (Berger, 1986) because those areas feature intermediate-composition volcanic rocks and associated graywackes, low-grade regional metamorphism, and stream-sediment geochemical anomalies (Au, Ag, As).

Rationale for Tract Delineation

The favorable geologic unit defining the tract is Upper Jurassic and Lower Cretaceous sedimentary and volcanic rocks of the Nutzotin Group that exhibit pervasive lower greenschist facies metamorphism, and local intense folding, faulting, and penetrative deformation of probable mid-Cretaceous age.

The distribution of the geologic units defining the tract is adapted from Nokleberg and others (1994). The distribution of this belt of mineral deposits is adapted from MacKevett and others (1978) and Nokleberg and others (1987, 1993). Mineral resource assessments of 250,000-scale quadrangles within the tract were done by Richter and others (1975), MacKevett (1976), Singer and others (1977), and Nokleberg and others (1990).

Important Examples of Deposit Type

There are no significant deposits, prospects, or occurrences of low-sulfide gold Au-quartz veins in the tract. Gold in placer Au mines in the Chisana, Chistochina, and Valdez Creek districts (Chapin, 1918; Capps, 1916, 1919; Tuck, 1938; Smith, 1941; Rose, 1967; Richter and Matson, 1972; Cobb, 1973; Yeend, 1981a, 1981b; Bressler and others, 1985; Fechner and Herzog, 1990; Reger and Bundtzen, 1990) may be derived in part from undiscovered low-sulfide gold Au-quartz veins, but its most likely sources are large porphyry Cu and Mo deposits, and associated skarn and polymetallic vein deposits.

Rationale for Numerical Estimates

Because no low-sulfide Au-quartz veins are known in this tract, and because the source of sparse favorable geochemical anomalies cannot be determined, no estimate of the number of undiscovered deposits was attempted.

References

- Berger, B.R., 1986, Descriptive model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239.
- Bressler, J.R., Jones, W.C. and Cleveland, Gaylord, 1985, Geology of a buried channel system of the Denali Placer Gold Mine: Alaska Miner, January, 1985, p. 9.
- Capps, S.R., 1916, The Chisana-White River district, Alaska: U.S. Geological Survey Bulletin 630, 130 p.
- Capps, S.R., 1919, The Kantishna region, Alaska: U.S. Geological Survey Bulletin 687, 118 p.
- Chapin, Theodore, 1918, The Nelchina-Susitna region, Alaska: U.S. Geological Survey Bulletin 668, 67 p.
- Cobb, E.H., 1973, Placer deposits of Alaska: U.S. Geological Survey Bulletin 1324, 213 p.
- Fechner, S.A. and Herzog, D.A., 1990, Gold- and PGM-bearing conglomerate of the Valdez Creek mining district, Alaska: U.S. Bureau of Mines Open File 12-90, 52 p.

- MacKevett, E.M., 1976, Mineral deposits and occurrences in the McCarthy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-773B, scale 1:250,000, 2 sheets.
- MacKevett, E.M., Jr., Singer, D.A., and Holloway, C.D., 1978, Maps and tables describing metalliferous mineral resource potential of southern Alaska: U.S. Geological Survey Open-File Report 78-1E, 2 sheets, scale 1:1,000,000, 45 p.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987. Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.
- Nokleberg, W.J., Bundtzen, T.K., Grybeck, Donald, Koch, R.D., Eremin, R.A., Rozenblum, I.S., Sidorov, A.A., Byalobzhesky, S.G., Sosunov, G.M., Shpikerman, V.I., and Gorodinsky, M.E., 1993, Metallogenesis of mainland Alaska and the Russian Northeast: Mineral deposit maps, models, and tables, metallogenic belt maps and interpretation, and references cited: U.S. Geological Survey Open-File Report 93-339, 222 pages, 1 map, scale 1:4,000,000; 5 maps, scale 1:10,000,000.
- Nokleberg, W.J., Lange, I.M., Singer, D.A., Curtin, G.C., Tripp, R.B., Campbell, D.L., and Yeend, Warren, 1990, Mineral resource assessment maps of the Mount Hayes quadrangle, eastern Alaska Range, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1996-A, 4 sheets, scale 1:250,000, 22 p.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 53 p., scale 1:2,500,000.
- Reger, R.D. and Bundtzen, T.K., 1990, Multiple glaciation and placer gold formation, Valdez Creek Valley, Western Clearwater Mountains, Alaska: Alaska Division of Geological and Geophysical Surveys Professional Paper 107, 29 p., 1 sheet, scale 1:63,360.
- Richter, D.H., and Matson, N.A., Jr., 1972, Metallic mineral resources map of the Nabesna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-422.
- Richter, D.H., Singer, D.A., and Cox, D.P., 1975, Mineral resources map of the Nabesna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-655-K, 1 sheet, scale 1:250,000.
- Rose, A.W., 1967, Geology of the upper Chistochina River area, Mt. Hayes quadrangle, Alaska: Alaska Division of Mines and Minerals Geologic Report 28, 41 p.
- Singer, D.A., Curtin, G.C., and Foster, H.L., 1977, Mineral resources map of the Tanacross quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-767-E, 1 sheet, scale 1:250,000.
- Smith, P.S., 1941, Mineral industry of Alaska in 1939: U.S. Geological Survey Bulletin 926-A, p. 1-106.
- Tuck, Ralph, 1938, The Valdez Creek mining district, Alaska, in 1936: U.S. Geological Survey Bulletin 897-B, p. 109-131.
- Yeend, Warren, 1981a, Placer gold deposits, Mt. Hayes quadrangle, Alaska, in Silberman, Miles and others, eds., Proceedings of the Symposium of Mineral Deposits of the Pacific Northwest: U.S. Geological Survey Open-File Report 81-355, p. 74-83.
- Yeend, Warren, 1981b, Placer gold deposits, Mount Hayes quadrangle, Alaska, in Albert, N.R.D., and Hudson, Travis, eds., The United States Geological Survey in Alaska: Accomplishments during 1979: U.S. Geological Survey Circular 823-B, p. B68.

Descriptive Model: 36a

Mark3 Index: 27

Area: 594 km²

Mean undiscovered deposits: 2.63

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Warren J. Nokleberg, Dennis P. Cox, and Richard J. Goldfarb.

Rationale for Model Choice

Parts of the Maclaren terrane in the Alaska Range are permissive for low-sulfide Au-quartz vein deposits (Berger, 1986) because of favorable bedrock geology, favorable regional metamorphism, known occurrences, and stream-sediment geochemical anomalies (Au, W).

Rationale for Tract Delineation

The favorable geologic unit defining the tract is the Upper Jurassic(?) flysch (argillite and metagraywacke) of the Maclaren Glacier metamorphic belt of the Maclaren terrane (Smith, 1981; Nokleberg and others, 1985), where metamorphosed to lower greenschist facies in the early Tertiary. One of Alaska's largest gold placer mines at Valdez Creek occurs downstream from the area of known deposits. The Maclaren Glacier metamorphic belt displays classic Barrovian-type metamorphism in which the lower, greenschist facies portions are judged to be highly favorable for low-sulfide Au-quartz vein deposits. The Maclaren terrane is interpreted as the offset equivalent of metamorphic rocks that contain major low-sulfide Au quartz vein deposits in the Juneau region of southeastern Alaska (Nokleberg and others, 1985, 1993).

The distribution of the geologic units defining the tract is adapted from Nokleberg and others (1994). The distribution of this belt of mineral deposits is adapted from MacKevett and others (1978) and Nokleberg and others (1987, 1993). Mineral resource assessments of 250,000-scale quadrangles within the tract were done by Singer and others (1980), Cox and others (1989), and Nokleberg and others (1990).

Important Examples of Deposit Type

The Lucky Hill, Timberline Creek, Gold Hill, and Surprise occurrences and prospects in the Healy quadrangle (Smith, 1981; Adams and others, 1992) are examples of low-sulfide Au-quartz vein deposits in this tract. The associated gold placer mines in the Valdez Creek district (Chapin, 1918; Capps, 1919; Tuck, 1938; Smith, 1970; Cobb, 1973; Bressler and others, 1985; Fechner and Herzog, 1990; Reger and Bundtzen, 1990) may be derived in part from undiscovered low-sulfide gold Au-quartz vein deposits.

Rationale for Numerical Estimates

This tract locally is covered by large ice fields and glaciers, therefore much of the area has not been available for exploration. Because of the presence of numerous low-sulfide Au-quartz veins, a major placer mine, and the limited outcrop area, the assessment team concluded that this tract probably contains at least one undiscovered low-sulfide Au-quartz vein deposit. The minimum number of undiscovered deposits that are consistent with the grade and tonnage model of Bliss (1986) is:

Percentile	90	50	10	5	1	
Estimated number of deposits		1	3	4	4	4

References

- Berger, B.R., 1986, Descriptive model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239.
- Bliss, J.D., 1986, Grade and tonnage model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239-243.

- Bressler, J.R., Jones, W.C. and Cleveland, Gaylord, 1985, Geology of a buried channel system of the Denali Placer Gold Mine: *Alaska Miner*, January, 1985, p. 9.
- Capps, S.R., 1919, The Kantishna region, Alaska: U.S. Geological Survey Bulletin 687, 116 p.
- Chapin, Theodore, 1918, The Nelchina-Susitna region, Alaska: U.S. Geological Survey Bulletin 668, 67 p.
- Cobb, E.H., 1973, Placer deposits of Alaska: U.S. Geological Survey Bulletin 1324, 213 p.
- Cox, D.P., Light, T.D., Csejtey, Béla, and Campbell, D.L., 1989, Mineral resource assessment map of the Healy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2058-A, scale 1:250,000.
- Fechner, S.A. and Herzog, D.A., 1990, Gold- and PGM-bearing conglomerate of the Valdez Creek mining district, Alaska: U.S. Bureau of Mines Open File 12-90, 52 p.
- MacKevett, E.M., Jr., Singer, D.A., and Holloway, C.D., 1978, Maps and tables describing metalliferous mineral resource potential of southern Alaska: U.S. Geological Survey Open-File Report 78-1E, 2 sheets, scale 1:1,000,000, 45 p.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987, Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.
- Nokleberg, W.J., Bundtzen, T.K., Grybeck, Donald, Koch, R.D., Eremin, R.A., Rozenblum, I.S., Sidorov, A.A., Byalobzhesky, S.G., Sosunov, G.M., Shpikerman, V.I., and Gorodinsky, M.E., 1993, Metallogenesis of mainland Alaska and the Russian Northeast: Mineral deposit maps, models, and tables, metallogenic belt maps and interpretation, and references cited: U.S. Geological Survey Open-File Report 93-339, 222 pages, 1 map, scale 1:4,000,000; 5 maps, scale 1:10,000,000.
- Nokleberg, W.J., Jones, D.L., Silberling, N.J., 1985, Origin, migration, and accretion of the Maclaren and Wrangellia terranes, eastern Alaska Range, Alaska: *Geological Society of America Bulletin*, v. 96, p. 1251-1270.
- Nokleberg, W.J., Lange, I.M., Singer, D.A., Curtin, G.C., Tripp, R.B., Campbell, D.L., and Yeend, Warren, 1990, Mineral resource assessment maps of the Mount Hayes quadrangle, eastern Alaska Range, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1996-A, 4 sheets, scale 1:250,000, 22 p.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 53 p., scale 1:2,500,000.
- Reger, R.D. and Bundtzen, T.K., 1990, Multiple glaciation and placer gold formation, Valdez Creek Valley, Western Clearwater Mountains, Alaska: *Alaska Division of Geological and Geophysical Surveys Professional Paper* 107, 29 p., 1 sheet, scale 1:63,360.
- Singer, D. A., Csejtey, Béla, Jr., and Miller, R.J., 1980, Map and discussion of the metalliferous and selected non-metalliferous mineral resources of Talkeetna Mountains quadrangle, Alaska: U.S. Geological Survey Open-File Report 78-558-Q, 34 p., 1 sheet, scale 1:250,000.
- Smith, T.E., 1970, Gold resource potential of the Denali bench gravels, Valdez Creek Mining District, Alaska: U.S. Geological Survey Professional Paper 700-D, p. D146-D152.
- Smith, T.E., 1981, Geology of the Clearwater Mountains, south-central Alaska: *Alaska Division of Geological and Geophysical Surveys Report* 60, 72 p.
- Tuck, Ralph, 1938, The Valdez Creek mining district, Alaska, in 1936: U.S. Geological Survey Bulletin 897-B, p. 109-131.

Descriptive Model: 36a

Mark3 Index: 27

Area: 11,786 km²

Mean undiscovered deposits: 4.33

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Warren J. Nokleberg, Dennis P. Cox, Richard J. Goldfarb, and Warren Yeend.

Rationale for Model Choice

This tract covers parts of the Talkeetna Mountains. It is permissive for low-sulfide Au-quartz vein deposits (Berger, 1986) because of known mines, gold placer deposits, favorable bedrock geologic units, favorable regional greenschist facies metamorphism, and geochemical anomalies (Ag, As, Au).

Rationale for Tract Delineation

The favorable geologic units that define the tract are the extensive Lower Jurassic Talkeetna Formation, local Upper Jurassic and Lower Cretaceous flysch, and Jurassic and Cretaceous granitic rocks where deformed and metamorphosed to lower greenschist facies.

The distribution of the geologic units defining the tract is adapted from Nokleberg and others (1994). The distribution of this belt of mineral deposits is adapted from MacKevett and others (1978) and Nokleberg and others (1987, 1993). Mineral resource assessments of 250,000-scale quadrangles within the tract were done by Singer and others (1977, 1980), Nokleberg and others (1990), and Madden-McGuire and Winkler (1993).

Important Examples of Deposit Type

The lode gold mines (Gold Cord, Independence, Thope) (Ray, 1954; Burleigh, 1987; Madden-McGuire and others, 1988) and associated placer mines of the Willow Creek district (Capps, 1915; Jasper, 1967; Cobb, 1973) in the Anchorage quadrangle are examples of low-sulfide Au-quartz veins in this tract. The Independence mine produced about 90% of the ore in the tract. Two significant smaller mines are at Gold Bullion and Lucky Shot. More than ten smaller mines occur in the district.

Rationale for Numerical Estimates

The Willow Creek district is a relatively small area that may have a possible extension to the north. The numerous low-sulfide Au-quartz veins known in the tract suggest that it probably contains at least one additional undiscovered deposit. The estimated minimum number of undiscovered deposits, consistent with the grade and tonnage model of Bliss (1986), is:

Percentile	90	50	10	5	1
Estimated number of deposits	1	5	7	7	7

References

- Berger, B.R., 1986, Descriptive model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239.
- Bliss, J.D., 1986, Grade and tonnage model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239-243.
- Burleigh, R.E., 1987, A stable isotope, fluid inclusion and ore petrographic study of gold-quartz veins in the Willow Creek mining district, Alaska: Unpublished M.Sc. thesis, University of Alaska, Fairbanks, 246 p.
- Capps, S.R., 1915, The Willow Creek district, Alaska: U.S. Geological Survey Bulletin 607, 86 p.
- Cobb, E.H., 1973, Placer deposits of Alaska: U.S. Geological Survey Bulletin 1324, 213 p.

- Jasper, M.W., 1967, Geochemical investigations, Willow Creek southerly to Kenai Lake region, south central Alaska: Alaska Division of Mines and Minerals Geochemical Report 14, 47 p.
- Madden-McGuire, D.J., Silberman, M.L., and Church, S.E., 1988, Geologic relationships, K-Ar ages, and isotopic data from the Willow Creek gold mining district, Alaska, in Keays, R.R., Ramsay, W.R.H., and Groves, D.I., eds., *The geology of gold deposits: Economic Geology Monograph 6*, p. 242-251.
- Madden-McGuire, D.J., and Winkler, G.R., 1993, Mineral resource maps of the Anchorage quadrangle, southern Alaska: U.S. Geological Survey Miscellaneous Investigations Map MI-2393, scale 1:250,000, 3 sheets.
- MacKevett, E.M., Jr., Singer, D.A., and Holloway, C.D., 1978, Maps and tables describing metalliferous mineral resource potential of southern Alaska: U.S. Geological Survey Open-File Report 78-1E, 2 sheets, scale 1:1,000,000, 45 p.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987, Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.
- Nokleberg, W.J., Bundtzen, T.K., Grybeck, Donald, Koch, R.D., Eremin, R.A., Rozenblum, I.S., Sidorov, A.A., Byalobzhesky, S.G., Sosunov, G.M., Shpikerman, V.I., and Gorodinsky, M.E., 1993, Metallogenesis of mainland Alaska and the Russian Northeast: Mineral deposit maps, models, and tables, metallogenic belt maps and interpretation, and references cited: U.S. Geological Survey Open-File Report 93-339, 222 pages, 1 map, scale 1:4,000,000; 5 maps, scale 1:10,000,000.
- Nokleberg, W.J., Lange, I.M., Singer, D.A., Curtin, G.C., Tripp, R.B., Campbell, D.L., and Yeend, Warren, 1990, Mineral resource assessment maps of the Mount Hayes quadrangle, eastern Alaska Range, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1996-A, 4 sheets, scale 1:250,000, 22 p.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 53 p., scale 1:2,500,000.
- Ray, R.G., 1954, Geology and ore deposits of the Willow Creek mining district, Alaska: U.S. Geological Survey Bulletin 1004, 86 p.
- Singer, D. A., Csejtey, Bèla, Jr., and Miller, R.J., 1980, Map and discussion of the metalliferous and selected non-metalliferous mineral resources of Talkeetna Mountains quadrangle, Alaska: U.S. Geological Survey Open-File Report 78-558-Q, 34 p., 1 sheet, scale 1:250,000.
- Singer, D.A., Curtin, G.C., and Foster, H.L., 1977, Mineral resources map of the Tanacross quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-767-E, 1 sheet, scale 1:250,000.

Descriptive Model: 36a.1
Area: 40,281 km²

Mark3 Index: 26
Mean undiscovered deposits: 498

[Cumulative Distribution](#)

[Histogram](#)

[Table](#)

[Model](#)

[Mineral Deposits](#)

by Warren J. Nokleberg, Dennis P. Cox, Richard J. Goldfarb, and David L. Campbell.

Rationale for Model Choice

A large part of the Chugach Range in south-central Alaska is permissive for early Tertiary Chugach-type low-sulfide Au-quartz vein (Bliss, 1992) deposits because of favorable bedrock geology, favorable regional metamorphism, known mines and occurrences, and geochemical anomalies (Au, W) (Goldfarb and others, 1995).

Rationale for Tract Delineation

The favorable geologic unit defining this tract is mainly the Upper Cretaceous flysch of the Valdez Group where metamorphosed to greenschist facies. Also favorable are: (1) the northern margin of the lower Tertiary Orca Group of the Prince William terrane where metamorphosed to lower greenschist facies; (2) the metasedimentary rocks of the Orca Group within a few kilometers of granitic plutons; and (3) the southern margin of the Upper Triassic through mid-Cretaceous McHugh Complex in the southern Seldovia quadrangle. Chugach-type low sulfide Au-quartz vein deposits occur both in (meta)sedimentary rocks and in Eocene and Oligocene granitic plutons intruding the Valdez and Orca Groups. Hydrothermal muscovite from gold-bearing veins has been dated at 53 Ma in the Port Valdez district (Winkler and others, 1981), at 52 Ma in the Hope-Sunrise district (Mitchell and others, 1981), and at 57 Ma in the Nuka Bay district (Borden and others, 1992).

The distribution of the geologic units defining the tract is adapted from Nokleberg and others (1994). The distribution of this belt of mineral deposits is adapted from MacKevett and others (1978) and Nokleberg and others (1987, 1993). Mineral resource assessments of 250,000-scale quadrangles within the tract were done by Tysdal and Case (1982), Nelson and others (1984), Goldfarb and others (1992), and Madden-McGuire and Winkler (1993).

Important Examples of Deposit Type

The Cliff mine in the Valdez quadrangle, the Granite, Crown Point, Alaska Oracle, Gilpatrick, Lucky Strike, Palmer Creek, and Kenai-Alaska mines in the Seward quadrangle, the Monarch and Jewel mines in the Anchorage quadrangle, and the mines of Nuka Bay district (Alaska Hills, Beauty Bay, Goyne, Lost Creek, Sonny Fox, and Nualaska) in the Seldovia quadrangle are all examples of low-sulfide Au-quartz veins in this tract (Johnson, 1914; Martin and others, 1915; Park, 1933; Tuck, 1933; Richter, 1970; McGee, 1972; Mitchell, 1979; Mitchell and others, 1981; Stuwe, 1984).

Rationale for Numerical Estimates

Chugach-type low-sulfide Au-quartz vein deposits (model 36a.1) are relatively small, averaging only about 3000 metric tons with an average grade of 6.2 grams per ton (Bliss, 1992), as compared to the generic low sulfide Au-quartz vein model (model 36a), which average 30,000 metric tons with 16 grams per ton Au (Bliss, 1986). Because the Chugach-type deposits are relatively small, a potential exists for a correspondingly larger number of deposits than would be expected for the generic low-sulfide Au-quartz veins. However, because this deposit model is only expected to have a total contained gold content of about 18,600 grams (about 600 oz.) the potential for development is significantly reduced.

There is a high probability of numerous undiscovered deposits in the tract. A reasonable estimate for the number of undiscovered deposits is about 0.02 deposits per km² (Bliss, 1986; J.D. Bliss, written commun., 1995) or about 20 deposits per 1,000 km². For the tract size, this ratio indicates that as many as 600 undiscovered deposits may exist at the 50% percentile. Accordingly, the mineral resource team

estimated the number of undiscovered low-sulfide Au-quartz vein deposits that are consistent with the grade and tonnage model of Bliss (1992) to be:

Percentile	90	50	10	5	1	
Estimated number of deposits		80	600	800	800	800

References

- Bliss, J.D., 1986, Grade and tonnage model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239-243.
- Bliss, J.D., 1992, Grade and tonnage model of Chugach-type low-sulfide Au-quartz veins, *in*, Bliss, J.D., editor, Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, p. 44-46.
- Borden, J.C., Goldfarb, R.J., Gent, C.A., Buruss, R.C., and Roushey, B.H., 1992, Geochemistry of lode gold deposits, Nuka Bay district, southern Kenai Peninsula: US Geological Survey Bulletin 2041, p. 13-22.
- Goldfarb, R.J., Carter Borden, J., and Winkler, G.R., 1995, Geochemical survey of the Valdez 1°x3° quadrangle, south-central Alaska: U.S. Geological Survey Bulletin 2084, 77 p., 1 sheet, scale 1:250,000.
- Goldfarb, R.J., Case, J.E., Plafker, George, and Winkler, G.R., 1992, Maps showing areas of potential for mineral resources in the Cordova and Middleton Island 1° x 3° quadrangles, southern Alaska: U.S. Geological Survey Miscellaneous Field Investigations Map MF-2190. 1 sheet, scale 1:250,000.
- Goldfarb, R.J., Leach, D.L., Miller, M.L., and Pickthorn, W.J., 1986, Geology, metamorphic setting, and genetic constraints of epigenetic lode-gold mineralization within the Cretaceous Valdez Group, south-central Alaska, *in* Keppie, J.D., Boyle, R.W., and Haynes, S.J., eds., Turbidite-hosted gold deposits: Geological Association of Canada Special Paper 32, p. 87-105.
- Goldfarb, R.J., Snee, L.W., and Pickthorn, W.J., 1993, Orogenesis, high-T thermal events, and gold vein formation within metamorphic rocks of the Alaskan Cordillera: Mineralogical Magazine, v. 57, p. 375-394.
- Johnson, B.L., 1914, The Port Wells gold-lode district: U.S. Geological Survey Bulletin 592-G, p. 195-236.
- Johnson, B.L., 1915, The gold and copper deposits of the Port Valdez district: U.S. Geological Survey Bulletin 622, p. 140-148.
- MacKevett, E.M., Jr., Singer, D.A., and Holloway, C.D., 1978, Maps and tables describing metalliferous mineral resource potential of southern Alaska: U.S. Geological Survey Open-File Report 78-1E, 2 sheets, scale 1:1,000,000, 45 p.
- Madden-McGuire, D.J., and Winkler, G.R., 1993, Mineral resource maps of the Anchorage quadrangle, southern Alaska: U.S. Geological Survey Miscellaneous Investigations Map MI-2393, scale 1:250,000, 3 sheets.
- Martin, G.C., Johnson, B. L., and Grant, U.S., 1915, Geology and mineral resources of Kenai Peninsula, Alaska: U.S. Geological Survey Bulletin 587, 243 p.
- McGee, D.L., 1972, Kodiak Island and vicinity, Alaska—Geology and mineral resources: Alaska Division of Geological and Geophysical Surveys Open-file Report 31, 7 p.
- Mitchell, P.A., 1979, Geology of the Hope-Sunrise (gold) mining district, north-central Kenai Peninsula, Alaska: Unpublished M.Sc. thesis, Stanford University, 123 p.
- Mitchell, P.A., Silberman, M.L., and O'Neil, J.R., 1981, Genesis of gold mineralization in an Upper Cretaceous turbidite sequence, Hope-Sunrise district: U.S. Geological Survey Open-File Report 81-103, 18 p.
- Nelson, S.W., Miller, M.L., Barnes, D.F., Dumoulin J.A., Goldfarb, R.J., Koski, R.A., Mull, G.C., Pickthorn, W.J., Jansons, Uldis, Hoekzema, R.B., Kurtak, J.M., Fechner, S.A., 1984, Mineral resource potential of the Chugach National Forest, Alaska: US Geological Survey Miscellaneous Field Studies Map MF-1645-A, scale 1:250,000, 23 p.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987. Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.
- Nokleberg, W.J., Bundtzen, T.K., Grybeck, Donald, Koch, R.D., Eremin, R.A., Rozenblum, I.S., Sidorov, A.A., Byalobzhesky, S.G., Sosunov, G.M., Shpikerman, V.I., and Gorodinsky, M.E., 1993, Metallogenesis of mainland Alaska and the Russian Northeast: Mineral deposit maps, models, and tables, metallogenic belt maps and interpretation, and references cited: U.S. Geological Survey Open-File Report 93-339, 222 pages, 1 map, scale 1:4,000,000; 5 maps, scale 1:10,000,000.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and

- overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 53 p., scale 1:2,500,000.
- Park, C.F., Jr., 1933, The Girdwood district, Alaska: U.S. Geological Survey Bulletin 849-G, p. 381-424.
- Richter, D.H., 1970, Geology and lode-gold deposits of the Nuka Bay area, Kenai Peninsula, Alaska: U.S. Geological Survey Professional Paper 625-G, 16 p.
- Stuwe, K., 1984, Granitoid intrusions and gold mineralization in the western Port Wells mining district, Prince William Sound, Alaska: Unpublished M.Sc. thesis, University of Leoben, Austria.
- Tuck, R., 1933, The Moose Pass-Hope district, Kenai Peninsula, Alaska: U.S. Geological Survey Bulletin 849-I, p. 469-530.
- Tysdal, R.G., and Case, J.E., 1982, Metalliferous mineral resource potential of the Seward and Blying Sound quadrangles, southern Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-880H, 2 sheets, scale 1:250,000, 23 p.
- Winkler, G.R., Silberman, M.L., Grantz, Arthur, Miller, R.J., and MacKevett, E.M., Jr., 1981, Geologic map and summary geochronology of the Valdez quadrangle, southern Alaska: US Geological Survey Open-File Report 80-892-A, 2 sheets, scale 1:250,000.

Descriptive Model 32c**Mark3 Index (none)****Area: 4,445 km²****Mean undiscovered deposits: (no estimate)****Model***by* Jeanine M. Schmidt and Bruce M. Gamble**Rationale for Model Choice**

Paleozoic platform carbonate rocks in south-central Alaska are permissive for Kipushi-type deposits as defined by Cox and Bernstein (1986), because they were formed in an appropriate geologic setting (a continental platform or shelf with continental or passive margin rifting) and because they contain appropriate host rocks (dolostone, shale and shallow-water or platform carbonate rocks) for the deposit model. Although no occurrences are known in this tract, correlative rocks in west-central Alaska host numerous strata-bound Zn prospects (informally called the Reef Ridge district) in carbonate rocks.

Rationale for Tract Delineation

This tract consists of areas locally underlain by Cambrian to Devonian shallow-water facies platform carbonate rocks of the Nixon Fork and Minchumina terranes (Patton and others, 1994). Locally, Pb and Zn anomalies are in stream-sediment and panned-concentrate samples in west-central Alaska. Sphalerite, chalcopyrite, cinnabar, pyrite, and malachite were identified in some concentrates.

Important Examples of Deposit Type

Examples of carbonate-hosted base-metal deposits occur in equivalent rocks in the informally named Reef Ridge district in the Medfra quadrangle of west-central Alaska (Schmidt, 1997).

Rationale for Numerical Estimates

There are no tonnage and grade curves for Kipushi-type deposits; no quantitative estimates of the number of undiscovered deposits were attempted.

References

- Cox, D.P., and Bernstein, L.R., 1986, Descriptive model of Kipushi Cu-Pb-Zn, *in* Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 227.
- Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1994, Geology of west-central Alaska, *in* Plafker, George, and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G-1, p. 241-269.
- Schmidt, J.M., 1997, Strata-bound carbonate-hosted Zn-Pb and Cu deposits of Alaska, *in* Goldfarb, R.J., and Miller, L.D., eds., Mineral Deposits of Alaska: Economic Geology Monograph 9, p. 90-119.

Descriptive Model: 28a

Mark3 Index: 93

Area: 31,989 km²

Mean undiscovered deposits: 10.20

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Warren J. Nokleberg, Dennis P. Cox, Richard J. Goldfarb, and David L. Campbell.

Rationale for Model Choice

Parts of the central and eastern Alaska Range, and the southern Yukon-Tanana Upland, are permissive for Devonian and Mississippian kuroko massive sulfide deposits (Singer, 1986; Singer and Mosier, 1986) because of favorable bedrock geologic units, known occurrences, anomalous concentrations of Cu, Pb, Zn, As, Au, and Ag in stream sediment samples, abundant sulfide minerals in heavy mineral concentrates, and favorable aeromagnetic and gravity anomalies.

Rationale for Tract Delineation

The favorable geologic unit in this tract is the marine Devonian and Mississippian felsic and intermediate metavolcanic and metasedimentary rocks in the upper structural levels of southern Yukon-Tanana terrane north of the Denali fault. These rocks have been polymetamorphosed and deformed, resulting in recrystallization and dismemberment of the massive sulfide deposits. Numerous heavy mineral concentrate samples from the tract contain chalcopyrite, sphalerite, galena, and pyrite. The tract displays broad low-amplitude aeromagnetic anomalies on the aeromagnetic map of Alaska (Godson, 1994). Gravity highs (Barnes and others, 1994) are used to extend the tract boundaries to the west and southwest in areas that are covered by Cenozoic sedimentary rocks.

The distribution of the geologic units defining the tract is adapted from Nokleberg and others (1994). The distribution of this belt of mineral deposits is adapted from MacKevett and others (1978) and Nokleberg and others (1987, 1993). Mineral resource assessments of 250,000-scale quadrangles within the tract were done by Richter and others (1975), MacKevett (1976), Singer and others (1977), Cox and others (1989), and Nokleberg and others (1990).

Important Examples of Deposit Type

The Red Mountain, WTF, Sheep Creek, and Anderson Mountain deposits in the Healy quadrangle (Gilbert and Bundtzen, 1979), the Liberty Bell mine in the Fairbanks quadrangle (Hawley, 1976; Gilbert and Bundtzen, 1979), the Miyaoka, Hayes Glacier, and McGinnis Glacier occurrences in the western Mount Hayes quadrangle, and the Delta district deposits in the eastern Mount Hayes quadrangle (Lange and others, 1993) are the best known examples in the area.

Rationale for Numerical Estimates

Tertiary and older rocks in the tract are locally covered by extensive ice fields, glaciers, glacial loess, and by Cenozoic basinal deposits. Because of the relatively abundant mines, deposits, and occurrences, abundant anomalies in geochemical samples, and abundant sulfide minerals in heavy mineral concentrates, several undiscovered deposits probably occur in the tract. We estimated the minimum number of undiscovered deposits, consistent with the grade and tonnage model of Singer and Mosier (1986), to be:

Percentile	90	50	10	5	1	
Estimated number of deposits		3	5	25	25	25

References

- Barnes, D.F., Mariano, John, Morin, R.L., Roberts, C.W., and Jachens, R.C., 1994, Incomplete isostatic gravity map of Alaska, *in* Plafker, G. and Berg, H.C., eds., *The Geology of Alaska: Boulder, Colorado, Geological Society of America: The Geology of North America*, v. G1, plate 9, scale 1:2,500,000.
- Cox, D.P., Light, T.D., Csejtey, Béla, and Campbell, D.L., 1989, Mineral resource assessment map of the Healy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2058-A, scale 1:250,000.
- Gilbert, W.G., and Bundtzen, T.K., 1979, Mid-Paleozoic tectonics, volcanism, and mineralization in north-central Alaska Range, *in* Sisson, A., ed., *The relationship of plate tectonics to Alaskan geology and resources: Alaska Geological Society Symposium*, 1977, p. F1-F21.
- Godson, Richard H., 1994, Composite magnetic anomaly map of Alaska and adjacent offshore area, *in* Plafker, G. and Berg, H.C., eds., *The Geology of Alaska: Boulder, Colorado, Geological Society of America: The Geology of North America*, v. G1, plate 10, scale 1:2,500,000.
- Hawley, C.C., 1976, Exploration and distribution of stratiform sulfide deposits in Alaska [abs.], *in* Miller, T.P., ed., *Symposium on recent and ancient sedimentary environments in Alaska [abs.]*: Alaska Geological Society Program with Abstracts, p. T1-T28.
- Lange, I.M., Nokleberg, W.J., Newkirk, S.R., Aleinikoff, J.N., Church, S.E., Krouse, H.R., 1993, Devonian volcanogenic massive sulfide deposits and occurrences, southern Yukon-Tanana terrane, eastern Alaska Range, Alaska: *Economic Geology*, v. 88, p. 344-376.
- MacKevett, E.M., 1976, Mineral deposits and occurrences in the McCarthy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-773B, scale 1:250,000, 2 sheets.
- MacKevett, E.M., Jr., Singer, D.A., and Holloway, C.D., 1978, Maps and tables describing metalliferous mineral resource potential of southern Alaska: U.S. Geological Survey Open-File Report 78-1E, 2 sheets, scale 1:1,000,000, 45 p.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987, Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.
- Nokleberg, W.J., Bundtzen, T.K., Grybeck, Donald, Koch, R.D., Eremin, R.A., Rozenblum, I.S., Sidorov, A.A., Byalobzhesky, S.G., Sosunov, G.M., Shpikerman, V.I., and Gorodinsky, M.E., 1993, Metallogenesis of mainland Alaska and the Russian Northeast: Mineral deposit maps, models, and tables, metallogenic belt maps and interpretation, and references cited: U.S. Geological Survey Open-File Report 93-339, 222 pages, 1 map, scale 1:4,000,000; 5 maps, scale 1:10,000,000.
- Nokleberg, W.J., Lange, I.M., Singer, D.A., Curtin, G.C., Tripp, R.B., Campbell, D.L., and Yeend, Warren, 1990, Mineral resource assessment maps of the Mount Hayes quadrangle, eastern Alaska Range, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1996-A, 4 sheets, scale 1:250,000, 22 p.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 53 p., scale 1:2,500,000.
- Richter, D.H., Singer, D.A., and Cox, D.P., 1975, Mineral resources map of the Nabesna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-655-K, 1 sheet, scale 1:250,000.
- Singer, D.A., 1986, Descriptive model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models: U.S. Geological Survey Bulletin* 1693, p. 189-190.
- Singer, D.A., Curtin, G.C., and Foster, H.L., 1977, Mineral resources map of the Tanacross quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-767-E, 1 sheet, scale 1:250,000.
- Singer, D.A., and Mosier, D.L., 1986, Grade and tonnage model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models: U.S. Geological Survey Bulletin* 1693, p. 190-197.

Descriptive Model: 28a.1**Mark3 Index: 44****Area: 7,593 km²****Mean undiscovered deposits: 1.33**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Warren J. Nokleberg, Dennis P. Cox, David L. Campbell, and Richard J. Goldfarb.

Rationale for Model Choice

Parts of the Talkeetna Mountains and western Alaska Range are permissive for kuroko massive sulfide deposits of Jurassic age (Singer, 1992) because of favorable bedrock geologic units. Because of the Jurassic age of the host rocks, the Sierran kuroko model of Singer (1992) represents the best estimates of tonnage and grade for undiscovered deposits.

Rationale for Tract Delineation

The favorable geologic unit in the tract is the Lower Jurassic andesite and associated basalt and volcanoclastic rocks of the Talkeetna Formation in the Peninsular terrane. Generally, aeromagnetic and gravity data are insufficient to help delineate the tract. The aeromagnetic map of Alaska (Godson, 1994) locally displays broken magnetic highs that may reflect covered volcanic rocks within the Talkeetna Formation.

The distribution of the geologic units defining the tract is adapted from Nokleberg and others (1994). The distribution of this belt of mineral deposits is adapted from MacKevett and others (1978) and Nokleberg and others (1987, 1993). Mineral resource assessments of 250,000-scale quadrangles within the tract were done by Singer and others (1980), Reed and others (1979), Cox and others (1989), and Nokleberg and others (1990).

Important Examples of Deposit Type

No kuroko deposits are known within this tract, but the Johnson River prospect occurs in correlative rocks in the Kenai quadrangle (Steefel, 1987), and is a kuroko massive sulfide deposit. At least 11 sporadic lenses of stratiform or strata-bound sulfides, mainly pyrite, exist in the Talkeetna Formation in the northern Chugach Mountains and may be related to marine volcanism (Newberry, 1986).

Rationale for Numerical Estimates

Prospective host rocks in the tract are partly covered by extensive ice fields, glaciers, and by Cenozoic basinal deposits. The mineral resource team estimated that the minimum number of undiscovered deposits consistent with the grade and tonnage model of Singer (1992) is:

Percentile	90	50	10	5	1	
Estimated number of deposits		0	1	2	4	10

References

- Cox, D.P., Light, T.D., Csejtey, Béla, and Campbell, D.L., 1989, Mineral resource assessment map of the Healy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2058-A, scale 1:250,000.
- Godson, Richard H., 1994, Composite magnetic anomaly map of Alaska and adjacent offshore area, *in* Plafker, G. and Berg, H.C., eds., *The Geology of Alaska*: Boulder, Colorado, Geological Society of America: *The Geology of North America*, v. G1, plate 10, scale 1:2,500,000.
- Heran, W.D., 1992, Geophysical model of massive sulfide deposits, *in* Heran, W.D., ed., *Codocil to The geophysical expression of selected mineral deposit models*: U.S. Geological Survey Open-file Report 94-174, p.4-15.

- MacKevett, E.M., Jr., Singer, D.A., and Holloway, C.D., 1978, Maps and tables describing metalliferous mineral resource potential of southern Alaska: U.S. Geological Survey Open-File Report 78-1E, 2 sheets, scale 1:1,000,000, 45 p.
- Newberry, R.J., 1986, Mineral resources of the north-central Chugach Mountains, Alaska: Alaska Division of Geological and Geophysical Surveys Report of Investigation 86-23, 44 p.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987. Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.
- Nokleberg, W.J., Bundtzen, T.K., Grybeck, Donald, Koch, R.D., Eremin, R.A., Rozenblum, I.S., Sidorov, A.A., Byalobzhesky, S.G., Sosunov, G.M., Shpikerman, V.I., and Gorodinsky, M.E., 1993, Metallogenesis of mainland Alaska and the Russian Northeast: Mineral deposit maps, models, and tables, metallogenic belt maps and interpretation, and references cited: U.S. Geological Survey Open-File Report 93-339, 222 pages, 1 map, scale 1:4,000,000; 5 maps, scale 1:10,000,000.
- Nokleberg, W.J., Lange, I.M., Singer, D.A., Curtin, G.C., Tripp, R.B., Campbell, D.L., and Yeend, Warren, 1990, Mineral resource assessment maps of the Mount Hayes quadrangle, eastern Alaska Range, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1996-A, 4 sheets, scale 1:250,000, 22 p.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 53 p., scale 1:2,500,000.
- Reed, B.L., Nelson, S.W., Curtin, G.C., and Singer, D.A., 1979, Mineral resources map of the Talkeetna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-870-D, 1 sheet, scale 1:250,000.
- Singer, D.A., 1992, Grade and tonnage model of Sierran kuroko massive sulfide, *in* Bliss, J.D., ed., Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, p. 29-32.
- Singer, D. A., Csejtey, Bèla, Jr., and Miller, R.J., 1980, Map and discussion of the metalliferous and selected non-metalliferous mineral resources of Talkeetna Mountains quadrangle, Alaska: U.S. Geological Survey Open-File Report 78-558-Q, 34 p., 1 sheet, scale 1:250,000.
- Steefel, C.I., 1987, The Johnson River prospect, Alaska: gold-rich sea-floor mineralization from the Jurassic: *Economic Geology*, v. 82, p. 894-914

Descriptive Model: 28a**Mark3 Index: 93****Area: 17,220 km²****Mean undiscovered deposits: 0.30**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Warren J. Nokleberg, Dennis P. Cox, Richard J. Goldfarb, and David L. Campbell.

Rationale for Model Choice

Parts of the eastern Alaska Range and Wrangell Mountains are permissive for Late Paleozoic kuroko massive sulfide deposits (Singer, 1986; Singer and Mosier, 1986) because of favorable bedrock geologic units, known occurrences, anomalous concentrations of Cu, Pb, Zn, As, Au, and Ag in stream sediment samples, and local sulfide minerals in heavy mineral concentrates.

Rationale for Tract Delineation

The geologic unit that defines this tract is the upper Paleozoic marine felsic and intermediate volcanic rocks and interlayered sedimentary rocks forming the upper part of the Skolai igneous arc in the Wrangellia terrane. In addition, stream-sediment geochemical samples yield abundant heavy mineral concentrates containing chalcopyrite, sphalerite, galena, and pyrite. Part of the Wrangellia terrane is tectonically dismembered and local fault-bounded segments may contain undiscovered deposits.

The distribution of the geologic units defining the tract is adapted from Nokleberg and others (1994). The distribution of this belt of mineral deposits is adapted from MacKevett and others (1978) and Nokleberg and others (1987, 1993). Mineral resource assessments of 250,000-scale quadrangles within the tract were done by Richter and others (1975), MacKevett (1976), Singer and MacKevett (1977), Singer and others (1980), Cox and others (1989), and Nokleberg and others (1990).

Important Examples of Deposit Type

There are no known deposits of this type in the tract. Kuroko massive sulfide mines exist in rocks of the same age in the Wrangellia terrane on Vancouver Island in southern British Columbia.

Rationale for Numerical Estimates

Potential host rocks in the tract are locally covered by extensive ice fields and glaciers, and by Cenozoic basinal deposits. Because kuroko massive sulfide deposits occur elsewhere in probably correlative rocks, the mineral resource team estimated the minimum number of undiscovered deposits that are consistent with the grade and tonnage model of Singer and Mosier (1986) to be:

Percentile	50	10	5	5	1
Estimated number of deposits	0	0	1	1	1

References

- Cox, D.P., Light, T.D., Csejtey, Béla, and Campbell, D.L., 1989, Mineral resource assessment map of the Healy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2058-A, scale 1:250,000.
- MacKevett, E.M., 1976, Mineral deposits and occurrences in the McCarthy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-773B, scale 1:250,000, 2 sheets.
- MacKevett, E.M., Jr., Singer, D.A., and Holloway, C.D., 1978, Maps and tables describing metalliferous mineral resource potential of southern Alaska: U.S. Geological Survey Open-File Report 78-1E, 2 sheets, scale 1:1,000,000, 45 p.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987. Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.

- Nokleberg, W.J., Bundtzen, T.K., Grybeck, Donald, Koch, R.D., Eremin, R.A., Rozenblum, I.S., Sidorov, A.A., Byalobzhesky, S.G., Sosunov, G.M., Shpikerman, V.I., and Gorodinsky, M.E., 1993, Metallogenesis of mainland Alaska and the Russian Northeast: Mineral deposit maps, models, and tables, metallogenic belt maps and interpretation, and references cited: U.S. Geological Survey Open-File Report 93-339, 222 pages, 1 map, scale 1:4,000,000; 5 maps, scale 1:10,000,000.
- Nokleberg, W.J., Lange, I.M., Singer, D.A., Curtin, G.C., Tripp, R.B., Campbell, D.L., and Yeend, Warren, 1990, Mineral resource assessment maps of the Mount Hayes quadrangle, eastern Alaska Range, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1996-A, 4 sheets, scale 1:250,000, 22 p.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 53 p., scale 1:2,500,000.
- Richter, D.H., Singer, D.A., and Cox, D.P., 1975, Mineral resources map of the Nabesna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-655-K, 1 sheet, scale 1:250,000.
- Singer, D.A., 1986, Descriptive model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 189-190.
- Singer, D. A., Csejtey, Béla, Jr., and Miller, R.J., 1980, Map and discussion of the metalliferous and selected non-metalliferous mineral resources of Talkeetna Mountains quadrangle, Alaska: U.S. Geological Survey Open-File Report 78-558-Q, 34 p., 1 sheet, scale 1:250,000.
- Singer, D.A., and MacKevett, E.M., Jr., 1977, Mineral resources map of the McCarthy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-773-C, 1 sheet, scale 1:250,000.
- Singer, D.A., and Mosier, D.L., 1986, Grade and tonnage model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 190-197.

Descriptive Model: 32a and 32b**Mark3 Index: 42****Area: 4,445 km²****Mean undiscovered deposits: (no estimate)**[Model](#)

by Jeanine M. Schmidt, Thomas D. Light, and Bruce M. Gamble

Rationale for Model Choice

Two Mississippi Valley type (MVT) deposits are described in Cox and Singer (1986). The differences between Southeast Missouri Pb-Zn (model 32a; Briskey 1986b) and Appalachian Zn (model 32b; Briskey, 1986a) are subtle enough that the grade and tonnage models for the two deposit types are plotted together with no differentiation between types (Mosier and Briskey, 1986). In Alaska, the lack of detailed geologic information prevents distinguishing between the two deposit types, and a generic Mississippi Valley type model has been used.

This tract is permissive for Mississippi Valley type deposits because it locally contains platform carbonate rocks, which in west-central Alaska, host deposits thought to be Mississippi Valley type.

Rationale for Tract Delineation

This tract includes the Nixon Fork and Minchumina terranes, both of which locally contain lower Paleozoic platform carbonate rocks (Patton and others, 1994), in the Mt. McKinley quadrangle.

Important Examples of Deposit Type

The Reef Ridge deposit in the Medfra quadrangle of west-central Alaska is an example of a Mississippi Valley type deposit (Andrews and Rishel, 1982).

Rationale for Numerical Estimates

No estimate of the number of undiscovered deposits was attempted.

References

- Andrews, T., and Rishel, John, 1982, 1981 Annual Report-Reef Ridge I-XIII project areas, Kuskokwim Block, Volume 1 of 3: unpublished report, Patino Inc., Anchorage, Alaska, 49 p.
- Briskey, J.A., 1986a, Descriptive model of Appalachian Zn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 222-223.
- Briskey, J.A., 1986b, Descriptive model of southeast Missouri Pb-Zn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 220-221.
- Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 130.
- Mosier, D.L., and Briskey, 1986, Grade and tonnage model of southeast Missouri Pb-Zn and Appalachian Zn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 224-226.
- Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1994, Geology of west-central Alaska, *in* Plafker, George, and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G-1, p. 241-269.

Descriptive Model: 7a**Mark3 Index: (none)****Area: 25441 km²****Mean undiscovered deposits: (no estimate)**[Model](#)

by Warren J. Nokleberg, Richard J. Goldfarb, and David L. Campbell.

Rationale for Model Choice

This tract, in the eastern Alaska Range, Nutzotin, and Wrangell Mountains, is permissive for Late Triassic gabbroic Ni-Cu deposits because of favorable bedrock geology, one known deposit, geophysical anomalies, and geochemical anomalies (Cu, Ni). The gabbroic Ni-Cu deposit type is a modification by Nokleberg and others (1987) of the synorogenic-synvolcanic Ni-Cu deposit type of Singer and others (1986) in Cox and Singer (1986).

Rationale for Tract Delineation

The favorable geologic units for the tract are the Upper Triassic Nikolai Greenstone and subjacent units of the Wrangellia terrane where intruded by coeval mafic and ultramafic plutons, dikes, and sills, such as the Fish Lake complex in the Mount Hayes quadrangle (Nokleberg and others, 1992). In the eastern Alaska Range, Nutzotin Mountains, and Wrangell Mountains, the Nikolai Greenstone, which also contains coeval mafic and ultramafic rocks, is up to 4350 m thick and consists mainly of massive, subaerial, amygdaloidal basalt flows, lesser pillow basalt flows, and thin beds of argillite, chert, and mafic volcanoclastic rocks (Nokleberg and others, 1994c, d). The flows are predominantly intermixed aa and pahoehoe flows; individual units range from 5 cm to more than 15 m thick. The Nikolai Greenstone is a thick and vast unit of submarine and subaerial Middle and Upper Triassic tholeiitic basalt and associated mafic and ultramafic sills and that forms a major part of the Wrangellia terrane. The Nikolai Greenstone and associated mafic and ultramafic plutonic rocks are interpreted as forming during a short-lived period of rifting or oceanic plume activity within the Wrangellia island arc terrane (Nokleberg and Lange, 1985; Nokleberg and others, 1984, 1985; 1987, 1989, 1994c, d, e, Plafker and others, 1989).

The distribution of the geologic units defining the tract is adapted from Nokleberg and others (1994d, e; 1997). The distribution of this belt of mineral deposits is adapted from MacKevett and others (1978), and Nokleberg and others (1987, 1993, 1994a, b, 1996, 1997). Mineral resource assessments of 250,000-scale quadrangles within the tract were done by Richter and others (1975), Singer and others (1977), Reed and others (1979), Cox and others (1989), and Nokleberg and others (1990, 1991).

Important Examples of Deposit Type

The Fish Lake and Wellgreen deposits are classified by Nokleberg and others (1996) as gabbroic Ni-Cu deposits. The Fish Lake gabbroic Ni-Cu deposit (63 13 00N, 146 48 00W: Nokleberg and others, 1984; I.M. Lange and W.J. Nokleberg, unpublished data, 1985; Nokleberg and others, 1991, 1996) consists of chromite, disseminated and in wispy layers, in serpentinized olivine cumulate. The occurrence occupies a zone up to 15 km long along strike and up to 2 km wide, and contains locally anomalous Cu and Ni in stream-sediment and rock samples. Isolated grab samples contain greater than 0.5% Cr and up to 0.3% Ni. This gabbroic Ni-Cu occurrence is hosted by small- to moderate-size gabbro plutons and local cumulate mafic and ultramafic rocks. The mafic and ultramafic rocks intrude the Nikolai Greenstone and older rocks, and are interpreted as being co-magmatic with the mafic magmas that formed the Middle and Upper Triassic Nikolai Greenstone.

The Wellgreen gabbroic Ni-Cu deposit (61 28 00N, 139 31 18W: Campbell, 1976; Nokleberg and others, 1984; Hulbert and others, 1988; EMR Canada, Nokleberg and others, 1989, 1991, 1996; Mining Review, 1991) contains reserves of 50 million tonnes grading 0.36% Ni, 0.35% Cu, 0.51g/t Pt, 0.34 g/t Pd. The deposit consists of massive pyrrhotite, pentlandite, chalcopyrite and magnetite lenses that are scattered along the footwall contact of a steeply dipping fault zone in gabbroic rocks of the Upper Triassic Quill Creek Complex. The deposit occurs within a 130 km belt of Ni-Cu-Co-PGE occurrences that are hosted in the Pennsylvanian Skolai Assemblage that includes the Canalsk deposit at White River. Cu-Ni sulfides are disseminated within mafic dikes and peridotite. Production occurred in 1972-73. The deposit age is interpreted as Late Triassic.

Rationale for Numerical Estimates

Because only two widely-separated deposits are known, and because the occurrence of mafic and ultramafic plutons, dikes, and sills in the Nikolai Greenstone is very erratic, this tract is considered to be permissive. No estimate of undiscovered gabbroic Ni-Cu was attempted.

References

- Campbell, S.W., 1976, Nickel-copper sulphide deposits in the Kluane Ranges, Yukon Territory: Department of Indian and Northern Affairs, Open File Report EGS 1976-10, 17 p.
- Cox, D.P., and Singer, D.A., 1986, eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, 329 p.
- Cox, D.P., Light, T.D., Csejtey, Béla, and Campbell, D.L., 1989, Mineral resource assessment map of the Healy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2058-A, scale 1:250,000.
- EMR Canada, 1989, Canadian mineral deposits not being mined in 1989: Energy, Mines and Resources Canada, Mineral Resource Sector, MR 223, 625 p.
- Hulbert, L.J., Carne, R.C., Gregoire, D.C., and Paktunc, D., 1992, Sedimentary nickel, zinc, and platinum-group-element mineralization in Devonian black shales at the Nick Property, Yukon, Canada: A new type of deposit: Exploration, Mining and Geology, Canadian Institute of Mining and Metallurgy, v. 1, no. 1, p. 39-62.
- Mackevett, E.M., Jr., Singer, D.A., and Holloway, C.D., 1978, Maps and tables describing metalliferous mineral resource potential of southern Alaska: U.S. Geological Survey Open-File Report 78-1E, 2 sheets, scale 1:1,000,000, 45 p.
- Mining Review, 1991, British Columbia and Yukon Chamber of Mines, v. 11, no. 3, p. 24-33.
- Nokleberg, W.J., Aleinikoff, J.N. Lange, I.M., Silva, S.R., Miyaoka, R.T., Schwab, C.E., and Zehner, R.E., 1992, Preliminary geologic map of the Mount Hayes quadrangle, eastern Alaska Range, Alaska: U.S. Geological Survey Open-File Report 92-594, 1 sheet, scale 1:250,000, 39 p.
- Nokleberg, W.J., and Lange, I.M., 1985, Metallogenetic history of the Wrangellia terrane, eastern Alaska Range, Alaska [abs.]: U.S. Geological Survey Circular 949, p. 36-38.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., Yeend, Warren, 1994a, Metallogeny and major mineral deposits of Alaska, *in* Plafker, G. and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America: The Geology of North America, v. G1, p. 855-904.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., Yeend, Warren, and 54 contributors, 1994b, Metallogenic map of significant metalliferous lode deposits and placer districts of Alaska, *in* Plafker, G. and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America: The Geology of North America, v. G1, Plate 11, scale 1:2,500,000.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987, Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.
- Nokleberg, W.J., Bundtzen, T.K., Dawson, K.M., Eremin, R.A., Goryachev, N.A., Koch, R.D. Ratkin, V.V., Rozenblum, I.S., Shpikerman, V.I., Frolov, Y.F., Gorodinsky, M.E., Melnikov, V.D., Ognyanov, N.V., Petrachenko, E.D., Petrachenko, R.I., Pozdeev, A.I., Ross, K.V., Wood, D.H., Grybeck, Donald, Khanchuk, A.I., Kovbas, L.I., Nekrasov, I.Ya., and Sidorov, A.A., 1996, Significant metalliferous lode deposits and placer districts for the Russian Far East, Alaska, and the Canadian Cordillera U.S. Geological Survey Open-File Report 96-513-A (paper format), 385 p.

- Nokleberg, W.J., Bundtzen, T.K., Dawson, K.M., Eremin, R.A., Ratkin, V.V., Shpikerman, V.I., Goryachev, N.A., Khanchuk, A.I., Koch, R.D., Rozenblum, I.S., Gorodinsky, M.E., Frolov, Y.F., Pozdeev, A.I., Parfenov, L.M., and Sidorov, A.A., 1997, Mineral deposit and metallogenic belt maps of the Russian Far East, Alaska, and the Canadian Cordillera: U.S. Geological Survey Open-File Report 97-161, 2 sheets, 5 million scale; 5 sheets, 10 million scale).
- Nokleberg, W.J., Bundtzen, T.K., Grybeck, Donald, Koch, R.D., Eremin, R.A., Rozenblum, I.S., Sidorov, A.A., Byalobzhesky, S.G., Sosunov, G.M., Shpikerman, V.I., and Gorodinsky, M.E., 1993, Metallogenesis of mainland Alaska and the Russian Northeast: Mineral deposit maps, models, and tables, metallogenic belt maps and interpretation, and references cited: U.S. Geological Survey Open-File Report 93-339, 222 pages, 1 map, scale 1:4,000,000; 5 maps, scale 1:10,000,000.
- Nokleberg, W.J., Foster, H.L., and Aleinikoff, J.N., 1989, Geology of the northern Copper River Basin, eastern Alaska Range, and southern Yukon-Tanana Basin, southern and east-central Alaska, *in*, Nokleberg, W.J., and Fisher, M.A., eds., Alaska Geological and Geophysical Transect: Field Trip Guidebook T104, 28th International Geological Congress, p. 34-63
- Nokleberg, W.J., Lange, I.M., Roback, R.C., Yeend, Warren, and Silva S.R., 1991, Map showing locations of metalliferous lode and placer mineral occurrences, deposits, prospects, and mines, Mount Hayes quadrangle, eastern Alaska Range, Alaska: U.S. Geological Survey Map MF-1996-C, 42 p., 1 sheet, scale 1:250,000.
- Nokleberg, W.J., Lange, I.M., and Roback, R.C., 1984, Preliminary accretionary terrane model for metallogenesis of the Wrangellia terrane, southern Mount Hayes quadrangle, eastern Alaska Range, Alaska, *in* Reed, K.M., and Bartsch-Winkler, Susan, eds., The United States Geological Survey in Alaska: Accomplishments during 1982: U.S. Geological Survey Circular 939, p. 60-65.
- Nokleberg, W.J., Lange, I.M., Singer, D.A., Curtin, G.C., Tripp, R.B., Campbell, D.L., and Yeend, Warren, 1990, Mineral resource assessment maps of the Mount Hayes quadrangle, eastern Alaska Range, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1996-A, 4 sheets, scale 1:250,000, 22 p.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994d, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 53 p., scale 1:2,500,000.
- Nokleberg, W.J., Parfenov, L.M., and Monger, J.W.H., and Baranov, B.V., Byalobzhesky, S.G., Bundtzen, T.K., Feeney, T.D., Fujita, Kazuya, Gordey, S.P., Grantz, Arthur, Khanchuk, A.I., Natal'in, B.A., Natapov, L.M., Norton, I.O., Patton, W.W., Jr., Plafker, George, Scholl, D.W., Sokolov, S.D., Sosunov, G.M., Stone, D.B., Tabor, R.W., Tsukanov, N.V., Vallier, T.L. and Wakita, Koji, 1994c, Circum-North Pacific tectono-stratigraphic terrane map: U.S. Geological Survey Open-File Report 94-714, 221 pages, 2 sheets, scale 1:5,000,000; 2 sheets, scale 1:10,000,000.
- Nokleberg, W.J., Plafker, George, and Wilson, F.H., 1994e, Geology of south-central Alaska, *in* Plafker, George, and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G-1, p. 311-366.
- Plafker, George, Nokleberg, W.J., and Lull, J.S., 1989, Bedrock geology and tectonic evolution of the Wrangellia, Peninsular, and Chugach terranes along the Trans-Alaska crustal transect in the Chugach Mountains and southern Copper River Basin, Alaska: Journal of Geophysical Research, v. 94, p. 4255-4295.
- Reed, B.L., Nelson, S.W., Curtin, G.C., and Singer, D.A., 1979, Mineral resources map of the Talkeetna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-870-D, 1 sheet, scale 1:250,000.
- Richter, D.H., Singer, D.A., and Cox, D.P., 1975, Mineral resources map of the Nabesna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-655-K, 1 sheet, scale 1:250,000.
- Singer, D.A., Curtin, G.C., and Foster, H.L., 1977, Mineral resources map of the Tanacross quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-767-E, 1 sheet, scale 1:250,000.
- Singer, D.A., Page, N.J., and Menzie, W.D., 1986, Descriptive model of synorogenic-synvolcanic Ni-Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 28-31.

Descriptive Model: 7a**Mark3 Index: (none)****Area: 3,994 km²****Mean undiscovered deposits: (no estimate)**[Model](#)

by Warren J. Nokleberg, Richard J. Goldfarb, and David L. Campbell.

Rationale for Model Choice

This tract, in the northern Chugach Mountains, is permissive for Upper Triassic and Lower Jurassic gabbroic Ni-Cu deposits because of favorable bedrock geology, one known deposit, geophysical anomalies, and geochemical anomalies (Cu, Ni). The gabbroic Ni-Cu deposit type is a modification by Nokleberg and others (1987) of the synorogenic-synvolcanic Ni-Cu deposit type of Singer and others (1986) in Cox and Singer (1986).

Rationale for Tract Delineation

The favorable geologic units for the tract are mafic and ultramafic plutonic rocks of the Border Ranges ultramafic-mafic complex of the southern part of the Peninsular terrane (Burns, 1985; Plafker and others, 1989; DeBari and Coleman, 1989; Nokleberg and others, 1994c). The tract occurs along the northern margin of Kodiak Island, on the Kenai Peninsula, and along the northern flank of the Chugach Mountains in coastal southern Alaska (Foley and Barker, 1985; Foley and others, 1985, 1987). This belt occurs sporadically along a strike distance of several hundred kilometers from Kodiak Island to the southwest to the eastern Chugach Mountains to the east.

The mainly Lower Jurassic Border Ranges ultramafic and mafic assemblage constitutes an igneous belt of ultramafic tectonites and cumulate gabbro and norite that occurs along the southern, faulted margin of the Peninsular sequence of the Wrangellia island arc superterrane immediately north of the Border Ranges fault system (MacKevett and Plafker, 1974; Burns, 1985; Plafker and others, 1989; Nokleberg and others, 1989, 1994c, d, e). The ultramafic and mafic rocks are interpreted as the deep-level root of the mainly Jurassic Talkeetna island arc of the Peninsular sequence of the Wrangellia superterrane. This sequence consists of the Lower Jurassic marine andesite volcanic rocks of the Talkeetna Formation and the Middle Jurassic plutonic rocks of the Alaska-Aleutian Range batholith. If these interpretations are correct, this tract is permissive for a deep-level suite of lode deposits formed in the Talkeetna island arc that is a key component of the Peninsular sequence. The Lower and Middle Jurassic island arc rocks of the Peninsular sequence of the Wrangellia terrane are tectonically linked to a discontinuous belt of Lower Triassic blueschist and to the McHugh Complex, a pair of partly coeval subduction zone units that occur along the northern margin of the Chugach terrane (Plafker and others, 1989; Nokleberg and others, 1994c, d, e).

The distribution of the geologic units defining the tract is adapted from Nokleberg and others (1994b, c, d, e). The distribution of this belt of mineral deposits is adapted from MacKevett and others (1978), and Nokleberg and others (1987, 1993, 1994a, 1996, 1997). Mineral resource assessments of 250,000-scale quadrangles within the tract were done by Goldfarb and others (1995).

Important Examples of Deposit Type

The Spirit Mountain deposit (61° 18' 30"N, 144° 12' 45"W; Kingston and Miller, 1945; Herreid, 1970; Nokleberg and others, 1996) is classified by Nokleberg and others (1996) as a gabbroic Ni-Cu deposit. The Spirit Mountain gabbroic Ni-Cu deposit (Nokleberg and others, 1984; Nokleberg and others, 1991)

contains at least 11,000 tonnes ranging up to 6.2 % Ni and 3.4 % Cu and 0.04 % Co. (Average 0.88 % Ni and 0.9 % Cu) The deposit consists of disseminated and locally massive pyrrhotite, pyrite, chalcopyrite, pentlandite, and ullmannite (a sulphantimonide of nickel), bravoite, and minor to trace galena and sphalerite in gabbro, peridotite, and hornblendite sills and dikes that cut Mississippian Strelina Formation with an east-west trend. Ultramafic and mafic rocks may be part of the Lower Jurassic or older, informally named Border Ranges ultramafic and mafic complex of Burns (1985). The sills and dikes are believed to intrude along a major thrust fault that juxtaposes a foliated quartz diorite pluton and the upper Paleozoic rocks. The deposit(s) occur as a series of lenses 1-3 m thick that extend along strike for about 2 km. Explored with trenches, pits, and two short tunnels.

Rationale for Numerical Estimates

Because only one deposit is known, this tract is considered to be permissive. No estimate of undiscovered gabbroic Ni-Cu was attempted.

References

- Burns, L.E., 1985, The Border Ranges ultramafic and mafic complex, south-central Alaska: cumulate fractionates of island-arc volcanics: Canadian Journal of Earth Sciences, v. 22, p. 1020-1038.
- Debari, S.M., and Coleman, R.G., 1989, Examination of the deep levels of an island arc: Evidence from the Tonsina ultramafic-mafic assemblage, Tonsina, Alaska: Journal of Geophysical Research, v. 94, p. 4373-4391.
- Cox, D.P., and Singer, D.A., 1986, eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, 329 p.
- Foley, J.Y., Mardock, C.L., and Dahlin, D.C., 1987, Platinum-group elements in the Tonsina ultramafic complex, southern Alaska: Metallurgical Society, Process Mineralogy VII, p. 165-195
- Foley, J.Y., Barker, J.C., and Brown, L.L., 1985, Critical and strategic mineral investigation in Alaska: Chromium: U.S. Bureau of Mines Open File Report 97-85, 54 p.
- Foley, J.Y., and Barker, J.C., 1985, Chromite deposits along the Border Ranges fault, southern Alaska: U.S. Bureau of Mines Information Circular IC-8990, 58 p.
- Goldfarb, R.J., Carter Borden, J., and Winkler, G.R., 1995, Geochemical survey of the Valdez 1°x3° quadrangle, south-central Alaska: U.S. Geological Survey Bulletin 2084, 77 p., 1 sheet, scale 1:250,000.
- Herreid, Gordon, 1970, Geology of the Spirit Mountain nickel-copper prospect and surrounding area: Alaska Division of Mines and Geology Geologic Report 40, 19 p., 1 sheet, scale 1:20,000.
- Kingston, Jack, and Miller, D.J., 1945, Nickel-copper prospect near Spirit Mountain, Copper River region, U.S. Geological Survey Bulletin 943-C, p. 49-57.
- Mackevett, E.M., Jr., and Plafker, George, 1974, The Border Ranges fault in south-central Alaska: U.S. Geological Survey Journal of Research, v. 2, no. 3, p. 323-329.
- Mackevett, E.M., Jr., Singer, D.A., and Holloway, C.D., 1978, Maps and tables describing metalliferous mineral resource potential of southern Alaska: U.S. Geological Survey Open-File Report 78-1E, 2 sheets, scale 1:1,000,000, 45 p.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987, Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., Yeend, Warren, 1994a, Metallogeny and major mineral deposits of Alaska, *in* Plafker, G. and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America: The Geology of North America, v. G1, p. 855-904.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., Yeend, Warren, and 54 contributors, 1994b, Metallogenic map of significant metalliferous lode deposits and placer districts of Alaska, *in* Plafker, G. and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America: The Geology of North America, v. G1, Plate 11, scale 1:2,500,000.
- Nokleberg, W.J., Bundtzen, T.K., Dawson, K.M., Eremin, R.A., Goryachev, N.A., Koch, R.D. Ratkin, V.V., Rozenblum, I.S., Shpikerman, V.I., Frolov, Y.F., Gorodinsky, M.E., Melnikov, V.D., Ognyanov, N.V., Petrachenko, E.D., Petrachenko, R.I., Pozdeev, A.I., Ross, K.V., Wood, D.H., Grybeck, Donald, Khanchuk, A.I., Kovbas, L.I., Nekrasov, I.Ya., and Sidorov, A.A., 1996, Significant metalliferous lode deposits and placer districts for the Russian Far East, Alaska, and the Canadian Cordillera U.S. Geological Survey Open-File Report 96-513-A, 385 p.

- Nokleberg, W.J., Bundtzen, T.K., Dawson, K.M., Eremin, R.A., Ratkin, V.V., Shpikerman, V.I., Goryachev, N.A., Khanchuk, A.I., Koch, R.D., Rozenblum, I.S., Gorodinsky, M.E., Frolov, Y.F., Pozdeev, A.I., Parfenov, L.M., and Sidorov, A.A., 1997, Mineral deposit and metallogenic belt maps of the Russian Far East, Alaska, and the Canadian Cordillera: U.S. Geological Survey Open-File Report 97-161, 2 sheets, 5 million scale; 5 sheets, 10 million scale).
- Nokleberg, W.J., Bundtzen, T.K., Grybeck, Donald, Koch, R.D., Eremin, R.A., Rozenblum, I.S., Sidorov, A.A., Byalobzhesky, S.G., Sosunov, G.M., Shpikerman, V.I., and Gorodinsky, M.E., 1993, Metallogenesis of mainland Alaska and the Russian Northeast: Mineral deposit maps, models, and tables, metallogenic belt maps and interpretation, and references cited: U.S. Geological Survey Open-File Report 93-339, 222 pages, 1 map, scale 1:4,000,000; 5 maps, scale 1:10,000,000.
- Nokleberg, W.J., Foster, H.L., and Aleinikoff, J.N., 1989, Geology of the northern Copper River Basin, eastern Alaska Range, and southern Yukon-Tanana Basin, southern and east-central Alaska, *in*, Nokleberg, W.J., and Fisher, M.A., eds., Alaska Geological and Geophysical Transect: Field Trip Guidebook T104, 28th International Geological Congress, p. 34-63
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994d, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 53 p., scale 1:2,500,000.
- Nokleberg, W.J., Parfenov, L.M., and Monger, J.W.H., and Baranov, B.V., Byalobzhesky, S.G., Bundtzen, T.K., Feeney, T.D., Fujita, Kazuya, Gordey, S.P., Grantz, Arthur, Khanchuk, A.I., Natal'in, B.A., Natapov, L.M., Norton, I.O., Patton, W.W., Jr., Plafker, George, Scholl, D.W., Sokolov, S.D., Sosunov, G.M., Stone, D.B., Tabor, R.W., Tsukanov, N.V., Vallier, T.L. and Wakita, Koji, 1994c, Circum-North Pacific tectono-stratigraphic terrane map: U.S. Geological Survey Open-File Report 94-714, 221 pages, 2 sheets, scale 1:5,000,000; 2 sheets, scale 1:10,000,000.
- Nokleberg, W.J., Plafker, George, and Wilson, F.H., 1994e, Geology of south-central Alaska, *in* Plafker, George, and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G-1, p. 311-366.
- Plafker, George, Nokleberg, W.J., and Lull, J.S., 1989, Bedrock geology and tectonic evolution of the Wrangellia, Peninsular, and Chugach terranes along the Trans-Alaska crustal transect in the Chugach Mountains and southern Copper River Basin, Alaska: Journal of Geophysical Research, v. 94, p. 4255-4295.
- Singer, D.A., Page, N.J., and Menzie, W.D., 1986, Descriptive model of synorogenic-synvolcanic Ni-Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 28-31.

AK-SC20

Porphyry Cu (BC-Ak type)

Alaska South Central

Descriptive Model: 17.1

Mark3 Index: 89

Area: 45,408 km²

Mean undiscovered deposits: 4.33

[Cumulative Distribution](#)

[Histogram](#)

[Table](#)

[Model](#)

[Mineral Deposits](#)

by Warren J. Nokleberg, Dennis P. Cox, Richard J. Goldfarb, David L. Campbell, and Warren Yeend.

Rationale for Model Choice

This tract, in the southern Yukon-Tanana Upland, is permissive for Late Cretaceous and early Tertiary porphyry Cu and other granitic-magmatism-related deposits because of favorable bedrock geology, porphyry Cu and Cu skarn occurrences in the extension of the tract to the north in east-central Alaska, and geochemical anomalies (Cu, Mo, Au, As, Ag, Bi, Pb, Zn). This porphyry Cu model (17) includes porphyry Cu (BC-Ak type) (17.1), porphyry Cu skarn (18a), porphyry Cu-Au (20c), and porphyry Cu-Mo (21). Details of the deposit model for this tract and other areas are provided by Hollister and others (1975), Cox (1986), Menzie and Singer (1993) .

Rationale for Tract Delineation

The favorable geologic units in the tract are the Late Cretaceous and early Tertiary granitic plutons of the Kluane arc that intrude Mesozoic and older rocks of the Yukon-Tanana and adjacent terranes, and carbonate rocks altered to skarn in areas where intruded by Late Cretaceous and early Tertiary igneous rocks. The extension of this tract to the north, in east-central Alaska, includes various small fragments of Paleozoic continental-margin sedimentary rocks, turbidite basin deposits, and oceanic crustal rocks in the Livengood, Manley, and Wickersham, White Mountain terranes that are intruded by Late Cretaceous and early Tertiary granitic plutonic rocks (Nokleberg and others, 1994). To the southwest in southwestern Alaska, the extension of this tract includes the porphyry Cu and other granitic-magmatism-related deposits related to intrusion of the Late Cretaceous and early Tertiary Kuskokwim Mountains volcanic-plutonic belt (Nokleberg and others, 1994).

The principal mineral deposit models are porphyry Cu and Cu skarn, but related coeval granitic-magmatism deposits could also occur. Local zonation of geochemical anomalies may exist. Local porphyry Cu occurrences in the extension of the tract to the north in east-central Alaska exhibit multiple phases of intrusion and propylitic and sericitic alteration. Areas of known and possibly large concealed granitic plutons (greater than several km diameter) in the tract are delineated by large, blotchy magnetic highs and (or) by eU or eTh cells interpreted from sparse data on radiometric maps.

The distribution of the geologic units defining the tract is adapted from Nokleberg and others (1994). The distribution of this belt of mineral deposits is adapted from MacKevett and others (1978), and Nokleberg and others (1987, 1993). This tract is the same area as tract AK-SC24 for plutonic porphyry Au deposits and tract AK-SC07 for gold-antimony vein deposits. This tract corresponds to part of the East-Central Alaska belt of granitic magmatism deposits described by Nokleberg and others (1993). Mineral resource assessments of 250,000-scale quadrangles within the tract were done by Richter and others (1975), Singer and others (1977), Reed and others (1979), Cox and others (1989), and Nokleberg and others (1990, 1991).

Important Examples of Deposit Type

The Taurus deposit, which has inferred reserves of 126 million tonnes (140 million tons) containing 0.30% Cu and 0.34grams/tonne (0.01 oz/ton) Au, and 0.03% Mo (Bundtzen and others, 1996) occurs in the Tanacross quadrangle. In the extension of this tract to the north are a wide variety of polymetallic vein, Sb-Au vein, porphyry Cu, and Sn greisen mines, deposits, and occurrences (Nokleberg and others, 1987, 1993). Associated placer gold deposits in the Bonnifield, Delta River, and Kantishna districts in the tract (Capps, 1912, 1919; Smith, 1941; Rose, 1965; Cobb, 1973; Bundtzen, 1981; Gilbert and Bundtzen, 1979;

Nokleberg and others, 1991) may be partly derived from porphyry Cu or other granitic-magmatism-related occurrences.

Rationale for Numerical Estimates

The tract is partly covered by extensive glacial loess, deep Tertiary weathering, and dense vegetation that could obscure porphyry Cu deposits. Because two major porphyry occurrences are in the extension of the tract to the north, undiscovered deposits probably occur in the tract. The minimum number of undiscovered porphyry Cu deposits, consistent with the grade and tonnage model of Menzie and Singer (1993), are estimated to be:

Percentile	90	50	10	5	1
Estimated number of deposits	1	5	7	7	7

References

- Bundtzen, T.K., 1981, Geology and mineral deposits of the Kantishna Hills, Mount McKinley quadrangle, Alaska: Fairbanks, Alaska, University of Alaska, M.S. thesis, 237 p, 4 sheets, scale 1:63,360.
- Capps, S.R., 1912, The Bonnifield region, Alaska: U.S. Geological Survey Bulletin 501, 64 p.
- Capps, S.R., 1919, The Kantishna region, Alaska: U.S. Geological Survey Bulletin 687, 116 p.
- Cobb, E.H., 1973, Placer deposits of Alaska: U.S. Geological Survey Bulletin 1324, 213 p.
- Cox, D.P., and Singer, D.A., 1986, eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, 329 p.
- Cox, D.P., Light, T.D., Csejtey, Béla, and Campbell, D.L., 1989, Mineral resource assessment map of the Healy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2058-A, scale 1:250,000.
- Gilbert, W.G., and Bundtzen, T.K., 1979, Mid-Paleozoic tectonics, volcanism, and mineralization in north-central Alaska Range, *in* Sisson, A., ed., The relationship of plate tectonics to Alaskan geology and resources: Alaska Geological Society, Symposium, 1977, p. F1-F21.
- Hollister, V.F., Anzalone, S.A., and Richter, D.H., 1975, Porphyry copper deposits of southern Alaska and contiguous Yukon Territory: Canadian Mining and Metallurgy Bulletin, v. 68, p. 104-112.
- MacKevett, E.M., Jr., Singer, D.A., and Holloway, C.D., 1978, Maps and tables describing metalliferous mineral resource potential of southern Alaska: U.S. Geological Survey Open-File Report 78-1E, 2 sheets, scale 1:1,000,000, 45 p.
- Menzie, W.D., and Singer, D.A., 1993, Grade and tonnage model of porphyry Cu deposits in British Columbia, Canada, and Alaska, U.S.A.: U.S. Geological Survey Open-File Report 93-275, 9 p.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987, Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.
- Nokleberg, W.J., Bundtzen, T.K., Grybeck, Donald, Koch, R.D., Eremin, R.A., Rozenblum, I.S., Sidorov, A.A., Byalobzhesky, S.G., Sosunov, G.M., Shpikerman, V.I., and Gorodinsky, M.E., 1993, Metallogenesis of mainland Alaska and the Russian Northeast: Mineral deposit maps, models, and tables, metallogenic belt maps and interpretation, and references cited: U.S. Geological Survey Open-File Report 93-339, 222 pages, 1 map, scale 1:4,000,000; 5 maps, scale 1:10,000,000.
- Nokleberg, W.J., Lange, I.M., Roback, R.C., Yeend, Warren, and Silva S.R., 1991, Map showing locations of metalliferous lode and placer mineral occurrences, deposits, prospects, and mines, Mount Hayes quadrangle, eastern Alaska Range, Alaska: U.S. Geological Survey Map MF-1996-C, 42 p., 1 sheet, scale 1:250,000.
- Nokleberg, W.J., Lange, I.M., Singer, D.A., Curtin, G.C., Tripp, R.B., Campbell, D.L., and Yeend, Warren, 1990, Mineral resource assessment maps of the Mount Hayes quadrangle, eastern Alaska Range, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1996-A, 4 sheets, scale 1:250,000, 22 p.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 53 p., scale 1:2,500,000.
- Reed, B.L., Nelson, S.W., Curtin, G.C., and Singer, D.A., 1979, Mineral resources map of the Talkeetna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-870-D, 1 sheet, scale 1:250,000.
- Richter, D.H., Singer, D.A., and Cox, D.P., 1975, Mineral resources map of the Nabesna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-655-K, 1 sheet, scale 1:250,000.

Rose, A.W., 1965, Geology and mineral deposits of the Rainy Creek area, Mt. Hayes quadrangle, Alaska: Alaska Division of Mines and Minerals Geologic Report 14, 51 p.

Singer, D.A., Curtin, G.C., and Foster, H.L., 1977, Mineral resources map of the Tanacross quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-767-E, 1 sheet, scale 1:250,000.

Smith, P.S., 1941, Mineral industry of Alaska in 1939: U.S. Geological Survey Bulletin 926-A, p. 1-106.

Descriptive Model: 17.1

Mark3 Index: 89

Area: 79,025 km²

Mean undiscovered deposits: 2.83

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Warren J. Nokleberg, Dennis P. Cox, Richard J. Goldfarb, David L. Campbell, and Warren Yeend.

Rationale for Model Choice

Parts of the Alaska Range and Wrangell Mountains are permissive for Late Cretaceous and early Tertiary porphyry Cu and other granitic-magmatism-related deposits because of favorable bedrock geology, two porphyry Cu occurrences and one associated Cu skarn occurrence, geochemical anomalies (Cu, Mo, Au, As, Ag, Bi, Pb, Zn, Co, Fe), and aeromagnetic anomalies. This porphyry Cu model (17) includes porphyry Cu (BC-Ak type) (17.1), porphyry Cu skarn (18a), porphyry Cu-Au (20c), and porphyry Cu-Mo (21). Details of the deposit model for this tract and for other areas of Alaska and British Columbia are provided by Hollister (1978), Hollister and others (1975), Cox (1986), and Menzie and Singer (1993).

Rationale for Tract Delineation

The favorable geologic unit defining this two-part tract is mainly the Wrangellia and Peninsular terranes where intruded by calc-alkaline granitic plutons, dikes, and sills of the Late Cretaceous and early Tertiary Kluane arc. Because concealed plutons and associated deposits may occur near the surface, the tract includes all of the Wrangellia and Peninsular terranes. About 30 areas of known and possibly concealed granitic plutons (greater than several km diameter) in the tract are delineated by large, blotchy magnetic highs on the aeromagnetic map of Alaska (Godson, 1994) and (or) by K and eU or eTh highs interpreted from sparse data on radiometric maps (J.D. Phillips, and F. Riggle, written commun., 1994).

The distribution of the geologic units defining the tract is adapted from Nokleberg and others (1994). The distribution of this belt of mineral deposits is adapted from MacKevett and others (1978) and Nokleberg and others (1987, 1993). Mineral resource assessments of 250,000-scale quadrangles within this tract were done by Richter and others (1975), MacKevett (1976), Singer and MacKevett (1977) Singer and others (1980), Reed and others (1979), Cox and others (1989), and Nokleberg and others (1990).

Important Examples of Deposit Type

Examples of polymetallic vein deposits that may indicate porphyry copper deposits at depth in this tract are the Golden Zone mine, and the Mayflower, Nim, and Nimbus prospects in the Healy quadrangle (Hawley and Clark, 1974; Swainbank and others, 1977). An example of a porphyry Cu-Mo deposit in this tract is the Treasure Creek deposit in the Talkeetna Mountains (Richter, 1963) quadrangle. An associated gold-bearing Cu skarn deposit occurs at the Zackly deposit (Nokleberg and others, 1990). Associated placer gold deposits in the Valdez Creek, Willow Creek, and Yenta districts in the tract (Capps, 1913, 1915, 1919; Chapin, 1918; Mertie, 1919; Tuck, 1938; Jasper, 1967; Smith, 1970; Cobb, 1973, Bressler and others, 1985; Fechner and Herzog, 1990; Reger and Bundtzen, 1990) may be partly derived from porphyry Cu deposits and occurrences.

Rationale for Numerical Estimates

Tertiary and older rocks in the tract locally are covered by extensive ice fields and glaciers, and by Cenozoic sedimentary and volcanic rocks. Additional detailed exploration might result in the discovery of additional deposits or occurrences. The minimum number of undiscovered porphyry Cu deposits, consistent with the grade and tonnage model of Menzie and Singer (1993), is estimated to be:

Percentile	90	50	10	5	1
Estimated number of deposits	1	2	6	6	6

References

- Bressler, J.R., Jones, W.C. and Cleveland, Gaylord, 1985, Geology of a buried channel system of the Denali Placer Gold Mine: Alaska Miner, January, 1985, p. 9.
- Capps, S.R., 1913, The Yentna district, Alaska: U.S. Geological Survey Bulletin 534, 75 p.
- Capps, S.R., 1915, The Willow Creek district, Alaska: U.S. Geological Survey Bulletin 607, 86 p.
- Capps, S.R., 1919, The Kantishna region, Alaska: U.S. Geological Survey Bulletin 687, 116 p.
- Chapin, Theodore, 1918, The Nelchina-Susitna region, Alaska: U.S. Geological Survey Bulletin 668, 67 p.
- Cobb, E.H., 1973, Placer deposits of Alaska: U.S. Geological Survey Bulletin 1324, 213 p.
- Cox, D.P., 1986, Descriptive model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p 76.
- Cox, D.P., Light, T.D., Csejtey, Béla, and Campbell, D.L., 1989, Mineral resource assessment map of the Healy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2058-A, scale 1:250,000.
- Fechner, S.A. and Herzog, D.A., 1990, Gold- and PGM-bearing conglomerate of the Valdez Creek mining district, Alaska: U.S. Bureau of Mines Open File 12-90, 52 p.
- Godson, Richard H., 1994, Composite magnetic anomaly map of Alaska and adjacent offshore area, *in* Plafker, G. and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America: The Geology of North America, v. G1, plate 10, scale 1:2,500,000.
- Hawley, C.C., and Clark, A.L., 1974, Geology and mineral deposits of the upper Chulitna district, Alaska: U.S. Geological Survey Professional Paper 758-B, 47 p.
- Hollister, V.F., 1978, Geology of the porphyry copper deposits of the Western Hemisphere: New York, Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., 219 p.
- Hollister, V.F., Anzalone, S.A., and Richter, D.H., 1975, Porphyry copper deposits of southern Alaska and contiguous Yukon Territory: Canadian Mining and Metallurgy Bulletin, v. 68, p. 104-112.
- Jasper, M.W., 1967, Geochemical investigations, Willow Creek southerly to Kenai Lake region, south central Alaska: Alaska Division of Mines and Minerals Geochemical Report 14, 47 p.
- MacKevett, E.M., 1976, Mineral deposits and occurrences in the McCarthy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-773B, scale 1:250,000, 2 sheets.
- MacKevett, E.M., Jr., Singer, D.A., and Holloway, C.D., 1978, Maps and tables describing metalliferous mineral resource potential of southern Alaska: U.S. Geological Survey Open-File Report 78-1E, 2 sheets, scale 1:1,000,000, 45 p.
- Menzie, W.D., and Singer, D.A., 1993, Grade and tonnage model of porphyry Cu deposits in British Columbia, Canada, and Alaska, U.S.A.: U.S. Geological Survey Open-File Report 93-275, 9 p.
- Mertie, J.B., 1919, Platinum-bearing placers of the Kahlitna Valley: U.S. Geological Survey Bulletin 692, p. 233-264.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987. Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.
- Nokleberg, W.J., Bundtzen, T.K., Grybeck, Donald, Koch, R.D., Eremin, R.A., Rozenblum, I.S., Sidorov, A.A., Byalobzhesky, S.G., Sosunov, G.M., Shpikerman, V.I., and Gorodinsky, M.E., 1993, Metallogenesis of mainland Alaska and the Russian Northeast: Mineral deposit maps, models, and tables, metallogenic belt maps and interpretation, and references cited: U.S. Geological Survey Open-File Report 93-339, 222 pages, 1 map, scale 1:4,000,000; 5 maps, scale 1:10,000,000.
- Nokleberg, W.J., Lange, I.M., Singer, D.A., Curtin, G.C., Tripp, R.B., Campbell, D.L., and Yeend, Warren, 1990, Mineral resource assessment maps of the Mount Hayes quadrangle, eastern Alaska Range, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1996-A, 4 sheets, scale 1:250,000, 22 p.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 53 p., scale 1:2,500,000.
- Reed, B.L., Nelson, S.W., Curtin, G.C., and Singer, D.A., 1979, Mineral resources map of the Talkeetna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-870-D, 1 sheet, scale 1:250,000.
- Reger, R.D. and Bundtzen, T.K., 1990, Multiple glaciation and placer gold formation, Valdez Creek Valley, Western Clearwater Mountains, Alaska: Alaska Division of Geological and Geophysical Surveys Professional Paper 107, 29 p., 1 sheet, scale 1:63,360.

- Richter, D.H., 1963, Geology of the Portage Creek-Susitna River area, Alaska: Alaska Division of Mines and Minerals Geologic Report 3, 2 sheets, scale 1:24,000.
- Richter, D.H., Singer, D.A., and Cox, D.P., 1975, Mineral resources map of the Nabesna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-655-K, 1 sheet, scale 1:250,000.
- Singer, D. A., Csejtey, Bèla, Jr., and Miller, R.J., 1980, Map and discussion of the metalliferous and selected non-metalliferous mineral resources of Talkeetna Mountains quadrangle, Alaska: U.S. Geological Survey Open-File Report 78-558-Q, 34 p., 1 sheet, scale 1:250,000.
- Singer, D.A., and MacKevett, E.M., Jr., 1977, Mineral resources map of the McCarthy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-773-C, 1 sheet, scale 1:250,000.
- Smith, T.E., 1970, Gold resource potential of the Denali bench gravels, Valdez Creek Mining District, Alaska: U.S. Geological Survey Professional Paper 700-D, p. D146-D152.
- Swainbank, R.C., Smith, T.E., and Turner, D.L., 1977, Geology and K-Ar age of mineralized intrusive rocks from the Chulitna mining district, central Alaska: Alaska Division of Geological and Geophysical Surveys Geologic Report 55, p. 23-28.
- Tuck, Ralph, 1938, The Valdez Creek mining district, Alaska, in 1936: U.S. Geological Survey Bulletin 897-B, p. 109-131.

Descriptive Model: 17.1

Mark3 Index: 89

Area: 37,930 km²

Mean undiscovered deposits: 15.93

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Warren J. Nokleberg, Dennis P. Cox, Richard J. Goldfarb, David L. Campbell, and Warren Yeend.

Rationale for Model Choice

Parts of the Alaska Range and Wrangell Mountains are permissive for Late Jurassic and Early Cretaceous porphyry Cu and associated granitic-magmatism-related deposits because of favorable bedrock geology, three large porphyry Cu deposits and two prospects, and two associated Cu skarn occurrences, geochemical anomalies (Cu, Mo, Bi, Au, As, Ag, Pb, Zn, Co, Fe), and local aeromagnetic anomalies. This porphyry Cu model (17) also includes porphyry Cu (BC-Ak type) (17.1), porphyry Cu skarn (18a), porphyry Cu-Au (20c), and porphyry Cu-Mo (21). Details of the deposit model for this tract and other areas of Alaska and British Columbia are provided by Hollister (1978), Hollister and others (1975), Cox (1986), and Menzie and Singer (1993).

Rationale for Tract Delineation

The favorable geologic units in this two-part tract are Late Jurassic and Early Cretaceous granitic rocks that intrude the Gravina-Nutzotin belt and adjacent sedimentary and volcanic rocks of Wrangellia terrane, and carbonate rocks altered to skarn in areas where intruded by the Jurassic and Early Cretaceous granitic rocks. The principal mineral deposit models are porphyry Cu, Cu skarn, porphyry Cu-Mo, and Cu (Au) skarn, and polymetallic vein, but related deposits could also occur. Local porphyry Cu occurrences exhibit multiple intrusive phases, propylitic and sericitic alteration. About 25 areas of known and possibly concealed granitic plutons (greater than several km diameter) in the tract are delineated by large, blotchy magnetic highs on the aeromagnetic map of Alaska (Godson, 1994) and (or) by K and eU or eTh highs interpreted from sparse data on radiometric maps (J.D. Phillips and F. Riggle, written commun., 1994).

The distribution of the geologic units defining the tract is adapted from Nokleberg and others (1994). The distribution of this belt of mineral deposits is adapted from MacKevett and others (1978) and Nokleberg and others (1987, 1993). Mineral resource assessments of 250,000-scale quadrangles within the tract were done by Richter and others (1975), MacKevett (1976), Singer and MacKevett (1977), Singer and others (1980), Reed and others (1979), Cox and others (1989), and Nokleberg and others (1990).

Important Examples of Deposit Type

Examples in the tract are the Baultoff, Orange Hill, Horsfeld, Bond Creek, and Carl Creek porphyry Cu and Cu-Mo deposits and occurrences, all in the Nabesna quadrangle (Van Alstine and Black, 1946; Richter and others, 1975). Associated deposits in the same area are the Lemons and Copper King Cu skarn occurrences, and the Nabesna Au (Cu) skarn mine. Associated placer gold deposits in the Chisana, Chistochina, Delta River, Nizina, and Valdez Creek districts in the tract (Moffit, 1914; Chapin, 1918; Capps, 1916, 1919; Tuck, 1938; Smith, 1941, 1970; Rose, 1965, 1967; Richter and Matson, 1972; Cobb, 1973; Cobb and MacKevett, 1980; Yeend, 1981a, b; Bressler and others, 1985; Fechner and Herzog, 1990; Nokleberg and others, 1990; Reger and Bundtzen, 1990) may be partly derived from porphyry Cu mines and occurrences.

Rationale for Numerical Estimates

Tertiary and older rocks in the tract are covered locally by extensive ice fields and glaciers, and by Cenozoic sedimentary and volcanic rocks. Additional detailed exploration might result in the discovery of additional deposits or occurrences. The minimum number of undiscovered porphyry Cu deposits, consistent with the grade and tonnage model of Menzie and Singer (1993), is estimated to be:

Percentile	90	50	10	5	1
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References

- Bressler, J.R., Jones, W.C. and Cleveland, Gaylord, 1985, Geology of a buried channel system of the Denali Placer Gold Mine: Alaska Miner, January, 1985, p. 9.
- Capps, S.R., 1916, The Chisana-White River district, Alaska: U.S. Geological Survey Bulletin 630, 130 p.
- Capps, S.R., 1919, The Kantishna region, Alaska: U.S. Geological Survey Bulletin 687, 116 p.
- Chapin, Theodore, 1918, The Nelchina-Susitna region, Alaska: U.S. Geological Survey Bulletin 668, 67 p.
- Capps, S.R., 1916, The Chisana-White River district, Alaska: U.S. Geological Survey Bulletin 630, 130 p.
- Cobb, E.H., 1973, Placer deposits of Alaska: U.S. Geological Survey Bulletin 1324, 213 p.
- Cobb, E.H., and MacKevett, E.M., Jr., 1980, Summaries of data on and lists of references to metallic and selected nonmetallic mineral deposits in the McCarthy quadrangle, Alaska: U.S. Geological Survey Open-File Report 80-885, 156 p.
- Cox, D.P., 1986, Descriptive model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p 76.
- Cox, D.P., Light, T.D., Csejtey, Béla, and Campbell, D.L., 1989, Mineral resource assessment map of the Healy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2058-A, scale 1:250,000.
- Fechner, S.A. and Herzog, D.A., 1990, Gold- and PGM-bearing conglomerate of the Valdez Creek mining district, Alaska: U.S. Bureau of Mines Open File 12-90, 52 p.
- Godson, Richard H., 1994, Composite magnetic anomaly map of Alaska and adjacent offshore area, *in* Plafker, G. and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America: The Geology of North America, v. G1, plate 10, scale 1:2,500,000.
- Hollister, V.F., 1978, Geology of the porphyry copper deposits of the Western Hemisphere: New York, Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., 219 p.
- Hollister, V.F., Anzalone, S.A., and Richter, D.H., 1975, Porphyry copper deposits of southern Alaska and contiguous Yukon Territory: Canadian Mining and Metallurgy Bulletin, v. 68, p. 104-112.
- MacKevett, E.M., Jr., Singer, D.A., and Holloway, C.D., 1978, Maps and tables describing metalliferous mineral resource potential of southern Alaska: U.S. Geological Survey Open-File Report 78-1E, 2 sheets, scale 1:1,000,000, 45 p.
- Menzie, W.D., and Singer, D.A., 1993, Grade and tonnage model of porphyry Cu deposits in British Columbia, Canada, and Alaska, U.S.A.: U.S. Geological Survey Open-File Report 93-275, 9 p.
- Moffit, F.H., 1914, Geology of the Hanagita-Bremner region, Alaska: U.S. Geological Survey Bulletin 576, 56 p.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987, Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.
- Nokleberg, W.J., Bundtzen, T.K., Grybeck, Donald, Koch, R.D., Eremin, R.A., Rozenblum, I.S., Sidorov, A.A., Byalobzhesky, S.G., Sosunov, G.M., Shpikerman, V.I., and Gorodinsky, M.E., 1993, Metallogenesis of mainland Alaska and the Russian Northeast: Mineral deposit maps, models, and tables, metallogenic belt maps and interpretation, and references cited: U.S. Geological Survey Open-File Report 93-339, 222 pages, 1 map, scale 1:4,000,000; 5 maps, scale 1:10,000,000.
- Nokleberg, W.J., Lange, I.M., Singer, D.A., Curtin, G.C., Tripp, R.B., Campbell, D.L., and Yeend, Warren, 1990, Mineral resource assessment maps of the Mount Hayes quadrangle, eastern Alaska Range, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1996-A, 4 sheets, scale 1:250,000, 22 p.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 53 p., scale 1:2,500,000.
- Reed, B.L., Nelson, S.W., Curtin, G.C., and Singer, D.A., 1979, Mineral resources map of the Talkeetna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-870-D, 1 sheet, scale 1:250,000.
- Reger, R.D. and Bundtzen, T.K., 1990, Multiple glaciation and placer gold formation, Valdez Creek Valley, Western Clearwater Mountains, Alaska: Alaska Division of Geological and Geophysical Surveys Professional Paper 107, 29 p., 1 sheet, scale 1:63,360.

- Richter, D.H., and Matson, N.A., Jr., 1972, Metallic mineral resources map of the Nabesna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-422.
- Richter, D.H., Singer, D.A., and Cox, D.P., 1975, Mineral resources map of the Nabesna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-655-K, 1 sheet, scale 1:250,000.
- Rose, A.W., 1965, Geology and mineral deposits of the Rainy Creek area, Mt. Hayes quadrangle, Alaska: Alaska Division of Mines and Minerals Geologic Report 14, 51 p.
- Rose, A.W., 1967, Geology of the upper Chistochina River area, Mt. Hayes quadrangle, Alaska: Alaska Division of Mines and Minerals Geologic Report 28, 41 p.
- Singer, D. A., Csejtey, Bèla, Jr., and Miller, R.J., 1980, Map and discussion of the metalliferous and selected non-metalliferous mineral resources of Talkeetna Mountains quadrangle, Alaska: U.S. Geological Survey Open-File Report 78-558-Q, 34 p., 1 sheet, scale 1:250,000.
- Singer, D.A., and MacKevett, E.M., Jr., 1977, Mineral resources map of the McCarthy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-773-C, 1 sheet, scale 1:250,000.
- Smith, P.S., 1941, Mineral industry of Alaska in 1939: U.S. Geological Survey Bulletin 926-A, p. 1-106.
- Smith, T.E., 1970, Gold resource potential of the Denali bench gravels, Valdez Creek Mining District, Alaska: U.S. Geological Survey Professional Paper 700-D, p. D146-D152.
- Tuck, Ralph, 1938, The Valdez Creek mining district, Alaska, in 1936: U.S. Geological Survey Bulletin 897-B, p. 109-131.
- Van Alstine, R.E., and Black, R.F., 1946, Copper deposits of the Kotsina-Kuskulana district, Alaska: U.S. Geological Survey Bulletin 947-G, p. 121-141.

Descriptive Model: 17.1

Mark3 Index: 89

Area: 17,242 km²

Mean undiscovered deposits: 1.93

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Warren J. Nokleberg, Dennis P. Cox, Richard J. Goldfarb, David L. Campbell, and Warren Yeend.

Rationale for Model Choice

Parts of the Alaska Range and Wrangell Mountains are permissive for late Paleozoic porphyry Cu deposits because of favorable bedrock geology, two porphyry Cu occurrences and one associated Cu skarn occurrence, and anomalous high concentrations of Cu, Mo, Au, As, Ag, Bi, Pb, Zn, Co, and Fe in stream-sediment and heavy-mineral-concentrate samples. This porphyry Cu model (17.1) includes porphyry Cu skarn (18a), porphyry Cu-Au (20c), and porphyry Cu-Mo (21). Details of the deposit model for this tract and other areas in Alaska and British Columbia are provided by Hollister (1978), Hollister and others (1975), Cox (1986), and Menzie and Singer (1993).

Rationale for Tract Delineation

The favorable geologic units defining this two-part tract are the Late Paleozoic granitic plutons of the Skolai arc that intrude Permian and older rocks of the Wrangellia terrane, and carbonate rocks altered to skarn in areas where intruded by the late Paleozoic igneous rocks. The principal mineral deposit models are porphyry Cu and Cu skarn, but related deposits could also occur. Local zonation of geochemical anomalies exists. Local porphyry Cu occurrences exhibit multiple intrusive phases and propylitic and sericitic alteration. About 15 areas of known and possibly concealed granitic plutons (greater than several km diameter) in the tract are delineated by large, blotchy magnetic highs on the aeromagnetic map of Alaska (Godson, 1994) and (or) by K and eU or eTh highs interpreted from sparse data on radiometric maps (J.D. Phillips, and F. Riggle, written commun., 1994).

The distribution of the geologic units defining the tract is adapted from Nokleberg and others (1994). The distribution of this belt of mineral deposits is adapted from MacKevett and others (1978) and Nokleberg and others (1987, 1993). Mineral resource assessments of 250,000-scale quadrangles within this tract were done by Richter and others (1975), MacKevett (1976), Singer and MacKevett (1977), Singer and others (1980), Reed and others (1979), Cox and others (1989), and Nokleberg and others (1990).

Important Examples of Deposit Type

Examples in this tract are the porphyry Cu occurrences at Rainbow Mountain and Slate Creek (Nokleberg and others, 1991) in the Mount Hayes quadrangle. Minor base metal polymetallic vein and Cu skarn occurrences are also in this tract. Associated placer gold deposits in the Chisana, Chistochina, and Delta River districts in the tract (Capps, 1916; Rose, 1965, 1967; Richter and Matson, 1972; Yeend, 1981a, b; Nokleberg and others, 1990) may be partly derived from porphyry Cu occurrences.

Rationale for Numerical Estimates

Tertiary and older rocks in the tract locally are covered by extensive ice fields and glaciers, and by Cenozoic sedimentary and volcanic rocks. Because deposits are known in the tract, additional detailed exploration might result in the discovery of porphyry Cu deposits. The minimum number of undiscovered deposits, consistent with the grade and tonnage model of Menzie and Singer (1993), is expected to be:

Percentile	90	50	10	5	1
Estimated number of deposits	0	0	1	2	3

References

Capps, S.R. 1916, The Chisana-White River district, Alaska: U.S. Geological Survey Bulletin 630, 130 p.

- Cox, D.P., 1986, Descriptive model of porphyry Cu deposits, *in* Cox, D.P., and Singer, D.A., 1986, eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 76.
- Cox, D.P., Light, T.D., Csejtey, Béla, and Campbell, D.L., 1989, Mineral resource assessment map of the Healy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2058-A, scale 1:250,000.
- Godson, Richard H., 1994, Composite magnetic anomaly map of Alaska and adjacent offshore area, *in* Plafker, G. and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America: The Geology of North America, v. G1, plate 10, scale 1:2,500,000.
- Hollister, V.F., 1978, Geology of the porphyry copper deposits of the Western Hemisphere: New York, Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., 219 p.
- Hollister, V.F., Anzalone, S.A., and Richter, D.H., 1975, Porphyry copper deposits of southern Alaska and contiguous Yukon Territory: Canadian Mining and Metallurgy Bulletin, v. 68, p. 104-112.
- MacKevett, E.M., 1976, Mineral deposits and occurrences in the McCarthy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-773B, scale 1:250,000, 2 sheets.
- MacKevett, E.M., Jr., Singer, D.A., and Holloway, C.D., 1978, Maps and tables describing metalliferous mineral resource potential of southern Alaska: U.S. Geological Survey Open-File Report 78-1E, 2 sheets, scale 1:1,000,000, 45 p.
- Menzie, W.D., and Singer, D.A., 1993, Grade and tonnage model of porphyry Cu deposits in British Columbia, Canada, and Alaska, U.S.A.: U.S. Geological Survey Open-File Report 93-275, 9 p.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987, Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.
- Nokleberg, W.J., Bundtzen, T.K., Grybeck, Donald, Koch, R.D., Eremin, R.A., Rozenblum, I.S., Sidorov, A.A., Byalobzhesky, S.G., Sosunov, G.M., Shpikerman, V.I., and Gorodinsky, M.E., 1993, Metallogenesis of mainland Alaska and the Russian Northeast: Mineral deposit maps, models, and tables, metallogenic belt maps and interpretation, and references cited: U.S. Geological Survey Open-File Report 93-339, 222 pages, 1 map, scale 1:4,000,000; 5 maps, scale 1:10,000,000.
- Nokleberg, W.J., Lange, I.M., Roback, R.C., Yeend, Warren, and Silva S.R., 1991, Map showing locations of metalliferous lode and placer mineral occurrences, deposits, prospects, and mines, Mount Hayes quadrangle, eastern Alaska Range, Alaska: U.S. Geological Survey Map MF-1996-C, 42 p., 1 sheet, scale 1:250,000.
- Nokleberg, W.J., Lange, I.M., Singer, D.A., Curtin, G.C., Tripp, R.B., Campbell, D.L., and Yeend, Warren, 1990, Mineral resource assessment maps of the Mount Hayes quadrangle, eastern Alaska Range, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1996-A, 4 sheets, scale 1:250,000, 22 p.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 53 p., scale 1:2,500,000.
- Reed, B.L., Nelson, S.W., Curtin, G.C., and Singer, D.A., 1979, Mineral resources map of the Talkeetna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-870-D, 1 sheet, scale 1:250,000.
- Richter, D.H., and Matson, N.A., Jr., 1972, Metallic mineral resources map of the Nabesna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-422.
- Richter, D.H., Singer, D.A., and Cox, D.P., 1975, Mineral resources map of the Nabesna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-655-K, 1 sheet, scale 1:250,000.
- Rose, A.W., 1965, Geology and mineral deposits of the Rainy Creek area, Mt. Hayes quadrangle, Alaska: Alaska Division of Mines and Minerals Geologic Report 14, 51 p.
- Rose, A.W., 1967, Geology of the upper Chistochina River area, Mt. Hayes quadrangle, Alaska: Alaska Division of Mines and Minerals Geologic Report 28, 41 p.
- Singer, D. A., Csejtey, Béla, Jr., and Miller, R.J., 1980, Map and discussion of the metalliferous and selected non-metalliferous mineral resources of Talkeetna Mountains quadrangle, Alaska: U.S. Geological Survey Open-File Report 78-558-Q, 34 p., 1 sheet, scale 1:250,000.
- Singer, D.A., and MacKevett, E.M., Jr., 1977, Mineral resources map of the McCarthy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-773-C, 1 sheet, scale 1:250,000.
- Yeend, Warren, 1981a, Placer gold deposits, Mt. Hayes quadrangle, Alaska, *in* Silberman, Miles and others, eds., Proceedings of the Symposium of Mineral Deposits of the Pacific Northwest: U.S. Geological Survey Open-File Report 81-355, p. 74-83.

Yeend, Warren, 1981b, Placer gold deposits, Mount Hayes quadrangle, Alaska, *in* Albert, N.R.D., and Hudson, Travis, eds., The United States Geological Survey in Alaska: Accomplishments during 1979: U.S. Geological Survey Circular 823-B, p. B68.

Descriptive Model: 43

Mark3 Index: 43

Area 46,929 k^m²

Mean undiscovered deposits: 4.33

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Warren J. Nokleberg, Dennis P. Cox, Richard J. Goldfarb, David L. Campbell, and Warren Yeend.

Rationale for Model Choice

This tract, in the southern Yukon-Tanana Upland, is permissive for Late Cretaceous and early Tertiary plutonic porphyry Au deposits (Hollister, 1992) because of favorable bedrock geology, a known mine, and geochemical anomalies (Au, As, Au).

Rationale for Tract Delineation

The tract is delineated by the distribution of deposits and of the Upper Cretaceous and possibly lower Tertiary (80-100 Ma) granitic plutons, dikes, and sills of the Kluane arc. The plutonic porphyry Au deposits are associated with polymetallic vein and Sb-Au polymetallic veins. Some known and possibly concealed granitic plutons in the tract are delineated by large, blotchy magnetic highs and (or) eU or eTh cells interpreted from sparse data on radiometric maps. For simplicity, the tract is restricted to the area east of the Delta River and north of the Tanana River where deposits of this type are known.

The distribution of the geologic units defining the tract is adapted from Nokleberg and others (1994). The distribution of this belt of mineral deposits is adapted from MacKevett and others (1978) and Nokleberg and others (1987, 1993). This tract is coincident with tracts described as permissive for porphyry Cu deposits and for gold-antimony vein deposits. Mineral resource assessments of 250,000-scale quadrangles within the tract were done by Richter and others (1975), Singer and others (1977), Cox and others (1989), and Nokleberg and others (1990).

Important Examples of Deposit Type

The Democrat mine in the Richardson district (Bundtzen and Reger, 1977; Nokleberg and others, 1993) is an important example of this deposit type, and may be similar to the Fort Knox plutonic porphyry Au deposit near Fairbanks (Robinson and others, 1990; Hollister, 1992). Placer Au mines in the Bonfield, Delta River, and Kantishna districts in the region (Capps, 1912, 1919; Smith, 1941; Rose, 1965; Cobb, 1973; Gilbert and Bundtzen, 1979; Bundtzen, 1981; Nokleberg and others, 1990) may in part be derived from plutonic porphyry Au deposits.

Rationale for Numerical Estimates

Much of the tract is covered by glacial loess and dense vegetation, which may obscure additional porphyry Au deposits. Favorable geological and geochemical data suggest that at least one additional undiscovered deposit probably occurs in the tract. The mineral resource team estimated the minimum number of undiscovered deposits, consistent with a tonnage and grade model constructed from deposit data reported by Hollister (1992), to be:

Percentile	90	50	10	5	1
Estimated number of deposits	1	5	7	7	7

References

- Bundtzen, T.K., 1981, Geology and mineral deposits of the Kantishna Hills, Mount McKinley quadrangle, Alaska: Fairbanks, Alaska, University of Alaska, M.S. thesis, 237 p, 4 sheets, scale 1:63,360.
- Bundtzen, T.K., and Reger, R.D., 1977. The Richardson lineament, a structural control for gold deposits in the Richardson mining district, interior Alaska. In Short Notes on Alaska Geology - 1977. Alaska Division of Geological and Geophysical Surveys Geologic Report 55, p. 29-34.

- Capps, S.R., 1912, The Bonnifield region, Alaska: U.S. Geological Survey Bulletin 501, 64 p.
- Capps, S.R., 1919, The Kantishna region, Alaska: U.S. Geological Survey Bulletin 687, 118 p.
- Cobb, E.H., 1973, Placer deposits of Alaska: U.S. Geological Survey Bulletin 1324, 213 p.
- Cox, D.P., Light, T.D., Csejtei, Béla, and Campbell, D.L., 1989, Mineral resource assessment map of the Healy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2058-A, scale 1:250,000.
- Gilbert, W.G., and Bundtzen, T.K., 1979, Mid-Paleozoic tectonics, volcanism, and mineralization in north-central Alaska Range, in Sisson, A., ed., The relationship of plate tectonics to Alaskan geology and resources: Alaska Geological Society, Symposium, 1977, p. F1-F21.
- Hollister, V.F., 1992. On a proposed plutonic porphyry gold deposit model. *Non-renewable resources*, 1, p. 293-302.
- MacKevett, E.M., Jr., Singer, D.A., and Holloway, C.D., 1978, Maps and tables describing metalliferous mineral resource potential of southern Alaska: U.S. Geological Survey Open-File Report 78-1E, 2 sheets, scale 1:1,000,000, 45 p.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987. Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.
- Nokleberg, W.J., Bundtzen, T.K., Grybeck, Donald, Koch, R.D., Eremin, R.A., Rozenblum, I.S., Sidorov, A.A., Byalobzhesky, S.G., Sosunov, G.M., Shpikerman, V.I., and Gorodinsky, M.E., 1993, Metallogenesis of mainland Alaska and the Russian Northeast: Mineral deposit maps, models, and tables, metallogenic belt maps and interpretation, and references cited: U.S. Geological Survey Open-File Report 93-339, 222 pages, 1 map, scale 1:4,000,000; 5 maps, scale 1:10,000,000.
- Nokleberg, W.J., Lange, I.M., Singer, D.A., Curtin, G.C., Tripp, R.B., Campbell, D.L., and Yeend, Warren, 1990, Mineral resource assessment maps of the Mount Hayes quadrangle, eastern Alaska Range, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1996-A, 4 sheets, scale 1:250,000, 22 p.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 53 p., scale 1:2,500,000.
- Richter, D.H., Singer, D.A., and Cox, D.P., 1975, Mineral resources map of the Nabesna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-655-K, 1 sheet, scale 1:250,000.
- Rose, A.W., 1965, Geology and mineral deposits of the Rainy Creek area, Mt. Hayes quadrangle, Alaska: Alaska Division of Mines and Minerals Geologic Report 14, 51 p.
- Robinson, M.S., Smith, T.E., and Metz, P.A., 1990, Bedrock geology of the Fairbanks mining district: Alaska Division of Geological and Geophysical Surveys Professional Report 106, 1 sheet, scale 1:63,360.
- Singer, D.A., Curtin, G.C., and Foster, H.L., 1977, Mineral resources map of the Tanacross quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-767-E, 1 sheet, scale 1:250,000.
- Smith, P.S., 1941, Mineral industry of Alaska in 1939: U.S. Geological Survey Bulletin 926-A, p. 1-106.

Descriptive Model: 39a**Mark3 Index: 54****Area: 266,047 km²****Mean undiscovered deposits: (no estimate)**[Model](#)[Mineral Deposits](#)

by Warren J. Nokleberg Dennis P. Cox, Richard J. Goldfarb, and Warren Yeend

Rationale for Model Choice

Placer gold can be expected to occur in unconsolidated deposits downstream from any of the gold-bearing deposit types. Therefore the permissive area for placer and paleoplacer gold is quite broad.

Rationale for Tract Delineation

Excluded from being permissive are the following areas: (1) prohibitively steep modern stream gradients; (2) elevations above approximately 1,600 m; (3) extensive ice-covered terrain; and (4) upper Tertiary and Quaternary volcanic rocks.

Important Examples of Deposit Type

Eleven placer districts in the region have produced substantial placer gold (Cobb, 1964; MacKevett and others, 1978). The most important of these is the Valdez Creek District, which has produced nearly 1/2 million ounces of gold (Bundtzen and others, 1994).

Rationale for Numerical Estimates

Because of the relative ease of exploring for placer gold deposits, much of the state has been thoroughly explored. There is a low probability that major new placer districts will be discovered, but it is likely that a few relatively small new deposits will be found in the known districts. No estimate of the number of undiscovered deposits was attempted.

References

- Bundtzen, T.K., Swainbank, R.C., Clough, A.H., Henning, M.W., and Hansen, E.W., 1994, Alaska's Mineral Industry: Alaska Division of Geological and Geophysical Surveys Special Report 48, 84 p.
- Cobb, E.H., 1964, Placer gold occurrences in Alaska: U.S. Geological Survey Mineral Investigations Resources Map MR-38, scale 1:250,000.
- MacKevett, E.M., Jr., Singer, D.A., and Holloway, C.D., 1978, Maps and tables describing metalliferous mineral resource potential of southern Alaska: U.S. Geological Survey Open-File Report 78-1E, 2 sheets, scale 1:1,000,000, 45 p.

Descriptive Model: 19a

Mark3 Index: 47

Area: 4,445 km²

Mean undiscovered deposits: (no estimate)

[Model](#)*by* Marti L. Miller, Bruce M. Gamble, and Thomas D. Light**Rationale for Model Choice**

In south-central Alaska and nearby parts of southwestern, west-central, and east-central Alaska, carbonate rocks that are locally intruded by small felsic plutons may host polymetallic replacement deposits as described by Morris (1986).

Rationale for Tract Delineation

The areas permissive for polymetallic replacement deposits are defined by Paleozoic carbonate rocks, belonging to the Nixon Fork and Minchumina terranes, that are locally intruded by Late Cretaceous and Tertiary plutons (Patton and others, 1994). This tract is a continuation of adjacent tracts in southwestern, east-central, and west-central Alaska.

Important Examples of Deposit Type

No examples of polymetallic replacement deposits are known in this tract.

Rationale for Numerical Estimates

No estimate of undiscovered resources was attempted.

References

- Morris, H.T., 1986, Descriptive model of polymetallic replacement deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 99-100.
- Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1994, Geology of west-central Alaska, *in* Plafker, George, and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G-1, p. 241-269.

Descriptive Model: 22c**Mark3 Index: 52****Area: 50,568 km²****Mean undiscovered deposits: (no estimate)**[Model](#)[Mineral Deposits](#)

by Donald Grybeck, Thomas D. Light, Warren J. Nokleberg, William J. Keith, Dennis P. Cox, Gregory K. Lee, and Jeffrey D. Phillips.

Rationale for Model Choice

Polymetallic vein deposits can be associated with intrusive rocks of any age and a wide range of compositions (Cox, 1986). Polymetallic veins may also be spatially related to a large number of other types of deposits, thus making their permissive area quite extensive. This model also serves as somewhat of a catch-all for deposits of unknown type that, given minimal information, do not appear to fit into other similar categories

Rationale for Tract Delineation

The permissive area for polymetallic veins is considered to be the entire extent of the Yukon-Tanana Upland and the Kohnen-Hodzana Highlands of Wahrhaftig (1965), which comprise the southern and western portions of east central Alaska and the northern portion of south-central Alaska. This area is predominately Paleozoic metamorphic and sedimentary units intruded by Late Cretaceous and early Tertiary granitic plutons, dikes, and sills of the Kluane arc. Geophysical and geochemical data may support the permissive classification of large areas where no polymetallic vein deposits are known. This tract is contiguous to the permissive tract in east-central Alaska.

Important Examples of Deposit Type

The Banjo and Quigley Ridge deposits in the Mount McKinley quadrangle (Nokleberg and others, 1987), as well as many of the veins in the Fairbanks area can be classified as polymetallic veins. Insufficient information precludes a more detailed classification in many cases.

Rationale for Numerical Estimates

No estimates of the undiscovered polymetallic veins in this tract was attempted because of the lack of detailed geologic information.

References

Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987. Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.
Wahrhaftig, Clyde, 1965, Physiographic Divisions of Alaska: U.S. Geological Survey Professional Paper 482, 52 p.

Descriptive Model: 22c

Mark3 Index: 52

Area: 79,025 km²

Mean undiscovered deposits: 4.33

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Warren J. Nokleberg, Dennis P. Cox, Richard J. Goldfarb, David L. Campbell, and Warren Yeend.

Rationale for Model Choice

Polymetallic vein deposits can be associated with intrusive rocks of any age and a wide range of compositions (Cox, 1986). Polymetallic veins may also be spatially related to a large number of other types of deposits, thus making their permissive area quite extensive. This model also serves as somewhat of a catch-all for deposits of unknown type that, given minimal information, do not appear to fit into other similar categories

Rationale for Tract Delineation

The favorable geologic units for this tract are mainly the Wrangellia and Peninsular terranes where locally intruded by the calc-alkaline granitic plutons, dikes, and sills of the Late Cretaceous and early Tertiary Kluane arc. Because concealed plutons and associated polymetallic vein deposits may occur near the surface, the tract includes all of the Wrangellia and Peninsular terranes. Placer Au mines in the region might be in part derived from polymetallic vein and associated granitic-magmatism-related deposits. Areas of known and possibly concealed granitic plutons (greater than several km diameter) in the tract are delineated by large, blotchy magnetic highs on the aeromagnetic map of Alaska (Godson, 1994) and (or) by K and eU or eTh highs interpreted from sparse data on radiometric maps (J.D. Phillips and F. Riggle, written commun., 1994). Geophysical and geochemical data support the permissive classification of large areas where no polymetallic vein deposits are known.

The distribution of the geologic units defining the tract is adapted from Nokleberg and others (1994). The distribution of this belt of mineral deposits is adapted from MacKevett and others (1978) and Nokleberg and others (1987, 1993). Mineral resource assessments of 250,000-scale quadrangles within the tract were done by Richter and others (1975), MacKevett (1976), Singer and MacKevett (1977), Singer and others (1980), Reed and others (1979), Cox and others (1989), Nokleberg and others (1990), and Madden-McGuire and Winkler (1993).

Important Examples of Deposit Type

Examples of polymetallic vein deposits in this tract are the Golden Zone mine, and the Nimbus, Silver King, and Mayflower deposits in the Healy quadrangle (Hawley and Clark, 1974; Swainbank and others, 1977), and the Nabesna Glacier prospect in the Nabesna quadrangle (Richter and others, 1975) are important examples of this type of deposit. Placer Au mines in the Bonnifield, Delta River, and Kantishna districts (Capps, 1912, 1919; Smith, 1941; Rose, 1965; Cobb, 1973; Gilbert and Bundtzen, 1979; Bundtzen, 1981; Nokleberg and others, 1991) may be partly derived from polymetallic veins.

Rationale for Numerical Estimates

The tract is covered locally by extensive ice fields and glaciers, and by Cenozoic sedimentary and volcanic rocks. Because deposits are known in the tract, detailed exploration might result in the discovery of additional deposits. An excellent possibility exists of at least one undiscovered deposit in the tract. The minimum number of undiscovered polymetallic vein deposits, consistent with the grade and tonnage model of Bliss and Cox (1986), are estimated to be:

Percentile	90	50	10	5	1
Estimated number of deposits	1	5	7	7	7

References

- Bliss, J.D., and Cox, D.P., 1986, Grade and tonnage model of polymetallic veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 125-129.
- Bundtzen, T.K., 1981, Geology and mineral deposits of the Kantishna Hills, Mount McKinley quadrangle, Alaska: Fairbanks, Alaska, University of Alaska, M.S. thesis, 237 p., 4 sheets, scale 1:63,360.
- Capps, S.R., 1912, The Bonnifield region, Alaska: U.S. Geological Survey Bulletin 501, 64 p.
- Capps, S.R., 1919, The Kantishna region, Alaska: U.S. Geological Survey Bulletin 687, 116 p.
- Cobb, E.H., 1973, Placer deposits of Alaska: U.S. Geological Survey Bulletin 1324, 213 p.
- Cox, D.P., 1986, Descriptive model of polymetallic veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 125.
- Cox, D.P., Light, T.D., Csejtey, Béla, and Campbell, D.L., 1989, Mineral resource assessment map of the Healy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2058-A, scale 1:250,000.
- Gilbert, W.G., and Bundtzen, T.K., 1979, Mid-Paleozoic tectonics, volcanism, and mineralization in north-central Alaska Range, *in* Sisson, A., ed., The relationship of plate tectonics to Alaskan geology and resources: Alaska Geological Society, Symposium, 1977, p. F1-F21.
- Godson, Richard H., 1994, Composite magnetic anomaly map of Alaska and adjacent offshore area, *in* Plafker, G. and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America: The Geology of North America, v. G1, plate 10, scale 1:2,500,000.
- Hawley, C.C., and Clark, A.L., 1974, Geology and mineral deposits of the upper Chulitna district, Alaska: U.S. Geological Survey Professional Paper 758-B, 47 p.
- MacKevett, E.M., Jr., Singer, D.A., and Holloway, C.D., 1978, Maps and tables describing metalliferous mineral resource potential of southern Alaska: U.S. Geological Survey Open-File Report 78-1E, 2 sheets, scale 1:1,000,000, 45 p.
- Madden-McGuire, D.J., and Winkler, G.R., 1993, Mineral resource maps of the Anchorage quadrangle, southern Alaska: U.S. Geological Survey Miscellaneous Investigations Map MI-2393, scale 1:250,000, 3 sheets.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987, Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.
- Nokleberg, W.J., Bundtzen, T.K., Grybeck, Donald, Koch, R.D., Eremin, R.A., Rozenblum, I.S., Sidorov, A.A., Byalobzhesky, S.G., Sosunov, G.M., Shpikerman, V.I., and Gorodinsky, M.E., 1993, Metallogenesis of mainland Alaska and the Russian Northeast: Mineral deposit maps, models, and tables, metallogenic belt maps and interpretation, and references cited: U.S. Geological Survey Open-File Report 93-339, 222 pages, 1 map, scale 1:4,000,000; 5 maps, scale 1:10,000,000.
- Nokleberg, W.J., Lange, I.M., Singer, D.A., Curtin, G.C., Tripp, R.B., Campbell, D.L., and Yeend, Warren, 1990, Mineral resource assessment maps of the Mount Hayes quadrangle, eastern Alaska Range, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1996-A, 4 sheets, scale 1:250,000, 22 p.
- Nokleberg, W.J., Lange, I.M., Roback, R.C., Yeend, Warren, and Silva S.R., 1991, Map showing locations of metalliferous lode and placer mineral occurrences, deposits, prospects, and mines, Mount Hayes quadrangle, eastern Alaska Range, Alaska: U.S. Geological Survey Map MF-1996-C, 42 p., 1 sheet, scale 1:250,000.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 53 p., scale 1:2,500,000.
- Reed, B.L., Nelson, S.W., Curtin, G.C., and Singer, D.A., 1979, Mineral resources map of the Talkeetna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-870-D, 1 sheet, scale 1:250,000.
- Rose, A.W., 1965, Geology and mineral deposits of the Rainy Creek area, Mt. Hayes quadrangle, Alaska: Alaska Division of Mines and Minerals Geologic Report 14, 51 p.
- Richter, D.H., Singer, D.A., and Cox, D.P., 1975, Mineral resources map of the Nabesna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-655-K, 1 sheet, scale 1:250,000.
- Singer, D. A., Csejtey, Béla, Jr., and Miller, R.J., 1980, Map and discussion of the metalliferous and selected non-metalliferous mineral resources of Talkeetna Mountains quadrangle, Alaska: U.S. Geological Survey Open-File Report 78-558-Q, 34 p., 1 sheet, scale 1:250,000.
- Singer, D.A., and MacKevett, E.M., Jr., 1977, Mineral resources map of the McCarthy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-773-C, 1 sheet, scale 1:250,000.

Smith, P.S., 1941, Mineral industry of Alaska in 1939: U.S. Geological Survey Bulletin 926-A, p. 1-106.

Swainbank, R.C., Smith, T.E., and Turner, D.L., 1977, Geology and K-Ar ages of mineralized intrusive rocks from the Chulitna mining district, central Alaska: Alaska Division of Geological and Geophysical Surveys Geologic Report 55, p. 23-28.

Descriptive Model: 22c**Mark3 Index: 52****Area: 16,669 km²****Mean undiscovered deposits: (no estimate)****Model**

by Warren J. Nokleberg, Dennis P. Cox, Richard J. Goldfarb, and David L. Campbell.

Rationale for Model Choice

Parts of the Wrangell Mountains are permissive for polymetallic vein deposits because of favorable Tertiary volcanic rocks and sparse hypabyssal granitic plutonic rocks, sparse geochemical anomalies (Ba, Pb, Zn, Sn, and Mo), local chalcopyrite and pyrite in heavy-mineral concentrates, and local aeromagnetic anomalies. The tract is not considered permissive for epithermal vein deposits because exploration geochemical data indicate undiscovered polymetallic rather than epithermal vein deposits, because of the lack of known epithermal vein deposits, and because of a lack of As, Sb, Ag, and Au geochemical anomalies.

Rationale for Tract Delineation

The favorable rock units defining the tract are the felsic volcanic and hypabyssal granitic plutonic rocks of the middle and late Cenozoic Wrangell Lava, a constructional Andean-arc-type volcanic complex. High volcanoes, mud volcanoes, and hot springs are characteristic of parts of the tract. Portions of the tract exhibit areas of bleaching and silicification; heavy mineral concentrates locally contain abundant chalcopyrite and pyrite, and exhibit anomalous Ba, Pb, Zn, Sn, and Mo. On the aeromagnetic map of Alaska (Godson, 1994), aeromagnetic anomalies indicate that the late Tertiary and Quaternary volcanic rocks that define the tract may continue beneath areas of late Quaternary and Recent sedimentary rocks. An annular magnetic high anomaly along the northern edge of the tract might reflect a concealed and related porphyry granitic pluton.

The distribution of the geologic units defining the tract is adapted from Nokleberg and others (1994). The distribution of this belt of mineral deposits is adapted from MacKevett and others (1978) and Nokleberg and others (1987, 1993). Mineral resource assessments of 250,000-scale quadrangles within the tract were done by Richter and others (1975), MacKevett (1976), and Singer and MacKevett (1977), Singer and others (1980).

Important Examples of Deposit Type

No polymetallic veins are known in the area, but the geologic setting is permissive for deposits of this type.

Rationale for Numerical Estimates

The tract consists mostly of high late Tertiary to currently active volcanoes and associated volcanic fields. Parts of the tract are covered by extensive snow and ice fields and glaciers. Access is poor. No estimate of undiscovered deposits is attempted because no polymetallic sulfide veins are known.

References

- Godson, Richard H., 1994, Composite magnetic anomaly map of Alaska and adjacent offshore area, *in* Plafker, G. and Berg, H.C., eds., *The Geology of Alaska: Boulder, Colorado, Geological Society of America: The Geology of North America*, v. G1, plate 10, scale 1:2,500,000.
- MacKevett, E.M., 1976, Mineral deposits and occurrences in the McCarthy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-773B, scale 1:250,000, 2 sheets.
- MacKevett, E.M., Jr., Singer, D.A., and Holloway, C.D., 1978, Maps and tables describing metalliferous mineral resource potential of southern Alaska: U.S. Geological Survey Open-File Report 78-1E, 2 sheets, scale 1:1,000,000, 45 p.

- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987. Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.
- Nokleberg, W.J., Bundtzen, T.K., Grybeck, Donald, Koch, R.D., Eremin, R.A., Rozenblum, I.S., Sidorov, A.A., Byalobzhesky, S.G., Sosunov, G.M., Shpikerman, V.I., and Gorodinsky, M.E., 1993, Metallogenesis of mainland Alaska and the Russian Northeast: Mineral deposit maps, models, and tables, metallogenic belt maps and interpretation, and references cited: U.S. Geological Survey Open-File Report 93-339, 222 pages, 1 map, scale 1:4,000,000; 5 maps, scale 1:10,000,000.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 53 p., scale 1:2,500,000.
- Richter, D.H., Singer, D.A., and Cox, D.P., 1975, Mineral resources map of the Nabesna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-655-K, 1 sheet, scale 1:250,000.
- Singer, D. A., Csejtey, Bèla, Jr., and Miller, R.J., 1980, Map and discussion of the metalliferous and selected non-metalliferous mineral resources of Talkeetna Mountains quadrangle, Alaska: U.S. Geological Survey Open-File Report 78-558-Q, 34 p., 1 sheet, scale 1:250,000.
- Singer, D.A., and MacKevett, E.M., Jr., 1977, Mineral resources map of the McCarthy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-773-C, 1 sheet, scale 1:250,000.

Descriptive Model: 18b**Mark3 Index: 8****Area: 4,445 km²****Mean undiscovered deposits:** (no estimate)[Model](#)

by Bruce M. Gamble, Marti L. Miller, and Thomas D. Light

Rationale for Model Choice

In the northwestern part of south-central Alaska, carbonate rocks and units containing carbonate rocks, which have been intruded by Late Cretaceous or Tertiary plutons, may host deposits that fit the Cu-(Au) skarn model of Cox and Theodore (1986) and Theodore and others (1991).

Rationale for Tract Delineation

The permissive area for skarn deposits in this tract encompasses carbonate rocks in the northeastern part of southwestern Alaska (Patton and others, 1994). This tract is a continuation of the permissive tracts in east-central and west-central Alaska.

Important Examples of Deposit Type

No Cu (Au) skarn deposits are known in this tract.

Rationale for Numerical Estimates

Because of the lack of detailed geological information, and the absence of known deposits, no estimate of the number of undiscovered Cu (Au) skarn deposits was attempted.

References

- Cox, D.P., and Theodore, T.G., 1986, Descriptive model of Cu skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 86.
- Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1994, Geology of west-central Alaska, *in* Plafker, George, and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G-1, p. 241-269.
- Theodore, T.G., Orris, G.J., Hammarstrom, J.M., and Bliss, J.D., 1991, Gold-bearing skarns, U.S. Geological Survey Bulletin 1930, 61 p.

AK-SC31

Cu-(Au) Skarn

Alaska South Central

Descriptive Model: 18b

Mark3 Index: 8

Area: 79,025 km²

Mean undiscovered deposits: 2.83

[Cumulative Distribution](#)

[Histogram](#)

[Table](#)

[Model](#)

[Mineral Deposits](#)

by Warren J. Nokleberg, Dennis P. Cox, Richard J. Goldfarb, David L. Campbell, and Warren Yeend.

Rationale for Model Choice

A large region of south-central Alaska is permissive for Late Cretaceous and early Tertiary Cu-(Au) skarn deposits as described by Cox and Theodore (1986) and Jones and Menzie (1986). Supporting data include favorable bedrock geology, one Cu skarn occurrence, two associated porphyry Cu occurrences, anomalously high concentrations of Cu, Mo, Au, As, Ag, Bi, Pb, Zn, Co, and Fe in stream-sediment and heavy-mineral-concentrate samples, and aeromagnetic anomalies.

Rationale for Tract Delineation

The favorable geologic units for this two-part tract are calc-alkaline granitic plutons, dikes, and sills of the Late Cretaceous age and their country rocks, mainly in the Wrangellia and Peninsular terranes. Because concealed plutons and associated deposits may occur near the surface, the tract includes all of the Wrangellia and Peninsular terranes. Areas of known and possibly concealed granitic plutons (greater than several kilometers in diameter) in the tract are delineated by large, blotchy magnetic highs on the aeromagnetic map of Alaska (Godson, 1994) and (or) by K and eU or eTh highs interpreted from sparse data on radiometric maps (J.D. Phillips and F. Riggle, written commun., 1994). About 30 annular aeromagnetic high anomalies, possibly indicative of granite porphyry plutons, exist in this tract.

The distribution of the geologic units defining the tract is adapted from Nokleberg and others (1994). The distribution of this belt of mineral deposits is adapted from MacKevett and others (1978) and Nokleberg and others (1987, 1993). Mineral resource assessments of 250,000-scale quadrangles within the tract were done by Richter and others (1975), MacKevett (1976), Singer and MacKevett (1977), Singer and others (1980), Reed and others (1979), Cox and others (1989), and Nokleberg and others (1990).

Important Examples of Deposit Type

The Zackly deposit in the Mount Hayes quadrangle (Rose, 1965; Nokleberg and others, 1991) is an example of a gold-bearing Cu skarn deposit in this tract. Examples of associated porphyry copper deposits in this tract are the Mayflower and Nim prospects in the Healy quadrangle. An example of an associated porphyry Cu-Mo deposit in this tract is the Treasure Creek deposit in the Talkeetna Mountains quadrangle. Associated placer gold deposits in the Valdez Creek, Willow Creek, and Yenta districts in the tract (Capps, 1913, 1915, 1919; Chapin, 1918; Mertie, 1919; Tuck, 1938; Jasper, 1967; Smith, 1970; Cobb, 1973, Bressler and others, 1985; Fechner and Herzog, 1990; Reger and Bundtzen, 1990) may be partly derived from gold-bearing Cu skarn occurrences.

Rationale for Numerical Estimates

Tertiary and older rocks in the tract locally are covered by extensive ice fields and glaciers, and by Cenozoic sedimentary and volcanic rocks. Because of known Cu-(Au) skarn deposits, porphyry copper deposits and numerous associated occurrences, additional detailed exploration might result in the discovery of additional Cu-(Au) skarn deposits. An excellent possibility exists of at least one additional undiscovered deposit occurring in the tract. The minimum number of undiscovered deposits, consistent with the grade and tonnage model of Jones and Menzie (1986), is estimated to be:

Percentile	90	50	10	5	1
Estimated number of deposits	1	2	6	6	6

References

- Bressler, J.R., Jones, W.C. and Cleveland, Gaylord, 1985, Geology of a buried channel system of the Denali Placer Gold Mine: Alaska Miner, January, 1985, p. 9.
- Capps, S.R., 1913, The Yentna district, Alaska: U.S. Geological Survey Bulletin 534, 75 p.
- Capps, S.R., 1915, The Willow Creek district, Alaska: U.S. Geological Survey Bulletin 607, 86 p.
- Capps, S.R., 1919, The Kantishna region, Alaska: U.S. Geological Survey Bulletin 687, 116 p.
- Chapin, Theodore, 1918, The Nelchina-Susitna region, Alaska: U.S. Geological Survey Bulletin 668, 67 p.
- Cobb, E.H., 1973, Placer deposits of Alaska: U.S. Geological Survey Bulletin 1324, 213 p.
- Cox, D.P., Light, T.D., Csejtey, Béla, and Campbell, D.L., 1989, Mineral resource assessment map of the Healy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2058-A, scale 1:250,000.
- Cox, D.P., and Theodore, T.G., 1986, Descriptive model of Cu skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p 86.
- Fechner, S.A. and Herzog, D.A., 1990, Gold- and PGM-bearing conglomerate of the Valdez Creek mining district, Alaska: U.S. Bureau of Mines Open File 12-90, 52 p.
- Godson, Richard H., 1994, Composite magnetic anomaly map of Alaska and adjacent offshore area, *in* Plafker, G. and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America: The Geology of North America, v. G1, plate 10, scale 1:2,500,000.
- Jasper, M.W., 1967, Geochemical investigations, Willow Creek southerly to Kenai Lake region, south central Alaska: Alaska Division of Mines and Minerals Geochemical Report 14, 47 p.
- Jones, G.M., and Menzie, W.D., 1986, Grade and tonnage of Cu skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p 86-89.
- MacKevett, E.M., 1976, Mineral deposits and occurrences in the McCarthy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-773B, scale 1:250,000, 2 sheets.
- MacKevett, E.M., Jr., Singer, D.A., and Holloway, C.D., 1978, Maps and tables describing metalliferous mineral resource potential of southern Alaska: U.S. Geological Survey Open-File Report 78-1E, 2 sheets, scale 1:1,000,000, 45 p.
- Mertie, J.B., 1919, Platinum-bearing placers of the Kahiltna Valley: U.S. Geological Survey Bulletin 692, p. 233-264.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987, Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.
- Nokleberg, W.J., Bundtzen, T.K., Grybeck, Donald, Koch, R.D., Eremin, R.A., Rozenblum, I.S., Sidorov, A.A., Byalobzhesky, S.G., Sosunov, G.M., Shpikerman, V.I., and Gorodinsky, M.E., 1993, Metallogenesis of mainland Alaska and the Russian Northeast: Mineral deposit maps, models, and tables, metallogenic belt maps and interpretation, and references cited: U.S. Geological Survey Open-File Report 93-339, 222 pages, 1 map, scale 1:4,000,000; 5 maps, scale 1:10,000,000.
- Nokleberg, W.J., Lange, I.M., Roback, R.C., Yeend, Warren, and Silva S.R., 1991, Map showing locations of metalliferous lode and placer mineral occurrences, deposits, prospects, and mines, Mount Hayes quadrangle, eastern Alaska Range, Alaska: U.S. Geological Survey Map MF-1996-C, 42 p., 1 sheet, scale 1:250,000.
- Nokleberg, W.J., Lange, I.M., Singer, D.A., Curtin, G.C., Tripp, R.B., Campbell, D.L., and Yeend, Warren, 1990, Mineral resource assessment maps of the Mount Hayes quadrangle, eastern Alaska Range, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1996-A, 4 sheets, scale 1:250,000, 22 p.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 53 p., scale 1:2,500,000.
- Reed, B.L., Nelson, S.W., Curtin, G.C., and Singer, D.A., 1979, Mineral resources map of the Talkeetna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-870-D, 1 sheet, scale 1:250,000.
- Reger, R.D. and Bundtzen, T.K., 1990, Multiple glaciation and placer gold formation, Valdez Creek Valley, Western Clearwater Mountains, Alaska: Alaska Division of Geological and Geophysical Surveys Professional Paper 107, 29 p., 1 sheet, scale 1:63,360.
- Richter, D.H., Singer, D.A., and Cox, D.P., 1975, Mineral resources map of the Nabesna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-655-K, 1 sheet, scale 1:250,000.

- Rose, A.W., 1965, Geology and mineral deposits of the Rainy Creek area, Mt. Hayes quadrangle, Alaska: Alaska Division of Mines and Minerals Geologic Report 14, 51 p.
- Singer, D. A., Csejtey, Bèla, Jr., and Miller, R.J., 1980, Map and discussion of the metalliferous and selected non-metalliferous mineral resources of Talkeetna Mountains quadrangle, Alaska: U.S. Geological Survey Open-File Report 78-558-Q, 34 p., 1 sheet, scale 1:250,000.
- Singer, D.A., and MacKevett, E.M., Jr., 1977, Mineral resources map of the McCarthy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-773-C, 1 sheet, scale 1:250,000.
- Smith, T.E., 1970, Gold resource potential of the Denali bench gravels, Valdez Creek Mining District, Alaska: U.S. Geological Survey Professional Paper 700-D, p. D146-D152.
- Tuck, Ralph, 1938, The Valdez Creek mining district, Alaska, in 1936: U.S. Geological Survey Bulletin 897-B, p. 109-131.

Descriptive Model: 18b

Mark3 Index: 8

Area: 37,930 km²

Mean undiscovered deposits: 2.83

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Warren J. Nokleberg, Dennis P. Cox, Richard J. Goldfarb, David L. Campbell, and Warren Yeend.

Rationale for Model Choice

Parts of the Alaska Range and Wrangell Mountains are permissive for Late Jurassic and Early Cretaceous Cu (Au) skarn deposits (Cox and Theodore, 1986; Jones and Menzie, 1986). Supporting data include the favorable areas underlain by carbonate rocks of Late Paleozoic and Late Triassic age, two known occurrences, associated porphyry Cu deposits, anomalously high concentrations of Cu, Mo, Bi, Au, As, Ag, Pb, Zn, Co, and Fe in stream-sediment and heavy-mineral-concentrate samples, and local aeromagnetic anomalies.

Rationale for Tract Delineation

The favorable geologic units in this two-part tract are the Late Jurassic and Early Cretaceous granitic rocks that intrude the Gravina-Nutzotin belt and adjacent sedimentary and volcanic rocks of Wrangellia terrane, and carbonate rocks altered to skarn in areas where intruded by the Jurassic and Early Cretaceous granitic rocks. The principal mineral deposit models are porphyry Cu and Cu skarn, but related deposits could also occur. Areas of known and possibly concealed granitic plutons (greater than several kilometers in diameter) in the tract are delineated by large, blotchy magnetic highs on the aeromagnetic map of Alaska (Godson, 1994) and (or) by K and eU or eTh highs interpreted from sparse data on radiometric maps (J.D. Phillips and F. Riggle, written commun., 1994). About 25 annular aeromagnetic high anomalies, possibly indicative of granite porphyry plutons, exist in this tract.

The distribution of the geologic units defining the tract is adapted from Nokleberg and others (1994). The distribution of this belt of mineral deposits is adapted from MacKevett and others (1978) and Nokleberg and others (1987, 1993). Mineral resource assessments of 250,000-scale quadrangles within the tract were done by Richter and others (1975), MacKevett (1976), Singer and MacKevett (1977), Singer and others (1980), Reed and others (1979), Cox and others (1989), and Nokleberg and others (1990).

Important Examples of Deposit Type

The Lemons and Copper King deposits in the Nabesna quadrangle (Richer and others, 1975) are examples of a Cu skarn deposits in this tract. Associated deposits in the tract are the Baultoff, Orange Hill, Horsfeld, Bond Creek, and Carl Creek porphyry Cu and Cu-Mo deposits and occurrences, all in the Nabesna quadrangle (Van Alstine and Black, 1946). Associated placer gold deposits in the Chisana, Chistochina, Delta River, Nizina, and Valdez Creek districts in the tract (Moffit, 1914; Chapin, 1918; Capps, 1916, 1919; Tuck, 1938; Smith, 1941, 1970; Rose, 1965, 1967; Cobb and Matson, 1972; Richter and Matson, 1972; Cobb, 1973; Cobb and MacKevett, 1980; Yeend, 1981a, b; Bressler and others, 1985; Fechner and Herzog, 1990; Nokleberg and others, 1990; Reger and Bundtzen, 1990) may be partly derived from gold-bearing Cu skarn occurrences.

Rationale for Numerical Estimates

Because of two known Cu-(Au) skarn occurrences and associated porphyry Cu deposits, an excellent possibility exists that further exploration might result in the discovery of additional deposits. The minimum number of undiscovered deposits, consistent with the grade and tonnage model of Jones and Menzie (1986), is estimated to be:

Percentile	90	50	10	5	1
Estimated number of deposits	1	2	6	6	6

References

- Bressler, J.R., Jones, W.C. and Cleveland, Gaylord, 1985, Geology of a buried channel system of the Denali Placer Gold Mine: Alaska Miner, January, 1985, p. 9.
- Capps, S.R., 1916, The Chisana-White River district, Alaska: U.S. Geological Survey Bulletin 630, 130 p.
- Capps, S.R., 1919, The Kantishna region, Alaska: U.S. Geological Survey Bulletin 687, 118 p.
- Chapin, Theodore, 1918, The Nelchina-Susitna region, Alaska: U.S. Geological Survey Bulletin 668, 67 p.
- Cobb, E.H., 1973, Placer deposits of Alaska: U.S. Geological Survey Bulletin 1324, 213 p.
- Cobb, E.H., and MacKevett, E.M., Jr., 1980, Summaries of data on and lists of references to metallic and selected nonmetallic mineral deposits in the McCarthy quadrangle, Alaska: U.S. Geological Survey Open-File Report 80-885, 156 p.
- Cobb, E.H., and Matson, N.A., 1972, Metallic mineral resources map of the Valdez quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-438.
- Cox, D.P., Light, T.D., Csejtey, Béla, and Campbell, D.L., 1989, Mineral resource assessment map of the Healy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2058-A, scale 1:250,000.
- Cox, D.P., and Theodore, T.G., 1986, Descriptive model of Cu skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p 86.
- Fechner, S.A. and Herzog, D.A., 1990, Gold- and PGM-bearing conglomerate of the Valdez Creek mining district, Alaska: U.S. Bureau of Mines Open File 12-90, 52 p.
- Godson, Richard H., 1994, Composite magnetic anomaly map of Alaska and adjacent offshore area, *in* Plafker, G. and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America: The Geology of North America, v. G1, plate 10, scale 1:2,500,000.
- Jones, G.M., and Menzie, W.D., 1986, Grade and tonnage of Cu skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p 86-89.
- MacKevett, E.M., 1976, Mineral deposits and occurrences in the McCarthy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-773B, scale 1:250,000, 2 sheets.
- MacKevett, E.M., Jr., Singer, D.A., and Holloway, C.D., 1978, Maps and tables describing metalliferous mineral resource potential of southern Alaska: U.S. Geological Survey Open-File Report 78-1E, 2 sheets, scale 1:1,000,000, 45 p.
- Moffit, F.H., 1914, Geology of the Hanagita-Bremner region, Alaska: U.S. Geological Survey Bulletin 576, 56 p.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987, Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.
- Nokleberg, W.J., Bundtzen, T.K., Grybeck, Donald, Koch, R.D., Eremin, R.A., Rozenblum, I.S., Sidorov, A.A., Byalobzhesky, S.G., Sosunov, G.M., Shpikerman, V.I., and Gorodinsky, M.E., 1993, Metallogenesis of mainland Alaska and the Russian Northeast: Mineral deposit maps, models, and tables, metallogenic belt maps and interpretation, and references cited: U.S. Geological Survey Open-File Report 93-339, 222 pages, 1 map, scale 1:4,000,000; 5 maps, scale 1:10,000,000.
- Nokleberg, W.J., Lange, I.M., Singer, D.A., Curtin, G.C., Tripp, R.B., Campbell, D.L., and Yeend, Warren, 1990, Mineral resource assessment maps of the Mount Hayes quadrangle, eastern Alaska Range, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1996-A, 4 sheets, scale 1:250,000, 22 p.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 53 p., scale 1:2,500,000.
- Reed, B.L., Nelson, S.W., Curtin, G.C., and Singer, D.A., 1979, Mineral resources map of the Talkeetna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-870-D, 1 sheet, scale 1:250,000.
- Reger, R.D. and Bundtzen, T.K., 1990, Multiple glaciation and placer gold formation, Valdez Creek Valley, Western Clearwater Mountains, Alaska: Alaska Division of Geological and Geophysical Surveys Professional Paper 107, 29 p., 1 sheet, scale 1:63,360.
- Richter, D.H., and Matson, N.A., Jr., 1972, Metallic mineral resources map of the Nabesna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-422.

- Richter, D.H., Singer, D.A., and Cox, D.P., 1975, Mineral resources map of the Nabesna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-655-K, 1 sheet, scale 1:250,000.
- Rose, A.W., 1965, Geology and mineral deposits of the Rainy Creek area, Mt. Hayes quadrangle, Alaska: Alaska Division of Mines and Minerals Geologic Report 14, 51 p.
- Rose, A.W., 1967, Geology of the upper Chistochina River area, Mt. Hayes quadrangle, Alaska: Alaska Division of Mines and Minerals Geologic Report 28, 41 p.
- Singer, D. A., Csejtey, Bèla, Jr., and Miller, R.J., 1980, Map and discussion of the metalliferous and selected non-metalliferous mineral resources of Talkeetna Mountains quadrangle, Alaska: U.S. Geological Survey Open-File Report 78-558-Q, 34 p., 1 sheet, scale 1:250,000.
- Singer, D.A., and MacKevett, E.M., Jr., 1977, Mineral resources map of the McCarthy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-773-C, 1 sheet, scale 1:250,000.
- Smith, P.S., 1941, Mineral industry of Alaska in 1939: U.S. Geological Survey Bulletin 926-A, p. 1-106.
- Smith, T.E., 1970, Gold resource potential of the Denali bench gravels, Valdez Creek Mining District, Alaska: U.S. Geological Survey Professional Paper 700-D, p. D146-D152.
- Tuck, Ralph, 1938, The Valdez Creek mining district, Alaska, in 1936: U.S. Geological Survey Bulletin 897-B, p. 109-131.
- Van Alstine, R.E., and Black, R.F., 1946, Copper deposits of the Kotsina-Kuskulana district, Alaska: U.S. Geological Survey Bulletin 947-G, p. 121-141
- Yeend, Warren, 1981a, Placer gold deposits, Mt. Hayes quadrangle, Alaska, in Silberman, Miles and others, eds., Proceedings of the Symposium of Mineral Deposits of the Pacific Northwest: U.S. Geological Survey Open-File Report 81-355, p. 74-83.
- Yeend, Warren, 1981b, Placer gold deposits, Mount Hayes quadrangle, Alaska, in Albert, N.R.D., and Hudson, Travis, eds., The United States Geological Survey in Alaska: Accomplishments during 1979: U.S. Geological Survey Circular 823-B, p. B68.

Descriptive Model: 18b

Mark3 Index: 8

Area: 17,242 km²

Mean undiscovered deposits: 0.41

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Warren J. Nokleberg, Dennis P. Cox, Richard J. Goldfarb, David L. Campbell, and Warren Yeend.

Rationale for Model Choice

Parts of the Alaska Range and Wrangell Mountains are permissive for late Paleozoic Cu-Au skarn deposits as described by Cox and Theodore (1986) and Jones and Menzie (1986). The bedrock geology is favorable, two porphyry Cu occurrences and one associated Cu skarn occurrence are known, and stream-sediment and heavy-mineral-concentrate samples contain anomalously high concentrations of Cu, Mo, Au, As, Ag, Bi, Pb, Zn, Co, and Fe. The principal mineral deposit models are Cu skarn and porphyry Cu, but related deposits could also occur.

Rationale for Tract Delineation

The favorable geologic units in this tract are the Late Paleozoic granitic plutons of Skolai arc that intrude Permian and older rocks of Wrangellia terrane, and carbonate rocks altered to skarn in areas where intruded by late Paleozoic igneous rocks. Areas of known and possibly concealed granitic plutons (greater than several km in diameter) in the tract are delineated by large, blotchy magnetic highs on the aeromagnetic map of Alaska (Godson, 1994) and (or) by K and eU or eTh highs interpreted from sparse data on radiometric maps (J.D. Phillips and F. Riggle, written commun., 1994). About 15 annular aeromagnetic high anomalies, possibly indicative of granite porphyry plutons, exist in this tract.

The distribution of the geologic units defining the tract is adapted from Nokleberg and others (1994). The distribution of this belt of mineral deposits is adapted from MacKevett and others (1978) and Nokleberg and others (1987, 1993). Mineral resource assessments of 250,000-scale quadrangles within the tract were done by Richter and others (1975), MacKevett (1976), Singer and MacKevett (1977), Singer and others (1980), Reed and others (1979), Cox and others (1989), and Nokleberg and others (1990).

Important Examples of Deposit Type

The Rainy Creek deposit in the Mount Hayes quadrangle (Rose, 1966; Nokleberg and others, 1991) is an example of a Cu skarn deposit in this tract. Associated porphyry Cu occurrences and minor base metal polymetallic vein occurrences also occur in the tract. Associated placer gold deposits in the Chisana, Chistochina, and Delta River districts in the tract (Capps, 1916; Smith, 1941; Rose, 1965, 1967; Richter and Matson, 1972; Yeend, 1981a, b; Nokleberg and others, 1991) might be partly derived from gold-bearing Cu skarn occurrences.

Rationale for Numerical Estimates

Tertiary and older rocks in the tract locally are covered by extensive ice fields and glaciers, and by overlying Cenozoic sedimentary and volcanic rocks. Because deposits are known in the tract, additional detailed exploration might result in the discovery of additional deposits. The minimum number of undiscovered deposits, consistent with the grade and tonnage model of Jones and Menzie (1986), is estimated to be:

Percentile	90	50	10	5	1
Estimated number of deposits	0	0	1	2	3

References

Capps, S.R., 1916, The Chisana-White River district, Alaska: U.S. Geological Survey Bulletin 630, 130 p.

- Cox, D.P., and Theodore, T.G., 1986, Descriptive model of Cu skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p 86.
- Cox, D.P., Light, T.D., Csejtey, Béla, and Campbell, D.L., 1989, Mineral resource assessment map of the Healy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2058-A, scale 1:250,000.
- Godson, Richard H., 1994, Composite magnetic anomaly map of Alaska and adjacent offshore area, *in* Plafker, G. and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America: The Geology of North America, v. G1, plate 10, scale 1:2,500,000.
- Jones, G.M., and Menzie, W.D., 1986, Grade and tonnage of Cu skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p 86-89.
- MacKevett, E.M., 1976, Mineral deposits and occurrences in the McCarthy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-773B, scale 1:250,000, 2 sheets.
- MacKevett, E.M., Jr., Singer, D.A., and Holloway, C.D., 1978, Maps and tables describing metalliferous mineral resource potential of southern Alaska: U.S. Geological Survey Open-File Report 78-1E, 2 sheets, scale 1:1,000,000, 45 p.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987, Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.
- Nokleberg, W.J., Bundtzen, T.K., Grybeck, Donald, Koch, R.D., Eremin, R.A., Rozenblum, I.S., Sidorov, A.A., Byalobzhesky, S.G., Sosunov, G.M., Shpikerman, V.I., and Gorodinsky, M.E., 1993, Metallogenesis of mainland Alaska and the Russian Northeast: Mineral deposit maps, models, and tables, metallogenic belt maps and interpretation, and references cited: U.S. Geological Survey Open-File Report 93-339, 222 pages, 1 map, scale 1:4,000,000; 5 maps, scale 1:10,000,000.
- Nokleberg, W.J., Lange, I.M., Roback, R.C., Yeend, Warren, and Silva S.R., 1991, Map showing locations of metalliferous lode and placer mineral occurrences, deposits, prospects, and mines, Mount Hayes quadrangle, eastern Alaska Range, Alaska: U.S. Geological Survey Map MF-1996-C, 42 p., 1 sheet, scale 1:250,000
- Nokleberg, W.J., Lange, I.M., Singer, D.A., Curtin, G.C., Tripp, R.B., Campbell, D.L., and Yeend, Warren, 1990, Mineral resource assessment maps of the Mount Hayes quadrangle, eastern Alaska Range, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1996-A, 4 sheets, scale 1:250,000, 22 p.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 53 p., scale 1:2,500,000.
- Reed, B.L., Nelson, S.W., Curtin, G.C., and Singer, D.A., 1979, Mineral resources map of the Talkeetna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-870-D, 1 sheet, scale 1:250,000.
- Richter, D.H., and Matson, N.A., Jr., 1972, Metallic mineral resources map of the Nabesna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-422.
- Richter, D.H., Singer, D.A., and Cox, D.P., 1975, Mineral resources map of the Nabesna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-655-K, 1 sheet, scale 1:250,000.
- Rose, A.W., 1965, Geology and mineral deposits of the Rainy Creek area, Mt. Hayes quadrangle, Alaska: Alaska Division of Mines and Minerals Geologic Report 14, 51 p.
- Rose, A.W., 1966, Geological and geochemical investigations in the Eureka Creek and Rainy Creek areas, Mt. Hayes quadrangle, Alaska: Alaska Division of Mines and Minerals Geologic Report 20, 37 p.
- Rose, A.W., 1967, Geology of the upper Chistochina River area, Mt. Hayes quadrangle, Alaska: Alaska Division of Mines and Minerals Geologic Report 28, 41 p.
- Singer, D. A., Csejtey, Béla, Jr., and Miller, R.J., 1980, Map and discussion of the metalliferous and selected non-metalliferous mineral resources of Talkeetna Mountains quadrangle, Alaska: U.S. Geological Survey Open-File Report 78-558-Q, 34 p., 1 sheet, scale 1:250,000.
- Singer, D.A., and MacKevett, E.M., Jr., 1977, Mineral resources map of the McCarthy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-773-C, 1 sheet, scale 1:250,000.
- Smith, P.S., 1941, Mineral industry of Alaska in 1939: U.S. Geological Survey Bulletin 926-A, p. 1-106.
- Yeend, Warren, 1981a, Placer gold deposits, Mt. Hayes quadrangle, Alaska, *in* Silberman, Miles and others, eds., Proceedings of the Symposium of Mineral Deposits of the Pacific Northwest: U.S. Geological Survey Open-File Report 81-355, p. 74-83.
- Yeend, Warren, 1981b, Placer gold deposits, Mount Hayes quadrangle, Alaska, *in* Albert, N.R.D., and Hudson, Travis, eds., The United States Geological Survey in Alaska: Accomplishments during 1979: U.S. Geological Survey Circular 823-B, p. B68.

Descriptive Model: 18c**Mark3 Index: 22****Area:****Mean undiscovered deposits: (no estimate)**[Model](#)

by Marti L. Miller, Bruce M. Gamble, and Warren J. Nokleberg

Rationale for Model Choice

The presence of intermediate to felsic plutonic rocks that may intrude carbonate-bearing units suggests that this tract is permissive for Zn-Pb skarn deposits as described by Cox (1986).

Rationale for Tract Delineation

This tract is defined by the distribution of carbonate rocks and possible carbonate-bearing units and by the known or inferred presence of intermediate to felsic plutonic rocks (Patton and others, 1994; Nokleberg and others, 1994). Known mineral deposits in the adjacent tract in west-central Alaska include a Cu-Au skarn and a Fe-skarn.

Important Examples of Deposit Type

No Zn-Pb skarn deposits are known in this tract.

Rationale for Numerical Estimates

Because of the lack of detailed geologic information, no estimates of the number of undiscovered deposits have been attempted.

References

- Cox, D.P., 1986, Descriptive model of Zn-Pb skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 90.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 45 manuscript p., scale 1:2,500,000.
- Patton, W.W., Jr., Box, S.E., and Grybeck, D.J., 1994, Ophiolites and other mafic-ultramafic complexes in Alaska, *in* Plafker, George, and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North American, v. G-1, p. 671-686.

Descriptive Model: 18c**Mark3 Index: 22****Area: 15,193 km²****Mean undiscovered deposits: (no estimate)**[Model](#)

by Marti L. Miller and Thomas K. Bundtzen

Rationale for Model Choice

Zn-Pb skarns (Cox, 1986; Mosier, 1986) are permissive in south-central Alaska where carbonate rock units are locally intruded by small felsic plutons.

Rationale for Tract Delineation

This permissive tract for skarn deposits in south-central Alaska is a continuation of the adjacent tract in southwestern Alaska. The area includes scattered carbonate roof pendants in proximity to porphyry Cu-type plutons similar to those described in the Lake Clark (Nelson and others, 1983) and Iliamna quadrangles (Detterman and Reed, 1980).

Important Examples of Deposit Type

No Pb-Zn skarns are known in this tract.

Rationale for Numerical Estimates

Several examples of Zn-Pb skarns occur within the adjacent tract in southwest Alaska, but none are known to occur within this tract. The number of undiscovered deposits for this tract was not estimated.

References

- Cox, D.P., 1986, Descriptive model of Zn-Pb skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 90.
- Detterman, R.L., and Reed, B.L., 1980, Stratigraphy, structure, and economic geology of the Iliamna quadrangle, Alaska: U.S. Geological Survey Bulletin 1368-B, 86 p., scale 1:250,000.
- Nelson, W.H., Carlson, Christine, and Case, J.E., 1983, Geologic map of the Lake Clark quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1114-A, scale 1:250,000.

Descriptive Model: 31a

Mark3 Index: 13

Area: 4,874 km²

Mean undiscovered deposits: (no estimate)

[Model](#)

by Jeanine M. Schmidt, Marti L. Miller, and Bruce M. Gamble

Rationale for Model Choice

Deposition in a deep-water environment suggests the possibility of sedex deposits as described by Briskey (1986). Bedded barite deposits may form distal to sedex occurrences. The presence of a bedded barite deposit in possibly correlative rocks in the continuation of this tract to the southwest supports the selection of this model type.

Rationale for Tract Delineation

This tract encompasses parts of the Nixon Fork and Minchumina terranes (Patton and others, 1994), both of which locally contain deep-water facies. The region is poorly known; reconnaissance geochemical data are not available.

Important Examples of Deposit Type

No examples of sedex deposits are known in this tract, but the Gagaryah barite deposit (Bundtzen and Gilbert, 1991), in similar rocks in the Lime Hills quadrangle of southwestern Alaska, may be related to sedex mineralization.

Rationale for Numerical Estimates

No attempt was made to estimate the number of undiscovered Sedex Zn-Pb deposits in this tract.

REFERENCES

- Briskey, J.A., 1986, Descriptive model of sedimentary exhalative Zn-Pb, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 211-212.
- Bundtzen, T.K., and Gilbert, W.G., 1991, Geology and geochemistry of the Gagaryah barite deposit, western Alaska Range, Alaska, *in*, Reger, R.D., ed., Short Notes on Alaskan Geology 1991: Alaska Division of Geological and Geophysical Surveys Professional Report 111, p. 9-20.
- Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1994, Geology of west-central Alaska, *in* Plafker, George, and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G-1, p. 241-269.

Descriptive Model: 31a**Mark3 Index: 13****Area: 9,064 km²****Mean undiscovered deposits: (no estimate)****Model**

by Warren J. Nokleberg, Dennis P. Cox, Richard J. Goldfarb, David L. Campbell.

Rationale for Model Choice

This tract, in the Bering Glacier region of coastal south-central Alaska, is permissive for sedimentary exhalative (SEDEX) Zn-Pb deposits of Cenozoic age because it has anomalous concentrations of Ba, Zn, Cu, Mo, and Pb in stream sediment samples (Pickthorn and others, 1985), barite occurs locally in heavy-mineral concentrates, and dark marine shale locally is interlayered with basalt of the Yakutat terrane. However, this type of deposit typically is in Carboniferous and older rocks (Briskey, 1986).

Rationale for Tract Delineation

The favorable geologic unit in the tract is the Cenozoic marine dark shales and interlayered basalts of the Yakutat terrane. Barite and sphalerite occur in stream-sediment samples.

The distribution of the geologic units defining the tract is adapted from Nokleberg and others (1994). The distribution of this belt of mineral deposits is adapted from MacKevett and others (1978) and Nokleberg and others (1987, 1993). Mineral resource assessments of 250,000-scale quadrangles within the tract were done by MacKevett (1976), Singer and others (1977, 1980), Tysdal and Case (1982), Goldfarb and others (1992), and Madden-McGuire and Winkler (1993).

Important Examples of Deposit Type

The geologic setting is permissive for Sedex Zn-Pb deposits but no deposits of this type are known in the tract.

Rationale for Numerical Estimates

The tract is locally covered by extensive ice fields and glaciers, and is partly bounded by the southern Alaska coast. Because no deposits or occurrences are known, and because most SEDEX deposits are Carboniferous or older, no attempt was made to estimate the number of undiscovered deposits.

References

- Briskey, J.A., 1986, Descriptive model of sedimentary exhalative Pb-Zn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p 211-213.
- Goldfarb, R.J., Case, J.E., Plafker, George, and Winkler, G.R., 1992, Maps showing areas of potential for mineral resources in the Cordova and Middleton Island 1° x 3° quadrangles, southern Alaska: U.S. Geological Survey Miscellaneous Field Investigations Map MF-2190. 1 sheet, scale 1:250,000.
- MacKevett, E.M., 1976, Mineral deposits and occurrences in the McCarthy quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-773B, scale 1:250,000, 2 sheets.
- MacKevett, E.M., Jr., Singer, D.A., and Holloway, C.D., 1978, Maps and tables describing metalliferous mineral resource potential of southern Alaska: U.S. Geological Survey Open-File Report 78-1E, 2 sheets, scale 1:1,000,000, 45 p.
- Madden-McGuire, D.J., and Winkler, G.R., 1993, Mineral resource maps of the Anchorage quadrangle, southern Alaska: U.S. Geological Survey Miscellaneous Investigations Map MI-2393, scale 1:250,000, 3 sheets.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987. Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.

- Nokleberg, W.J., Bundtzen, T.K., Grybeck, Donald, Koch, R.D., Eremin, R.A., Rozenblum, I.S., Sidorov, A.A., Byalobzhesky, S.G., Sosunov, G.M., Shpikerman, V.I., and Gorodinsky, M.E., 1993, Metallogenesis of mainland Alaska and the Russian Northeast: Mineral deposit maps, models, and tables, metallogenic belt maps and interpretation, and references cited: U.S. Geological Survey Open-File Report 93-339, 222 pages, 1 map, scale 1:4,000,000; 5 maps, scale 1:10,000,000.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 53 p., scale 1:2,500,000.
- Pickthorn, W.J., Goldfarb, R.J., O'Leary, R.M., Sutley, S.J., and Weaver, Sarah, 1985, Kayak Island-Analysis of a geochemical anomaly, in Barsch-Winkler, Susan, and Reed, K.M., eds., The United States Geological Survey in Alaska: Accomplishments in 1983: U.S. Geological Survey Circular 945, p. 82-83.
- Singer, D. A., Csejtey, Bèla, Jr., and Miller, R.J., 1980, Map and discussion of the metalliferous and selected non-metalliferous mineral resources of Talkeetna Mountains quadrangle, Alaska: U.S. Geological Survey Open-File Report 78-558-Q, 34 p., 1 sheet, scale 1:250,000.
- Singer, D.A., Curtin, G.C., and Foster, H.L., 1977, Mineral resources map of the Tanacross quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-767-E, 1 sheet, scale 1:250,000.
- Tysdal, R.G., and Case, J.E., 1982, Metalliferous mineral resource potential of the Seward and Blying Sound quadrangles, southern Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-880H, 2 sheets, scale 1:250,000, 23 p.

[AK-SE01](#)

Besshi Massive Sulfide

Alaska Southeast

Descriptive Model: 24b

Mark3 Index: 30

Area: 754 km²

Mean undiscovered deposits: 0.06

[Cumulative Distribution](#)

[Histogram](#)

[Table](#)

[Model](#)

by David A. Brew, Cliff D. Taylor, Robert C. Jachens, Richard D. Koch, Donald Grybeck, James L. Drinkwater, David F. Barnes, and Larry J. Drew

Rationale for deposit type selection:

Slightly metamorphosed Paleozoic clastic sedimentary and minor volcanic rocks on Prince of Wales Island contain sparse thin lenses of sulfide minerals. These units are permissive for Besshi massive sulfide deposits (Cox, 1986).

Rationale for tract delineation:

This tract is delineated by the outcrop areas of Silurian turbidite and minor volcanic rocks, and by favorable geochemical data, on Prince of Wales Island (Brew and others, 1991; Brew, 1993).

Important example of deposit type:

The McCullogh deposit may be an example of a Besshi massive sulfide (Brew and others, 1991).

Rationale for numerical estimate:

Permissive rock types and associations and appropriate geochemical patterns were the main basis for the estimates. The team estimated the minimum number of undiscovered Besshi massive sulfide deposits, consistent with the grade and tonnage model of Singer (1986), to be:

Percentile	90	50	10	5	1
Estimated number of deposits	0	0	0	0	1

References

- Brew, D.A., 1993, Regional geologic setting of mineral resources in southeastern Alaska, *in* Godwin, L.H., and Smith, B. D., eds., Economic mineral resources of the Annette Islands Reserve, Alaska: U.S. Dept. of the Interior, Bureau of Indian Affairs, Division of Energy and Mineral Resources Publication, p.13-20.
- Brew, D.A., Drew, L.J., Schmidt, L.M., Root, D.H., and Huber, D.F, 1991, Undiscovered locatable mineral resources of the Tongass National Forest and adjacent areas, southeastern Alaska: U.S. Geological Survey Open-File Report 91-10, 370 p., 15 maps at 1:250,000, 1 map at 1:500,000, 11 figs.
- Cox, D.P., 1986, Descriptive model of Besshi massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 136.
- Singer, D.A., 1986, Grade and tonnage model of Besshi massive sulfide deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 136-138.

Descriptive Model 25b

Mark3 Index: 58

Area: 688 km²

Mean undiscovered deposits: 0.11

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by David A. Brew, Cliff D. Taylor, Robert C. Jachens, Richard D. Koch, Donald Grybeck, James L. Drinkwater, David F. Barnes, and Larry J. Drew

Rationale for deposit type selection:

Middle Tertiary felsic and intermediate volcanic rocks occur in a possible eruptive center, and in close association with granitic rocks of about the same age. Some intensely altered areas are present. Geochemical patterns and mineral occurrences suggest Creede epithermal vein deposits.

Rationale for tract delineation:

The tract boundaries were delineated mainly by the distribution of the Tertiary volcanic rock units (Brew, 1993), and the appropriate geochemical patterns.

Important examples of deposit type:,

The Kushneahin Lake occurrence in the Petersburg quadrangle is a highly altered area of rhyolite, rhyolite tuff, and rhyolitic glass (Grybeck and others, 1984) that is believed to be a possible epithermal vein occurrence (Brew and others, 1991).

Rationale for numerical estimate:

Permissive rock types and associations and appropriate geochemical patterns were the main basis for the estimates. The minimum number of undiscovered deposits consistent with the grade and tonnage model of Mosier and other (1986) has been estimated as:

Percentile	90	50	10	5	1
Estimated no. of deposits	0	0	0	1	2

References

- Brew, D.A., 1993, Regional geologic setting of mineral resources in southeastern Alaska, *in* Godwin, L.H., and Smith, B. D., eds., Economic mineral resources of the Annette Islands Reserve, Alaska: U.S. Dept. of the Interior, Bureau of Indian Affairs, Division of Energy and Mineral Resources Publication, p.13-20.
- Brew, D.A., Drew, L.J., Schmidt, L.M., Root, D.H., and Huber, D.F., 1991, Undiscovered locatable mineral resources of the Tongass National Forest and adjacent areas, southeastern Alaska: U.S. Geological Survey Open-File Report 91-10, 370 p., 15 maps at 1:250,000, 1 map at 1:500,000, 11 figs.
- Grybeck, Donald, Berg, H.C., and Karl, S.M., 1984, Map and description of the mineral deposits in the Petersburg and eastern Port Alexander quadrangles, southeastern Alaska: U.S. Geological Survey Open-File Report 84-837, 87 p.,
- Mosier, D.L., Sato, T., and Singer, D.A., 1986, Grade and tonnage model of Creede epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 146-149.

Descriptive Model: 36a

Mark3 Index: 27

Area: 14,559 km²

Mean undiscovered deposits: 6.3

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by David A. Brew, Cliff D. Taylor, Robert C. Jachens, Richard D. Koch, Donald Grybeck, James L. Drinkwater, David F. Barnes, and Larry J. Drew

Rationale for deposit type selection:

In southeastern Alaska low-sulfide Au-quartz vein deposits occur in Mesozoic and Paleozoic low- to medium-grade metamorphosed clastic, volcanic, and some carbonate rocks along or near large through-going high-angle faults that are close to Cretaceous and Tertiary mesozonal to epizonal subduction- and post-subduction-related calcalkaline granitic plutons and dikes. Additional low-sulfide gold-quartz vein deposits are expected.

Rationale for tract delineation:

This tract includes 20 separate tracts that were delineated, evaluated, and estimated individually by Brew and others (1991) and summarized by Brew (1993). The tract boundaries were delineated mainly by combining the distribution of deposits and occurrences, the distribution of the plutons, metaclastic units and large faults, and the distribution of favorable geochemical patterns.

Important examples of deposit type:

The Alaska-Juneau, Treadwell, Chichagof, Hirst-Chichagof, and Helm Bay mines are examples of low-sulfide Au-quartz vein deposits.

Rationale for numerical estimate:

Permissive rock types and associations, geochemical patterns, and the numerous low-sulfide Au-quartz vein occurrences were the main basis for the estimates. The expected minimum number of undiscovered low-sulfide Au-quartz vein deposits consistent with the grade and tonnage model of Bliss (1986) is:

Percentile	90	50	10	5	1
Estimated number of deposits	1	5	13	14	17

References

- Bliss, J.D., 1986, Grade and tonnage model of low-sulfide gold-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239-243.
- Brew, D.A., 1993, Regional geologic setting of mineral resources in southeastern Alaska, *in* Godwin, L.H., and Smith, B. D., eds., Economic mineral resources of the Annette Islands Reserve, Alaska: U.S. Dept. of the Interior, Bureau of Indian Affairs, Division of Energy and Mineral Resources Publication, p.13-20.
- Brew, D.A., Drew, L.J., Schmidt, L.M., Root, D.H., and Huber, D.F., 1991, Undiscovered locatable mineral resources of the Tongass National Forest and adjacent areas, southeastern Alaska: U.S. Geological Survey Open-File Report 91-10, 370 p., 15 maps at 1:250,000, 1 map at 1:500,000, 11 figs.

Descriptive Model: 28a**Mark3 Index: 93****Area: 4,914 km²****Mean undiscovered deposits: 0.66**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by David A. Brew, Cliff D. Taylor, Robert C. Jachens, Richard D. Koch, Donald Grybeck, James L. Drinkwater, David F. Barnes, and Larry J. Drew

Rationale for deposit type selection:

Paleozoic and upper Proterozoic intermediate, felsic, and mafic volcanic rocks occur in heterogeneous units on Prince of Wales Island. Local altered areas are present. Geochemical patterns and mineral occurrences suggest kuroko massive sulfide deposits as described by Singer (1986).

Rationale for tract delineation:

This multi-part tract is delineated mainly by the distribution of volcanic and metavolcanic units, the distribution of known deposits and occurrences, and the distribution of favorable geochemical patterns (Brew and others, 1991; Brew, 1993).

Important examples of deposit type:

Big Harbor and Niblack on Prince of Wales Island are examples of kuroko massive sulfide deposits in this tract (Berg, 1984; Brew and others, 1991).

Rationale for numerical estimate:

Permissive rock types and associations, appropriate geochemical patterns, and the occurrence of known deposits were the main basis for the estimates. The mineral resource team estimated the minimum number of undiscovered deposits, consistent with the grade and tonnage model of Singer and Mosier (1986), to be:

Percentile	90	50	10	5	1
Estimated number of deposits	0	0	2	2	4

References

- Berg, H.C., 1984, Regional geologic summary, metallogensis, and mineral resources of southeastern Alaska, U.S. Geological Survey Open-File Report 84-572, 298 p.
- Brew, D.A., 1993, Regional geologic setting of mineral resources in southeastern Alaska, in Godwin, L.H., and Smith, B. D., eds., Economic mineral resources of the Annette Islands Reserve, Alaska: U.S. Dept. of the Interior, Bureau of Indian Affairs, Division of Energy and Mineral Resources Publication, p.13-20.
- Brew, D.A., Drew, L.J., Schmidt, L.M., Root, D.H., and Huber, D.F, 1991, Undiscovered locatable mineral resources of the Tongass National Forest and adjacent areas, southeastern Alaska: U.S. Geological Survey Open-File Report 91-10, 370 p., 15 maps at 1:250,000, 1 map at 1:500,000, 11 figs.
- Singer, D.A., 1986, Descriptive model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 189-190.
- Singer, D.A., and Mosier, D.L., 1986, Grade and tonnage model of kuroko massive sulfide deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 190-197.

Descriptive Model: 28a**Mark3 Index: 44****Area: 797 km²****Mean undiscovered deposits: 3.5**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by David A. Brew, Cliff D. Taylor, Robert C. Jachens, Richard D. Koch, Donald Grybeck, James L. Drinkwater, David F. Barnes, and Larry J. Drew

Rationale for deposit type selection:

Upper Triassic and inferred Upper Triassic intermediate, felsic, and some mafic volcanic rocks occur in heterogeneous and locally metamorphosed units. Local altered areas are present. Geochemical patterns and mineral occurrences suggest Sierran kuroko massive sulfide deposits (Singer, 1992).

Rationale for tract delineation:

This three-part tract is delineated mainly by the distribution of volcanic and metavolcanic units, and the distribution of known deposits and occurrences (Brew and others, 1991; Brew, 1993).

Important examples of deposit type:

Mount Henry Clay(?), Orange Point in Glacier Bay National Park, Greens Creek, Sumdum Glacier in Tracy Arm-Fords Terror Wilderness Area, and Castle Island(?) are all known or inferred to be Sierran kuroko massive sulfide deposits.

Rationale for numerical estimate:

Permissive rock types and associations, appropriate geochemical patterns, and the occurrence of known deposits were the main basis for the estimates. The mineral resource team estimated the minimum number of undiscovered deposits, consistent with the grade and tonnage model of Singer (1992), to be:

Percentile	90	50	10	5	1
Estimated number of deposits	1	3	7	9	13

References

- Brew, D.A., 1993, Regional geologic setting of mineral resources in southeastern Alaska, in Godwin, L.H., and Smith, B. D., eds., Economic mineral resources of the Annette Islands Reserve, Alaska: U.S. Dept. of the Interior, Bureau of Indian Affairs, Division of Energy and Mineral Resources Publication, p.13-20.
- Brew, D.A., Drew, L.J., Schmidt, L.M., Root, D.H., and Huber, D.F, 1991, Undiscovered locatable mineral resources of the Tongass National Forest and adjacent areas, southeastern Alaska: U.S. Geological Survey Open-File Report 91-10, 370 p., 15 maps at 1:250,000, 1 map at 1:500,000, 11 figs.
- Singer, D.A., 1992, Grade and tonnage model of Sierran kuroko massive sulfide deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 2004, p. 29-32.

Descriptive Model: 32a

Mark3 Index: 42

Area: 150 km²

Mean undiscovered deposits: 0.03

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by David A. Brew, Cliff D. Taylor, Robert C. Jachens, Richard D. Koch, Donald Grybeck, James L. Drinkwater, David F. Barnes, and Larry J. Drew

Rationale for deposit type selection:

Middle and upper Paleozoic carbonate rocks and Upper Triassic and inferred Upper Triassic carbonate, and intermediate, felsic, and some mafic volcanic rocks occur in heterogeneous and highly faulted units. Geochemical patterns and one mineral occurrence suggest a Mississippi Valley type deposit, possibly the SE Missouri Pb-Zn model.

Rationale for tract delineation:

This tract was delineated mainly by the distribution of the carbonate units, the known occurrence of a deposit thought to be a Mississippi Valley type, and the appropriate geochemical patterns (Brew and others, 1991; Brew, 1993).

Important examples of deposit type:

The Saginaw Bay-Cornwallis Peninsula deposits on Kuiu Island are Zn-Pb-Ba prospects in carbonate rocks, and may be Mississippi Valley type deposits.

Rationale for numerical estimate:

Permissive rock types and associations, appropriate geochemical patterns, and the occurrence of 1 inferred deposit of this type were the main basis for the estimate. The estimated minimum number of Mississippi Valley type deposits, consistent with the grade and tonnage model of Mosier and Briskey (1986), expected to occur in this tract is:

Percentile	90	50	10	5	1
Estimated number of deposits	0	0	0	0	1

References

- Brew, D.A., 1993, Regional geologic setting of mineral resources in southeastern Alaska, in Godwin, L.H., and Smith, B. D., eds., Economic mineral resources of the Annette Islands Reserve, Alaska: U.S. Dept. of the Interior, Bureau of Indian Affairs, Division of Energy and Mineral Resources Publication, p.13-20.
- Brew, D.A., Drew, L.J., Schmidt, L.M., Root, D.H., and Huber, D.F, 1991, Undiscovered locatable mineral resources of the Tongass National Forest and adjacent areas, southeastern Alaska: U.S. Geological Survey Open-File Report 91-10, 370 p., 15 maps at 1:250,000, 1 map at 1:500,000, 11 figs.
- Mosier, D.L., and Briskey, J.A., 1986, Grade and tonnage model of southeast Missouri Pb-Zn and Appalachian Zn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 224-226.

Descriptive Model: 17

Mark3 Index: 81

Area: 9,382 km²

Mean undiscovered deposits: 0.840

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by David A. Brew, Cliff D. Taylor, Robert C. Jachens, Richard D. Koch, Donald Grybeck, James L. Drinkwater, David F. Barnes, and Larry J. Drew

Rationale for deposit type selection:

A few porphyry Cu (Cox, 1986a), porphyry Cu-Mo (Cox, 1986b), and porphyry Cu, skarn related (Cox, 1986c) deposits are known in the Cretaceous and Tertiary calcalkaline granitic plutons and dikes in southeastern Alaska.

Rationale for tract delineation:

Tract boundaries were delineated by the combination of Paleozoic carbonate rocks and Tertiary intrusive rocks (Brew and others, 1991; Brew, 1993). This multi-part tract includes most of the Tertiary subduction- and post-subduction-related calcalkaline granitic plutons in southeastern Alaska, and the tract boundaries are those of the areas known or interpreted to be underlain by those rocks. The tract also includes some similar plutons of middle Cretaceous age. In detail, Paleozoic clastic and carbonate rocks are intruded by mesozonal to epizonal Cretaceous and Tertiary granitic dikes, with local fracturing and alteration.

Important examples of deposit type:

The most important known porphyry Cu deposit in southeastern Alaska is the Margerie Glacier deposit, in Glacier Bay National Park. Minnesota Ridge, in Glacier Bay National Park, is the best example of a porphyry Cu, skarn related, deposit. Muir Inlet Nunatak, Bruce Hills, and Threesome Mountain in Glacier Bay National Park; and Shakan Bay on Prince of Wales Island are porphyry Cu-Mo deposits.

Rationale for numerical estimate:

Permissive rock types and appropriate geochemical patterns were the main basis for estimating the number of undiscovered deposits. The minimum number of undiscovered porphyry Cu; porphyry Cu, skarn related; and porphyry Cu-Mo deposits, consistent with the grade and tonnage models of Singer and others (1986b), Singer and others (1986a), and Singer (1986), respectively, is estimated to be:

Percentile	90	50	10	5	1
Estimated number of deposits	0	0	2	4	7

References

- Brew, D.A., 1993, Regional geologic setting of mineral resources in southeastern Alaska, *in* Godwin, L.H., and Smith, B. D., eds., Economic mineral resources of the Annette Islands Reserve, Alaska: U.S. Dept. of the Interior, Bureau of Indian Affairs, Division of Energy and Mineral Resources Publication, p.13-20.
- Brew, D.A., Drew, L.J., Schmidt, L.M., Root, D.H., and Huber, D.F., 1991, Undiscovered locatable mineral resources of the Tongass National Forest and adjacent areas, southeastern Alaska: U.S. Geological Survey Open-File Report 91-10, 370 p., 15 maps at 1:250,000, 1 map at 1:500,000, 11 figs.

- Cox, D.P., 1986a, Descriptive model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 76.
- Cox, D.P., 1986b, Descriptive model of porphyry Cu-Mo, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 115.
- Cox, D.P., 1986c, Descriptive model of porphyry Cu, skarn-related deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 82.
- Singer, D.A., 1986, Grade and tonnage model of porphyry Cu, skarn-related deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 82-85.
- Singer, D.A., Cox, D.P., and Mosier, D.L., 1986a, Grade and tonnage model of porphyry Cu-Mo deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 116-119.
- Singer, D.A., Mosier, D.L., and Cox, D.P., 1986b, Grade and tonnage model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 77-81.

[AK-SE08](#)

Placer Gold

Alaska Southeast

Descriptive Model: 39a
Area: 973 km²

Mark3 Index: 54
Mean undiscovered deposits: 0.03

[Cumulative Distribution](#)

[Histogram](#)

[Table](#)

[Model](#)

[Mineral Deposits](#)

by David A. Brew, Cliff D. Taylor, Robert C. Jachens, Richard D. Koch, Donald Grybeck, James L. Drinkwater, David F. Barnes, and Larry J. Drew

Rationale for deposit type selection:

Small placer Au-PGE deposits have been exploited throughout southeastern Alaska, particularly in association with low-sulfide- gold-quartz vein districts, but the Porcupine Creek area is the only one that continues to be of interest.

Rationale for tract delineation:

This tract includes the Porcupine Creek drainage basin and is defined by the distribution of deposits and occurrences, and the distribution of extensive recent stream-gravel deposits (Brew and others, 1991). Because of both steep topography and the scouring effects of the Pleistocene ice sheets and glaciers, other parts of southeastern Alaska generally do not have large accumulations of gravels in proximity to lode gold deposits and past placer operations have been generally small and short-lived.

Important examples of deposit type:

Porcupine Creek and McKinley Creek are examples of placer gold deposits in this tract.

Rationale for numerical estimate:

Permissive sediment types and the occurrence of known placer deposits were the main basis for the estimate. The estimated minimum number of placer gold deposits, consistent with the grade and tonnage model of Orris and Bliss (1986), expected to occur in this tract is:

Percentile	90	50	10	5	1
Estimated number of deposits	0	0	0	0	1

References

Brew, D.A., Drew, L.J., Schmidt, L.M., Root, D.H., and Huber, D.F., 1991, Undiscovered locatable mineral resources of the Tongass National Forest and adjacent areas, southeastern Alaska: U.S. Geological Survey Open-File Report 91-10, 370 p., 15 maps at 1:250,000, 1 map at 1:500,000, 11 figs.
Orris, G.J., and Bliss, J.D., 1986, Grade and tonnage model of placer Au-PGE, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 261-264.

AK-SE09**Cu-(Au) Skarn****Alaska
Southeast****Descriptive Model: 18b****Mark3 Index: 8****Area: 8,009 km²****Mean undiscovered deposits: 3.7**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by David A. Brew, Cliff D. Taylor, Robert C. Jachens, Richard D. Koch, Donald Grybeck, James L. Drinkwater, David F. Barnes, and Larry J. Drew

Rationale for deposit type selection:

In this composite tract, Late Proterozoic and Paleozoic carbonate and some clastic rocks are intruded by Cretaceous and Tertiary mesozonal to epizonal subduction- and post-subduction-related calcalkaline granitic plutons and dikes, with local development of extensive thermally altered areas. Many Cu skarn deposits are recognized on the basis of their mineralogy, and association with carbonates adjacent to intrusive contacts. The area is permissive for Cu skarn deposits as described Cox and Theodore (1986).

Rationale for tract delineation:

Tract boundaries were delineated by the combination of Paleozoic carbonate rocks and Cretaceous and Tertiary intrusive rocks, together with the known distribution of Cu skarns. This tract comprises several tracts that were defined by Brew and others (1991) and whose regional relations were summarized by Brew (1993).

Important examples of deposit type:

Many Cu skarn deposits (Mt. Andrew, Stevenstown, Mamie, etc.) occur on the Kasaan Peninsula and in the vicinity of the Jumbo Mine on Hetta Inlet, both localities are on Prince of Wales Island. The Alaska Chief deposit is in Glacier Bay National Park.

Rationale for numerical estimate:

Permissive rock types and associations, the many known deposits of this type, and appropriate geochemical patterns were the main basis for the estimates. The minimum number of undiscovered Cu skarn deposits, consistent with the grade and tonnage model of Jones and Menzie (1986), is estimated to be:

Percentile	90	50	10	5	1
Estimated number of deposits	1	4	6	7	8

References

- Brew, D.A., 1993, Regional geologic setting of mineral resources in southeastern Alaska, *in* Godwin, L.H., and Smith, B. D., eds., Economic mineral resources of the Annette Islands Reserve, Alaska: U.S. Dept. of the Interior, Bureau of Indian Affairs, Division of Energy and Mineral Resources Publication, p.13-20.
- Brew, D.A., Drew, L.J., Schmidt, L.M., Root, D.H., and Huber, D.F., 1991, Undiscovered locatable mineral resources of the Tongass National Forest and adjacent areas, southeastern Alaska: U.S. Geological Survey Open-File Report 91-10, 370 p., 15 maps at 1:250,000, 1 map at 1:500,000, 11 figs.
- Cox, D.P., and Theodore, T.G., 1986, Descriptive model of Cu skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p 86.
- Jones, G.M., and Menzie, W.D., 1986, Grade and tonnage model of Cu skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 86-89.

Descriptive Model 23Area = 1,236 km²

Mark3 Index: (none)

Mean undiscovered deposits: 0.18

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by David A. Brew, Cliff D. Taylor, Robert C. Jachens, Richard D. Koch, Donald Grybeck, James L. Drinkwater, David F. Barnes, and Larry J. Drew

Rationale for deposit type selection

In this tract Triassic subaerial basalts (greenstones) of the Wrangellia terrane contain local concentrations of Cu-sulfide minerals that are interpreted to be basaltic Cu deposits.

Rationale for tract delineation

This tract includes Paleozoic mafic volcanic and carbonate rocks, Triassic(?) and Cretaceous greenstones, and Triassic mafic volcanic rocks. Tract boundaries were delineated mainly by the distribution of mafic volcanic rocks and greenstones, occurrence of known deposits, and Ag, Cu, Pb, and Zn geochemical anomalies associated with mafic volcanic rocks and greenstones (Brew and others, 1991).

Important example of deposit type

Baker Peak on Chichagof Island contains massive to disseminated chalcopyrite, and pyrite in Triassic(?) basalt flows, and is possibly a basaltic Cu deposit (Brew and others, 1991).

Rationale for numerical estimate

Permissive rock types and associations, a few known deposits, and appropriate geochemical patterns were the main basis for the estimates. For assessment purposes, the team used an assumed mean grade and tonnage similar to the basaltic Cu deposits of the Upper Peninsula of Michigan, which have a median size of 15.7 million metric tons and a median grade of 1.1 percent Cu (White, 1968). This model may overestimate the number of deposits in this distant location, but it at least provides a preliminary and tentative estimate. The estimated number of undiscovered basaltic Cu deposits in this tract is:

Percentile	90	50	10	5	1
Estimated number of deposits	0	0	0	2	3

References

- Brew, D.A., 1993, Regional geologic setting of mineral resources in southeastern Alaska, in Godwin, L.H., and Smith, B. D., eds., Economic mineral resources of the Annette Islands Reserve, Alaska: U.S. Dept. of the Interior, Bureau of Indian Affairs, Division of Energy and Mineral Resources Publication, p.13-20.
- Brew, D.A., Drew, L.J., Schmidt, L.M., Root, D.H., and Huber, D.F, 1991, Undiscovered locatable mineral resources of the Tongass National Forest and adjacent areas, southeastern Alaska: U.S. Geological Survey Open-File Report 91-10, 370 p., 15 maps at 1:250,000, 1 map at 1:500,000, 11 figs.
- White, W.S., 1968, The native-copper deposits of northern Michigan, *in* Ridge, J.D., editor, Ore Deposits of the United States 1933-1967; The Graton-Sales Volume, American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York, v. 1, p. 303-326.

[AK-SE11](#)

Cyprus Massive Sulfide

Alaska Southeast

Descriptive Model: 24a

Mark3 Index: 11

Area: 1,374 km²

Mean undiscovered deposits: 0.06

[Cumulative Distribution](#)

[Histogram](#)

[Table](#)

[Model](#)

by David A. Brew, Cliff D. Taylor, Robert C. Jachens, Richard D. Koch, Donald Grybeck, James L. Drinkwater, David F. Barnes, and Larry J. Drew

Rationale for deposit type selection:

Triassic greenstones, derived from pillow basalts of the Wrangellia terrane, contain local concentrations of Cu-sulfide minerals interpreted to be Cyprus massive sulfide deposits, as described by Singer (1986). Except for the part of the tract that is in the Coast Mountains, any connection with ophiolitic complexes is tenuous.

Rationale for tract delineation:

This tract was delineated mainly by the distribution of Triassic meta-pillow basalts and by favorable geochemical patterns (Brew and others, 1991; Brew, 1993).

Important examples of deposit type:

The Northern Copper Co. deposit on Kupreanof Island is a Cyprus massive sulfide (Brew and others, 1991).

Rationale for numerical estimate:

Permissive rock types and associations, a few known deposits, and appropriate geochemical patterns were the main basis for the estimates. The team estimated the minimum number of undiscovered deposits, consistent with the grade and tonnage model of Singer and Mosier (1986), to be:

Percentile	90	50	10	5	1
Estimated number of deposits	0	0	0	0	2

References

- Brew, D.A., 1993, Regional geologic setting of mineral resources in southeastern Alaska, in Godwin, L.H., and Smith, B. D., eds., Economic mineral resources of the Annette Islands Reserve, Alaska: U.S. Dept. of the Interior, Bureau of Indian Affairs, Division of Energy and Mineral Resources Publication, p.13-20.
- Brew, D.A., Drew, L.J., Schmidt, L.M., Root, D.H., and Huber, D.F., 1991, Undiscovered locatable mineral resources of the Tongass National Forest and adjacent areas, southeastern Alaska: U.S. Geological Survey Open-File Report 91-10, 370 p., 15 maps at 1:250,000, 1 map at 1:500,000, 11 figs.
- Singer, D.A., 1986, Descriptive model of Cyprus massive sulfide, in Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 131.
- Singer, D.A., and Mosier, D.L., 1986, Grade and tonnage model of Cyprus massive sulfide deposits, in Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 131-135.

Descriptive Model: 19a

Mark3 Index: 47

Area: 594 km²

Mean undiscovered deposits: 0.14

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by David A. Brew, Cliff D. Taylor, Robert C. Jachens, Richard D. Koch, Donald Grybeck, James L. Drinkwater, David F. Barnes, and Larry J. Drew

Rationale for deposit type selection

In southeastern Alaska, small polymetallic replacement deposits are possible where Paleozoic carbonate and some clastic rocks are intruded by Cretaceous and Tertiary mesozonal to epizonal subduction- and post-subduction-related calcalkaline granitic plutons and dikes.

Rationale for tract delineation

Tract boundaries were delineated by the combination of Paleozoic carbonate rocks and Cretaceous and Cretaceous and Tertiary intrusive rocks (Brew and others, 1991). These criteria are the regional metallogenic factors cited by Brew (1993).

Important example of deposit type

Coronation Island is a Pb-Ag polymetallic replacement deposit in Silurian limestone and marble intruded by Tertiary(?) diorite (Twenhofel and others, 1949).

Rationale for numerical estimate

Permissive rock types and associations and appropriate geochemical patterns (Brew and others, 1991) were the main basis for the estimates. The minimum number of undiscovered polymetallic replacement deposits, consistent with the grade and tonnage model of Mosier and others (1986), estimated to occur in this tract is:

Percentile	90	50	10	5	1
Estimated number of deposits	0	0	0	1	3

References

- Brew, D.A., 1993, Regional geologic setting of mineral resources in southeastern Alaska, *in* Godwin, L.H., and Smith, B. D., eds., Economic mineral resources of the Annette Islands Reserve, Alaska: U.S. Dept. of the Interior, Bureau of Indian Affairs, Division of Energy and Mineral Resources Publication, p.13-20.
- Brew, D.A., Drew, L.J., Schmidt, L.M., Root, D.H., and Huber, D.F, 1991, Undiscovered locatable mineral resources of the Tongass National Forest and adjacent areas, southeastern Alaska: U.S. Geological Survey Open-File Report 91-10, 370 p., 15 maps at 1:250,000, 1 map at 1:500,000, 11 figs.
- Mosier, D.L., Morris, H.T., and Singer, D.A., 1986, Grade and tonnage model of polymetallic replacement deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 101-104.
- Twenhofel, W.S., Reed, J.C., and Gates, G.O., 1949, Some mineral investigations in southeastern Alaska: U.S. Geological Survey Bulletin 963-A, 45 p.

Descriptive Model: 22c

Mark3 Index: 46

Area: 21,295 km²

Mean undiscovered deposits: 9.5

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by David A. Brew, Cliff D. Taylor, Robert C. Jachens, Richard D. Koch, Donald Grybeck, James L. Drinkwater, David F. Barnes, and Larry J. Drew

Rationale for model choice:

In southeast Alaska, Mesozoic and Paleozoic clastic, volcanic and some carbonate rocks that are intruded by scattered Cretaceous and Tertiary mesozonal to epizonal subduction- and post-subduction-related calcalkaline granitic plutons and dikes host numerous polymetallic vein deposits..

Rationale for tract delineation:

This multi-part tract is delineated by outcrop areas of Mesozoic and Paleozoic sedimentary, volcanic, and metamorphic rocks that are intruded by Cretaceous and Tertiary granitic plutons, by numerous occurrences of polymetallic veins, and by favorable geochemical patterns (Brew and others, 1991; Brew, 1993).

Important examples of deposit type:

Numerous deposits occur in the Hyder Mining District, including the Homestake and Riverside. The Lucky Nell, Puyallup, Dawson, Valparaiso, and Golden Fleece deposits are on Prince of Wales Island. Admiralty Alaska (Willoughby) and Alaska Dano are on Admiralty Island. The Hoadley and Goldstream occurrences are near Ketchikan, and the Lost Charlie Ross deposit is near the Whiting River.

Rationale for numerical estimate:

Permissive rock types and associations, abundant known deposits, and appropriate geochemical patterns were the main basis for the estimates. The minimum number of undiscovered polymetallic vein deposits, consistent with the grade and tonnage model of Bliss and Cox (1986) was estimated to be:

Percentile	90	50	10	5	1
Estimated number of deposits	5	9	15	17	21

References:

- Bliss, J.D., and Cox, D.P., 1986, Grade and tonnage model of polymetallic veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 125-129.
- Brew, D.A., 1993, Regional geologic setting of mineral resources in southeastern Alaska, *in* Godwin, L.H., and Smith, B. D., eds., Economic mineral resources of the Annette Islands Reserve, Alaska: U.S. Dept. of the Interior, Bureau of Indian Affairs, Division of Energy and Mineral Resources Publication, p.13-20.
- Brew, D.A., Drew, L.J., Schmidt, L.M., Root, D.H., and Huber, D.F., 1991, Undiscovered locatable mineral resources of the Tongass National Forest and adjacent areas, southeastern Alaska: U.S. Geological Survey Open-File Report 91-10, 370 p., 15 maps at 1:250,000, 1 map at 1:500,000, 11 figs.

AK-SE14

Zn-Pb Skarn

Alaska Southeast

Descriptive Model: 18c

Mark3 Index: 22

Area: 3,476 km²

Mean undiscovered deposits: 1.7

[Cumulative Distribution](#)

[Histogram](#)

[Table](#)

[Model](#)

by David A. Brew, Cliff D. Taylor, Robert C. Jachens, Richard D. Koch, Donald Grybeck, James L. Drinkwater, David F. Barnes, and Larry J. Drew

Rationale for deposit type selection:

In this tract, Paleozoic carbonate and some clastic rocks are intruded by Cretaceous and Tertiary mesozonal to epizonal subduction- and post-subduction-related calcalkaline granitic plutons and dikes, with local development of extensive thermally altered areas. Zn-Pb skarn deposits (Cox, 1986) are inferred on the basis of their mineralogy, and association with carbonates adjacent to intrusive contacts.

Rationale for tract delineation:

This tract encompasses 18 separate areas defined by Brew and others (1991) on the basis of the distribution of Paleozoic carbonate and some clastic rocks that are intruded by Cretaceous and Tertiary granitic plutons and dikes, together with the known distribution of Zn-Pb skarns. The detailed information from these individual areas comprise the regional metallogenic factors cited by Brew (1993). Tract boundaries were delineated by the combination of Paleozoic carbonate rocks and Cretaceous and Tertiary intrusive rocks.

Important examples of deposit type:

Groundhog Basin, east of Wrangell, Alaska is a Zn-Pb skarn deposit (Newberry and Brew, 1989).

Rationale for numerical estimate:

Permissive rock types and associations and appropriate geochemical patterns are the main basis for the estimates. The minimum number of undiscovered Zn-Pb skarn deposits, consistent with the grade and tonnage model of Mosier (1986), is estimated to be:

Percentile	90	50	10	5	1
Estimated number of deposits	0	1	4	5	7

References

- Brew, D.A., 1993, Regional geologic setting of mineral resources in southeastern Alaska, *in* Godwin, L.H., and Smith, B. D., eds., Economic mineral resources of the Annette Islands Reserve, Alaska: U.S. Dept. of the Interior, Bureau of Indian Affairs, Division of Energy and Mineral Resources Publication, p.13-20.
- Brew, D.A., Drew, L.J., Schmidt, L.M., Root, D.H., and Huber, D.F, 1991, Undiscovered locatable mineral resources of the Tongass National Forest and adjacent areas, southeastern Alaska: U.S. Geological Survey Open-File Report 91-10, 370 p., 15 maps at 1:250,000, 1 map at 1:500,000, 11 figs.
- Cox, D.P., 1986, Descriptive model of Zn-Pb skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 90.
- Mosier, D.L., 1986, Grade and tonnage model of Zn-Pb skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 90-93.
- Newberry, R.J., and Brew, D.A., 1989, Epigenetic hydrothermal origin of the Groundhog Basin-Glacier Basin silver-tin-lead-zinc deposits, southeastern Alaska, *in*, Galloway, J.P., and Dover, J.H., eds., Geologic studies in Alaska by the U.S. Geological Survey in 1988: U.S. Geological Survey Bulletin 1903, p. 113-121.

Descriptive model: 7a
Area: 1,324 km²

Mark3 Index: ????
Mean undiscovered deposits: 0.1

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by David A. Brew

Rationale for Model Choice

This model (Page, 1986) was selected because it best fit the combination of tectonic environment, deposit mineralogy, and host rocks of this tract and its subtracts. There was some discussion, though, as the fit isn't perfect!

Rationale for Tract Delineation

This tract includes the tracts designated as 09JU, 04MF, 10MF, 01SI, and 08SI by Brew and others (1991, 1996). Those tracts, and therefore this composite tract, were delineated by a combination of criteria: (1) distribution of known deposits of this type, (2) distribution of geologic map units considered to be permissive for this deposit type, and (3) geophysical signature. Re (1): Each of the subtracts of this composite tract contains deposits or occurrences of the type assigned to the deposit model. Re (2) The boundaries of the permissive map units are the delineating factors. Re (3): Each of these subtracts have known significant geophysical anomalies.

Important Examples of Deposit Type

Examples of this deposit type include Bohemia Basin, on Yakobi Island (subtract 01SI), Brady Glacier (subtract 09MF, no undiscovered deposits estimated for this tract, however), and Mertie Lode (subtract 09JU).

Rationale for Numerical Estimates

Significant numerical estimates were made only for the areas considered to be most like Brady Glacier (subtract 04MF at Mt. Fairweather) and Bohemia Basin (subtract 01SI). In both of those areas it was estimated that there was a 0.5 probability of one or more deposits and lesser probabilities of more deposits. Other areas were considered to have only lower probabilities. For the entire tract, the mineral resource team estimated the minimum number of undiscovered deposits, consistent with a tonnage and grade model of Singer, and others (1986), to be:

Percentile	90	50	10	5	1
Estimated number of deposits	0	1	3	8	13

References

- Brew, D.A., 1993, Regional geologic setting of mineral resources in southeastern Alaska, in Godwin, L.H., and Smith, B. D., eds., Economic mineral resources of the Annette Islands Reserve, Alaska: U.S. Dept. of the Interior, Bureau of Indian Affairs, Division of Energy and Mineral Resources Publication, p. 13-20.
- Brew, D.A., Drew, L.J., and Ludington. S.D., 1992, The study of the undiscovered mineral resources of the Tongass National Forest and adjacent lands, southeastern Alaska: Nonrenewable Resources, v. 1, no. 4, p. 303-321.

- Brew, D.A., Drew, L.J., Schmidt, L.M., Root, D.H., and Huber, D.F., 1991, Undiscovered locatable mineral resources of the Tongass National Forest and adjacent areas, southeastern Alaska: U.S. Geological Survey Open-File Report 91-10, 370 p., 15 maps at 1:250,000, 1 map at 1:500,000, 11 figs.
- Brew, D.A., and Drinkwater, J.L., 1991, Tongass Timber Reform Act Wilderness Areas supplement to U.S. Geological Survey Open-File Report 91-10 (Undiscovered locatable mineral resources of the Tongass National Forest and adjacent lands, southeastern Alaska): U.S. Geological Survey Open-File Report 91-343: 56 p.
- Brew, D.A., Grybeck, D.J., Taylor, C.D., Jachens, R.C., Cox, D.P., Barnes, D.F., Koch, R.D., Morin, R.L., and Drinkwater, J.L., 1996, Undiscovered mineral resources of southeastern Alaska—Revised mineral-resource-assessment-tract descriptions: U.S. Geological Survey Open-File Report 96-716, 131 p.; one map, scale 1:1,000,000.
- Page, N.J., 1986, descriptive model of synorogenic-synvolcanic Ni-Cu: *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 28.
- Singer, D.A., Page, N.J., and Menzie, W.D., 1986, Grade and tonnage model of synorogenic-synvolcanic Ni-Cu: *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 28-31.

Descriptive model: 9
Area: 448 km²

Mark3 Index: None
Mean undiscovered deposits: 0.05

[Cumulative Distribution](#)

[Histogram](#)

[Table](#)

[Model](#)

by David A. Brew

Rationale for Model Choice

All of these tracts consist of ultramafic and mafic rocks that are the "type" Alaskan-type mafic-ultramafic complexes. As such, the deposits and occurrences in these tracts define the model.

Rationale for Tract Delineation

This tract includes the tracts designated as by Brew and others (1991, 1996) as 08CR, 11CR, 09KC, 15KC, 10PE, 17PE, 03PR, 13SK, 15SK, 02SD, and 07SD. Those tracts, and therefore this composite tract, were delineated by a combination of criteria: (1) distribution of known deposits of this type, (2) distribution of geologic map units considered to be permissive for this deposit type, and (3) geophysical signature. Re (1): Known deposits with calculated resources that occur in these rocks include Union Bay, Kasaan-Salt Chuck, Yellow Hill, Blashke Islands, Duke Island, Snettisham, Klukwan, and Haines. Re (2): As described above, all of these deposits are in Alaskan-type mafic-ultramafic complexes, whose boundaries define the tracts. Re (3): All of these host mafic-ultramafic bodies have prominent steep-sided aeromagnetic and gravity anomalies associated with them.

Important Examples of Deposit Type

Union Bay, Kasaan-Salt Chuck, Duke Island, Snettisham, and Klukwan are all examples of Alaskan PGE deposits.

Rationale for Numerical Estimates

Consistent numerical estimates of 0.05 probability of one or more deposits were made for the Union Bay (08CR), Snettisham (02SD), and Turn Mountain (07SD) tracts. These estimates were largely based on the extent of exploration and focused on the Fe and Ti content of the deposits.

Percentile	90	50	10	5	1
Estimated number of deposits	0	0	0	1	2

References

- Brew, D.A., 1993, Regional geologic setting of mineral resources in southeastern Alaska, in Godwin, L.H., and Smith, B. D., eds., Economic mineral resources of the Annette Islands Reserve, Alaska: U.S. Dept. of the Interior, Bureau of Indian Affairs, Division of Energy and Mineral Resources Publication, p. 13-20.
- Brew, D.A., Drew, L.J., and Ludington, S.D., 1992, The study of the undiscovered mineral resources of the Tongass National Forest and adjacent lands, southeastern Alaska: Nonrenewable Resources, v. 1, no. 4, p. 303-321.
- Brew, D.A., Drew, L.J., Schmidt, L.M., Root, D.H., and Huber, D.F, 1991, Undiscovered locatable mineral resources of the Tongass National Forest and adjacent areas, southeastern Alaska: U.S. Geological Survey Open-File Report 91-10, 370 p., 15 maps at 1:250,000, 1 map at 1:500,000, 11 figs.
- Brew, D.A., and Drinkwater, J.L., 1991, Tongass Timber Reform Act Wilderness Areas supplement to U.S. Geological Survey Open-File Report 91-10 (Undiscovered locatable mineral resources of the

Tongass National Forest and adjacent lands, southeastern Alaska): U.S. Geological Survey Open-File Report 91-343: 56 p.

Brew, D.A, Grybeck, D.J., Taylor, C.D., Jachens, R.C., Cox, D.P., Barnes, D.F., Koch, R.D., Morin, R.L., and Drinkwater, J.L., 1996, Undiscovered mineral resources of southeastern Alaska—Revised mineral-resource-assessment-tract descriptions: U.S. Geological Survey Open-File Report 96-716, 131 p.; one map, scale 1:1,000,000.

Descriptive Model: 18a

Mark3 Index: 4, 9, and 2

Area: 9,382 km²

Mean undiscovered deposits: 0.135

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by David A. Brew, Cliff D. Taylor, Robert C. Jachens, Richard D. Koch, Donald Grybeck, James L. Drinkwater, David F. Barnes, and Larry J. Drew

Rationale for deposit type selection:

A few porphyry Cu (Cox, 1986a), porphyry Cu-Mo (Cox, 1986b), and porphyry Cu, skarn related (Cox, 1986c) deposits are known in the Cretaceous and Tertiary calcalkaline granitic plutons and dikes in southeastern Alaska.

Rationale for tract delineation:

Tract boundaries were delineated by the combination of Paleozoic carbonate rocks and Tertiary intrusive rocks (Brew and others, 1991; Brew, 1993). This multi-part tract includes most of the Tertiary subduction- and post-subduction-related calcalkaline granitic plutons in southeastern Alaska, and the tract boundaries are those of the areas known or interpreted to be underlain by those rocks. The tract also includes some similar plutons of middle Cretaceous age. In detail, Paleozoic clastic and carbonate rocks are intruded by mesozonal to epizonal Cretaceous and Tertiary granitic dikes, with local fracturing and alteration.

Important examples of deposit type:

The most important known porphyry Cu deposit in southeastern Alaska is the Margerie Glacier deposit, in Glacier Bay National Park. Minnesota Ridge, in Glacier Bay National Park, is the best example of a porphyry Cu, skarn related, deposit. Muir Inlet Nunatak, Bruce Hills, and Threesome Mountain in Glacier Bay National Park; and Shakan Bay on Prince of Wales Island are porphyry Cu-Mo deposits.

Rationale for numerical estimate:

Permissive rock types and appropriate geochemical patterns were the main basis for estimating the number of undiscovered deposits. The minimum number of undiscovered porphyry Cu; porphyry Cu, skarn related; and porphyry Cu-Mo deposits, consistent with the grade and tonnage models of Singer and others (1986b), Singer and others (1986a), and Singer (1986), respectively, is estimated to be:

Percentile	90	50	10	5	1
Estimated number of deposits	0	0	0	1	3

References

- Brew, D.A., 1993, Regional geologic setting of mineral resources in southeastern Alaska, *in* Godwin, L.H., and Smith, B. D., eds., Economic mineral resources of the Annette Islands Reserve, Alaska: U.S. Dept. of the Interior, Bureau of Indian Affairs, Division of Energy and Mineral Resources Publication, p.13-20.
- Brew, D.A., Drew, L.J., Schmidt, L.M., Root, D.H., and Huber, D.F., 1991, Undiscovered locatable mineral resources of the Tongass National Forest and adjacent areas, southeastern Alaska: U.S. Geological Survey Open-File Report 91-10, 370 p., 15 maps at 1:250,000, 1 map at 1:500,000, 11 figs.
- Cox, D.P., 1986a, Descriptive model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 76.
- Cox, D.P., 1986b, Descriptive model of porphyry Cu-Mo, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 115.

- Cox, D.P., 1986c, Descriptive model of porphyry Cu, skarn-related deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 82.
- Singer, D.A., 1986, Grade and tonnage model of porphyry Cu, skarn-related deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 82-85.
- Singer, D.A., Cox, D.P., and Mosier, D.L., 1986a, Grade and tonnage model of porphyry Cu-Mo deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 116-119.
- Singer, D.A., Mosier, D.L., and Cox, D.P., 1986b, Grade and tonnage model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 77-81.

Descriptive Model: 21a

Mark3 Index: 4, 9, and 2

Area: 9,382 km²

Mean undiscovered deposits: 0.555

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by David A. Brew, Cliff D. Taylor, Robert C. Jachens, Richard D. Koch, Donald Grybeck, James L. Drinkwater, David F. Barnes, and Larry J. Drew

Rationale for deposit type selection:

A few porphyry Cu (Cox, 1986a), porphyry Cu-Mo (Cox, 1986b), and porphyry Cu, skarn related (Cox, 1986c) deposits are known in the Cretaceous and Tertiary calcalkaline granitic plutons and dikes in southeastern Alaska.

Rationale for tract delineation:

Tract boundaries were delineated by the combination of Paleozoic carbonate rocks and Tertiary intrusive rocks (Brew and others, 1991; Brew, 1993). This multi-part tract includes most of the Tertiary subduction- and post-subduction-related calcalkaline granitic plutons in southeastern Alaska, and the tract boundaries are those of the areas known or interpreted to be underlain by those rocks. The tract also includes some similar plutons of middle Cretaceous age. In detail, Paleozoic clastic and carbonate rocks are intruded by mesozonal to epizonal Cretaceous and Tertiary granitic dikes, with local fracturing and alteration.

Important examples of deposit type:

The most important known porphyry Cu deposit in southeastern Alaska is the Margerie Glacier deposit, in Glacier Bay National Park. Minnesota Ridge, in Glacier Bay National Park, is the best example of a porphyry Cu, skarn related, deposit. Muir Inlet Nunatak, Bruce Hills, and Threesome Mountain in Glacier Bay National Park; and Shakan Bay on Prince of Wales Island are porphyry Cu-Mo deposits.

Rationale for numerical estimate:

Permissive rock types and appropriate geochemical patterns were the main basis for estimating the number of undiscovered deposits. The minimum number of undiscovered porphyry Cu; porphyry Cu, skarn related; and porphyry Cu-Mo deposits, consistent with the grade and tonnage models of Singer and others (1986b), Singer and others (1986a), and Singer (1986), respectively, is estimated to be:

Percentile	90	50	10	5	1
Estimated number of deposits	0	0	1	4	5

References

- Brew, D.A., 1993, Regional geologic setting of mineral resources in southeastern Alaska, *in* Godwin, L.H., and Smith, B. D., eds., Economic mineral resources of the Annette Islands Reserve, Alaska: U.S. Dept. of the Interior, Bureau of Indian Affairs, Division of Energy and Mineral Resources Publication, p.13-20.
- Brew, D.A., Drew, L.J., Schmidt, L.M., Root, D.H., and Huber, D.F., 1991, Undiscovered locatable mineral resources of the Tongass National Forest and adjacent areas, southeastern Alaska: U.S. Geological Survey Open-File Report 91-10, 370 p., 15 maps at 1:250,000, 1 map at 1:500,000, 11 figs.
- Cox, D.P., 1986a, Descriptive model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 76.
- Cox, D.P., 1986b, Descriptive model of porphyry Cu-Mo, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 115.

- Cox, D.P., 1986c, Descriptive model of porphyry Cu, skarn-related deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 82.
- Singer, D.A., 1986, Grade and tonnage model of porphyry Cu, skarn-related deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 82-85.
- Singer, D.A., Cox, D.P., and Mosier, D.L., 1986a, Grade and tonnage model of porphyry Cu-Mo deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 116-119.
- Singer, D.A., Mosier, D.L., and Cox, D.P., 1986b, Grade and tonnage model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 77-81.

Descriptive Model 23**Mark3 Index: (none)****Area: 1,347 km²****Mean undiscovered deposits: (no estimate)**[Model](#)*by* Marti L. Miller and Thomas K. Bundtzen**Rationale for Model Choice**

The well known Kennecott copper deposits are associated with carbonate and greenstone units of the Wrangellia terrane (Jones and others, 1987). Similar carbonate and greenstone lithologies, which may correlate with those of the Wrangellia terrane (Detterman and Reed, 1980), occur locally in the Iliamna quadrangle. The Kennecott copper deposits were included in the basaltic copper descriptive model (Cox, 1986), and there has been considerable debate over this classification. However, whether the Kennecott deposits are classified as basaltic Cu, replacement, or sabkha, the controlling factor for the delineation of a permissive tract is the distribution of the greenstones. With this consideration, we have avoided the controversy by lumping the models together.

Rationale for Tract Delineation

This tract includes the Cottonwood Bay Greenstone as mapped and described by Detterman and Reed (1980), and the overlying Upper Triassic carbonate, shale, siltstone, and chert of the Kamishak Formation.

Important Examples of Deposit Type

No basaltic copper or Kennecott-type mineral occurrences are known in southwest Alaska. Most copper occurrences in the Iliamna quadrangle are contact metamorphic skarns (Detterman and Reed, 1980). One locality described only as a "bedrock occurrence of copper sulfide" reportedly is in carbonate rock in the vicinity of greenstone (Cobb and Reed, 1981).

Rationale for Numerical Estimates

Because the geologic host rock associations are inferred, and there are no known deposits, this tract is considered to be speculative. No estimate of undiscovered basaltic copper or Kennecott-type deposits was attempted.

References

- Cobb, E.H., and Reed, B.L., 1981, Summaries of data on and lists of references to metallic and selected nonmetallic mineral occurrences in the Iliamna, Lake Clark, Lime Hills, and McGrath quadrangles, Alaska—supplement to Open-file Report 76-485, Part A: U.S. Geological Survey Open-file Report 81-1343A, 25 p.
- Cox, D.P., 1986, Descriptive model of basaltic Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 130.
- Detterman, R.L., and Reed, B.L., 1980, Stratigraphy, structure, and economic geology of the Iliamna quadrangle, Alaska: U.S. Geological Survey Bulletin 1368-B, 86 p., scale 1:250,000.
- Jones, D.L., Silberling, N.J., Coney, P.J., and Plafker, George, 1987, Lithotectonic terrane map of Alaska (west of the 141st meridian): U.S. Geological Survey, Miscellaneous Field Studies Map MF-1874-A, scale 1:2,500,000.

Descriptive Model: 24b**Mark3 Index: 30****Area: 28,702 km²****Mean undiscovered deposits: (no estimate)****Model**

by Marti L. Miller, Thomas K. Bundtzen, Dennis P. Cox, John E. Gray, and Jeffrey D. Phillips.

Rationale for Model Choice

Several areas in southwest Alaska are considered permissive for Besshi massive sulfide deposits (Cox, 1986) because they contain outcrops of mixed sedimentary and tuffaceous rocks of marine origin (mainly volcanic sandstone and andesite tuff).

Rationale for Tract Delineation

This tract is delineated on the basis of geology considered permissive for Besshi massive sulfide deposits. No Besshi-type deposits are known in the area, but the lack of geological and geochemical data to constrain the model leads to delineation of large permissive areas. The permissive rock types are concentrated in two areas of southwestern Alaska. (1) In the north, permissive mixed sedimentary and tuffaceous rocks are found in parts of the Koyukuk, Ruby, and Innoko terranes (Patton and others, 1994). Rocks belonging to the Koyukuk terrane crop out in the Kwiguk, Marshall, Holy Cross, and Russian Mission quadrangles and include Lower Cretaceous andesitic tuffs and volcanic sandstones (Csejtey, 1992). Mafic schists and metasedimentary rocks of the Ruby terrane are in the north-central part of the Iditarod quadrangle (Miller and Bundtzen, 1994). Triassic to Mississippian chert, andesitic tuff, and metasandstone of the Innoko terrane also crop out in north-central Iditarod quadrangle (Miller and Bundtzen, 1994). (2) In the southwestern part of southwest Alaska, permissive mixed sedimentary and tuffaceous rocks are found in the Bethel, Goodnews Bay, Hagemeister Island, Dillingham, Taylor Mountains, and Sleetmute quadrangles. This extensive area includes all of the Goodnews terrane and most of the Togiak terrane (Decker and others, 1994). The heterogeneous Goodnews terrane locally includes tuff and graywacke (Hoare and Coonrad, 1978; Box and others, 1993). Stream-sediment samples from the southwestern part of the Goodnews terrane are anomalous in Cu, Zn, Co, Cr, and Au (Kilburn and others, 1993). The Hagemeister subterrane of the Togiak terrane (Decker and others, 1994) includes tuffs, tuffaceous sedimentary rocks, graywackes, and siltstone (Hoare and Coonrad, 1978; Miller and others, 1989). Zn and Cu anomalies are found locally in the Togiak terrane (Kilburn and others, 1993).

Important Examples of Deposit Type

No examples of Besshi massive sulfide deposits are known in southwestern Alaska.

Rationale for Numerical Estimates

No estimate of undiscovered resources was attempted.

References

- Box, S.E., Moll-Stalcup, E.J., Frost, T.P., and Murphy, J.M., 1993, Preliminary geologic map of the Bethel and southern Russian Mission quadrangles, southwestern Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2226-A, 20 p., scale 1:250,000.
- Cox, D.P., 1986, Descriptive model of Besshi massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 136.
- Csejtey, Bela, Jr., compiler, 1992, Reconnaissance geologic compilation map of the Holy Cross quadrangle, Alaska, plate 1 *in*, Csejtey, Bela, Jr., and Keith, W.J., eds., Preassessment report on the Holy Cross Quadrangle, Alaska: Menlo Park, California, U.S. Geological Survey unpublished administrative report, 52 p., 3 sheets, scale 1:250,000.

- Decker, John, Bergman, S.C., Blodgett, R.B., Box S.E., Bundtzen, T.K., Clough, J.G., Coonrad, W.L., Gilbert, W.G., Miller, M.L., Murphy, J.M., Robinson, M.S., and Wallace, W.K., 1994, Geology of southwestern Alaska, *in* Plafker, G., and Berg, H.C., eds., The geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G1, p. 285-310.
- Hoare, J.M., and Coonrad, W.L., 1978, Geologic map of the Goodnews and Hagemeister Island quadrangles region, southwestern Alaska: U.S. Geological Survey Open-file Report 78-9-B, 2 sheets, scale 1:250,000.
- Kilburn, J.E., Goldfarb, R.J., Griscom, Andrew, and Box, S.E., 1993, Map showing metallic mineral resource potential in the Goodnews Bay, Hagemeister Island, and Nushagak Bay 1° x 3° quadrangles, southwest Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2228, 4 sheets, scale 1:250,000.
- Miller, M.L., Belkin, H.E., Blodgett, R.B., Bundtzen, T.K., Cady, J.W., Goldfarb, R.J., Gray, J.E., McGimsey, R.G., and Simpson, S.L., 1989, Pre-field study and mineral resource assessment of the Sleetmute quadrangle, southwestern Alaska: U.S. Geological Survey Open-File Report 89-363, 115 p., 3 plates, scale 1:250,000.
- Miller, M.L., and Bundtzen, T.K., 1994, Generalized geologic map of the Iditarod quadrangle, Alaska, showing potassium-argon, major-oxide, trace-element, fossil, paleocurrent, and archaeological sample localities: U.S. Geological Survey Miscellaneous Field Studies Map MF-2219-A, 48 p., scale 1:250,000.
- Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1994, Geology of west-central Alaska, chap. 7, *in* Plafker, George, and Berg, H.C., eds., The Geology of Alaska, v. G-1 of Geology of North America: Boulder, Colorado, Geological Society of America, Decade of North American Geology series, p. 241-269.

AK-SW03

Cyprus Massive Sulfide

Alaska South West

Descriptive Model: 24a

Mark3 Index: 11

Area: 6,310 km²

Mean undiscovered deposits: 0.44

[Cumulative Distribution](#)

[Histogram](#)

[Table](#)

[Model](#)

by Marti L. Miller, Thomas K. Bundtzen, Dennis P. Cox, John E. Gray, and Jeffrey D. Phillips.

Rationale for Model Choice

Pillow basalt or greenstone units that are associated with ophiolitic sequences may host Cyprus massive sulfide deposits (Singer, 1986). In most parts of southwest Alaska, we lack sufficient geologic information to separate the lava units from the rest of the ophiolite, therefore ophiolite assemblages in general are considered permissive.

Rationale for Tract Delineation

This tract, which consists of scattered ophiolite assemblages, is permissive for the occurrence of Cyprus massive sulfide deposits, although none are known in the region. Ophiolitic rocks are concentrated in two areas of southwestern Alaska. (1) In the north, ophiolite assemblages are in both Holy Cross and Iditarod quadrangles. In the Holy Cross quadrangle these rocks consist of altered basalt, diabase, and scattered ultramafic rocks (Csejtey, 1992; T.K. Bundtzen, written commun., 1992) that may correlate with ophiolitic rocks of the Angayucham or Tozitna terranes (Patton and others, 1992; 1994b). A mafic-ultramafic complex in the northern part of the Iditarod quadrangle (Miller and Bundtzen, 1994) was not included as permissive for Cyprus massive sulfide deposits, even though it too is ophiolitic. This complex was deleted from the permissive tract because it is mapped in enough detail that we are certain it does not contain basalt lavas (Miller, 1990). (2) In the southwestern part of southwest Alaska, ophiolitic rocks are in the Goodnews Bay and Hagemeister Island quadrangles. In this area, mafic-ultramafic complexes and associated pillow basalt and gabbro are interpreted to represent an ophiolite succession (Patton and others, 1994a). Stream-sediment samples from this area are locally anomalous in Co, Cu, Cr, and Ni (Kilburn and others, 1993).

Important Examples of Deposit Type

No examples of Cyprus massive sulfide deposits are known in southwest Alaska.

Rationale for Numerical Estimates

Although permissive rock sequences are present, the lack of known occurrences of Cyprus massive sulfide type mineralization led to a low estimate of undiscovered deposits. The estimated minimum number of undiscovered Cyprus massive sulfide deposits, consistent with the tonnage and grade model of Singer and Mosier (1986), is:

Percentile	90	50	10	5	1
Estimated number of deposits	0	0	1	2	4

REFERENCES

- Csejtey, Bela, Jr., compiler, 1992, Reconnaissance geologic compilation map of the Holy Cross quadrangle, Alaska, plate 1 in, Csejtey, Bela, Jr., and Keith, W.J., eds., Preassessment Report on the Holy Cross quadrangle, Alaska: Menlo Park, California, U.S. Geological Survey unpublished administrative report, 52 p., 3 sheets, scale 1:250,000.
- Kilburn, J.E., Goldfarb, R.J., Griscom, Andrew, and Box, S.E., 1993, Map showing metallic mineral resource potential in the Goodnews Bay, Hagemeister Island, and Nushagak Bay 1° x 3° quadrangles, southwest Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2228, 4 sheets, scale 1:250,000.

- Miller, M.L., 1990, Mafic and ultramafic rocks of the Dishna River area, north-central Iditarod quadrangle, west-central Alaska, *in* Dover, J.H., and Galloway, J.P., eds., *Geologic studies in Alaska by the U.S. Geological Survey*, 1989: U.S. Geological Survey Bulletin 1946, p. 44-50.
- Miller, M.L., and Bundtzen, T.K., 1994, Generalized geologic map of the Iditarod quadrangle, Alaska, showing potassium-argon, major-oxide, trace-element, fossil, paleocurrent, and archaeological sample localities: U.S. Geological Survey Miscellaneous Field Studies Map MF-2219-A, 48 p., scale 1:250,000.
- Patton, W.W., Jr., Box, S.E., and Grybeck, D.J., 1994a, Ophiolites and other mafic-ultramafic complexes in Alaska, chap. 21, *in* Plafker, George, and Berg, H.C., eds., *The Geology of Alaska*: Boulder, Colorado, Geological Society of America, *The Geology of North America*, v. G-1, p. 671-686.
- Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1994b, Geology of west-central Alaska, chap. 7, *in* Plafker, George, and Berg, H.C., eds., *The Geology of Alaska*: Boulder, Colorado, Geological Society of America, *The Geology of North America*, v. G-1, p. 241-269.
- Patton, W.W., Jr., Murphy, J.M., Burns, L.E., Nelson, S.W., and Box, S.E., 1992, Geologic map of ophiolitic and associated volcanic arc and metamorphic terranes of Alaska (west of the 141st meridian): U.S. Geological Survey Open-File Report OF 92-20A, scale 1:2,500,000.
- Singer, D.A., 1986, Descriptive model of Cyprus massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 131.
- Singer, D.A., and Mosier, D.L., 1986, Grade and tonnage model of Cyprus massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 131-135.

Descriptive Models 25a-d**Area: 24,276 km²****Mark3 Index : (none)****Mean undiscovered deposits: (no estimate)****Model**

by Frederic H. Wilson, Stanley E. Church, Richard W. Saltus, Lawrence J. Drew, and W. David Menzie.

Rationale for Model Choice

Epithermal vein deposit models in the conterminous US have been divided into several types based largely on the underlying basement rocks (Cox and Singer, 1986). For the most part, information about Alaska is inadequate to classify individual epithermal gold vein types. Therefore, we have combined deposit models for Creede epithermal veins (Mosier and others, 1986b), Comstock epithermal veins (Mosier and others, 1986c), Sado epithermal veins (Mosier and others, 1986a), and epithermal quartz-alunite gold (Berger, 1986) into a generic epithermal vein model. We evaluated the permissive area for undiscovered deposits of all types of epithermal veins based on this generic model, which includes gold and/or silver veins associated with intermediate to felsic volcanic rocks similar to those described by Panteleyev (1987).

The mineral resource assessment of the Katmai 1:250,000 scale quadrangle (Church and others, 1992) was used to infer the possibility of the epithermal vein deposits in the Eocene and Oligocene volcanic rocks in this tract.

Rationale for Tract Delineation

This tract consists of Tertiary volcanic and shallow intrusive rocks (Detterman and Reed, 1980; Nelson and others, 1983) permissive for epithermal vein deposits. Isolated gold and silver stream-sediment geochemical anomalies, in addition to other metals, and placer gold in drainages west and north of Sugarloaf Mountain (see Church and Bennett, 1989, cited in Church and others, 1992) suggest that this tract is similar to other tracts of Tertiary volcanic rock on the Alaska Peninsula and is permissive for epithermal gold veins.

Important Examples of Deposit Type

None known.

Rationale for Numerical Estimates

No estimates of the number of undiscovered deposits were made for this tract.

References

- Berger, B.R., 1986, Descriptive model of epithermal quartz-alunite Au, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 158.
- Church, S.E., Riehle, J.R., Magoon, L.B., and Campbell, D.L., 1992, Mineral and energy resource assessment maps of the Mount Katmai, Naknek, and western Afognak quadrangles, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2021-F, 22 p., scale 1:250,000.
- Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 130.
- Detterman, R.L., and Reed, B.L., 1980, Stratigraphy, structure, and economic geology of the Iliamna quadrangle, Alaska: U.S. Geological Survey Bulletin 1368-B, 86 p., scale 1:250,000.
- Mosier, D.L., Berger, B.R., and Singer, D.A., 1986a, Descriptive model of Comstock epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 154.

- Mosier, D.L., Sato, Takeo, Page, N.J., Singer, D.A., and Berger, B.R., 1986b, Descriptive model of Creede epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 145.
- Mosier, D.L., Singer, D.A., and Berger, B.R., 1986c, Descriptive model of Comstock epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 150.
- Nelson, W.H., Carlson, Christine, and Case, J.E., 1983, Geologic map of the Lake Clark quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1114-A, scale 1:250,000.
- Panteleyev, Andrejs, 1987, A Canadian cordilleran model for epithermal gold-silver deposits, *in* Roberts, R.G., and Sheahan, P.A., Ore Deposit Models: Geoscience Canada Reprint Series 3, p. 31-43.

Descriptive Model: (none)**Mark3 Index : 120****Area: 36,097 km²****Mean undiscovered deposits: (no estimate)**[Model](#)[Mineral Deposits](#)

by Marti L. Miller, Thomas K. Bundtzen, Dennis P. Cox, John E. Gray, and Jeffrey D. Phillips.

Rationale for Model Choice

Gold-bearing deposits in this tract are associated with Upper Cretaceous and lower Tertiary peraluminous granite porphyry and rhyolite dikes that intrude Cretaceous turbidite and volcanic rocks. Little is known about these occurrences, but they appear to represent a distinct model type, herein called peraluminous granite porphyry gold deposits. The peraluminous granite porphyry gold deposits have some features in common with polymetallic veins (Cox, 1986) and felsic intrusion-associated veins (Sangster, 1984), but their association with peraluminous dikes across much of southwest Alaska (Bundtzen and Miller, 1997) makes designation of a distinct model type more useful in understanding and predicting their occurrence. The felsic dikes are probably structurally controlled, but their origin is unknown. The model is more fully described by Bundtzen and Miller (1997).

Rationale for Tract Delineation

The extent of the permissive tract is defined by the known or inferred distribution of peraluminous granite porphyry dikes intruding the turbidites of the Cretaceous Kuskokwim Group or the volcanic and sedimentary rocks of the Yukon-Koyukuk terrane. The dikes are granitic in composition, contain about equal amounts of plagioclase and potassium feldspar, and range from porphyritic to aphanitic. They are depleted in heavy REE, and have high Rb/Sr ratios, suggesting a possible crustal melt source (Miller and Bundtzen, 1994). As further information becomes known, the permissive area for deposit occurrences of this type may be revised.

Important Examples of Deposit Type

Examples of this deposit type include the Stuyahok occurrence in the Holy Cross quadrangle (Miller and others, 1996) and the Donlin Creek deposit in the Iditarod quadrangle. Exploration and drilling at Donlin Creek yielded a preliminary resource of 3.6 million ounces of gold (Dodd, 1996).

Rationale for Numerical Estimates

Insufficient geologic information about the distribution of deposits, or about the controls for ore genesis preclude the possibility of estimating quantity or size of undiscovered deposits, but additional deposits are expected.

References

- Bundtzen, T.K., and Miller, M.L., 1997, Precious metals associated with Late Cretaceous-early Tertiary igneous rocks of southwestern Alaska, *in* Goldfarb, R.J., and Miller, L.D., eds., *Mineral deposits of Alaska: Economic Geology Monograph 9*, p. 242-286.
- Cox, D.P., 1986, Descriptive Model of polymetallic veins, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models: U.S. Geological Survey Bulletin 1693*, p. 125.
- Dodd, Stan, 1996, Donlin Creek project, southwest Alaska [abs], in *Alaska mining—no longer just a dream: Alaska Miners Association, Abstracts, 1996 Annual Convention, November 6-8, 1996, Anchorage, Alaska*, p. 27-28.
- Miller, M.L., and Bundtzen, T.K., 1994, Generalized geologic map of the Iditarod quadrangle, Alaska, showing potassium-argon, major-oxide, trace-element, fossil, paleocurrent, and archaeological sample

localities: U.S. Geological Survey Miscellaneous Field Studies Map MF-2219-A, 48 p., scale 1:250,000.

Miller, M.L., Bundtzen, T.K., Keith, W.J., Bailey, E.A., and Bickerstaff, Damon, 1996, Geology and mineral resources of the Stuyahok area, part of Holy Cross A-4 and A-5 quadrangles, Alaska: U.S. Geological Survey Open-File Report 96-505-A, 47 p., scale 1:63,360.

Sangster, D.F., 1984, Felsic intrusion-associated silver-lead-zinc veins, in Eckstrand, O.R., ed., Canadian mineral deposit types: A geologic synopsis: Geological Survey of Canada Economic Geology Report 36, p. 66.

Descriptive Model: 36a**Mark3 Index: 27****Area: 11,948 km²****Mean undiscovered deposits: 2.07**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Marti L. Miller, Thomas K. Bundtzen, Dennis P. Cox, John E. Gray, and Jeffrey D. Phillips

Rationale for Model Choice

In southwest Alaska, mixed oceanic lithologies that show greenschist facies metamorphism are considered permissive for low-sulfide Au-quartz vein deposits. The local presence of placer gold in association with these rocks is consistent with the model designation (Berger, 1986).

Rationale for Tract Delineation

This tract consists of two main areas and a third smaller area: (1) The central area lies south of Kako Creek in the Russian Mission and Holy Cross quadrangles. This area is underlain by a mixed lithology that includes part of the Angayucham-Tozitna terrane (mixed PzMz basalt, ultramafic, and sedimentary rocks) overlain by volcanic and volcanoclastic rocks of the Yukon-Koyukuk terrane. The tract was extended west over a covered region on the basis of gamma ray geophysics. The regional metamorphic facies map (Dusel-Bacon, 1991) shows prehnite-pumpellyite facies in this area, but 1992 field work indicates it is actually greenschist facies (T.K. Bundtzen, oral commun., 1993). Five placer gold mines have operated within this area. (2) The southern area forms a belt through the Bethel, Goodnews, and Hagemeister Island quadrangles and contains the Kilbuck terrane and part of the Goodnews terrane. The Goodnews terrane lithologies include mudstone, basalt, serpentine, ophiolitic rocks, and schists. The Kilbuck terrane contains mafic and felsic schists. Metamorphic grade across much of the belt is low greenschist, although locally higher grades exist (Dusel-Bacon, 1991). Gold placers in the area south of the Kilbuck terrane may indicate the presence of either low-sulfide Au-quartz veins or an unexposed pluton. (3) The northern area lies in the north-central Iditarod and south-central Ophir quadrangles. It is underlain by greenschist-facies metavolcanic rocks and lesser quartz-mica schist of the Ruby terrane (Miller and Bundtzen, 1994). The area is outlined on the basis of permissive greenschist facies rocks alone; no gold occurrences are known in the northern area.

Important Examples of Deposit Type

The Arnold prospect in the Russian Mission quadrangle, area (1) described above, is probably a low-sulfide Au-quartz vein deposit.

Rationale for Numerical Estimates

Given the presence of permissive rock types of the appropriate metamorphic grade and the occurrence of placer gold deposits in the two main areas of the tract, the assessment team concluded that the likelihood of a low-sulfide Au-quartz vein deposit was high. The third small area discussed above (underlain by Ruby terrane), was excluded from the estimate. The estimated minimum number of undiscovered low-sulfide Au-quartz vein deposits, consistent with the grade and tonnage model of Bliss (1986) is:

Percentile	90	50	10	5	1
Estimated number of deposits	1	2	3	4	6

References

- Berger, B.R., 1986, Descriptive model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239.
- Bliss, J.D., 1986, Grade and tonnage model of low-sulfide gold-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239-243.
- Dusel-Bacon, Cynthia, 1991, Metamorphic history of Alaska: U.S. Geological Survey Open-file Report 91-556, 48 p., 2 sheets, scale 1:2,500,000.
- Miller, M.L., and Bundtzen, T.K., 1994, Generalized geologic map of the Iditarod quadrangle, Alaska, showing potassium-argon, major-oxide, trace-element, fossil, paleocurrent, and archeological sample localities: U.S. Geological Survey Miscellaneous Field Studies Map MF-2219-A, 48 p., scale 1:250,000.

Descriptive Model 32c**Mark3 Index (none)****Area: 6,926 km²****Mean undiscovered deposits: (no estimate)**[Model](#)*by* Marti L. Miller, Jeanine M. Schmidt, and Bruce M. Gamble**Rationale for Model Choice**

Paleozoic platform carbonate rocks in southwest Alaska are permissive for Kipushi-type deposits as defined by Cox and Bernstein (1986), because they were formed in an appropriate geologic setting (a continental platform or shelf with continental or passive margin rifting) and because they contain appropriate host rocks (dolostone, shale, and shallow-water or platform carbonate rocks) for the deposit model. Although no occurrences are known in this tract, correlative rocks in west-central Alaska contain several carbonate-hosted base-metal prospects.

Rationale for Tract Delineation

This tract consists of three areas that form a northeast-trending belt. The northeast area (in the McGrath quadrangle) and central area (in the Sleetmute, Taylor Mountains, and Lime Hills quadrangles) are both underlain by Cambrian to Devonian shallow-water facies platform carbonate rocks of the Farewell terrane (Decker and others, 1994). No geochemical data are available to assist in evaluating the Kipushi Cu-Pb-Zn potential of these rocks, but the depositional environment is appropriate, and correlative rocks to the northeast host several Zn prospects. The southwestern area (in Goodnews Bay quadrangle) contains blocks of Ordovician, Devonian, and Permian limestone, which constitute less than 5 percent of a structurally disrupted unit of mixed marine sedimentary and volcanic rock that forms the Nukluk subterrane of the Goodnews terrane (Decker and others, 1994). The limestone blocks show algal reef and reef breccia textures (Hoare and Coonrad, 1978), indicating a depositional environment permissive for Kipushi-type deposits.

Important Examples of Deposit Type

Examples of carbonate-hosted base-metal deposits occur in equivalent rocks in the Reef Ridge district in the Medfra quadrangle of west-central Alaska (Schmidt, 1997).

Rationale for Numerical Estimates

There are no tonnage and grade curves for Kipushi-type deposits; no quantitative estimates of the number of undiscovered deposits were attempted.

References

- Cox, D.P., and Bernstein, L.R., 1986, Descriptive model of Kipushi Cu-Pb-Zn, *in* Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 227.
- Decker, John, Bergman, S.C., Blodgett, R.B., Box S.E., Bundtzen, T.K., Clough, J.G., Coonrad, W.L., Gilbert, W.G., Miller, M.L., Murphy, J.M., Robinson, M.S., and Wallace, W.K., 1994, Geology of southwestern Alaska, *in* Plafker, George, and Berg, H.C., eds., The geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G1, p. 285-310.
- Hoare, J.M., and Coonrad, W.L., 1978, Geologic map of the Goodnews and Hagemester Island quadrangles region, southwestern Alaska: U.S. Geological Survey Open-file Report 78-9-B, 2 sheets, scale 1:250,000.
- Schmidt, J.M., 1997, Strata-bound carbonate-hosted Zn-Pb and Cu deposits of Alaska, *in* Goldfarb, R.J., and Miller, L.D., eds., Mineral Deposits of Alaska: Economic Geology Monograph 9, p. 90-119.

Descriptive Model: 28a

Mark3 Index: 93

Area: 6,536 km²

Mean undiscovered deposits: 0.14

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Marti L. Miller, Thomas K. Bundtzen, Dennis P. Cox, John E. Gray, and Jeffrey D. Phillips.

Rationale for Model Choice

The lack of limiting geologic and geochemical data for southwestern Alaska leads to delineation of large areas permissive for kuroko massive sulfide deposits as described by Singer (1986). The permissive areas are underlain by mixed assemblages that include basaltic to andesitic marine volcanic rocks and local felsic volcanic units.

Rationale for Tract Delineation

This tract is delineated on the basis of geology considered permissive for kuroko massive sulfide deposits; no mineral occurrences of this type are known in the region. The permissive rock types are concentrated in three areas of southwest Alaska. (1) In the north, marine volcanic assemblages of the Koyukuk terrane (Patton and others, 1994) crop out in the Kwiguk, Marshall, Holy Cross, and Russian Mission quadrangles. These rocks constitute a mixed assemblage largely composed of Upper Jurassic(?) and Lower Cretaceous andesitic volcanic and volcanoclastic rocks, but which locally includes dacitic lava flows (T.K. Bundtzen, written commun., 1992). (2) In the southwestern part of southwest Alaska, permissive marine volcanic rocks occur in the Bethel, Goodnews Bay, Hagemeister Island, and Dillingham quadrangles. This extensive area includes nearly all of the Goodnews terrane, parts of the Togiak terrane, and all of the Kilbuck terrane (as defined by Decker and others, 1994). Here the Goodnews terrane includes mixed pillow basalts, intermediate to mafic flows, volcanoclastic rocks, and sedimentary rocks (Hoare and Coonrad, 1978; Box and others, 1993); felsic volcanic rocks occur locally. Stream-sediment samples from the southwestern part of the Goodnews terrane are anomalous in Cu, Zn, Co, Cr, and Au (Kilburn and others, 1993). The Hagemeister subterrane of the Togiak terrane (Decker and others, 1994) is also included as permissive for kuroko type deposits. These rocks consist largely of marine volcanic and volcanoclastic strata, which include mafic, andesitic, and trachytic compositions (Hoare and Coonrad, 1978). Zn and Cu anomalies occur locally in the Togiak terrane (Kilburn and others, 1993). The Proterozoic Kilbuck terrane (Box and others, 1990) is also included as permissive, because it locally contains metamorphosed felsic (unpublished mapping by M.L. Miller and T.K. Bundtzen, 1992) and mafic volcanic rocks (D.L. Turner and others, written commun., 1982). (3) The third area considered permissive for kuroko type deposits lies in the Lake Clark quadrangle where there are scattered roof pendants consisting in part of metavolcanic rocks (Nelson and others, 1983).

Important Examples of Deposit Type

No examples of kuroko massive sulfide deposits are known in southwest Alaska.

Rationale for Numerical Estimates

Felsic volcanic rocks are a criterion for kuroko massive sulfide deposits. The volume of felsic volcanic rocks within this tract is probably quite small; therefore, the probability of undiscovered kuroko-type deposits is correspondingly low. The estimated minimum number of undiscovered deposits, consistent with the grade and tonnage model of Singer and Mosier (1986) is:

Percentile	90	50	10	5	1	0.5
Estimated number of deposits	0	0	0	1	3	20

References

- Box, S.E., Moll-Stalcup, E.J., Frost, T.P., and Murphy, J.M., 1993, Preliminary geologic map of the Bethel and southern Russian Mission quadrangles, southwestern Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2226-A, 20 p., scale 1:250,000.
- Box, S.E., Moll-Stalcup, E.J., Wooden, J.L., and Bradshaw, J.Y., 1990, Kilbuck terrane: Oldest known rocks in Alaska: *Geology*, v. 18, p. 1219-1222.
- Decker, John, Bergman, S.C., Blodgett, R.B., Box S.E., Bundtzen, T.K., Clough, J.G., Coonrad, W.L., Gilbert, W.G., Miller, M.L., Murphy, J.M., Robinson, M.S., and Wallace, W.K., 1994, Geology of southwestern Alaska, *in* Plafker, G., and Berg, H.C., eds., *The geology of Alaska*: Boulder, Colorado, Geological Society of America, *The Geology of North America*, v. G1, p. 285-310.
- Hoare, J.M., and Coonrad, W.L., 1978, Geologic map of the Goodnews and Hagemeister Island quadrangles region, southwestern Alaska: U.S. Geological Survey Open-file Report 78-9-B, 2 sheets, scale 1:250,000.
- Kilburn, J.E., Goldfarb, R.J., Griscom, Andrew, and Box, S.E., 1993, Map showing metallic mineral resource potential in the Goodnews Bay, Hagemeister Island, and Nushagak Bay 1° x 3° quadrangles, southwest Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2228, 4 sheets, scale 1:250,000.
- Nelson, W.H., Carlson, Christine, and Case, J.E., 1983, Geologic map of the Lake Clark quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1114-A, scale 1:250,000.
- Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1994, Geology of west-central Alaska, chap. 7, *in* Plafker, George, and Berg, H.C., eds., *The Geology of Alaska*: Boulder, Colorado, Geological Society of America, *The Geology of North America*, v. G-1, p. 241-269.
- Singer, D.A., 1986, Descriptive model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 189-190.
- Singer, D.A., and Mosier, D.L., 1986, Grade and tonnage model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 190-197.

Descriptive Model: 28a**Mark3 Index: 93****Area: 1,433 km²****Mean undiscovered deposits: (no estimate)****Model**

by Marti L. Miller, and Warren J. Nokleberg

Rationale for Model Choice

Volcanic rocks of the Talkeetna Mountain Formation in southwestern Alaska are permissive for kuroko massive sulfide deposits as described by Singer (1986).

Rationale for Tract Delineation

This tract is composed of Lower Jurassic andesite to basaltic volcanic and volcanoclastic rocks of the Talkeetna Formation (Detterman and Reed, 1980). It is an extension of the adjacent tract defined in south-central Alaska.

Important Examples of Deposit Type

No kuroko deposits are known within this tract, but the Johnson River kuroko massive sulfide prospect (Steefel, 1987) occurs in the extension of this tract into the Kenai quadrangle of south-central Alaska.

Rationale for Numerical Estimates

No attempt was made to estimate the number of undiscovered kuroko massive sulfide deposits in this tract. However, because of the Jurassic age of the volcanic rocks, if an estimate were to be made, then the Sierran Kuroko model of Singer (1992) would be the most appropriate tonnage and grade model to use.

References

- Detterman, R.L., and Reed, B.L., 1980, Stratigraphy, structure, and economic geology of the Iliamna quadrangle, Alaska: U.S. Geological Survey Bulletin 1368-B, 86 p., scale 1:250,000.
- Singer, D.A., 1986, Descriptive model of kuroko massive sulfide, *in*, Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 189-190.
- Singer, D.A., 1992, Grade and tonnage model of Sierran kuroko massive sulfide, *in* Bliss, J.D., ed., Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, p. 29-32.
- Steefel, C.I., 1987, The Johnson River prospect, Alaska: gold-rich sea-floor mineralization from the Jurassic: Economic Geology, v. 82, p. 894-914.

Descriptive Model: 32a and 32b

Mark3 Index: 42

Area: 6,926 km²

Mean undiscovered deposits: 0.33

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Marti L. Miller, Thomas K. Bundtzen, Dennis P. Cox, John E. Gray, and Jeffrey D. Phillips

Rationale for Model Choice

Two Mississippi Valley type (MVT) deposits are described in Cox and Singer (1986). The differences between Southeast Missouri Pb-Zn (model 32a; Briskey 1986b) and Appalachian Zn (model 32b; Briskey, 1986a) are subtle enough that the grade and tonnage models for the two deposit types are plotted together with no differentiation between types (Mosier and Briskey, 1986). In Alaska, the lack of detailed geologic information prevents distinguishing between the two deposit types, and a generic Mississippi Valley type model has been used.

Paleozoic platform carbonate rocks in southwest Alaska are permissive for Mississippi Valley type deposits. Although no occurrences are known in this tract, correlative rocks in west-central Alaska host numerous strata-bound Zn prospects in carbonate rocks (informally called the Reef Ridge district in Medfra quadrangle), which are probably Mississippi Valley type deposits.

Rationale for Tract Delineation

This tract consists of three areas that form a north-east trending belt. The northeast area (in McGrath quadrangle) and central area (in Sleetmute, Taylor Mountains, and Lime Hills quadrangles) are both underlain by Cambrian to Devonian shallow-water facies platform carbonate rocks of the Farewell terrane (Decker and others, 1994). No geochemical data are available to assist in evaluating the Mississippi Valley type potential of these rocks, but the depositional environment is appropriate, and correlative rocks to the northeast host several Zn prospects that are probably Mississippi Valley type. The southwestern area (in Goodnews Bay quadrangle) contains blocks of Ordovician, Devonian, and Permian limestone, which constitute less than 5 percent of a structurally disrupted unit of mixed marine sedimentary and volcanic rock that forms the Nukluk subterrane of the Goodnews terrane (Decker and others, 1994). The limestone blocks show algal reef and reef breccia textures (Hoare and Coonrad, 1978) indicating a depositional environment appropriate for Mississippi Valley type host rocks.

Important Examples of Deposit Type

Examples of this type of deposit are found in similar rocks in the Medfra quadrangle of west-central Alaska, and make up the informally named Reef Ridge district (Schmidt, 1997).

Rationale for Numerical Estimates

Although permissive host rocks are present, the limited areal extent of the tract led to a low numerical estimate. The estimate of the minimum number of undiscovered Mississippi Valley type deposits, consistent with the mean tonnage and grade values of Mosier and Briskey (1986), is:

Percentile	90	50	10	5	1
Estimated number of deposits	0	0	1	1	2

References

- Briskey, J.A., 1986a, Descriptive model of Appalachian Zn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 222-223.
- Briskey, J.A., 1986b, Descriptive model of southeast Missouri Pb-Zn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 220-221.

- Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 379 p.
- Decker, John, Bergman, S.C., Blodgett, R.B., Box S.E., Bundtzen, T.K., Clough, J.G., Coonrad, W.L., Gilbert, W.G., Miller, M.L., Murphy, J.M., Robinson, M.S., and Wallace, W.K., 1994, Geology of southwestern Alaska, *in* Plafker, George, and Berg, H.C., eds., The geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G1 p. 285-310.
- Hoare, J.M., and Coonrad, W.L., 1978, Geologic map of the Goodnews and Hagemester Island quadrangles region, southwestern Alaska: U.S. Geological Survey Open-file Report 78-9-B, 2 sheets, scale 1:250,000.
- Mosier, D.L., and Briskey, 1986, Grade and tonnage model of southeast Missouri Pb-Zn and Appalachian Zn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 224-226.
- Schmidt, J.M., 1997, Strata-bound carbonate-hosted Zn-Pb and Cu deposits of Alaska, *in* Goldfarb, R.J., and Miller, L.D., eds., Mineral Deposits of Alaska: Economic Geology Monograph 9, p. 90-119.

AK-SW11**Porphyry Cu (BC-Ak type)****Alaska
South West****Descriptive Model: 17, 17.1, 18a, and 21a****Mark3 Index: 4, 89, 9, and 2****Area: 15,970 km²****Mean undiscovered deposits: (no estimate)****Model**

by Marti L. Miller and Bruce M. Gamble

Rationale for Model Choice

This tract is permissive for porphyry Cu (Cox, 1986a), BC-Ak type porphyry Cu (Menzie and Singer, 1993), porphyry Cu, skarn related (Cox, 1986c), and porphyry Cu-Mo (Cox, 1986b) deposits based on presence of felsic to intermediate plutons (Patton and others, 1994), and the occurrence of numerous similar or related deposit types. St. Matthew Island is also considered permissive for porphyry Cu type deposits on the basis of permissive host rocks.

Rationale for Tract Delineation

The geology of the area is poorly known, but several apparently high-level felsic plutons occur in the region, and others could be present at shallow depths. The presence of permissive host rocks is the primary basis for the areal delineation of this tract. On St. Matthew Island, Patton and others (1975) mapped a small Tertiary granodiorite body; the possibility of porphyry-type mineralization here cannot be ruled out on the basis of available information.

Important Examples of Deposit Type

A molybdenum prospect at Molybdenum Mountain. (Russian Mission quadrangle), described by Hoare and Cobb (1977), could be related to porphyry Cu or porphyry Cu-Mo occurrences.

Rationale for Numerical Estimates

Because of the lack of detailed geologic information, no estimates of the number of undiscovered deposits have been attempted.

REFERENCES

- Cox, D.P., 1986a, Descriptive model of porphyry Cu, *in* Cox, D.P. and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 76.
- Cox, D.P., 1986b, Descriptive model of porphyry Cu-Mo, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 115.
- Cox, D.P., 1986c, Descriptive model of porphyry Cu, skarn-related deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 82.
- Hoare, J.M., and Cobb, E.H., 1977, Mineral occurrences (other than mineral fuels and construction materials) in the Bethel, Goodnews, and Russian Mission quadrangles, Alaska: U.S. Geological Survey Open-file Report 77-156, 98 p.
- Menzie, W.D., and Singer, D.A., 1993, Grade and tonnage model of porphyry Cu deposits in British Columbia, Canada, and Alaska, U.S.A.: U.S. Geological Survey Open-file Report 93-275, 8 p.
- Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1994, Geology of west-central Alaska, *in* Plafker, George, and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G-1, p. 241-269.
- Patton, W.W., Jr., Miller, T.P., Berg, H.C., Gryc, George, Hoare, J.M., and Ovenshine, A.T., 1975, Reconnaissance geologic map of St. Matthew Island, Bering Sea, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-642, scales 1:125,000 and 1:250,000.

Descriptive Model: 17.1

Mark3 Index: 89

Area: 46,986 km²

Mean undiscovered deposits: 3.04

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Marti L. Miller, Thomas K. Bundtzen, Dennis P. Cox, John E. Gray, and Jeffrey D. Phillips.

Rationale for Model Choice

High-level felsic intrusive rocks, some of which host porphyry-type mineral occurrences similar to that described by Cox (1986), occur in a broad belt that encompasses the Alaska and Aleutian Ranges in the eastern part of southwestern Alaska. Most reported occurrences have some Mo or Au in addition to Cu, but too little is known to determine whether specific deposits are porphyry Cu, porphyry Cu-Au, or porphyry Cu-Mo types. The BC-Ak type porphyry Cu model (Menzie and Singer, 1993), is considered to be the best example of the expected grade and tonnage for undiscovered deposits.

Rationale for Tract Delineation

Porphyry copper deposits are permissive in a large area that encompasses parts of McGrath, Lime Hills, Lake Clark, Iliamna, and Dillingham quadrangles and connects with similar tracts to the east and south. Numerous examples of porphyry-type mineral occurrences occur within this region. The permissive area was extended into the Dillingham quadrangle on the basis of geophysical data that indicate the possible presence of buried plutons.

Important Examples of Deposit Type

There are numerous occurrences that have been described as porphyry-type mineralization. The Pebble Copper deposit in the Iliamna quadrangle (St. George, 1991) is the largest known porphyry Cu-Au deposit in the tract. Pebble Copper is reported to have an identified resource of 454 million tonnes grading 0.35% copper, 0.4 g/tonne Au, and 0.03-0.04% Mo (Swainbank and others, 1993). A second example, the Kijik River deposit in the Lake Clark quadrangle was estimated to contain 91 million tonnes; grab samples yield up to 0.25% Cu and 0.17% Mo (Wilson and others, 1987). A prospect in the Crystal Creek area of the Lime Hills quadrangle (the Chill Group) is listed by MacKevett and Holloway (1977; p. 22, loc. 12) as having porphyry-copper-type mineralization.

Rationale for Numerical Estimates

We believe that additional deposits of the BC-Ak porphyry-type lie within the tract. The minimum number of undiscovered porphyry Cu deposits, consistent with the grade and tonnage curve of Menzie and Singer (1993), is estimated to be:

Percentile	90	50	10	5	1
Estimated no. of deposits	1	2	6	8	10

References

- Cox, D.P., 1986, Descriptive model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 76.
- MacKevett, E.M., Jr., and Holloway, C.D., 1977, Table describing metalliferous mineral deposits in the western part of southern Alaska: U.S. Geological Survey Open-file Report 77-169-F, 39 p., scale 1:1,000,000.
- Menzie, W.D., and Singer, D.A., 1993, Grade and tonnage model of porphyry Cu deposits in British Columbia, Canada, and Alaska, U.S.A.: U.S. Geological Survey Open-file Report 93-275, 8 p.
- St. George, Phillip, 1991, The Pebble porphyry copper-gold deposit [abs]: Paper presented at 15th Alaska Miners Association Annual Convention, Anchorage, Alaska.

Swainbank, R.C., Bundtzen, T.K., Clough, A.H., Hansen, E.W., and Nelson, M.G., 1993, Alaska's mineral industry 1992: Alaska Division of Geological and Geophysical Surveys Special Report 47, 80 p.

Wilson, F.H., Anderson, G.L., Bundtzen, T.K., and Nokleberg, W.J., 1987, Significant metalliferous lode deposits, Aleutian Islands and Alaska Peninsula, *in* Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, p. 41-46.

Descriptive Model: 43

Mark3 Index: 43

Area: 67,723 km²

Mean undiscovered deposits: 6.62

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Marti L. Miller, Thomas K. Bundtzen, Dennis P. Cox, John E. Gray, and Jeffrey D. Phillips.

Rationale for Model Choice

This tract contains numerous Cretaceous and Tertiary calc-alkaline stocks that may host plutonic porphyry Au deposits as described by Hollister (1992). Quartz stockwork vein systems that locally carry gold, scheelite, molybdenite, and bismuth (Bundtzen and others, 1992; Bundtzen and Miller, 1997) are associated with some of the stocks.

Rationale for Tract Delineation

This tract trends northeast from the Bethel quadrangle to the McGrath quadrangle, and continues into the west-central region. The tract is defined by the Kuskokwim Mountain belt, which features volcano-plutonic complexes (and related stocks), gold-quartz vein deposits, and favorable geochemical data (Bundtzen and Miller, 1997).

Important Examples of Deposit Type

This tract contains several gold deposits including those at Chicken Mountain and Golden Horn (Bundtzen and others, 1992) in the Iditarod quadrangle, and at Vinasale Mt. (DiMarchi, 1993) in the McGrath quadrangle. Although these deposits are plutonic-related, it is not clear what model(s) they represent.

Rationale for Numerical Estimates

Assuming a mean tonnage and grade of about 15 million tons averaging 1 gram per ton Au, similar to the size of the Chicken Mountain deposit (Bundtzen and others, 1992), estimates of the minimum number undiscovered deposits are as follows:

Percentile	90	50	10	5	1
Estimated number of deposits	3	6	10	15	20

References

- Bundtzen, T.K., and Miller, M.L., 1997, Precious metals associated with Late Cretaceous-early Tertiary igneous rocks of southwestern Alaska, *in* Goldfarb, R.J., and Miller, L.D., eds., Mineral deposits of Alaska, Economic Geology Monograph 9, p. 242-286.
- Bundtzen, T.K., Miller, M.L., Laird, G.M., and Bull, K.F., 1992, Geology and mineral resources of Iditarod mining district, Iditarod B-4 and eastern B-5 quadrangles, southwestern Alaska: Alaska Division of Geological and Geophysical Surveys Professional Report 97, 46 p. scale 1:63,360 and 1:770.
- DiMarchi, J.J., 1993, Geology, alteration, and mineralization of the Vinasale Mountain gold deposit, west-central Alaska, *in* Solie, D.N., and Tannian, Fran, eds., Short Notes on Alaskan Geology 1993: Alaska Division of Geological and Geophysical Surveys Professional Report 113, p. 17-29.
- Hollister, V.F., 1992, On a proposed plutonic porphyry gold deposit model: Nonrenewable Resources, v. 1, no. 4, p. 293-302.

Descriptive Model: 39a

Mark3 Index: 54

Area: 187,525 km²

Mean undiscovered deposits: (no estimate)

[Model](#)[Mineral Deposits](#)

by Marti L. Miller, Thomas K. Bundtzen, Dennis P. Cox, John E. Gray, and Jeffrey D. Phillips

Rationale for Model Choice

Placer gold (Yeend, 1986) can be expected to occur in unconsolidated deposits downstream from any of the gold-bearing lode deposit types. Therefore the placer gold permissive area for southwest Alaska is quite broad. In addition, glaciation over parts of the tract has redistributed unconsolidated deposits, possibly concentrating some into gold placers and eroding others.

Rationale for Tract Delineation

The placer gold tract encompasses most of southwestern Alaska. It represents an extension of the peraluminous granite porphyry Au, epithermal vein, low-sulfide Au-quartz vein, and plutonic porphyry Au tracts, and in part the polymetallic vein tract. A portion of the polymetallic vein tract was excluded because it contains no known placer occurrences despite relatively extensive placer exploration. The placer gold tract was extended into a covered region of the Dillingham quadrangle because it contains one small granodiorite body and an indication in the geophysical data of unexposed plutons. The eastern boundary of the tract is defined by the glacial front on the west flank of the Alaska-Aleutian Range.

Important Examples of Deposit Type

All of the known placer districts in southwestern Alaska are contained in the tract (Cobb, 1973). They include the Goodnews Bay, Marshall, Aniak, and Iditarod districts, all of which are wholly contained within the region, and also the Innoko and McGrath districts, which straddle the boundary with the west-central region.

Rationale for Numerical Estimates

Because of the relative ease of exploring for placer gold deposits, much of the state has been thoroughly explored. There is a low probability that major new placer districts will be discovered, but it is likely that a few relatively small new deposits will be found in the known districts. No estimate of undiscovered resources was made.

References

Cobb, E.H., 1973, Placer deposits of Alaska: U.S. Geological Survey Bulletin 1374, 213 p.
Yeend, Warren, 1986, Descriptive model of placer Au-PGE, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 261.

Descriptive Model: 19a**Mark3 Index: 47****Area: 6,926 km²****Mean undiscovered deposits: (no estimate)****Model**

by Marti L. Miller, Thomas K. Bundtzen, Dennis P. Cox, John E. Gray, and Jeffrey D. Phillips.

Rationale for Model Choice

In southwestern Alaska and nearby parts of west-central, east-central, and south-central Alaska, carbonate rocks that are locally intruded by small felsic plutons may host polymetallic replacement deposits as described by Morris (1986).

Rationale for Tract Delineation

The areas permissive for polymetallic replacement deposits are defined by Paleozoic carbonate rocks that are locally intruded by Late Cretaceous and Tertiary plutons. The main permissive area lies in the McGrath, Sleetmute, Taylor Mountains, and Lime Hills quadrangles and forms the Farewell terrane (Decker and others, 1994). A smaller permissive area in the Goodnews Bay quadrangle contains blocks of Ordovician, Devonian, and Permian limestone (Hoare and Coonrad, 1978), that may correlate with the Farewell terrane units (R.B. Blodgett, oral commun., 1992). This tract is a continuation of adjacent tracts in west-central, east-central, and south-central Alaska.

Important Examples of Deposit Type

No examples of polymetallic replacement deposits are known in this tract.

Rationale for Numerical Estimates

No estimate of undiscovered resources was attempted.

References

- Decker, John, Bergman, S.C., Blodgett, R.B., Box S.E., Bundtzen, T.K., Clough, J.G., Coonrad, W.L., Gilbert, W.G., Miller, M.L., Murphy, J.M., Robinson, M.S., and Wallace, W.K., 1994, Geology of southwestern Alaska, *in* Plafker, G., and Berg, H.C., eds., The geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G1, p. 285-310.
- Hoare, J.M., and Coonrad, W.L., 1978, Geologic map of the Goodnews and Hagemester Island quadrangles region, southwestern Alaska: U.S. Geological Survey Open-file Report 78-9-B, 2 sheets, scale 1:250,000.
- Morris, H.T., 1986, Descriptive model of polymetallic replacement deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 99-100.

Descriptive Model: 22c

Mark3 Index: 52

Area: 229,939 km²

Mean undiscovered deposits: (no estimate)

[Model](#)[Mineral Deposits](#)

by Marti L. Miller, Thomas K. Bundtzen, Dennis P. Cox, John E. Gray, Jeffrey D. Phillips

Rationale for Model Choice

Polymetallic vein deposits can be associated with intrusive rocks of any age and a wide range of compositions (Cox, 1986). Polymetallic veins may also be spatially related to a large number of other types of deposits, thus making their permissive area quite extensive. This model also serves as somewhat of a catch-all for deposits of unknown type that, given minimal information, are not clearly described by other deposit models.

Rationale for Tract Delineation

This tract includes most of southwestern Alaska and extends into the northwest corner of the Alaska Peninsula. It is drawn on the basis of the distribution of known and inferred plutonic rocks in sedimentary and metamorphic terranes. The tract was extended to include the covered areas of Dillingham, Marshall, Black, and Kwiguk quadrangles on the basis of geophysical data (gamma ray and aeromag), which indicate the possibility of shallow plutons.

The area contains numerous scattered gold-sulfide mineral occurrences, which (on the basis of available data) do not fit other model types, so are tentatively classified as polymetallic veins.

Important Examples of Deposit Type

Although insufficient data are available for definitive classification, the Fortyseven Creek lode occurrence in Sleetmute quadrangle (Miller and others, 1989) may be a polymetallic vein deposit (Bundtzen and Nokleberg, 1987).

Rationale for Numerical Estimates

Due to the paucity of geologic data in most of the area, no estimate of undiscovered resources was made.

References

- Bundtzen, T.K., and Nokleberg, W.J., 1987, Significant metalliferous lode deposits, west-central Alaska, *in* Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, Significant Metalliferous Lode Deposits and Placer Districts of Alaska: U.S. Geological Survey Bulletin 1786, p. 23-31.
- Cox, D.P., 1986, Descriptive model of polymetallic veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 125.
- Miller, M.L., Belkin, H.E., Blodgett, R.B., Bundtzen, T.K., Cady, J.W., Goldfarb, R.J., Gray, J.E., McGimsey, R.G., and Simpson, S.L., 1989, Pre-field study and mineral resource assessment of the Sleetmute quadrangle, southwestern Alaska: U.S. Geological Survey Open-File Report 89-363, 115 p., 3 plates, scale 1:250,000.

Descriptive Model: 18b

Mark3 Index: 8

Area: 33,372 km²

Mean undiscovered deposits: 4.73

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Marti L. Miller, Thomas K. Bundtzen, Dennis P. Cox, John E. Gray, and Jeffrey D. Phillips.

Rationale for Model Choice

In southwestern Alaska carbonate rocks and units containing carbonate rocks, which have been intruded by Late Cretaceous or Tertiary plutons, may host deposits that fit the Cu-(Au) skarn model of Cox and Theodore (1986), and Theodore and others (1991).

Rationale for Tract Delineation

The permissive tract for skarn deposits in southwestern Alaska encompasses one larger area in the eastern part of the region, and a smaller area in the southwestern part of the region. The larger area is delineated by three geologic settings: (1) Cambrian to Devonian carbonate rocks of the Farewell terrane (Decker and others, 1994) crop out in the McGrath, Sleetmute, Taylor Mountains, and Lime Hills quadrangles; Late Cretaceous and Tertiary plutons locally intrude the limestone (Bundtzen and others, 1987; Miller and others, 1989). (2) Carbonate roof pendants are scattered throughout a belt that also contains porphyry Cu-type plutons in the Lake Clark (Nelson and others, 1983) and Iliamna quadrangles (Detterman and Reed, 1980); the porphyry plutons locally intrude limestone pendants. (3) Triassic limestones of the Kamishak Formation also lie within the belt that contains porphyry Cu-type plutons in the Iliamna quadrangle (Detterman and Reed, 1980); the limestone may have been intruded locally. The smaller area, in the Goodnews Bay quadrangle, contains blocks of Ordovician, Devonian, and Permian limestone (Hoare and Coonrad, 1978), which are part of a structurally disrupted unit of mixed marine sedimentary and volcanic rock that forms the Nukluk subterrane of the Goodnews terrane (Decker and others, 1994). Late Cretaceous and early Tertiary granitic plutons occur within the Nukluk subterrane in this area, but none is known to intrude limestone.

Important Examples of Deposit Type

There are numerous small Cu skarn occurrences in carbonate rocks in roof pendants in the northern Aleutian Range of southwestern Alaska. The Kasma Creek prospect in the Lake Clark quadrangle, for example, is a chalcopyrite- and hematite-bearing skarn that contains an estimated 9 million tons grading 1 percent Cu; it occurs in Upper Triassic dolomite and limestone near the contact with Jurassic tonalite (Wilson and others, 1987).

Rationale for Numerical Estimates

The presence of several Cu skarns within the tract led the team to conclude that the likelihood of undiscovered deposits is relatively high. The estimate of the minimum number of undiscovered Cu skarn deposits, consistent with the tonnage and grade model of Jones and Menzie (1986), is:

Percentile	90	50	10	5	1
Expected number of deposits	2	3	8	12	24

References

- Bundtzen, T.K., Kline, J.T., Smith, T.E., and Albanese, M.D., 1987, Geologic map of the McGrath A-2 quadrangle, Alaska: Alaska Division of Geological and Geophysical Surveys Professional Report 91, 20 p., scale 1:63,360.
- Cox, D.P., and Theodore, T.G., 1986, Descriptive model of Cu skarn deposits, in Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 86.

- Decker, John, Bergman, S.C., Blodgett, R.B., Box S.E., Bundtzen, T.K., Clough, J.G., Coonrad, W.L., Gilbert, W.G., Miller, M.L., Murphy, J.M., Robinson, M.S., and Wallace, W.K., 1994, Geology of southwestern Alaska, *in* Plafker, G., and Berg, H.C., eds., The geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G1, p. 285-310.
- Detterman, R.L., and Reed, B.L., 1980, Stratigraphy, structure, and economic geology of the Iliamna quadrangle, Alaska: U.S. Geological Survey Bulletin 1368-B, 86 p., scale 1:250,000.
- Hoare, J.M., and Coonrad, W.L., 1978, Geologic map of the Goodnews and Hagemeister Island quadrangles region, southwestern Alaska: U.S. Geological Survey Open-file Report 78-9-B, 2 sheets, scale 1:250,000.
- Jones, G.M., and Menzie, W.D., 1986, Grade and tonnage model of Cu skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 86-89.
- Miller, M.L., Belkin, H.E., Blodgett, R.B., Bundtzen, T.K., Cady, J.W., Goldfarb, R.J., Gray, J.E., McGimsey, R.G., and Simpson, S.L., 1989, Pre-field study and mineral resource assessment of the Sleetmute quadrangle, southwestern Alaska: U.S. Geological Survey Open-File Report 89-363, 115 p., 3 plates, scale 1:250,000.
- Nelson, W.H., Carlson, Christine, and Case, J.E., 1983, Geologic map of the Lake Clark quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1114-A, scale 1:250,000.
- Theodore, T.G., Orris, G.J., Hammarstrom, J.M., and Bliss, J.D., 1991, Gold-bearing skarns, U.S. Geological Bulletin 1930, 61 p.
- Wilson, F.H., Anderson, G.L., Bundtzen, T.K., and Nokleberg, W.J., 1987, Significant metalliferous lode deposits, Aleutian Islands and Alaska Peninsula, *in* Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, p. 41-46.

Descriptive Model: 18c

Mark3 Index: 22

Area: 33,372 km²

Mean undiscovered deposits: 2.56

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Marti L. Miller, Thomas K. Bundtzen, Dennis P. Cox, John E. Gray, and Jeffrey D. Phillips.

Rationale for Model Choice

Zn-Pb skarns (Cox, 1986) are permissive in southwestern Alaska where carbonate rock units are locally intruded by small felsic plutons.

Rationale for Tract Delineation

The permissive tract for skarn deposits in southwestern Alaska consists of a large area in the eastern part of the region, and a smaller area in the southwestern part of the region. The larger area includes three geologic settings: (1) Cambrian to Devonian carbonate rocks of the Farewell terrane (Decker and others, 1994) that crop out in the McGrath, Sleetmute, Taylor Mountains, and Lime Hills quadrangles and are locally intruded by Late Cretaceous and Tertiary plutons (Bundtzen and others, 1987; Miller and others, 1989); (2) Scattered carbonate roof pendants in proximity to porphyry Cu-type plutons in the Lake Clark (Nelson and others, 1983) and Iliamna quadrangles (Detterman and Reed, 1980); and (3) Triassic limestones of the Kamishak Formation that may be intruded by porphyry Cu-type plutons in the Iliamna quadrangle (Detterman and Reed, 1980). A small area in the Goodnews Bay quadrangle contains blocks of Ordovician, Devonian, and Permian limestone (Hoare and Coonrad, 1978), which are part of a structurally disrupted unit of mixed marine sedimentary and volcanic rock that forms the Nukluk subterrane of the Goodnews terrane (Decker and others, 1994). Although none is known to intrude limestone, Late Cretaceous and early Tertiary granitic plutons lie within the Nukluk subterrane in this area.

Important Examples of Deposit Type

The Bowser Creek skarn deposit in the McGrath quadrangle (Bundtzen and others, 1987) is estimated to contain 272,000 tonnes grading 20% Pb and Zn, and 100 g/t Ag (Nokleberg and others, 1987).

Rationale for Numerical Estimates

The presence of several examples of Zn-Pb skarns within the tract led the assessment team to conclude the likelihood of undiscovered deposits is relatively high. The estimated minimum number of undiscovered Zn-Pb skarn deposits, consistent with the tonnage and grade model of Mosier (1986) is:

Percentile	90	50	10	5	1
Expected number of deposits	1	2	4	6	12

References

- Bundtzen, T.K., Kline, J.T., Smith, T.E., and Albanese, M.D., 1987, Geologic map of the McGrath A-2 quadrangle, Alaska: Alaska Division of Geological and Geophysical Surveys Professional Report 91, 20 p., scale 1:63,360.
- Cox, D.P., 1986, Descriptive model of Zn-Pb skarn deposits, in Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 90.
- Decker, John, Bergman, S.C., Blodgett, R.B., Box S.E., Bundtzen, T.K., Clough, J.G., Coonrad, W.L., Gilbert, W.G., Miller, M.L., Murphy, J.M., Robinson, M.S., and Wallace, W.K., 1994, Geology of southwestern Alaska, in Plafker, G., and Berg, H.C., eds., The geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G1, p. 285-310.

Detterman, R.L., and Reed, B.L., 1980, Stratigraphy, structure, and economic geology of the Iliamna quadrangle, Alaska: U.S. Geological Survey Bulletin 1368-B, 86 p., scale 1:250,000.

Hoare, J.M., and Coonrad, W.L., 1978, Geologic map of the Goodnews and Hagemester Island quadrangles region, southwestern Alaska: U.S. Geological Survey Open-file Report 78-9-B, 2 sheets, scale 1:250,000.

Miller, M.L., Belkin, H.E., Blodgett, R.B., Bundtzen, T.K., Cady, J.W., Goldfarb, R.J., Gray, J.E., McGimsey, R.G., and Simpson, S.L., 1989, Pre-field study and mineral resource assessment of the Sleetmute quadrangle, southwestern Alaska: U.S. Geological Survey Open-File Report 89-363, 115 p., 3 plates, scale 1:250,000.

Nelson, W.H., Carlson, Christine, and Case, J.E., 1983, Geologic map of the Lake Clark quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1114-A, scale 1:250,000.

Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987. Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.

Descriptive Model: 31a

Mark3 Index: 13

Area: 14,717 km²

Mean undiscovered deposits: 1.14

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Marti L. Miller, Thomas K. Bundtzen, Dennis P. Cox, John E. Gray, and Jeffrey D. Phillips.

Rationale for Model Choice

The presence of siltstone, shale, chert, and carbonate rocks that were deposited in a deep-water environment suggests the possibility of sedex deposits as described by Briskey (1986). Selection of this model type is supported by one bedded barite deposit, a model type considered to form distal to sedex occurrences.

Rationale for Tract Delineation

This tract encompasses the deep-water facies rocks of the Farewell terrane (as defined by Decker and others, 1994), which are found in the McGrath, Lime Hills, and Sleetmute quadrangles. The Farewell terrane comprises two sequences: the Middle Cambrian through Middle Devonian White Mountain sequence and the overlying Upper Devonian through Lower Cretaceous Mystic sequence. Deep-water facies consisting of siltstone, shale, chert, and carbonate rocks are contained in parts of both sequences. The region is poorly known; reconnaissance geochemical data are not available.

Important Examples of Deposit Type

No examples of sedex deposits are known in the tract, but the Gagaryah barite deposit in the Lime Hills quadrangle (Bundtzen and Gilbert, 1991) may be related to sedex mineralization.

Rationale for Numerical Estimates

For estimating the number of undiscovered deposits, the median deposit is assumed to be 15 mt containing 5.6% Zn, 2.8% Pb, and 30 g/t Ag (Menzie and Mosier, 1986). The estimated number of undiscovered deposits is:

Percentile	90	50	10	5	1
Estimated number of deposits	0	1	2	3	5

REFERENCES

- Briskey, J.A., 1986, Descriptive model of sedimentary exhalative Zn-Pb, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 211-212.
- Bundtzen, T.K., and Gilbert, W.G., 1991, Geology and geochemistry of the Gagaryah barite deposit, western Alaska Range, Alaska, *in* Reger, R.D., ed., Short Notes on Alaskan Geology 1991: Alaska Division of Geological and Geophysical Surveys Professional Report 111, p. 9-20.
- Decker, John, Bergman, S.C., Blodgett, R.B., Box S.E., Bundtzen, T.K., Clough, J.G., Coonrad, W.L., Gilbert, W.G., Miller, M.L., Murphy, J.M., Robinson, M.S., and Wallace, W.K., 1994, Geology of southwestern Alaska, *in* Plafker, George, and Berg, H.C., eds., The geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G1, p. 285-310.
- Menzie, W.D., and Mosier, D.L., 1986, Grade and tonnage model of sedimentary exhalative Zn-Pb, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 212-215.

*Descriptive Model 25a**Mark3 Index: 45***Area: 17,898 km²****Mean undiscovered deposits: 1.17**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Marti L. Miller, Thomas K. Bundtzen, Dennis P. Cox, John E. Gray, and Jeffrey D. Phillips.

Rationale for Model Choice

This tract is underlain by Late Cretaceous and early Tertiary subaerial volcanic rocks that are permissive for Hot Spring Au (\pm Hg) epithermal deposits. One prospect in the tract is thought to be an epithermal Hot Spring Au occurrence similar to those described by Berger (1986).

Rationale for Tract Delineation

This tract comprises several areas underlain by Late Cretaceous and early Tertiary subaerial volcanic rocks, predominately andesites, rhyolites, and minor basalts. The volcanic rocks of the Yetna River area in the western Iditarod (Miller and Bundtzen, 1994) and eastern Holy Cross quadrangles locally show chalcedonic silicification and elevated Au and Hg values. Similar subaerial volcanic rocks in the Russian Mission and Bethel quadrangles host the only identified Hot Spring Au type occurrence in the tract; this belt of permissive rocks was extended to the southwest by geophysical data. Subaerial volcanic rocks and a caldera complex in the central Holy Cross quadrangle, and a possible caldera complex inferred from geophysical data in the Russian Mission quadrangle, are all permissive for hot-spring gold deposits. Hg and Au anomalies in the McGrath and Lime Hills quadrangles are associated with hot springs in Tertiary subaerial volcanic rocks. St. Matthew Island is in part underlain by calc-alkaline felsic and intermediate volcanic rocks (Patton and others, 1975), but no mineral occurrences are known on the island.

Important Examples of Deposit Type

The Firebear prospect (informal name) near the Poison Creek volcanic field in the Russian Mission quadrangle is thought to be a Hot Spring Au type deposit (Miller and Bundtzen, 1997).

Rationale for Numerical Estimates

The median deposit size is expected to be 13 million tonnes at 1.6 g/tonne Ag (Berger and Singer, 1992). Even though the geology in this region is known only at reconnaissance scale, the team was confident enough in the model designation, supported locally by geochemical data, to provide a numerical estimate. The estimated minimum number of undiscovered deposits expected to occur in southwestern Alaska is:

Percentile	90	50	10	5	1
Estimated number of deposits	0	1	2	3	6

References

- Berger, B.R., 1986, Descriptive model of hot-spring Au-Ag, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 143.
- Berger, B.R., and Singer, D.A., 1992, Grade and tonnage model of hot-spring Au-Ag, *in* Bliss, J.D., Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, p. 23-25.
- Bundtzen, T.K., and Miller, M.L., 1997, Precious metals associated with Late Cretaceous-early Tertiary igneous rocks of southwestern Alaska, *in* Goldfarb, R.J., and Miller, L.D., eds., Mineral deposits of Alaska, Economic Geology Monograph 9, p. 242-286.
- Miller, M.L., and Bundtzen, T.K., 1994 Generalized geologic map of the Iditarod quadrangle, Alaska, showing potassium-argon, major-oxide, trace-element, fossil, paleocurrent, and archaeological sample

localities: U.S. Geological Survey Miscellaneous Field Studies Map MF-2219-A, 48 p., scale 1:250,000.

Patton, W.W., Jr., Miller, T.P., Berg, H.C., Gryc, George, Hoare, J.M., and Ovenshine, A.T., 1975, Reconnaissance geologic map of St. Matthew Island, Bering Sea, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-642, scale 1:125,000.

Descriptive model: 9
Area: 6302 km²

Mark3 Index: 120
Mean undiscovered deposits: not estimated

[Model](#)

by Thomas D. Light and Marti L. Miller

Rationale for Model Choice

Gold occurs in placer PGE deposits derived from the Jurassic Goodnews Bay ultramafic complex (Cobb, 1973; Foley and others, 1997). Alaskan PGE deposits (Page and Gray, 1986) are inferred to be the source of the precious metals.

Rationale for Tract Delineation

This tract is delineated by the extent of the Mesozoic and Paleozoic of island arc sequences or associated oceanic rocks. These units are known to host ultramafic rocks in the vicinity of Goodnews Bay.

Important Examples of Deposit Type

The Goodnews Bay complex is an Alaskan-PGE type system that shows well-developed concentric zoning (Bird and Clark, 1976). This complex was the source for the platinum group elements in the Goodnews Bay placer deposits, which also yielded over 900,000 grams of Au (Yeend and others, 1986).

Rationale for Numerical Estimates

No attempt was made to estimate the number of undiscovered Alaska-PGE type deposits for this tract.

References

- Bird, M.L., and Clark, A.L., 1976, Microprobe study of olivine chromitites of the Goodnews Bay ultramafic complex, Alaska, and the occurrence of platinum: U.S. Geological Survey Journal of Research, v. 4, p. 717-725.
- Cobb, E.H., 1973, Placer deposits of Alaska: U.S. Geological Survey Bulletin 1374, 213 p.
- Foley, J.Y., Light, T.D., Nelson, S.W., and Harris, R.A., 1997, Mineral occurrences associated with mafic-ultramafic and related alkaline complexes in Alaska: Economic Geology Monograph 9, p. 396-449.
- Page, N.J., and Gray Floyd, 1986, Descriptive model of Alaskan PGE: U.S. Geological Survey Bulletin 1693, p. 49-50.
- Yeend, Warren, Bundtzen, T.K., and Nokleberg, W.J., 1987, Significant placer deposits of Alaska, *in* Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987. Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, p. 73-82.

Descriptive Model: 24b

Mark3 Index: 30

Area: 37,861 km²

Mean undiscovered deposits: (no estimate)

[Model](#)

by Bruce M. Gamble, Robert G. Eppinger, John W. Cady, Stanley E. Church, Byron R. Berger, Gregory T. Spanski

Rationale for Model Choice

The presence of marine metasedimentary and mafic metavolcanic lithologies indicates that this area may be permissive for Besshi massive sulfide deposits as described by Cox (1986).

Rationale for Tract Delineation

This tract includes all of the Nome Group, including high-grade equivalents, containing in part mafic metavolcanic rocks (Casadepaga Schist) and metasedimentary rocks (Solomon Schist, mixed unit) (Till and others, 1986). Anomalously high concentrations of elements in stream-sediment and panned-concentrate samples include As, Sb, Au, Cu, Pb, Zn, Ag, Ni, Co, Ba, and Mn (Gamble and Till, 1993). This is a speculative tract.

Important Examples of Deposit Type

No Besshi massive sulfide deposits are known in this tract.

Rationale for Numerical Estimates

No estimate of the number of undiscovered deposits was attempted.

References

- Cox, D.P., 1986, Descriptive model of Besshi massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 136.
- Gamble, B.M., and Till, A.B., 1993, Maps showing metallic mineral resources of the Bendeleben and Solomon quadrangles, western Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF 1838-D, 3 sheets, scale 1:250,000, 22 p.
- Till, A.B., Dumoulin, J.A., Gamble, B.M., Kaufman, D.S., and Carroll, P.I., 1986, Preliminary geologic maps and fossil data, Solomon, Bendeleben, and southern Kotzebue quadrangles, Seward Peninsula, Alaska: U.S. Geological Survey Open-File Report 86-276, 62 p., scale 1:250,000.

Descriptive Model: 24b

Mark3 Index: 30

Area: 57,393 km²

Mean undiscovered deposits: (no estimate)

[Model](#)

by Bruce M. Gamble, Robert G. Eppinger, John W. Cady, Stanley E. Church, Byron R. Berger, Gregory T. Spanski

Rationale for Model Choice

Although no massive sulfide deposits are known in this tract, the presence of the appropriate rock types suggest that the tract is geologically permissible for Besshi massive sulfide deposits as described by Cox (1986).

Rationale for Tract Delineation

This tract covers the area of the Koyukuk magmatic arc, which consists of Upper Jurassic(?) and Lower Cretaceous andesitic volcanics and subordinate sedimentary rocks (Patton and others, 1989; Nokleberg and others, 1994). The tract includes areas underlain by Koyukuk rocks as inferred from aeromagnetism. Locally stream sediment samples contain anomalously high concentrations of As, Sb, Pb, Cu, Au, Ag, and W.

Important Examples of Deposit Type

No Besshi massive sulfide deposits are known in this tract.

Rationale for Numerical Estimates

No estimate of the number of undiscovered deposits was attempted because of the highly speculative nature of this model for this area.

References

- Cox, D.P., 1986, Descriptive model of Besshi massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 136.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 45 manuscript p., scale 1:2,500,000.
- Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1989, Geology of west-central Alaska: U.S. Geological Survey Open-File Report 89-554, 41 p.

Descriptive Model: 24b**Mark3 Index: 30****Area: 13,309 km²****Mean undiscovered deposits: (no estimate)****Model**

by Bruce M. Gamble, Robert G. Eppinger, John W. Cady, Stanley E. Church, Byron R. Berger, and Gregory T. Spanski

Rationale for Model Choice

No massive sulfide deposits are known in this tract. The presence of altered basalts containing pyrite, and locally high copper values may suggest submarine hydrothermal activity, and suggest that the area is permissive for Besshi massive sulfide deposits as described by Cox (1986).

Rationale for Tract Delineation

This tract encompasses mafic rocks of Proterozoic(?), Paleozoic, or Mesozoic age (Murchey and Harris, 1985; Pallister and others, 1989). The tract consists of mafic and ultramafic oceanic assemblages of the Kanuti, Tozitna, and Innoko terranes (Patton and others, 1989; Nokleberg and others, 1994). Also included are pillow basalts, chert, gabbro, and diabase of the Narvak complex. Stream sediment geochemical anomalies are sparse and consist of scattered Cu, Zn, and rare As.

In west-central Alaska, the Ruby and Nixon Fork terranes, which comprise Precambrian(?) to lower Paleozoic pelitic schist, metabasites, quartzite, orthogneiss, and marble, are permissive for Besshi massive sulfide deposits. Arsenic is the most common stream sediment anomaly; Zn, W, Cu, and rare Au, Ag and Bi are present locally.

Important Examples of Deposit Type

No Besshi massive sulfide deposits are known in this tract.

Rationale for Numerical Estimates

No deposits of this type are known in the area, and no estimates of the number of undiscovered deposits have been attempted.

References

- Cox, D.P., 1986, Descriptive model of Besshi massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 136.
- Murchey, B.L., and Harris, A.G., 1985, Devonian to Jurassic sedimentary rocks in the Angayucham Mountains of Alaska: possible sea mount or oceanic plateau deposits [abs]: EOS, Transactions of the American Geophysical Union, v. 66, no. 46, p. 1102.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 45 manuscript p., scale 1:2,500,000.
- Pallister, J.S., Budahn, J.R., and Murchey, B.L., 1989, Pillow basalts of the Angayucham terrane: oceanic plateau and island crust accreted to the Brooks Range: *Journal of Geophysical Research*, v. 94, no. B11, p. 15,901-15,923.
- Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1989, Geology of west-central Alaska: U.S. Geological Survey Open-File Report 89-554, 41 p.

Descriptive Model: 24b

Mark3 Index: 30

Area: 1,054 km²

Mean undiscovered deposits: (no estimate)

[Model](#)

by Marti L. Miller and Bruce M. Gamble

Rationale for Model Choice

Several small areas in west-central Alaska contain outcrops of mixed sedimentary and tuffaceous rocks of marine origin (mainly volcanic sandstone and andesite tuff). These areas are similar to nearby areas of southwestern Alaska, and are considered permissive for Besshi massive sulfide deposits as described by Cox (1986).

Rationale for Tract Delineation

This tract is delineated on the basis of geology considered permissive for Besshi massive sulfide deposits. No Besshi-type deposits are known in the area. The permissive rock types are mixed sedimentary and tuffaceous rocks of the Koyukuk terrane in parts of the Unalakleet quadrangle (Patton and Moll-Stalcup, 1996).

Important Examples of Deposit Type

No examples of Besshi massive sulfide deposits are known in west-central Alaska.

Rationale for Numerical Estimates

No estimate of undiscovered resources was attempted.

References

- Cox, D.P., 1986, Descriptive model of Besshi massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 136.
- Patton, W.W., Jr. and Moll-Stalcup, E.J., 1996, Geology of the Unalakleet quadrangle, west-central Alaska: U.S. Geological Survey Miscellaneous Investigations Map I-2559, scale 1:250,000.

Descriptive Model: 24a

Mark3 Index: 11

Area: 57,393 km²

Mean undiscovered deposits: (no estimate)

[Model](#)

by Bruce M. Gamble, Robert G. Eppinger, John W. Cady, Stanley E. Church, Byron R. Berger, Gregory T. Spanski

Rationale for Model Choice

Although no massive sulfide deposits are known in this tract, the occurrence of appropriate rock units and Cu anomalies suggest that it is geologically permissible for Cyprus and Besshi massive sulfide deposits as described by Singer (1986).

Rationale for Tract Delineation

This tract covers the area of the Koyukuk magmatic arc, which consists of Upper Jurassic(?) and Lower Cretaceous andesitic volcanics (Patton and others, 1989; Nokleberg and others, 1994). The tract includes areas underlain by Koyukuk rocks as inferred from aeromagnetics. Anomalously high concentrations of elements in stream-sediment samples include As, Sb, Pb, Cu, Au, Ag, and W.

Important Examples of Deposit Type

No Cyprus massive sulfide deposits are known in this tract.

Rationale for Numerical Estimates

An estimate of the number of undiscovered deposits was not attempted.

REFERENCES

- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 45 manuscript p., scale 1:2,500,000.
- Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1989, Geology of west-central Alaska: U.S. Geological Survey Open-File Report 89-554, 41 p.
- Singer, D.A., 1986, Descriptive model of Cyprus massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 131.

AK-WC06

Cyprus Massive Sulfide

Alaska West Central

Descriptive Model: 24a

Mark3 Index: 11

Area: 1,789 km²

Mean undiscovered deposits: (no estimate)

Model

by Bruce M. Gamble, Robert G. Eppinger, John W. Cady, Stanley E. Church, Byron R. Berger, Gregory T. Spanski

Rationale for Model Choice

The occurrence of appropriate rock units suggests that this tract may be permissive for Cyprus massive sulfide deposits as described by Singer (1986).

Rationale for Tract Delineation

This tract consists of mafic and ultramafic oceanic assemblages of the Kanuti, Tozitna, and Innoko subterrane (Patton and others, 1989; Nokleberg and others, 1994). Also included are some phyllite and argillite of the Slate Creek thrust panel; pillow basalts, chert, gabbro, and diabase of the Narvak complex; and mafic-ultramafic rocks of the Kanuti complex. Narvak is clearly the most common assemblage in west-central Alaska. Known mineral deposits are podiform chromite occurrences (Mt. Hurst in the Ophir quadrangle; Kaiyuh Hills in the Nulato quadrangle), and placer gold deposits and occurrences. Stream sediment anomalies are sparse and consist of scattered Cu and Zn, and one area of As.

Important Examples of Deposit Type

No Cyprus massive sulfide deposits are known in this tract.

Rationale for Numerical Estimates

No estimate of the number of undiscovered deposits was attempted.

REFERENCES

- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 45 manuscript p., scale 1:2,500,000.
- Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1989, Geology of west-central Alaska: U.S. Geological Survey Open-File Report 89-554, 41 p.
- Singer, D.A., 1986, Descriptive model of Cyprus massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 131.

Descriptive Model 25aArea: 4,402 km²

Mark3 Index: 45

Mean undiscovered deposits:

[Model](#)*by* Bruce M. Gamble and Marti L. Miller**Rationale for Model Choice**

This tract is underlain by Late Cretaceous subaerial volcanic rocks that are permissive for Hot Spring Au (\pm Hg) epithermal deposits similar to those described by Berger (1986).

Rationale for Tract Delineation

This tract comprises several areas underlain by Late Cretaceous subaerial volcanic rocks (Patton and others, 1994; Moll-Stalcup, 1994), consisting of andesites, rhyolites, and minor basalts.

Important Examples of Deposit Type

No epithermal vein deposits are known in the tract.

Rationale for Numerical Estimates

Estimates of the number of undiscovered epithermal vein deposits for west-central Alaska were not attempted.

References

- Berger, B.R., 1986, Descriptive model of hot-spring Au-Ag, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 143.
- Moll-Stalcup, E.J., 1994, Latest Cretaceous and Cenozoic magmatism in mainland Alaska, *in* Plafker, George, and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G-1, p. 589-619.
- Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1994, Geology of west-central Alaska, *in* Plafker, George, and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G-1, p. 241-269.

Descriptive Model 25a-d**Area: 57,393 km²****Mark3 Index : (none)****Mean undiscovered deposits: (no estimate)**[Model](#)

by Bruce M. Gamble, Robert G. Eppinger, John W. Cady, Stanley E. Church, Byron R. Berger, Gregory T. Spanski

Rationale for Model Choice

Models for epithermal vein deposits in the conterminous US have been divided into several types based largely on the underlying basement rocks (Cox and Singer, 1986). For the most part, information in Alaska is inadequate to classify individual epithermal gold vein types. Therefore, we have combined deposit models for Creede epithermal veins (Mosier and others, 1986b), Comstock epithermal veins (Mosier and others, 1986c), Sado epithermal veins (Mosier and others, 1986a), and epithermal quartz-alunite gold (Berger, 1986a) into a generic epithermal vein model. We evaluated the permissive area for undiscovered deposits of all types of epithermal veins based on this generic model, which includes gold and/or silver veins associated with intermediate to felsic volcanic rocks similar to those described by Panteleyev (1987).

Rationale for Tract Delineation

This tract encompasses the Koyukuk Magmatic arc, which consists chiefly of Upper Jurassic(?) and Lower Cretaceous island arc andesitic volcanic rocks (Patton and others, 1989, Nokleberg and others, 1994). Two major suites of intrusions are present: (1) a 79-89 Ma I-type tonalite to granite, typically granodiorite group in the east; and (2) a 99-113 Ma S-type group in the west which consists of 2 distinct subtypes: (a) potassic syenites, monzonites, etc., and (b) ultrapotassic nepheline-bearing intrusions (Patton and others, 1989). Anomalous concentrations of As, Sb, Pb, Cu, Au, Ag, and W in stream sediment samples are sometimes clearly related to plutonic rocks, but often there is no evidence of an intrusion. Noteworthy is the "3 day slough" anomaly (Cu, Pb, Cd) in the Kateel River quadrangle, in an area of surficial cover.

Important Examples of Deposit Type

No epithermal vein deposits are known in this tract.

Rationale for Numerical Estimates

Insufficient data exist to estimate the expected number of undiscovered epithermal vein deposits.

References

- Berger, B.R., 1986a, Descriptive model of epithermal quartz-alunite Au, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 158.
- Berger, B.R., 1986b, Descriptive model of hot-spring Au-Ag, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 143.
- Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 130.
- Mosier, D.L., Berger, B.R., and Singer, D.A., 1986a, Descriptive model of Comstock epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 154.
- Mosier, D.L., Sato, Takeo, Page, N.J., Singer, D.A., and Berger, B.R., 1986b, Descriptive model of Creede epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 145.

- Mosier, D.L., Singer, D.A., and Berger, B.R., 1986c, Descriptive model of Comstock epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 150.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 45 manuscript p., scale 1:2,500,000.
- Panteleyev, Andrejs, 1987, A Canadian cordilleran model for epithermal gold-silver deposits, in Roberts, R.G., and Sheahan, P.A., Ore Deposit Models: Geoscience Canada Reprint Series 3, p. 31-43.
- Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1989, Geology of west-central Alaska: U.S. Geological Survey Open-File Report 89-554, 41 p.

Descriptive Model: 36a

Mark3 Index: 27

Area : 31,471 km²

Mean undiscovered deposits: 2.23

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Bruce M. Gamble, Robert G. Eppinger, John W. Cady, Stanley E. Church, Byron R. Berger, Gregory T. Spanski

Rationale for Model Choice

Low-sulfide gold-quartz veins (Berger, 1986) are known to occur in this tract, and additional deposits are permissive. A large part of the Seward Peninsula is underlain by greenschist (after blueschist) facies rocks containing numerous low-sulfide gold-quartz vein deposits and occurrences (Gamble and others, 1985), and numerous worldclass Au-placer deposits. Local As, Sb, Au and other geochemical anomalies in stream sediment and heavy-mineral concentrate samples are scattered throughout the area.

Rationale for Tract Delineation

The favorable geologic unit defining this tract includes all of the Nome Group exclusive of high-grade (amphibolite and above) parts, which are confined to the mountain ranges. The Nome Group consists chiefly of pelitic schist, calc-schist, pure and impure marble, graphitic quartzite and quartz-mica schist, and mafic schist (Till and others, 1986). The metamorphic grade within the tract is blueschist that has a pronounced greenschist retrograde overprint. Anomalous elements in stream sediment and panned concentrate samples are chiefly As and Sb, and local Au, W, Bi.

Important Examples of Deposit Type

Numerous low-sulfide gold-quartz veins and gold placers are present. The Big Hurrah mine produced about 27,000 ounces, chiefly between 1903 and 1907 (Read and Meinert, 1986).

Rationale for Numerical Estimates

The estimated minimum number of undiscovered low-sulfide Au-quartz vein deposits consistent with the tonnage and grade model of Bliss (1986) is:

Percentile	90	50	10	5	1	
Estimated number of deposits		1	2	3	5	10

References

- Berger, B.R., 1986c, Descriptive model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239.
- Bliss, J.D., 1986, Grade and tonnage model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239-243.
- Gamble, B.M., Ashley, R.P., and Pickthorn, W.J., 1985, Preliminary study of lode gold deposits, Seward Peninsula, *in* Bartsch-Winkler, Susan, editor, The United States Geological Survey in Alaska, Accomplishments during 1984: U.S. Geological Circular 967, p. 27-29.
- Read, J.J., and Meinert, L.D., 1986, Gold-bearing quartz vein mineralization at the Big Hurrah Mine, Seward Peninsula, Alaska: *Economic Geology*, v. 81, no.7, p. 1760-1774.
- Till, A.B., Dumoulin, J.A., Gamble, B.M., Kaufman, D.S., and Carroll, P.I., 1986, Preliminary geologic maps and fossil data, Solomon, Bendeleben, and southern Kotzebue quadrangles, Seward Peninsula, Alaska: U.S. Geological Survey Open-File Report 86-276, 62 p., scale 1:250,000.

Descriptive Model: 36a**Mark3 Index: 27****Area: 11,935 km²****Mean undiscovered deposits: (no estimate)**[Model](#)

by Bruce M. Gamble, Robert G. Eppinger, John W. Cady, Stanley E. Church, Byron R. Berger, Gregory T. Spanski

Rationale for Model Choice

The presence of placer Au deposits in the greenschist facies rocks of the Ruby and Nixon Fork terranes, and local geochemical anomalies support a potential for low-sulfide Au-quartz veins.

Rationale for Tract Delineation

This tract is defined by the metamorphic basement of the Ruby and Nixon Fork terranes, which comprises Precambrian(?) and Paleozoic pelitic schists, metabasites, quartzites, orthogneiss, and marbles (Patton and others, 1989; Nokleberg and others, 1994). Permissive deposit types are placer gold and low-sulfide gold-quartz vein. Arsenic is the most common stream sediment anomaly; Zn, W, Cu, and rare Au, Ag and Bi are present locally.

Important Examples of Deposit Type

No low-sulfide Au-quartz veins are known in the tract, but the geologic environment and the presence of placer Au deposits in the Ruby district suggest that low-sulfide Au-quartz veins may be present.

Rationale for Numerical Estimates

No estimate of the number of undiscovered low-sulfide Au-quartz vein deposits was attempted.

References

- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 45 manuscript p., scale 1:2,500,000.
- Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1989, Geology of west-central Alaska: U.S. Geological Survey Open-File Report 89-554, 41 p.

Descriptive Model 32c

Mark3 Index (none)

Area: 7,891 km²

Mean undiscovered deposits: (no estimate)

[Model](#)[Mineral Deposits](#)*by* Jeanine M. Schmidt, Bruce M. Gamble, and Marti L. Miller**Rationale for Model Choice**

Paleozoic carbonate rocks that locally include platform carbonates in west-central Alaska are permissive for Kipushi-type deposits as defined by Cox and Bernstein (1986), because they were formed in an appropriate geologic setting (a continental platform or shelf with continental or passive margin rifting) and because they contain appropriate host rocks (dolostone, shale and shallow-water or platform carbonate rocks) for the deposit model. Although no occurrences of Kipushi deposits occur in this tract, it does host strata-bound Zn prospects in carbonate rocks (informally called the Reef Ridge district).

Rationale for Tract Delineation

This tract consists of areas underlain by Cambrian to Devonian shallow-water facies platform carbonate rocks of the Nixon Fork terrane (Patton and others, 1994). Locally, Pb and Zn anomalies are in stream-sediment and panned-concentrate samples in west-central Alaska. Sphalerite, chalcopyrite, cinnabar, pyrite and malachite were identified in some concentrates.

Important Examples of Deposit Type

Examples of carbonate-hosted base-metal deposits (mainly Zn) occur in equivalent rocks in the Reef Ridge district in the Medfra quadrangle of west-central Alaska (Schmidt, 1997).

Rationale for Numerical Estimates

There are no tonnage and grade curves for Kipushi-type deposits; no quantitative estimates of the number of undiscovered deposits were attempted.

References

- Cox, D.P., and Bernstein, L.R., 1986, Descriptive model of Kipushi Cu-Pb-Zn, *in* Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 227.
- Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1994, Geology of west-central Alaska, *in* Plafker, George, and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G-1, p. 241-269.
- Schmidt, J.M., 1997, Strata-bound carbonate-hosted Zn-Pb and Cu deposits of Alaska, *in* Goldfarb, R.J., and Miller, L.D., eds., Economic Geology Special Volume, p. 90-119.

Descriptive Model: 28a

Mark3 Index: 93

Area: 1,054 km²

Mean undiscovered deposits:

[Model](#)

by Marti L. Miller and Bruce M. Gamble

Rationale for Model Choice

Kuroko massive sulfide deposits as described by Singer (1986) are permissive in areas underlain by mixed assemblages that include basaltic to andesitic marine volcanic rocks and local felsic volcanic units.

Rationale for Tract Delineation

This tract is delineated on the basis of geology considered permissive for kuroko massive sulfide deposits; no mineral occurrences of this type are known in the region. The permissive rock types are marine volcanic assemblages of the Koyukuk terrane (Patton and Moll-Stalcup, 1996). These rocks constitute a mixed assemblage largely composed of Upper Jurassic(?) and Lower Cretaceous andesitic volcanic and volcanoclastic rocks, but which locally includes dacitic lava flows (T.K. Bundtzen, written commun., 1992).

Important Examples of Deposit Type

No examples of kuroko massive sulfide deposits are known in west-central Alaska.

Rationale for Numerical Estimates

No attempt was made to estimate the number of undiscovered kuroko massive sulfide deposits in this tract.

References

- Patton, W.W., Jr. and Moll-Stalcup, E.J., 1996, Geology of the Unalakleet quadrangle, west-central Alaska: U.S. Geological Survey Miscellaneous Investigations Map I-2559, scale 1:250,000.
- Singer, D.A., 1986, Descriptive model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 189-190.

Descriptive Model: 32a and 32b**Mark3 Index: 42****Area: 7,891 km²****Mean undiscovered deposits: (no estimate)**[Model](#)

by Jeanine M. Schmidt, Thomas D. Light, Bruce M. Gamble, and Marti L. Miller

Rationale for Model Choice

Two Mississippi Valley type (MVT) deposits are described in Cox and Singer (1986). The differences between Southeast Missouri Pb-Zn (model 32a; Briskey 1986b) and Appalachian Zn (model 32b; Briskey, 1986a) are subtle enough that the grade and tonnage models for the two deposit types are plotted together with no differentiation between types (Mosier and Briskey, 1986). In Alaska, the lack of detailed geologic information prevents distinguishing between the two deposit types, and a generic Mississippi Valley type model has been used.

This tract is permissive for Mississippi Valley type deposits because it contains platform carbonate rocks hosting deposits thought to be Mississippi Valley type, and local Pb-Zn geochemical anomalies.

Rationale for Tract Delineation

This tract consists of lower Paleozoic (Ordovician through Devonian) platform carbonate rocks of the Nixon Fork terrane (Patton and others, 1994) in the Medfra and Ruby quadrangles. Pb and Zn locally occur in stream-sediment and panned-concentrate samples. Sphalerite, chalcopyrite, cinnabar, pyrite and malachite are present in some concentrates.

Important Examples of Deposit Type

The Reef Ridge deposit in the Medfra quadrangle is an example of a Mississippi Valley type deposit (Andrews and Rishel, 1982).

Rationale for Numerical Estimates

No estimate of the number of undiscovered deposits was attempted.

References

- Andrews, T., and Rishel, John, 1982, 1981 Annual Report-Reef Ridge I-XIII project areas, Kuskokwim Block, Volume 1 of 3: unpublished report, Patino Inc., Anchorage, Alaska, 49 p.
- Briskey, J.A., 1986a, Descriptive model of Appalachian Zn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 222-223.
- Briskey, J.A., 1986b, Descriptive model of southeast Missouri Pb-Zn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 220-221.
- Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 130.
- Mosier, D.L., and Briskey, 1986, Grade and tonnage model of southeast Missouri Pb-Zn and Appalachian Zn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 224-226.
- Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1994, Geology of west-central Alaska, *in* Plafker, George, and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G-1, p. 241-269.

Descriptive Model: 17.1

Mark3 Index: 89

Area: 57,404 km²

Mean undiscovered deposits: (no estimate)

[Model](#)

by Bruce M. Gamble, Robert G. Eppinger, John W. Cady, Stanley E. Church, Byron R. Berger, Gregory T. Spanski

Rationale for Model Choice

This tract encompasses the Koyukuk magmatic arc, which chiefly consists of Upper Jurassic(?) and Lower Cretaceous island arc andesitic volcanic rocks (Patton and others, 1989; Nokleberg and others, 1994). Two major suites of intrusions are present: (1) a 79-89 Ma I-type tonalite to granite, typically granodiorite, group in the east; and (2) a 99-113 Ma S-type group in the west which consists of 2 distinct subtypes: (a) potassic syenites, monzonites, etc., and (b) ultrapotassic nepheline-bearing intrusions (Patton and others, 1989). In the west, the Peace River porphyry Mo occurrence is associated with the Granite Mountain pluton. In the east are Black Creek, a possible porphyry Cu; Dakli Cu-rich occurrences near the Zane Hills pluton; an occurrence of Mo-bearing quartz veins, also at Dakli; and an unnamed Mo occurrence of unknown type.

Rationale for Tract Delineation

This tract is delineated by the occurrence of intrusive rocks of the appropriate compositions, a known porphyry Mo occurrence, several Cu and (or) Mo occurrences of unknown type, and stream sediment anomalies of As, Sb, Pb, Cu, Au, Ag, and W, some of which are clearly related to intrusions.

Important Examples of Deposit Type

The Dakli and Black Creek deposits are examples of porphyry copper occurrences in this tract.

Rationale for Numerical Estimates

Insufficient data exist to support estimating the number of undiscovered porphyry copper deposits.

References

- Miller T.P., and Elliott, R.L., 1969, Metalliferous deposits near Granite Mountain, eastern Seward Peninsula, Alaska: U.S. Geological Survey Circular 614, 19 p.
- Miller, T.P., and Ferrians, O.J., 1968, Suggested areas for prospecting in the central Koyukuk River region, Alaska: U.S. Geological Survey Circular 570, 12 p.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 45 manuscript p., scale 1:2,500,000.
- Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1989, Geology of west-central Alaska: U.S. Geological Survey Open-File Report 89-554, 41 p.

Descriptive Model: 17, 17.1, 18a, and 21a**Mark3 Index: 4, 89, 9, and 2****Area: 28,279 km²****Mean undiscovered deposits: (no estimate)****Model***by* Bruce M. Gamble and Marti L. Miller**Rationale for Model Choice**

This tract is permissive for porphyry Cu (Cox, 1986a), BC-Ak type porphyry Cu (Menzie and Singer, 1993), porphyry Cu, skarn related (Cox, 1986c), and porphyry Cu-Mo (Cox, 1986b) deposits based on presence of felsic to intermediate plutons (Patton and others, 1994), and the occurrence of numerous similar or related deposit types. St. Lawrence Island is also considered permissive for porphyry Cu type deposits on the basis of permissive host rocks.

Rationale for Tract Delineation

The geology of the area is poorly known, but several apparently high-level felsic plutons occur in the region, and others could be present at shallow depths. The presence of permissive host rocks is the primary basis for the areal delineation of this tract.

Important Examples of Deposit Type

Known mineral deposits in the area include the McLeod Mo occurrence, and a porphyry Cu/porphyry Cu-Mo deposit at Round Top (Harris, 1985).

Rationale for Numerical Estimates

Because of the lack of detailed geologic information, no estimates of the number of undiscovered deposits have been attempted.

REFERENCES

- Cox, D.P., 1986a, Descriptive model of porphyry Cu, *in* Cox, D.P. and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 76.
- Cox, D.P., 1986b, Descriptive model of porphyry Cu-Mo, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 115.
- Cox, D.P., 1986c, Descriptive model of porphyry Cu, skarn-related deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 82.
- Harris, T.D., 1985, Geology of the Round Top porphyry copper-molybdenum deposit, west-central Alaska: unpublished Masters Thesis, University of Colorado, Boulder, Colorado, 55 p.
- Menzie, W.D., and Singer, D.A., 1993, Grade and tonnage model of porphyry Cu deposits in British Columbia, Canada, and Alaska, U.S.A.: U.S. Geological Survey Open-file Report 93-275, 8 p.
- Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1994, Geology of west-central Alaska, *in* Plafker, George, and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G-1, p. 241-269.

Descriptive Model: 43**Mark3 Index: 43****Area: 9,976 km²****Mean undiscovered deposits: (no estimate)**[Model](#)*by* Marti L. Miller and Thomas K. Bundtzen**Rationale for Model Choice**

This tract contains numerous Cretaceous and Tertiary calc-alkaline stocks that may host plutonic porphyry Au deposits as described by Hollister (1992). It is a continuation of a tract defined for southwest Alaska.

Rationale for Tract Delineation

This tract trends northeast through the Ophir, Medfra, Nulato, and Ruby quadrangles, and is contiguous to the tract in the southwestern region. It is defined by the Kuskokwim Mountain belt, which features volcano-plutonic complexes (and related stocks), gold-quartz vein deposits, and favorable geochemical data (Bundtzen and Miller, 1997).

Important Examples of Deposit Type

There are no known porphyry gold deposits in this tract; however, the contiguous tract in the southwest region contains several plutonic-related gold deposits including those at Chicken Mountain and Golden Horn (Bundtzen and others, 1992) in the Iditarod quadrangle, and at Vinasale Mt. (DiMarchi, 1993) in the McGrath quadrangle.

Rationale for Numerical Estimates

No estimate of the number of undiscovered porphyry gold deposits for this tract was attempted.

References

- Bundtzen, T.K., and Miller, M.L., 1997, Precious metals associated with Late Cretaceous-early Tertiary igneous rocks of southwestern Alaska, *in* Goldfarb, R.J., and Miller, L.D., eds., Mineral deposits of Alaska: Economic Geology Monograph 9, p. 242-286.
- Bundtzen, T.K., Miller, M.L., Laird, G.M., and Bull, K.F., 1992, Geology and mineral resources of Iditarod mining district, Iditarod B-4 and eastern B-5 quadrangles, southwestern Alaska: Alaska Division of Geological and Geophysical Surveys Professional Report 97, 46 p. scale 1:63,360 and 1:770.
- DiMarchi, J.J., 1993, Geology, alteration, and mineralization of the Vinasale Mountain gold deposit, west-central Alaska, *in* Solie, D.N., and Tannian, Fran, eds., Short Notes on Alaskan Geology 1993: Alaska Division of Geological and Geophysical Surveys Professional Report 113, p. 17-29.
- Hollister, V.F., 1992, On a proposed plutonic porphyry gold deposit model: *Nonrenewable Resources*, v. 1, no. 4, p. 293-302.

Descriptive Model: 39a

Mark3 Index: 54

Area: 163,424 km²

Mean undiscovered deposits: (no estimate)

[Model](#)[Mineral Deposits](#)*by* Bruce M. Gamble and Thomas D. Light**Rationale for Model Choice**

Numerous areas in west-central Alaska are permissive for placer gold deposits. The Seward Peninsula contains large placer gold deposits and numerous low-sulfide gold-quartz vein occurrences. The Koyukuk magmatic arc, Ruby and Nixon Fork terranes each contains small gold occurrences associated with plutons.

Rationale for Tract Delineation

On the Seward Peninsula, this tract includes all of the Nome Group rocks exclusive of high-grade (amphibolite and above) portions, which are confined to the mountain ranges. The Nome Group consists chiefly of pelitic schist, calc-schist, pure and impure marble, graphitic quartzite and quartz-mica schist, and mafic schist. Metamorphic grade within the tract is blueschist having a pronounced greenschist overprint (Till and others, 1986). Known placer Au deposits and low-sulfide gold-quartz vein deposits are confined to these rocks. Stream sediment and panned concentrate samples commonly contain anomalous As and Sb, and, locally, Au, W, Bi, and other elements.

Low-level gold geochemical anomalies are scattered across the Koyukuk magmatic arc, and gold lodes are associated with plutons throughout the area.

Stream-sediment geochemical samples in the Ruby terrane, which comprises Precambrian(?) to lower Paleozoic pelitic schist, metabasites, quartzite, orthogneiss, and marble, locally show anomalous values of such metals as As, Zn, W, Cu, Au, Ag and Bi. Stream-sediment samples in the Nixon Fork terrane, which includes greenschist facies pelitic- and calc-schist, greenstone, and minor felsic metaplutonic and metavolcanic rocks, show scattered Au, Zn, and As anomalies.

Mafic and ultramafic oceanic assemblages of the Kanuti, Tozitna, and Innoko subterrane are included in the tract because they contain phyllite and argillite of the Slate Creek thrust panel; pillow basalts, chert, gabbro, and diabase of the Narvak complex; and mafic-ultramafic rocks of the Kanuti complex (Patton and others, 1989b). The Narvak complex is the most common assemblage in west-central Alaska (Patton and others, 1989a).

Important Examples of Deposit Type

The famous placer gold deposits of the Nome and Council districts (Collier and others, 1908; Yeend, 1988) are included in this tract, as well as the smaller Kougarkok, McGrath, Hughes, Fairhaven, Ruby, Innoko, and Koyuk districts (Nokleberg and others, 1987).

Rationale for Numerical Estimates

Because of the relative ease of exploring for placer gold deposits, much of the state has been thoroughly explored. There is a low probability that major new placer districts will be discovered, but a few relatively small new deposits probably will be found.

No estimate of the number of undiscovered deposits was attempted.

References

- Collier, A.J., Hess, F.L., Smith, P.S., and Brooks, A.H., 1908, The gold placers of parts of Seward Peninsula, Alaska: U.S. Geological Survey Bulletin 328, 343 p.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, MS., Smith, T.E., and Yeend, Warren, 1987, Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, p. 104.
- Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1989a, Geology of west-central Alaska: U.S. Geological Survey Open-File Report 89-554, 41 p.
- Patton, W.W., Jr., Box, S.E., and Grybeck, Donald, 1989b, Ophiolites and other mafic-ultramafic complexes in Alaska: U.S. Geological Survey Open-File Report OF 89-648, 27 p., scale 1:5,000,000.
- Till, A.B., Dumoulin, J.A., Gamble, B.M., Kaufman, D.S., and Carroll, P.I., 1986, Preliminary geologic maps and fossil data, Solomon, Bendeleben, and southern Kotzebue quadrangles, Seward Peninsula, Alaska: U.S. Geological Survey Open-File Report 86-276, 62 p., scale 1:250,000.
- Yeend, Warren, Kaufman, D.S., and Till, A.B., 1988, Map showing placer gold in the Solomon, Bendeleben, and southern part of the Kotzebue quadrangles, western Alaska: US Geological Survey Miscellaneous Field Studies Map MF-1838-C, scale 1:250,000.

Descriptive Model: 19a**Mark3 Index: 47****Area: 11,026 km²****Mean undiscovered deposits: (no estimate)****Model**

by Bruce M. Gamble, Robert G. Eppinger, John W. Cady, Stanley E. Church, Byron R. Berger, Gregory T. Spanski

Rationale for Model Choice

Numerous felsic to intermediate composition intrusions and metacarbonate rocks occur throughout the Seward Peninsula. Polymetallic vein deposits are locally present, such as the Billiken (Kugruk) Fe-Cu skarn suggesting that polymetallic replacement deposits as described by Morris (1986) are possible for this tract.

Rationale for Tract Delineation

This tract encompasses the Seward Peninsula plutons, exclusive of tin-granites. Three distinct suites of plutonic rocks are present (Till and others, 1986; Gamble, 1988, Gamble and Till, 1988): (1) 99-108 Ma alkaline, nepheline-bearing intrusions; (2) 90-96 Ma sub-alkaline to alkaline plutons, typically monzonite, quartz monzonite, monzogranite, and granodiorite; and (3) 81-83 Ma calc-alkaline plutons, typically quartz monzodiorite, granodiorite, and monzogranite. All of these suites intrude units known to contain metacarbonate lithologies. Anomalous stream sediment and concentrate geochemistry includes: Ag, Cu, Pb, Zn, Mo, Sn, As, Sb, and rare Au.

Important Examples of Deposit Type

No polymetallic replacement deposits are known.

Rationale for Numerical Estimates

Insufficient data exist to estimate the expected number of undiscovered polymetallic replacement deposits in this tract.

References

- Gamble, B.M., 1988, Non-placer mineral occurrences in the Solomon, Bendeleben, and parts of the Kotzebue quadrangles, western Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF 1838-B, 1 sheet, scale 1:250,000, 13 p.
- Gamble, B.M., and Till, A.B., 1993, Maps showing metallic mineral resources of the Bendeleben and Solomon quadrangles, western Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF 1838-D, 3 sheets, scale 1:250,000, 22 p.
- Morris, H.T., 1986, Descriptive model of polymetallic replacement deposits, *in* Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 99.
- Till, A.B., Dumoulin, J.A., Gamble, B.M., Kaufman, D.S., and Carroll, P.I., 1986, Preliminary geologic maps and fossil data, Solomon, Bendeleben, and southern Kotzebue quadrangles, Seward Peninsula, Alaska: U.S. Geological Survey Open-File Report 86-276, 62 p., scale 1:250,000.

Descriptive Model: 19a

Mark3 Index: 47

Area: 7,891 km²

Mean undiscovered deposits: (no estimate)

[Model](#)

by Marti L. Miller, Bruce M. Gamble, and Thomas D. Light

Rationale for Model Choice

In west-central Alaska and nearby parts of southwestern, east-central, and south-central Alaska, carbonate rocks that are locally intruded by small felsic plutons may host polymetallic replacement deposits as described by Morris (1986).

Rationale for Tract Delineation

The area permissive for polymetallic replacement deposits is defined by Paleozoic carbonate rocks and carbonate-bearing units that are locally intruded by Late Cretaceous and Tertiary plutons. The permissive area lies in the Ruby and Medfra quadrangles and forms part of the Nixon Fork and Minchumina terranes (Patton and others, 1994). This tract is a continuation of adjacent tracts in southwestern, east-central, and south-central Alaska.

Important Examples of Deposit Type

No examples of polymetallic replacement deposits are known in this tract.

Rationale for Numerical Estimates

No estimate of undiscovered resources was attempted.

References

- Morris, H.T., 1986, Descriptive model of polymetallic replacement deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 99-100.
- Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1994, Geology of west-central Alaska, *in* Plafker, George, and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G-1, p. 241-269.

Descriptive Model: 22c

Mark3 Index: 52

Area: 11,026 km²

Mean undiscovered deposits: (no estimate)

[Model](#)

by Bruce M. Gamble, Robert G. Eppinger, John W. Cady, Stanley E. Church, Byron R. Berger, Gregory T. Spanski

Rationale for Model Choice

Polymetallic vein deposits are associated with hypabyssal intrusions of nearly any age and a wide range of compositions, in sedimentary and metamorphic terranes (Cox, 1986). Polymetallic veins may also be spatially related to a large number of other types of deposits, thus making their permissive area quite extensive. This model also serves as somewhat of a catch-all for deposits of unknown type that, given minimal information, do not appear to fit into other similar categories.

Rationale for Tract Delineation

This tract includes contains several polymetallic vein deposits associated with three distinct suites of Late Cretaceous plutonic rocks (Till and others, 1986): (1) 99-108 Ma alkaline, nepheline-bearing intrusions; (2) 90-96 Ma sub-alkaline to alkaline plutons, typically monzonite, quartz monzonite, monzogranite, and granodiorite; and (3) 81-83 Ma calc-alkaline plutons, typically quartz monzodiorite, granodiorite, and monzogranite. The tract also includes several types of polymetallic veins, and areas of Ag, Cu, Pb, Zn, Mo, Sn, As, Sb, and rare Au anomalies in stream sediments and heavy-mineral concentrates (Gamble, 1988a, 1988b).

Important Examples of Deposit Type

Mineral deposits include the Independence Ag-Pb-Zn polymetallic vein, Omilak East and Foster Ag-Pb polymetallic veins(?), and Cu-rich polymetallic veins of the upper Niukluk River

Rationale for Numerical Estimates

Because of the limited exposure, uncertainty of classification of polymetallic vein varieties, and lack of information on controls of mineralization, estimating the expected number of undiscovered polymetallic vein deposits was not attempted.

References

- Cox, D.P., 1986, Descriptive model of polymetallic veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 125.
- Gamble, B.M., 1988, Non-placer mineral occurrences in the Solomon, Bendeleben, and parts of the Kotzebue quadrangles, western Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF 1838-B, 1 sheet, scale 1:250,000, 13 p.
- Gamble, B.M., and Till, A.B., 1993, Maps showing metallic mineral resources of the Bendeleben and Solomon quadrangles, western Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF 1838-D, 3 sheets, scale 1:250,000, 22 p.
- Till, A.B., Dumoulin, J.A., Gamble, B.M., Kaufman, D.S., and Carroll, P.I., 1986, Preliminary geologic maps and fossil data, Solomon, Bendeleben, and southern Kotzebue quadrangles, Seward Peninsula, Alaska: U.S. Geological Survey Open-File Report 86-276, 62 p., scale 1:250,000.

Descriptive Model: 22c**Mark3 Index: 52****Area: 57,404 km²****Mean undiscovered deposits: (no estimate)****Model**

by Bruce M. Gamble, Robert G. Eppinger, John W. Cady, Stanley E. Church, Byron R. Berger, Gregory T. Spanski

Rationale for Model Choice

Polymetallic vein deposits are associated with hypabyssal intrusions of nearly any age and a wide range of compositions, in sedimentary and metamorphic terranes (Cox, 1986). Polymetallic veins may also be spatially related to a large number of other types of deposits, thus making their permissive area quite extensive. This model also serves as somewhat of a catch-all for deposits of unknown type that, given minimal information, do not appear to fit into other similar categories.

Rationale for Tract Delineation

This tract encompasses the Koyukuk magmatic arc, which chiefly consists of Upper Jurassic(?) and Lower Cretaceous island arc andesitic volcanic rocks (Patton and others, 1989; Nokleberg and others, 1994). Two major suites of intrusive rocks are present: (1) a 79-89 Ma I-type tonalite to granite in the east; and (2) a 99-113 Ma S-type group in the west containing potassic syenites and monzonites, and ultrapotassic nepheline-bearing intrusive rocks (Patton and others, 1989). Stream sediment anomalies include As, Sb, Pb, Cu, Au, Ag, and W. Some of these anomalies are spatially associated with intrusions.

Important Examples of Deposit Type

Polymetallic veins are known at Granite Mountain, Quartz Creek, at Hawk River in the Shungnak quadrangle, and in the Selawik area (Miller and Ferrians, 1968; Nokleberg and others, 1987).

Rationale for Numerical Estimates

Because of the lack of data for this tract, no attempt was made to estimate the number of undiscovered polymetallic vein deposits.

References

- Cox, D.P., 1986, Descriptive model of polymetallic veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 125.
- Miller, T.P., and Ferrians, O.J., 1968, Suggested areas for prospecting in the central Koyukuk River region, Alaska: U.S. Geological Survey Circular 570, 12 p.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987. Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 45 manuscript p., scale 1:2,500,000.
- Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1989, Geology of west-central Alaska: U.S. Geological Survey Open-File Report 89-554, 41 p.

Descriptive Model: 22c

Mark3 Index: 52

Area: 66,650 km²

Mean undiscovered deposits: (no estimate)

[Model](#)[Mineral Deposits](#)

by Bruce M. Gamble, Robert G. Eppinger, John W. Cady, Stanley E. Church, Byron R. Berger, Gregory T. Spanski

Rationale for Model Choice

Polymetallic vein deposits can be associated with intrusive rocks of any age and a wide range of compositions (Cox, 1986). Polymetallic veins may also be spatially related to a large number of other types of magmatic-hydrothermal deposits, thus making their permissive area quite extensive.

Rationale for Tract Delineation

This tract includes that part of west-central Alaska south of the Kaltag fault, and is contiguous to the tract in southwestern Alaska. It is based on the distribution of known and inferred plutonic rocks, some of which are Late Cretaceous or early Tertiary volcano-plutonic complexes, in sedimentary and metamorphic terranes. Only reconnaissance level data are available to define the extent of the tract. Stream-sediment and/or concentrate anomalies of Au, As, Sb, Cu, Pb, n, Sn, Hg, and Bi are scattered throughout the area..

Important Examples of Deposit Type

There are several scattered occurrences that have been tentatively classified as polymetallic veins. The Wyoming Creek, Illinois Creek, and Perseverance Valley occurrences may be polymetallic veins.

Rationale for Numerical Estimates

Due to the paucity of geologic data in most of the area, and our uncertainty assigning this model, no estimate of undiscovered resources was made.

References

Cox, D.P., 1986, Descriptive model of polymetallic veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 125.

Descriptive Model: 18b

Mark3 Index: 8

Area: 11,026 km²

Mean undiscovered deposits: (no estimate)

[Model](#)

by Bruce M. Gamble, Robert G. Eppinger, John W. Cady, Stanley E. Church, Byron R. Berger, Gregory T. Spanski

Rationale for Model Choice

Felsic to intermediate plutons and carbonate rocks are widespread throughout the Seward Peninsula. A Fe-Cu skarn deposit is present on the flank of the Kugruk pluton. Presence of the felsic to intermediate plutonic rocks in the vicinity of carbonate rocks, plus the occurrence of related or similar deposits, indicate that this area is permissive for Cu-(Au) skarn deposits as described by Cox and Theodore (1986).

Rationale for Tract Delineation

This tract encompasses the Seward Peninsula plutons, exclusive of tin-granites. There are three distinct suites of plutonic rocks: (1) 99-108 Ma alkaline, nepheline-bearing intrusions (Till and others, 1986); (2) 90-96 Ma sub-alkaline to alkaline plutons, typically monzonite, quartz monzonite, monzogranite, and granodiorite; and (3) 81-83 Ma calc-alkaline plutons, typically quartz monzodiorite, granodiorite, and monzogranite. Stream-sediment and heavy-mineral-concentrate geochemistry include anomalously high concentrations of Ag, Cu, Pb, Zn, Mo, Sn, As, Sb, and rare Au (Gamble, 1988).

Important Examples of Deposit Type

No Cu-Au skarns are known in the tract. Similar or related mineral deposit types include the Kugruk Fe-Cu skarn; Independence Ag-Pb polymetallic vein; Windy Creek porphyry Mo; Omilak East and Foster Ag-Pb polymetallic veins(?); Cu-rich polymetallic veins of the upper Niukluk River; and many deposits/occurrences, chiefly Ag-Pb-(Zn), of unknown type (Gamble and Till, 1988).

Rationale for Numerical Estimates

Insufficient data exist to support an estimate of the expected number of undiscovered Cu-(Au) skarn deposits.

References

- Cox, D.P., and Theodore, T.G., 1986, Descriptive model of Cu skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 86.
- Gamble, B.M., 1988, Non-placer mineral occurrences in the Solomon, Bendeleben, and parts of the Kotzebue quadrangles, western Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF 1838-B, 1 sheet, scale 1:250,000, 13 p.
- Gamble, B.M., and Till, A.B., 1993, Maps showing metallic mineral resources of the Bendeleben and Solomon quadrangles, western Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF 1838-D, 3 sheets, scale 1:250,000, 22 p.
- Till, A.B., Dumoulin, J.A., Gamble, B.M., Kaufman, D.S., and Carroll, P.I., 1986, Preliminary geologic maps and fossil data, Solomon, Bendeleben, and southern Kotzebue quadrangles, Seward Peninsula, Alaska: U.S. Geological Survey Open-File Report 86-276, 62 p., scale 1:250,000.

Descriptive Model: 18b

Mark3 Index: 8

Area: 7,891 km²

Mean undiscovered deposits: : (no estimate)

[Model](#)[Mineral Deposits](#)

by Marti L. Miller and Bruce M. Gamble

Rationale for Model Choice

In the southeastern part of west-central Alaska, carbonate rocks and units containing carbonate rocks, which have been intruded by Late Cretaceous or Tertiary plutons, may host deposits that fit the Cu-(Au) skarn model of Cox and Theodore (1986) and Theodore and others (1991). The Nixon Fork skarn deposit lies within this tract.

Rationale for Tract Delineation

The permissive tract for skarn deposits in west-central Alaska encompasses an area of carbonate rocks in the southeastern part of the region. This area is a continuation of the permissive area in southwestern Alaska, and is delineated by Cambrian to Devonian carbonate rocks of the Farewell terrane (Decker and others, 1994) and by carbonate-bearing rocks of the Minchumina terrane (Patton and others, 1994).

Important Examples of Deposit Type

The Nixon Fork deposit (Bundtzen and others, 1996; Swanson, 1996), which lies within this tract, has reported reserves of about 117,000 tons containing 1.32 ounce/ton gold (Northern Miner, 1995).

Rationale for Numerical Estimates

Insufficient data exist to estimate the expected number of undiscovered Cu-(Au) skarn deposits for this tract.

References

- Bundtzen, T.K., Swainbank, R.C., Clough, A.H., Henning, M.W., and Charlie, K.M., 1996, Alaska's Mineral Industry, 1995: Alaska Division of Geological and Geophysical Surveys Special Report 50, 72 p.
- Cox, D.P., and Theodore, T.G., 1986, Descriptive model of Cu skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 86.
- Decker, John, Bergman, S.C., Blodgett, R.B., Box S.E., Bundtzen, T.K., Clough, J.G., Coonrad, W.L., Gilbert, W.G., Miller, M.L., Murphy, J.M., Robinson, M.S., and Wallace, W.K., 1994, Geology of southwestern Alaska, *in* Plafker, G., and Berg, H.C., eds., The geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G1, p. 285-310.
- Northern Miner, 1995, v. 81, no. 36, November 6, 1995, p. 1-2.
- Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1994, Geology of west-central Alaska, *in* Plafker, George, and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G-1, p. 241-269.
- Patton, W.W., Jr., Moll, E.J., Dutro, J.T., Silberman, M.L., and Chapman, R.M., 1980, Preliminary geologic map of Medfra quadrangle, Alaska: U.S. Geological Survey Open-File Report 80-811-A, 1 sheet, scale 1:250,000.
- Swanson, Mel, 1996, Nixon Fork mine [abs], *in* Alaska mining-no longer just a dream: Alaska Miners Association, Abstracts, 1996 Annual Convention, Nov. 6-8, 1996, Anchorage, Alaska, p. 30-31.
- Theodore, T.G., Orris, G.J., Hammarstrom, J.M., and Bliss, J.D., 1991, Gold-bearing skarns, U.S. Geological Bulletin 1930, 61 p.

Descriptive Model: 18c

Mark3 Index: 22

Area: 11,026 km²

Mean undiscovered deposits: (no estimate)

[Model](#)

by Bruce M. Gamble, Robert G. Eppinger, John W. Cady, Stanley E. Church, Byron R. Berger, Gregory T. Spanski

Rationale for Model Choice

The presence of intermediate to felsic plutonic rocks intruding carbonate rocks suggest that this tract is permissive for Zn-Pb skarn deposits as described by Cox (1986).

Rationale for Tract Delineation

This tract encompasses all the Seward Peninsula plutons, exclusive of tin-granites. There are three distinct suites of plutonic rocks (Till and others, 1986): (1) 99-108 Ma alkaline, nepheline-bearing intrusions; (2) 90-96 Ma sub-alkaline to alkaline plutons, typically monzonite, quartz monzonite, monzogranite, and granodiorite; and (3) 81-83 Ma calc-alkaline plutons, typically quartz monzodiorite, granodiorite, and monzogranite. Metacarbonate rocks are widespread throughout the tract. Known mineral deposits (Gamble, 1988; Gamble and Till, 1988) include the Kugruk Fe-Cu skarn; Independence Ag-Pb polymetallic vein; Windy Creek porphyry Mo; Omilak East and Foster Ag-Pb polymetallic veins(?); Cu-rich polymetallic veins of the upper Niukluk River; and many deposits/occurrences, chiefly Ag-Pb-(Zn), of unknown type. Stream-sediment and heavy-mineral-concentrate samples from within the tract contain anomalous Ag, Cu, Pb, Zn, Mo, Sn, As, Sb, and rare Au.

Important Examples of Deposit Type

No Zn-Pb skarn deposits are known in this tract.

Rationale for Numerical Estimates

Insufficient data exist to estimate the expected number of undiscovered Zn-Pb deposits for this tract.

References

- Cox, D.P., 1986, Descriptive model of Zn-Pb skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 90.
- Gamble, B.M., 1988, Non-placer mineral occurrences in the Solomon, Bendeleben, and parts of the Kotzebue quadrangles, western Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF 1838-B, 1 sheet, scale 1:250,000, 13 p.
- Gamble, B.M., and Till, A.B., 1993, Maps showing metallic mineral resources of the Bendeleben and Solomon quadrangles, western Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF 1838-D, 3 sheets, scale 1:250,000, 22 p.
- Till, A.B., Dumoulin, J.A., Gamble, B.M., Kaufman, D.S., and Carroll, P.I., 1986, Preliminary geologic maps and fossil data, Solomon, Bendeleben, and southern Kotzebue quadrangles, Seward Peninsula, Alaska: U.S. Geological Survey Open-File Report 86-276, 62 p., scale 1:250,000.

Descriptive Model: 18c

Mark3 Index: 22

Area: 7,891 km²

Mean undiscovered deposits: (no estimate)

[Model](#)

by Bruce M. Gamble, Robert G. Eppinger, John W. Cady, Stanley E. Church, Byron R. Berger, Gregory T. Spanski

Rationale for Model Choice

The presence of intermediate to felsic plutonic rocks intruding carbonate rocks suggest that this tract is permissive for Zn-Pb skarn deposits as described by Cox (1986).

Rationale for Tract Delineation

This tract is defined by the distribution of carbonate rocks and the known or inferred presence of intermediate to felsic plutonic rocks (Patton and others, 1994; Nokleberg and others, 1994). Known mineral deposits in the area include a Cu-Au skarn and a Fe-skarn. Stream-sediment and heavy-mineral-concentrate samples from within the tract contain anomalous concentrations of Au, As, Sb, Cu, Pb, Zn, Sn, Hg, W, and Bi scattered throughout the area.

Important Examples of Deposit Type

No Zn-Pb skarn deposits are known in this tract.

Rationale for Numerical Estimates

Because of the lack of detailed geologic information, no estimates of the number of undiscovered deposits have been attempted.

References

- Cox, D.P., 1986, Descriptive model of Zn-Pb skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 90.
- Nokleberg, W.J., Moll-Stalcup, E.J., Miller, T.P., Brew, D.A., Grantz, Arthur, Reed, J.C., Jr., Plafker, George, Moore, T.E., Silva, S.R., and Patton, William W., Jr., 1994, Tectonostratigraphic terrane and overlap assemblage map of Alaska: U.S. Geological Survey Open-File Report 94-194, 45 manuscript p., scale 1:2,500,000.
- Patton, W.W., Jr., Box, S.E., and Grybeck, D.J., 1994, Ophiolites and other mafic-ultramafic complexes in Alaska, *in* Plafker, George, and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North American, v. G-1, p. 671-686.

Descriptive Model: 31a**Mark3 Index: 13****Area: 37,861 km²****Mean undiscovered deposits: (no estimate)**[Model](#)

by Bruce M. Gamble, Robert G. Eppinger, John W. Cady, Stanley E. Church, Byron R. Berger, Gregory T. Spanski

Rationale for Model Choice

Several mineral occurrences on the Seward Peninsula consist, at least in part, of stratiform stringers of galena and (or) sphalerite in metasedimentary rocks, chiefly carbonates and argillites. These occur in the mixed unit of the Nome Group, and have alternatively been interpreted as vein, polymetallic replacement, sedimentary exhalative Zn-Pb, and kuroko volcanogenic deposits. Therefore, the area is considered permissive for syngenetic base metal mineralization including sedimentary exhalative Zn-Pb deposits.

Rationale for Tract Delineation

This tract includes all of the Nome Group, including high-grade rocks, and is essentially equivalent to the Seward terrane (Till and others, 1986). Anomalously high concentrations of elements in stream-sediment and panned-concentrate samples include As, Sb, Au, Cu, Pb, Zn, Ag, Ni, Co, Ba, and Mn. The stratiform galena and(or) sphalerite stringers are within this tract.

Important Examples of Deposit Type

A metamorphosed sulfide deposit at Hannum Creek has been interpreted as a sedimentary exhalative Zn-Pb deposit (Nokleberg and others, 1987), or alternatively as a vein deposit (Herreid, 1966). Other examples of possible sedex deposits include Galena, Aurora Creek, and Quarry in the Nome quadrangle (Mulligan and others, 1965).

Rationale for Numerical Estimates

No estimate of the number of undiscovered deposits was attempted because of uncertainty of deposit type.

REFERENCES

- Herreid, Gordon, 1966, The geology and geochemistry of the Inmachuk River map area, Seward Peninsula, Alaska: Alaska Division of Mines and Minerals Geologic Report No. 23, 25 p., scale 1:63,360, 1 sheet.
- Mulligan, J.J., and Hess, H.D., 1965, Examination of the Sinuk Iron Deposits: U.S. Bureau of Mines Open-File Report, 34 p.
- Nokleberg, W.J., Bundtzen, T.K., Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987. Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, 104 p.
- Till, A.B., Dumoulin, J.A., Gamble, B.M., Kaufman, D.S., and Carroll, P.I., 1986, Preliminary geologic maps and fossil data, Solomon, Bendeleben, and southern Kotzebue quadrangles, Seward Peninsula, Alaska: U.S. Geological Survey Open-File Report 86-276, 62 p., scale 1:250,000.

Descriptive Model: 31a

Mark3 Index: 13

Area: 3,918 km²

Mean undiscovered deposits: (no estimate)

[Model](#)

by Marti L. Miller, Bruce M. Gamble, and Jeanine M. Schmidt

Rationale for Model Choice

The presence of siltstone, shale, chert, and carbonate rocks that were deposited in a deep-water environment suggests the possibility of sedex deposits as described by Briskey (1986). Bedded barite deposits may form distal to sedex occurrences. The presence of a bedded barite deposit in possibly correlative rocks in the continuation of this tract to the south supports the selection of this model type.

Rationale for Tract Delineation

This tract includes parts of the Nixon Fork and Minchumina terranes (Patton and others, 1994), both of which locally contain deep-water facies consisting of siltstone, shale, chert, and carbonate rocks.

Important Examples of Deposit Type

No examples of sedex deposits are known in this tract, but the Gagaryah barite deposit (Bundtzen and Gilbert, 1991), in similar rocks in the Lime Hills quadrangle of southwestern Alaska, may be related to sedex mineralization.

Rationale for Numerical Estimates

No attempt was made to estimate the number of undiscovered Sedex Zn-Pb deposits in this tract.

REFERENCES

- Briskey, J.A., 1986, Descriptive model of sedimentary exhalative Zn-Pb, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 211-212.
- Bundtzen, T.K., and Gilbert, W.G., 1991, Geology and geochemistry of the Gagaryah barite deposit, western Alaska Range, Alaska, *in*, Reger, R.D., ed., Short Notes on Alaskan Geology 1991: Alaska Division of Geological and Geophysical Surveys Professional Report 111, p. 9-20.
- Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1994, Geology of west-central Alaska, *in* Plafker, George, and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G-1, p. 241-269.

AD01**Sandstone-hosted Pb-Zn Deposits****New York****Descriptive Model 30a****Area = 4,620 km²**[Model](#)*by* John F. Slack, Sandra H.B. Clark, and John D. Peper**Rationale for Model Choice**

No major sandstone-hosted lead-zinc deposits are known in the United States, and deposits of this type are of relatively minor economic importance by world standards. The only significant deposit in the United States was developed at the Goose Creek mine in the Indian Creek district of southeast Missouri (Kyle and Gutierrez, 1988). However, the importance of some deposits, such as the large (80 million metric tons) Laisvall lead-zinc deposit in northern Sweden, demonstrates the importance of considering the occurrence of similar deposits in geologically analogous settings. Sandstone-hosted lead-zinc deposits are stratabound concentrations of galena and generally minor sphalerite that occur within quartz-rich sandstone and quartzite overlying feldspathic basement rocks (Rickard and others, 1979; Bjørlykke and Sangster, 1981). The origin of sandstone-hosted lead-zinc deposits by transport of metals through permeable channels to an environment with sufficiently high H₂S content to precipitate sulfides from groundwater or basinal brines resembles that of sediment-hosted copper and Mississippi Valley deposits.

Clastic sedimentary sequences that occur near crystalline basement rocks are potential hosts for lead-zinc deposits. Although no deposits are known in the United States Appalachians, several occurrences have been described from Quebec (Schrijver and Beaudoin, 1987), suggesting potential for mineralization of the Cheshire Quartzite and correlative units of Early Cambrian age that overlie feldspathic basement rocks. Galena samples from the Rossie veins of northern New York have lead isotopic compositions and fluid inclusions (Ayuso and others, 1987) that are compatible with an origin from a Paleozoic basinal brine that migrated into fractures during tectonism. The proposed migration of base-metals in brines suggests the possibility of the formation of sandstone-hosted lead-zinc deposits in favorable host rocks such as the Upper Cambrian Potsdam Sandstone that forms a basal unit overlying the Grenvillian basement of the Adirondacks.

Rationale for Tract Delineation

The permissive tract includes the Potsdam Sandstone and other stratigraphically equivalent units that are considered permissive for sandstone-hosted lead-zinc deposits because of their predominantly clastic composition and their position overlying feldspathic basement rocks.

Where rocks are exposed at the surface, boundaries for the tract were derived from contacts on the map showing the generalized geologic setting for metal deposits in the Appalachians (J.D. Peper, written communication; see Gair and others, 1987) and from the State geologic map. Contacts were projected to 1 km beneath the surface by structural interpretation.

Rationale for Numerical Estimate

No estimates of undiscovered deposits were made because, while occurrences of galena are known in the region, large sandstone-hosted lead-zinc deposits are uncommon on a worldwide basis and there are no known large deposits in the eastern United States. Appropriate geologic

settings over broad areas were not considered an adequate basis for estimating undiscovered resources of this deposit type.

References

- Ayuso, R.A., Foley, N.K., and Brown, C.E., 1987, Source of lead and mineralizing brines for Rossie-type Pb-Zn veins in the Frontenac axis area, New York: *Economic Geology*, v. 82, no. 2, p. 489-496.
- Bjørlykke, A., and Sangster, D.F., 1981, An overview of sandstone lead deposits and their relation to red-bed copper and carbonate-hosted lead-zinc deposits, *in* Skinner, B.J., ed., *Economic Geology Seventy-Fifth Anniversary Volume, 1905-1980*: Lancaster, Pennsylvania, Economic Geology Publishing Company, p. 179-213.
- Gair, J.F., Cannon, W.F., Peper, J.D., Cannon, S.S., and Martin, B., 1987, Appalachian metallogenic map (abs.), *in* Sachs, J.S., ed., *USGS research on mineral resources—1987, Third Annual V.E. McKelvey Forum on Mineral and Energy Resources*: U.S. Geological Survey Circular 995, p. 22-23.
- Kyle, J.R., and Gutierrez, G.N., 1988, Origin of the Indian Creek sandstone-hosted lead deposits, southeast Missouri, USA, *in* Zachrisson, Ebbe, ed., *Proceedings of the Seventh Quadrennial IAGOD Symposium*, Luleå, Sweden, 1986: Stuttgart, E. Schweizerbart'sche Verlagsbuchhandlung, p. 669-684.
- Rickard, D.T., Willdén, M.Y., Marinder, N.-E., and Donnelly, T.H., 1979, Studies on the genesis of the Laisvall sandstone lead-zinc deposit, Sweden: *Economic Geology*, v. 74, no. 5, p. 1255-1285.
- Schrijver, K., and Beaudoin, G., 1987, Diverse occurrences of galena-cemented sandstones in the Paleozoic, northern Appalachians, Quebec: *Canadian Institute of Mining and Metallurgy Bulletin*, v. 80, no. 908, p. 54-62.

AD02**Sedimentary exhalative Zn Deposits****New York****Descriptive Model 31a • Mark3 Index 106****Area = 253 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Sandra H.B. Clark and Michael P. Foose, with advice and consultation from C. Ervin Brown

Rationale for Model Choice

Major deposits of probable sedimentary exhalative origin are known in the Balmat-Edwards-Pierrepont district of northern New York. The polydeformed and highly metamorphosed nature of host rocks and the ore bodies have led to different interpretations about the origin of the mineralization. The deposits have been interpreted as Mississippi Valley type because of the carbonate host rocks and simple nature of the sulfides. However, later interpretations are that the Balmat-Edwards-Pierrepont deposits may be carbonate-hosted sedimentary-exhalative deposits (deLorraine and Dill, 1982; Whelan and others, 1984).

The deposits have a unique combination of characteristics that do not clearly fit either model. The main features of these deposits that were used to select a model for this assessment were the occurrence of a thin pyritic schist unit in the sequence, the stromatolite-bearing shelf environment of deposition of the carbonate strata, association of evaporites with the deposits, and the association with a paragneiss in the district that was probably derived from a dacitic volcanic rock. No clear exhalites have been identified, and any original alteration has been obscured by metamorphism. The host rocks are metamorphosed carbonate rocks, rather than black shales, as is characteristic of many sedimentary-exhalative deposits. The assessment team concluded that the deposits of the Balmat-Edwards-Pierrepont deposits more closely fit a distal variety of the sedimentary exhalative model of Menzie and Mosier (1986).

Grades and tonnages of production and reserves are poorly known. Estimated production figures suggest that the major production has been from the Balmat mines, but a significant proportion of ore came from the Edwards mine, which is no longer being mined, in the past along with a much smaller production from the Hyatt mine. The Pierrepont deposit, which was discovered in 1979, was estimated to contain 2.3 million metric tons of 16 percent Zn ore, which would be about 360,000 metric tons of contained Zn (Burger, 1983). Even if more accurate data for the district were available, the relationship to original grades would be uncertain because present grades may have been altered by metamorphism.

Estimated tonnages, which are based mainly on production, put the Balmat deposit well above the median on the tonnage curve of Menzie and Mosier (1986); Edwards and Pierrepont are below the median, but above the 90th percentile. A minimum estimate for the Hyatt deposit puts it at the low end of the tonnage distribution. The zinc grade for these deposits is above the median on the grade curve of Menzie and Mosier (1986). Comparison with zinc grades in the deposit model is complicated because these deposits have been strongly metamorphosed, and it is likely that the original zinc grades have been increased. The lead and silver grades of the deposits are well below the 90th percentile on the grade curves of Menzie and Mosier (1986). The grade of lead is one of the lowest on the curve, and silver is reported only from the Edwards mine. No geologic reason for the low lead and silver contents of Balmat ores is known. The Balmat ores may be part of a low lead-silver subtype of sedimentary exhalative ores, but no consistent geologic basis for separating low lead-silver deposits from other deposits in the worldwide model has been identified.

Rationale for Tract Delineation

All Middle Proterozoic marbles in the Adirondack Mountains and surrounding lowlands are considered to be permissive for the occurrence of sedimentary exhalative zinc-lead deposits. Contacts were extended to 1 km depth based on dips. In most of the areas, dips are about 45°, and some tract boundaries are high-angle faults. The permissive tract includes Middle Proterozoic marbles that are west of the Beaver Creek fault, and that contain sulfidic and graphitic schists associated with marble, as well as rhyolitic metatuff (Brown, 1983). Sulfides, mainly pyrrhotite, are abundant. The tract contains no known deposits, but there have been minor Cu shows in exploration drilling and an old prospect.

Rationale for Numerical Estimate

Because of the geologic characteristics of the known zinc mineralization, it is considered more likely that undiscovered mineralization would have low lead-silver contents similar to deposits in the Balmat-Edwards-Pierrepont district than to worldwide distribution curves for sedimentary-exhalative deposits. For the 90th, 50th, and 10th percentiles, the team estimated respectively 0, 0, and 1 as the probable number of undiscovered districts in that area consistent with the grade and tonnage model of Menzie and Mosier (1986), modified to report no lead or silver.

References

- Brown, C.E., 1983, Mineralization, mining, and mineral resources in the Beaver Creek area of the Grenville Lowlands in St. Lawrence County, New York: U.S. Geological Survey Professional Paper 1279, 21 p.
- Burger, John R., 1983, St. Joe's Pierrepont mine: *Engineering and Mining Journal*, v. 184, no. 2, p. 58-60.
- Menzie, W.D., and Mosier, D.L., 1986, Grade and tonnage model of sedimentary exhalative Zn-Pb, in Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 212-215.
- Whelan, J.F., Rye, R.O., and deLorraine, W.F., 1984, The Balmat-Edwards zinc-lead deposits—Synsedimentary ore from Mississippi Valley-type fluid: *Economic Geology*, v. 79, no. 2, p. 239–265.

AD03**Sedimentary exhalative Zn Deposits****New York****Descriptive Model 31a • Mark3 Index 106****Area = 986 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Sandra H.B. Clark and Michael P. Foose, with advice and consultation from C. Ervin Brown

Rationale for Model Choice

Major deposits of probable sedimentary exhalative origin are known in the Balmat-Edwards-Pierrepont district of northern New York. The polydeformed and highly metamorphosed nature of host rocks and the ore bodies have led to different interpretations about the origin of the mineralization. The deposits have been interpreted as Mississippi Valley type because of the carbonate host rocks and simple nature of the sulfides. However, later interpretations are that the Balmat-Edwards-Pierrepont deposits may be carbonate-hosted sedimentary-exhalative deposits (deLorraine and Dill, 1982; Whelan and others, 1984).

The deposits have a unique combination of characteristics that do not clearly fit either model. The main features of these deposits that were used to select a model for this assessment were the occurrence of a thin pyritic schist unit in the sequence, the stromatolite-bearing shelf environment of deposition of the carbonate strata, association of evaporites with the deposits, and the association with a paragneiss in the district that was probably derived from a dacitic volcanic rock. No clear exhalites have been identified, and any original alteration has been obscured by metamorphism. The host rocks are metamorphosed carbonate rocks, rather than black shales, as is characteristic of many sedimentary-exhalative deposits. The assessment team concluded that the deposits of the Balmat-Edwards-Pierrepont deposits more closely fit a distal variety of the sedimentary exhalative model of Menzie and Mosier (1986).

Grades and tonnages of production and reserves are poorly known. Estimated production figures suggest that the major production has been from the Balmat mines, but a significant proportion of ore came from the Edwards mine, which is no longer being mined, in the past along with a much smaller production from the Hyatt mine. The Pierrepont deposit, which was discovered in 1979, was estimated to contain 2.3 million metric tons of 16 percent Zn ore, which would be about 360,000 metric tons of contained Zn (Burger, 1983). Even if more accurate data for the district were available, the relationship to original grades would be uncertain because present grades may have been altered by metamorphism.

Estimated tonnages, which are based mainly on production, put the Balmat deposit well above the median on the tonnage curve of Menzie and Mosier (1986); Edwards and Pierrepont are below the median, but above the 90th percentile. A minimum estimate for the Hyatt deposit puts it at the low end of the tonnage distribution. The zinc grade for these deposits is above the median on the grade curve of Menzie and Mosier (1986). Comparison with zinc grades in the deposit model is complicated because these deposits have been strongly metamorphosed, and it is likely that the original zinc grades have been increased. The lead and silver grades of the deposits are well below the 90th percentile on the grade curves of Menzie and Mosier (1986). The grade of lead is one of the lowest on the curve, and silver is reported only from the Edwards mine. No geologic reason for the low lead and silver contents of Balmat ores is known. The Balmat ores may be part of a low lead-silver subtype of sedimentary exhalative ores, but no consistent geologic basis for separating low lead-silver deposits from other deposits in the worldwide model has been identified.

Rationale for Tract Delineation

All Middle Proterozoic marbles in the Adirondack Mountains and surrounding lowlands are considered to be permissive for the occurrence of sedimentary exhalative zinc-lead deposits. Contacts were extended to 1 km depth based on dips. In most of the areas, dips are about 45°, and some tract boundaries are high-angle faults. The permissive tract includes Middle Proterozoic marbles that are east of the Beaver Creek fault and west of the marbles in the Balmat-Edwards district, and which form a contiguous carbonate body that extends through the town of Gouverneur. The most favorable part of this tract is the area containing talc schist, pyritic layers, and evaporite-type tourmalinites (Brown, 1983; Brown and Ayuso, 1985). The tract contains some zinc showings but no deposits.

Rationale for Numerical Estimate

Because of the geologic characteristics of the known zinc mineralization, it is considered more likely that undiscovered mineralization would have low lead-silver contents similar to deposits in the Balmat-Edwards-Pierrepont district than to worldwide distribution curves for sedimentary-exhalative deposits. For the 90th, 50th, and 10th percentiles, the team estimated respectively 0, 0, and 1 as the probable number of undiscovered districts in that area consistent with the grade and tonnage model of Menzie and Mosier (1986), modified to report no lead or silver.

References

- Brown, C.E., 1983, Mineralization, mining, and mineral resources in the Beaver Creek area of the Grenville Lowlands in St. Lawrence County, New York: U.S. Geological Survey Professional Paper 1279, 21 p.
- Brown, C.E., and Ayuso, R.A., 1985, Significance of tourmaline-rich rocks in the Grenville complex of St. Lawrence County, New York: U.S. Geological Survey Bulletin 1626-C, 33 p.
- Burger, John R., 1983, St. Joe's Pierrepont mine: *Engineering and Mining Journal*, v. 184, no. 2, p. 58-60.
- Menzie, W.D., and Mosier, D.L., 1986, Grade and tonnage model of sedimentary exhalative Zn-Pb, in Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 212-215.
- Whelan, J.F., Rye, R.O., and deLorraine, W.F., 1984, The Balmat-Edwards zinc-lead deposits—Synsedimentary ore from Mississippi Valley-type fluid: *Economic Geology*, v. 79, no. 2, p. 239–265.

AD04**Sedimentary exhalative Zn Deposits****New York****Descriptive Model 31a****Area = 51 km²****Model**

by Sandra H.B. Clark and Michael P. Foose, with advice and consultation from C. Ervin Brown

Rationale for Model Choice

Major deposits of probable sedimentary exhalative origin are known in the Balmat-Edwards-Pierrepont district of northern New York. The polydeformed and highly metamorphosed nature of host rocks and the ore bodies have led to different interpretations about the origin of the mineralization. The deposits have been interpreted as Mississippi Valley type because of the carbonate host rocks and simple nature of the sulfides. However, later interpretations are that the Balmat-Edwards-Pierrepont deposits may be carbonate-hosted sedimentary-exhalative deposits (deLorraine and Dill, 1982; Whelan and others, 1984).

The deposits have a unique combination of characteristics that do not clearly fit either model. The main features of these deposits that were used to select a model for this assessment were the occurrence of a thin pyritic schist unit in the sequence, the stromatolite-bearing shelf environment of deposition of the carbonate strata, association of evaporites with the deposits, and the association with a paragneiss in the district that was probably derived from a dacitic volcanic rock. No clear exhalites have been identified, and any original alteration has been obscured by metamorphism. The host rocks are metamorphosed carbonate rocks, rather than black shales, as is characteristic of many sedimentary-exhalative deposits. The assessment team concluded that the deposits of the Balmat-Edwards-Pierrepont deposits more closely fit a distal variety of the sedimentary exhalative model of Menzie and Mosier (1986).

Grades and tonnages of production and reserves are poorly known. Estimated production figures suggest that the major production has been from the Balmat mines, but a significant proportion of ore came from the Edwards mine, which is no longer being mined, in the past along with a much smaller production from the Hyatt mine. The Pierrepont deposit, which was discovered in 1979, was estimated to contain 2.3 million metric tons of 16 percent Zn ore, which would be about 360,000 metric tons of contained Zn (Burger, 1983). Even if more accurate data for the district were available, the relationship to original grades would be uncertain because present grades may have been altered by metamorphism.

Estimated tonnages, which are based mainly on production, put the Balmat deposit well above the median on the tonnage curve of Menzie and Mosier (1986); Edwards and Pierrepont are below the median, but above the 90th percentile. A minimum estimate for the Hyatt deposit puts it at the low end of the tonnage distribution. The zinc grade for these deposits is above the median on the grade curve of Menzie and Mosier (1986). Comparison with zinc grades in the deposit model is complicated because these deposits have been strongly metamorphosed, and it is likely that the original zinc grades have been increased. The lead and silver grades of the deposits are well below the 90th percentile on the grade curves of Menzie and Mosier (1986). The grade of lead is one of the lowest on the curve, and silver is reported only from the Edwards mine. No geologic reason for the low lead and silver contents of Balmat ores is known. The Balmat ores may be part of a low lead-silver subtype of sedimentary exhalative ores, but no consistent geologic basis for separating low lead-silver deposits from other deposits in the worldwide model has been identified.

Rationale for Tract Delineation

All Middle Proterozoic marbles in the Adirondack Mountains and surrounding lowlands are considered to be permissive for the occurrence of sedimentary exhalative zinc-lead deposits. Contacts were extended to 1 km depth based on dips. In most of the areas, dips are about 45° and some tract boundaries are high angle faults. The permissive tract includes the Middle Proterozoic marble that is the host rock in the Balmat-Edwards-Pierrepont district.

Rationale for Numerical Estimate

The grade and tonnage models for sedimentary exhalative deposits (Menzie and Mosier, 1986) are based on ore districts and not on occurrences of individual concentrations or lenses of ore. This fact constrains numerical estimates to be an expression of the probability that new districts remain undiscovered. The likelihood that significant undiscovered ore exists in the tract is high, but it is probable that all ore bodies would be a part of the existing Balmat-Edwards-Pierrepont district. Therefore, the probability that a new sedimentary exhalative ore district exists in this tract is rated as less than 0.01. This estimate reflects the extensive exploration that this area has received, as well as its small size.

References

- Burger, John R., 1983, St. Joe's Pierrepont mine: *Engineering and Mining Journal*, v. 184, no. 2, p. 58-60.
- deLorraine, W.F., and Dill, D.B., 1982, Structure, stratigraphic controls, and genesis of the Balmat zinc deposits, northwest Adirondacks, New York: Geological Association of Canada, Special Paper No. 25, p. 571-596.
- Lea E.R., and Dill, D.B., Jr., 1968, Ore deposits of the Balmat-Edwards district, New York, *in* Ridge, J.D., ed., *Ore deposits of the United States, 1933-1967*, v. 1: New York, American Institute of Mining, Metallurgical, and Petroleum Engineers, v. 1, p. 95-107.
- Menzie, W.D., and Mosier, D.L., 1986, Grade and tonnage model of sedimentary exhalative Zn-Pb, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 212-215.
- Whelan, J.F., Rye, R.O., and deLorraine, W.F., 1984, The Balmat-Edwards zinc-lead deposits—Synsedimentary ore from Mississippi Valley-type fluid: *Economic Geology*, v. 79, no. 2, p. 239-265.

AD05**Sedimentary exhalative Zn Deposits****New York****Descriptive Model 31a****Area = 251 km²**[Model](#)

by Sandra H.B. Clark and Michael P. Foose, with advice and consultation from C. Ervin Brown

Rationale for Model Choice

Major deposits of probable sedimentary exhalative origin occur in Middle Proterozoic marbles in the Balmat-Edwards-Pierrepont district of northern New York.

Rationale for Tract Delineation

All Middle Proterozoic marbles in the lowlands of the Adirondack Mountains are considered to be permissive for the occurrence of sedimentary exhalative zinc-lead deposits because of lithologic similarities to the productive areas near Balmat-Edwards. The tract includes the Middle Proterozoic marbles south and east of the Adirondack Mountains that contain no zinc-lead occurrences or other indications of deposits.

Rationale for Numerical Estimate

The team believes that the tract is permissive for an undiscovered deposit, but that there is less than one chance in 100 that a deposit exists in this tract.

AD06**Appalachian Zn Deposits****New York****Descriptive Model 32b****Area = 14,300 km²**[Model](#)*by* Sandra H.B. Clark, Joseph A. Briskey, Jr. and Dennis P. Cox**Rationale for Model Choice**

Large resources of zinc occur in major strata-bound Appalachian-zinc (Mississippi Valley type, MVT) districts that extend from Tennessee to Newfoundland. Because of the distinctive geological features and importance of the eastern United States deposits, they are the basis for definition of the worldwide Appalachian zinc model (Briskey, 1986). Known Appalachian zinc districts in the east-central United States are strata-bound within Lower Cambrian to Lower Ordovician dolostones and limestones that formed as platform carbonate deposits in the Appalachian basin sedimentary sequence. No examples are known in this tract in New York, but carbonate rocks of the Lower and Middle Ordovician Beekmantown Group and stratigraphically equivalent units are host rocks for deposits in Pennsylvania.

Rationale for Tract Delineation

The identification of brines with compositions of MVT fluids in Rossie vein deposits (Ayuso and others, 1987) is considered a possible indication of undiscovered MVT deposits in carbonate rocks of northern New York. The permissive tract includes carbonate rocks of the Lower and Middle Ordovician Beekmantown Group and stratigraphically equivalent units and their extensions under less than 1 km of cover. No estimate of undiscovered districts was made.

Rationale for Numerical Estimate

The team believes that although the tract is permissive for an undiscovered deposit, the probability of an undiscovered deposit is so small that we are unable to make a numerical estimate.

References

- Ayuso, R.A., Foley, N.K., and Brown, C.E., 1987, Source of lead and mineralizing brines for Rossie-type Pb-Zn veins in the Frontenac axis area, New York: *Economic Geology*, v. 82, no. 2, p. 489-496.
- Briskey, J.A., 1986, Descriptive model of Appalachian Zn, *in* Cox, D.P., and Singer, D.A., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 222.

CP01**Sediment-hosted Cu Deposits, Red-bed Type****Descriptive Model 30b.2 • Mark3 Index 97****Area = 36,300 km²****Utah
Arizona
Colorado
New Mexico**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* David A. Lindsey**Rationale for Model Choice**

Deposits in Upper Triassic rocks are generally associated with concentrations of organic plant remains (logs, leaves, etc.) in permeable sandstone. The host rock and mechanism of precipitation matches the red-bed model. The White Canyon deposit, Utah (530,000 metric tons at 0.75 percent Cu) occurs in the Shinarump Member of Chinle Formation (Finch, 1959). The world red-bed model is appropriate.

Rationale for Tract Delineation

The permissive tract includes the permeable sandstones in the lower part of the Upper Triassic Chinle Formation (including the Shinarump and Agua Zarca Sandstone Members).

Rationale for Numerical Estimate

For the 90th, 50th, 10th, 5th and 1st percentiles, respectively, the team estimated 0, 0, 1, 2, and 4 or more red-bed copper deposits of Triassic age, consistent with the grade and tonnage model. Our estimate focused primarily on the highly-explored (for uranium), near-surface rocks, and may not accurately reflect the presence of undiscovered deposits in deeper parts of the tract.

Reference

Finch, W.I., 1959, Geology of uranium deposits in Triassic rocks of the Colorado Plateau region: U.S. Geological Survey Bulletin 1074-D, p. 125-164.

CP02**Sediment-hosted Cu Deposits, Red-bed Type**

Descriptive Model 30b.2 • Mark3 Index 97

Area = 17,800 km²Utah
Arizona
New Mexico[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* David A. Lindsey**Rationale for Model Choice**

Deposits in this tract are small, lenticular bodies of reduced rock in permeable gray sandstone, siltstone, and shale. Most host rocks contain organic plant remains and some contain pyrite. The small mineralized bodies occur in reduced zones preserved in red beds. Anomalous concentrations of uranium are commonly present. These features match those of other red-bed-type copper deposits.

Rationale for Tract Delineation

Deposits and occurrences are in two areas in the Colorado Plateau. Permissive units include the Hermosa Group and Cutler Formation in Utah, and the Naco Formation in Arizona.

Important Examples of Deposit Type

A cluster of small mines and occurrences in the Naco Formation in Arizona and scattered occurrences in Utah are the only evidence of red-bed-type copper deposition.

Rationale for Numerical Estimate

Because production and reserves from the largest deposits in this age group in this region are much smaller than the median red-bed deposit tonnage, and because of the lack of known deposits in this tract, for the 90th, 50th, 10th, 5th, and 1st percentiles, we estimated 0, 0, 0, 1, and 3 or more deposits consistent with the grade and tonnage model. Our estimate focused primarily on the highly-explored (for uranium), near-surface rocks, and may not accurately reflect the presence of undiscovered deposits in deeper parts of the tract.

CP03**Sediment-hosted Cu Deposits, Red-bed Type**

Descriptive Model 30b.2 • Mark3 Index 97

Area = 937 km²Utah
Arizona
Colorado[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by David A. Lindsey

Rationale for Model Choice

Structurally-controlled deposits in sedimentary rocks are no different than other red-bed-type copper deposits in that their mechanism of metal transport (oxidizing chloride brines in equilibrium with hematite) and precipitation (reduction by sulfides or organic matter) is the same. However, the path of mineralizing fluids was determined at least in part by structures that cut across stratigraphic horizons, as well as by permeable beds. In addition to mineralized rock in a structure, mineralized beds and lenses (mantos) may extend into favorable formations adjacent to a structure.

Deposits in this tract span the general range of tonnages and grade for red-bed copper deposits. Thus, the world red-bed model is appropriate (Mark3 index 97).

Rationale for Tract Delineation

Structurally controlled red-bed deposits occur where faults and solution-collapse pipes allow basin fluids to ascend through reducing environments. Because existing geologic maps do not show all of the possible structures in which deposits could occur, the tract was delineated by the distribution of the sediment-hosted copper occurrences that appear to have structural control, and thus, may be too restrictive.

Important Examples of Deposit Type

The most important examples of fault-controlled red-bed copper deposits are found in Lisbon Valley, Utah (8.6 million metric tons at more than 1 percent Cu) (Morrison and Parry, 1986), and at White Mesa, Arizona (2.2 million metric tons at 1 percent Cu) (Mayo, 1956). Solution-collapse breccia pipes, some of which contain copper with uranium in the Grand Canyon region (e.g., Hack Canyon) (Wenrich, 1985), were excluded from consideration because they differ greatly in form from typical red-bed deposits and because they are primarily uranium deposits. Deposits at four districts in the Grand Canyon region have produced mainly copper and are probably controlled by faults and solution (Van Gosen and Wenrich, in press); these were included within the structurally-controlled tract.

Rationale for Numerical Estimate

Estimates are based on entirely on known areas of occurrence. Although the Lisbon Valley, White Mesa, and four Grand Canyon districts have been prospected extensively, the team considered at least one undiscovered copper deposit likely (90th percentile). For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 1, 3, 4, 4, and 5 or more deposits consistent with the grade and tonnage model.

References

Mayo, E.B., 1956, Copper, in Kiersch, G.A., ed., *Metalliferous minerals and mineral fuels—Geology, evaluation, and uses, and a section on the general geology*, v. 1 of *Mineral resources, Navajo-Hopi Indian Reservation, Arizona-Utah*: Tucson, Arizona University Press, p. 19-32.

- Morrison, S.J., and Parry, W.T., 1986, Formation of carbonate-sulfate veins associated with copper ore deposits from saline basin brines, Lisbon Valley, Utah: fluid inclusion and isotopic evidence: *Economic Geology*, v. 81, no. 8, p. 1853-1866.
- Van Gosen, B.S., and Wenrich, K.J., in press, Strata-bound copper deposits in the Kaibab Limestone, Coconino County, northern Arizona: U.S. Geological Survey Bulletin.
- Wenrich, K.J., 1985, Mineralization of breccia pipes in northern Arizona: *Economic Geology*, v. 80, no. 6, p. 1722-1735.

CR01**Skarn Cu Deposits (Laramide)****Colorado****Descriptive Model 18b • Mark3 Index 8****Area = 4,450 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Steve Ludington**Rationale for Model Choice**

In Colorado, many Laramide felsic to intermediate intrusive rocks are emplaced into carbonate rocks, the chief requirement for copper skarn formation.

Rationale for Tract Delineation

Skarn deposits may form where intermediate to felsic intrusive rocks, which are the principal sources of the metals, are emplaced into carbonate rocks, which, in Colorado, are principally of Paleozoic age. Therefore, the permissive tract for Laramide copper skarn deposits is that broad area where Laramide intrusive rocks are coincident with Paleozoic carbonate units, as defined by the State map (Tweto, 1979). This tract generally consists of the part of the northeast-trending Colorado mineral belt that contains carbonate rocks.

Important Examples of Deposit Type

There are no known deposits or prospects.

Rationale for Numerical Estimate

Perhaps due to relatively deep erosion and a small area of carbonate rock outcrop, mineralized skarns appear uncommon in Colorado, and there are no known deposits. Nevertheless, there are a few Laramide intrusions near carbonate rock outcrops, and, for the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, and 1 or more deposits consistent with the copper skarn model of Jones and Menzie (1986).

References

- Tweto, Ogden, 1979, Geologic map of Colorado: U.S. Geological Survey Map, scale 1:500,000.
- Jones, G.M., and Menzie, W.D., 1986, Grade and tonnage model of Cu skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 86-89.

CR02**Skarn Cu Deposits (Middle Tertiary)****Colorado****Descriptive Model 18b • Mark3 Index 8****Area = 7,490 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Steve Ludington**Rationale for Model Choice**

In Colorado, middle Tertiary felsic to intermediate intrusive rocks are emplaced into Paleozoic carbonate rocks. The model used here follows Einaudi and others (1981) and Cox and Singer (1986) that distinguish two type of copper skarns, those related to porphyry copper deposits and those not. Porphyry copper deposits are all but absent from Colorado, and we assess here for the latter model.

Rationale for Tract Delineation

Skarn deposits form where intermediate to felsic intrusive rocks, which are the principal sources of the metals, are emplaced into carbonate rocks, which, in Colorado, are principally of Paleozoic age. Therefore, the permissive tract for middle Tertiary copper skarn deposits is that broad area where middle Tertiary intrusive rocks are coincident with Paleozoic carbonate units, as defined by the State map (Tweto, 1979).

Important Examples of Deposit Type

No deposits or prospects of this type are known.

Rationale for Numerical Estimate

In Colorado, skarns are extremely uncommon, but middle Tertiary igneous rocks and Paleozoic carbonate rocks are widespread and coincident. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, and 1 or more deposits consistent with the copper skarn model of Jones and Menzie (1986).

References

- Cox, D.P., and Theodore, T.G., 1986, Descriptive model of Cu skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 86-89.
- Einaudi, M.T., Meinert, L.D., and Newberry, R.J., 1981, Skarn deposits, *in* Skinner, B.J., ed., Economic Geology Seventy-Fifth Anniversary Volume, 1905-1980: Lancaster, Pennsylvania, Economic Geology Publishing Company, p. 317-392.
- Jones, G.M., and Menzie, W.D., 1986, Grade and tonnage model of Cu skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 86-89.
- Tweto, Ogden, 1979, Geologic map of Colorado: U.S. Geological Survey Map, scale 1:500,000.

CR03**Skarn Cu Deposits****New Mexico****Descriptive Model 18b • Mark3 Index 8****Area = 81,100 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Steve Ludington

Rationale for Model Choice

In New Mexico, middle Tertiary felsic to intermediate intrusive rocks are emplaced into Paleozoic carbonate rocks. The model used here follows Einaudi and others (1981) and Cox and Singer (1986) that distinguish two type of copper skarns, those related to porphyry copper deposits and those not. Known examples of this deposit type are related to alkaline intrusions; this type of occurrence is accounted for by the assessment for alkaline porphyry Cu-Au deposits.

Rationale for Tract Delineation

In New Mexico, known copper skarn deposits formed where alkaline intrusive rocks, which are the principal sources of the metals, and are related to the alkaline porphyry copper-gold deposit type, are emplaced into carbonate rocks. But because such deposits may also form during calc-alkaline igneous activity, the permissive tract for copper skarn deposits in New Mexico is that area where carbonate rocks are present at or within a kilometer of the surface in the area of all middle Tertiary and younger igneous rocks. Areas of exposed carbonate rocks outside of the area of igneous activity were judged to have no potential for a copper skarn deposit because they are beyond the thermal and chemical influence of middle Tertiary and younger igneous systems.

Important Examples of Deposit Type

Gold-bearing copper skarn deposits in the Orogrande and New Placers (San Pedro) districts are associated with the middle Tertiary intrusive systems that may also host Cu-Au porphyry deposits or alkaline Au-Te deposits. No examples are known that are related to calc-alkaline intrusions.

Rationale for Numerical Estimate

In addition to the known deposits, we judged that more may exist based primarily on the wide extent of carbonate rocks. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, and 2 or more deposits consistent with the copper skarn model of Jones and Menzie (1986).

References

- Cox, D.P., and Theodore, T.G., 1986, Descriptive model of Cu skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 86-89.
- Einaudi, M.T., Meinert, L.D., and Newberry, R.J., 1981, Skarn deposits, *in* Skinner, B.J., ed., Economic Geology Seventy-Fifth Anniversary Volume, 1905-1980: Lancaster, Pennsylvania, Economic Geology Publishing Company, p. 317-392.
- Jones, G.M., and Menzie, W.D., 1986, Grade and tonnage model of Cu skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 86-89.

CR04**Skarn Cu Deposits****Texas****Descriptive Model 18b • Mark3 Index 8****Area = 36,900 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Alan R. Wallace**Rationale for Model Choice**

Tertiary felsic intrusive rocks were emplaced into Paleozoic carbonate rocks in western Texas, and the coincidence of the two rock types requires that this deposit type be considered. Einaudi and others (1981) distinguished two types of copper skarns, those related to porphyry copper deposits (Cox, 1986) and those related to barren intrusions (Cox and Theodore, 1986). Because porphyry copper deposits are uncommon in Texas, we used the grade and tonnage model of Jones and Menzie (1986).

Rationale for Tract Delineation

These deposits form where intermediate to felsic intrusive rocks, which are the principal sources of the metals, are emplaced into carbonate rocks. Therefore, the permissive tract for copper skarn deposits in western Texas is that area where carbonate rocks are present at or within a kilometer of the surface in areas where Tertiary felsic igneous rocks are also found. Skarn-type mineralization associated with alkaline intrusions is accounted for by the assessment for alkaline porphyry copper-gold deposits.

Important Examples of Deposit Type

No deposits of this type are known; there is a small prospect in the Infiernito caldera (Price and others, 1983).

Rationale for Numerical Estimate

Relatively few intrusive bodies are known in the carbonate terrane, and the chance for the existence of undiscovered copper skarn deposits was considered to be less than the possibility for porphyry copper deposits. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, and 1 or more deposits consistent with the grade and tonnage model for copper skarn deposits of Jones and Menzie (1986).

References

- Cox, D.P., 1986, Descriptive model of porphyry Cu, skarn-related deposits: Descriptive model of Cu skarn Deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 82-85.
- Cox, D.P., and Theodore, T.G., 1986, Descriptive model of Cu skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 86-89.
- Einaudi, M.T., Meinert, L.D., and Newberry, R.J., 1981, Skarn deposits, *in* Skinner, B.J., ed., Economic Geology Seventy-Fifth Anniversary Volume, 1905-1980: Lancaster, Pennsylvania, Economic Geology Publishing Company, p. 317-392.
- Jones, G.M., and Menzie, W.D., 1986, Grade and tonnage model for Cu skarns, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 86-89.
- Price, J.G., Henry, C.D., and Standen, A.R., 1983, Annotated bibliography of mineral deposits in Trans-Pecos Texas: Bureau of Economic Geology, Mineral Resource Circular, no. 73, 108 p.

CR05**Skarn Zn-Pb Deposits (Laramide)**

Colorado

Descriptive Model 18c • Mark3 Index 22

Area = 4,450 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Steve Ludington

Rationale for Model Choice

In Colorado, Laramide felsic to intermediate intrusive rocks are emplaced into Phanerozoic carbonate rocks, and, thus, provide a permissive environment for skarn Zn-Pb deposits. The descriptive model of Cox (1986) and the grade and tonnage model of Mosier (1986) were used for the assessment.

Rationale for Tract Delineation

Skarn deposits may form where intermediate to felsic intrusive rocks, which are the principal sources of the metals, are emplaced into carbonate rocks. Therefore, the permissive tract for Laramide zinc-lead skarn deposits is that area where Laramide intrusive rocks are emplaced into Paleozoic carbonate units. Laramide intrusions are found only in that part of the mountainous part of Colorado defined as the Colorado mineral belt (Tweto and Sims, 1963).

Important Examples of Deposit Type

No deposits or prospects of this deposit type are known.

Rationale for Numerical Estimate

Perhaps due to the relatively great depth of erosion and small area of carbonate rock outcrops, mineralized skarns appear to be uncommon in Colorado, and there are no known deposits. Nevertheless, there are a few Laramide intrusions near carbonate rock outcrops, and, for the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, and 1 or more deposits consistent with the zinc-lead skarn model of Mosier (1986).

References

- Cox, D.P., 1986, Descriptive model of Zn-Pb skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 90.
- Mosier, D.L., 1986, Grade and tonnage model of Zn-Pb deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 90-93.
- Tweto, Ogden, 1979, Geologic map of Colorado: U.S. Geological Survey Map, scale 1:500,000.
- Tweto, Ogden, and Sims, P.K., 1963, Precambrian ancestry of the Colorado mineral belt: Geological Society of America Bulletin, v. 74, p. 991-1014.

CR06**Skarn Zn-Pb Deposits (Middle Tertiary)**

Colorado

Descriptive Model 18c • Mark3 Index 22

Area = 7,490 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Steve Ludington

Rationale for Model Choice

In Colorado, middle Tertiary felsic to intermediate intrusive rocks are emplaced into Phanerozoic carbonate rocks, and, thus, provide a permissive environment for skarn Zn-Pb deposits. The descriptive model of Cox (1986) and the grade and tonnage model of Mosier (1986) were used for the assessment.

Rationale for Tract Delineation

Skarn deposits may form where intermediate to felsic intrusive rocks, which are the principal sources of the metals, are emplaced into carbonate rocks. Therefore, the permissive tract for middle Tertiary zinc-lead skarn deposits is that broad area where middle Tertiary intrusive rocks are emplaced into Paleozoic carbonate units. Middle Tertiary intrusions are found throughout the mountainous part of Colorado.

Important Examples of Deposit Type

No deposits or prospects of this deposit type are known, although polymetallic replacement deposits are relatively common, and skarn minerals have been described from the deep parts of polymetallic vein deposits in the western San Juan Mountains (Mayor and Fisher, 1972).

Rationale for Numerical Estimate

In Colorado, skarns are extremely uncommon; the team failed to identify any known deposits or prospects. Nevertheless, largely because middle Tertiary igneous rocks are widespread, there is some possibility for skarn deposits. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, and 1 or more deposits consistent with the grade and tonnage model of Mosier (1986).

References

- Cox, D.P., 1986, Descriptive model of Zn-Pb skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 90.
- Mayor, J.N., and Fisher, F.S., 1972, Middle Tertiary replacement ore bodies and associated veins in the northwest San Juan Mountains, Colorado: *Economic Geology*, v. 67, no. 2, p. 214–230.
- Mosier, D.L., 1986, Grade and tonnage model of Zn-Pb skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 90-93.

CR07**Skarn Zn-Pb Deposits****Texas****Descriptive Model 18c • Mark3 Index 22****Area = 36,900 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Alan R. Wallace**Rationale for Model Choice**

Zinc-lead skarn deposits form by the replacement of carbonate rocks by base-metal sulfides (especially sphalerite and galena) and silicate skarn assemblage minerals, in close proximity to felsic- to intermediate-composition intrusive bodies.

Rationale for Tract Delineation

These deposits form where intermediate to felsic intrusive rocks, which are the principal sources of the metals, are emplaced into carbonate rocks. Therefore, the permissive tract for zinc-lead skarn deposits in Texas is that area where carbonate rocks are present at or within a kilometer of the surface in the area of Tertiary felsic igneous rocks.

Important Examples of Deposit Type

No deposits or prospects of this type are known.

Rationale for Numerical Estimate

This is a very rare type of deposit worldwide. Relatively few intrusions are known in the Texas carbonate terrane, and they are given a low estimate for porphyry copper deposits, which are most commonly associated with copper skarn deposits. Thus, the chance for there being an undiscovered zinc-lead skarn deposit is considered to be even less. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, and 1 or more deposits consistent with the grade and tonnage model for zinc-lead skarn deposits (Mosier, 1986).

Reference

Mosier, D.L., 1986, Grade and tonnage model of Zn-Pb skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 90-93.

CR08**Porphyry Cu Deposits (Laramide)**

Colorado

Descriptive Model 17 • Mark3 Index 4

Area = 47,600 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Steve Ludington

Rationale for Model Choice

The Colorado mineral belt (Tweto and Sims, 1963) contains numerous Laramide calc-alkaline intrusive rocks. Some of these intrusive rocks have a halo of polymetallic vein deposits that might reflect a concealed porphyry copper deposit associated with the intrusive bodies. The two known prospects exhibit high Cu:Mo ratios, which distinguishes them from stockwork molybdenum deposits and suggests the possibility for porphyry Cu deposits.

Rationale for Tract Delineation

The general rule for delineating permissive areas for porphyry copper deposits of Laramide age is to exclude all areas that show no evidence for Laramide intrusive activity. In addition, areas where intrusions are overwhelmingly gabbroic or granitic, or strongly alkaline, are also excluded. Manifestation of intrusive activity may include exposed intrusive terranes, known polymetallic vein, skarn, and(or) replacement deposits, unexposed intrusions, inferred to exist by geophysical or other means, and any other inferred magmatic trends. Laramide-age calc-alkaline rocks were identified using maps by Mutschler and others (1988). Most Laramide-age intrusions in Colorado are found in the Colorado mineral belt.

Important Examples of Deposit Type

Colorado contains no known Laramide porphyry copper deposits. Two possible prospects were identified, The Blowout, in the San Juan Mountains near Ouray, and Blodgett Lake, west of Homestake Reservoir in the northern Sawatch Range.

Rationale for Numerical Estimate

Erosion exposes many of the intrusive systems in the Colorado mineral belt at a level below which porphyry copper deposits might have been emplaced; there are few known Laramide intrusions. The team judged, however, that it would be misleading to indicate that the presence of such deposits here is impossible. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, and 1 or more deposits consistent with the worldwide porphyry copper grade and tonnage model (Singer and others, 1986).

References

- Mutschler, R.E., Larson, E.E., and Bruce, R.M., 1988, Laramide and younger magmatism in Colorado — New petrologic and tectonic variations on old themes: *Colorado School of Mines Quarterly*, v. 82, p. 1-47.
- Singer, D.A., Mosier, D.L., and Cox, D.P., 1986, Grade and tonnage model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 77-81.
- Tweto, Ogden, and Sims, P.K., 1963, Precambrian ancestry of the Colorado mineral belt: *Geological Society of America Bulletin*, v. 74, p. 991-1014.

CR09**Porphyry Cu Deposits (Middle Tertiary)****Colorado****Descriptive Model 17 • Mark3 Index 4****Area = 84,400 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Steve Ludington**Rationale for Model Choice**

Colorado contains numerous prospects that meet many of the criteria for porphyry copper deposits, but there is uncertainty about how well the overall characteristics of any of the individual mineralized systems fit the descriptive model for porphyry copper deposits. Only one of the prospects, the A-O in northern Colorado, has been formally described in the literature as a porphyry copper deposit (Karimpour and Atkinson, 1983). Nevertheless, there are many prospects, and in addition, many intrusions have a halo of polymetallic vein deposits that might reflect a concealed porphyry copper deposit associated with the intrusive bodies.

Rationale for Tract Delineation

The general rule for delineating permissive areas for porphyry copper deposits of middle Tertiary and younger age is to exclude all areas that show no evidence for intrusive activity of this age. In addition, areas where intrusions are overwhelmingly gabbroic or granitic, or strongly alkaline, are also excluded. Manifestation of intrusive activity may include exposed intrusive terranes, known polymetallic vein, skarn, and(or) replacement deposits, unexposed intrusions, inferred to exist by geophysical or other means, and any other inferred magmatic trends. In Colorado, middle Tertiary intrusive rocks are widespread (Mutschler and others, 1988).

Important Examples of Deposit Type

No middle to late Tertiary porphyry copper deposits are known, but fifteen porphyry targets were identified in Colorado, although classification was not always certain. Some of the more prominent include: Timberline Lake, near Leadville, and Whitepine-Tomichi, east of Gunnison, which were partially explored in the 1970s; and Conundrum Creek and East Maroon Creek, southwest of Aspen.

Rationale for Numerical Estimate

We judged the area to be about 85 percent exposed and 15 percent covered. The assessment team evaluated the known Colorado prospects individually; then, considering the extent of exploration and the amount of covered area, the team extrapolated those judgments to the entire area. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 1, 2, and 8 or more deposits consistent with the worldwide porphyry copper grade and tonnage model (Singer and others, 1986).

References

- Karimpour, M.H., and Atkinson, W.W., Jr., 1983, Petrogenesis of the A.O. porphyry copper complex in Jackson and Grand Counties, northwestern Colorado: *Global Tectonics and Metallogeny*, v. 2, p. 15-27.
- Mutschler, R.E., Larson, E.E., and Bruce, R.M., 1988, Laramide and younger magmatism in Colorado — New petrologic and tectonic variations on old themes: *Golden, Colorado School of Mines Quarterly*, v. 82, p. 1-47.
- Singer, D.A., Mosier, D.L., and Cox, D.P., 1986, Grade and tonnage model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models: U.S. Geological Survey Bulletin 1693*, p. 77-81.

CR10**Porphyry Cu Deposits****New Mexico****Descriptive Model 17 • Mark3 Index 4****Area = 44,600 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Alan R. Wallace and Virginia McLemore**Rationale for Model Choice**

The characteristics of some known prospects meet many of the published criteria for porphyry copper deposits. Deposits often related to porphyry copper deposits, such as polymetallic replacement and vein deposits, are quite common in New Mexico. Middle Tertiary and younger deposits are assessed because Laramide intrusions, which generated many porphyry copper deposits in nearby Arizona and southwesternmost New Mexico, are not present in this area.

Rationale for Tract Delineation

The general rule for delineating permissive areas for porphyry copper deposits is to exclude all areas that show no evidence for intrusive activity during middle Tertiary time. In addition, areas where intrusions are overwhelmingly gabbroic or granitic, or strongly alkaline, are excluded. Manifestation of intrusive activity may include exposed intrusive terranes, known polymetallic vein, skarn, and (or) replacement deposits, unexposed intrusions, inferred to exist by geophysical or other means, and any other inferred magmatic trends. The permissive tract for deposits of this age is continuous from northernmost Colorado to the border with Mexico (exclusive of southwestern New Mexico), but the probability of occurrence is much lower throughout much of northern New Mexico.

Important Examples of Deposit Type

No deposits are known in the permissive tract, and no specific prospects were identified, other than those classified as porphyry copper-gold, which were assessed separately.

Rationale for Numerical Estimate

Much of the permissive area for deposits of this age in New Mexico has not been deeply eroded since the Miocene, and many deposits that might be present could be covered by surficial deposits. The area concealed by younger material is somewhat less than half the total. The known prospects have not been thoroughly explored, and the assessment team was hampered by a lack of reliable information. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, and 1 or more deposits consistent with the worldwide porphyry copper grade and tonnage model (Singer and others, 1986).

Reference

Singer, D.A., Mosier, D.L., and Cox, D.P., 1986, Grade and tonnage model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 77-81.

CR11**Porphyry Cu-Au Deposits (Laramide)**

Colorado

Descriptive Model 20c • Mark3 Index 34

Area = 9,690 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Steve Ludington**Rationale for Model Choice**

Singer and Cox (1986) presented a grade and tonnage model for porphyry copper-gold deposits, and Cox (1986) published an accompanying descriptive model that emphasized coeval volcanic rocks, an oxidized ore fluid, and the presence of magnetite in alteration assemblages. In a later paper (Cox and Singer, 1992), that further analyzes a subset of the deposits included in the grade and tonnage model, a relatively shallow depth of emplacement is postulated as the factor primarily responsible for geochemical differences between the gold-rich deposits and other porphyry copper deposits. Ratios among Cu, Mo, and Au remained the basis for classification.

Barr and others (1976) apparently originated the ideal that porphyry copper deposits associated with alkaline rocks are different. Their data suggest gold enrichment, but they took no note of it. Later, Mutschler and others (1985, 1991), speculated that porphyry copper deposits associated with alkaline rocks would be rich in precious metals, but presented few numerical data. They, like Cox and Singer (1992), also emphasized the role of an oxidized ore fluid. McMillan and Pantaleyev (1988) acknowledge alkaline as a subdivision of their volcanic type of porphyry copper deposit. Lowell (1989) states his opinion that gold content of porphyry copper deposits can be grouped according to their whole-rock geochemistry.

While Singer and Cox find both calc-alkaline and alkaline magma chemistries in their class of gold-rich porphyry copper deposits, all 6 of the deposits that they classified as alkaline, without exception, displayed high Au:Mo ratios. This observation leads us to believe that porphyry deposits associated with alkaline rocks can be appropriately represented by the grade and tonnage model published by Singer and Cox (1986). Grade and tonnage information in Schroeter and others (1989) seems to confirm that, whereas not all gold-rich porphyry copper deposits are alkaline, all alkaline porphyry copper deposits seem to be gold-rich. An important exception may be the Allard stock (Werle and others, 1984).

In southwestern Colorado, the alkaline Allard stock in the La Plata Mountains hosts an incompletely-explored precious metal- and platinum group-rich porphyry copper deposit (Werle and others, 1984). At the northeastern end of the Colorado mineral belt, a field of Laramide-age alkaline intrusions is associated with productive precious-metal deposits, but none of the deposits and prospects closely resemble porphyry copper deposits. We note in passing that the Canadian examples of alkaline porphyry copper deposits that are described in the literature formed in island arcs, and not on the continent, so some caution is exercised in application of this model to Colorado. There are several known porphyry copper prospects related to alkaline rocks in nearby New Mexico, but their gold grades are not known.

Rationale for Tract Delineation

Based upon the sufficient, but not necessary evidence of the occurrence of alkaline rocks, there are two permissive areas, both subsets of the Laramide general porphyry copper permissive tract. At the northeastern end of the Colorado mineral belt, Laramide-age alkaline intrusions

define an area permissive for the occurrence of porphyry copper-gold deposits, and in southwestern Colorado, the deposits in the La Plata Mountains suggest another. Together, they make up the permissive tract.

Important Examples of Deposit Type

The La Plata district in southwestern Colorado is the best example of an alkaline porphyry copper deposit; its gold content is not well known, though it does contain anomalous PGE.

Rationale for Numerical Estimate

The amount of covered area is roughly equal to that exposed. In general, the level of erosion is relatively deep, and possible porphyry copper-gold systems that may have been present have a high probability of having been eroded away, especially in the northeastern area. Exploration in the La Plata district has revealed a deposit that is similar in size and copper grade to others in the model. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 1, 1, and 2 or more deposits consistent with the porphyry copper-gold grade and tonnage model (Singer and Cox, 1986).

References

- Barr, D.A., Fox, P.E., Northcote, K.E., and Preto, V.A., 1976, The alkaline suite porphyry deposits—A summary: Special volume of the Canadian Institution for Mining and Metallurgy, v. 15, p. 359–367.
- Cox, D.P., 1986, Descriptive model of porphyry Cu-Au, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 110.
- Cox, D.P., and Singer, D.A., 1992, Gold—Distribution of gold in porphyry copper deposits, *in* DeYoung, J.H., Jr., and Hammarstrom, J.M., eds., Contributions to commodity geology research: U.S. Geological Survey Bulletin 1877, p. C1–C14.
- Lowell, J.D., 1989, Gold mineralization in porphyry copper deposits discussed: Mining Engineering, v. 41, no. 4, p. 227–231.
- McMillan, W.J., and Pantaleyev, A., 1988, Porphyry copper deposits, *in* Roberts, R.G., and Sheahan, P.A., eds., Ore deposit models: Reprint Series 3, Geoscience Canada, p. 45–58.
- Mutschler, F.E., Griffen, M.E., Stevens, D.S., and Shannon, S.S. Jr., 1985, Precious metal deposits related to alkaline rocks in the North American Cordillera; an interpretive review: Transactions of the Geological Society of South Africa, v. 88, p. 355–377.
- Mutschler, F.E., Mooney, T.C., and Johnson, D.C., 1991, Precious metal deposits related to alkaline igneous rocks—A space-time trip through the Cordillera: Mining Engineering, v. 43, no. 3, p. 304–309.
- Schroeter, T.G., Lund, C., and Carter, G., (1989), Gold production and reserves in British Columbia: B.C. Ministry of Energy, Mines and Petroleum Resources, Open File 1989–22, 86 p.
- Singer, D.A., and Cox, D.P., 1986, Grade and tonnage model of porphyry Cu-Au, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 110–114.
- Werle, J.L., Ikramuddin, M., and Mutschler, F.E., 1984, Allard stock, La Plata Mountains, Colorado—An alkaline rock-hosted porphyry copper-precious metal deposit: Canadian Journal of Earth Sciences, v. 21, p. 630–641.

CR12**Porphyry Cu-Au Deposits (Middle Tertiary)****Colorado****Descriptive Model 20c • Mark3 Index 34****Area = 12,900 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Steve Ludington**Rationale for Model Choice**

Singer and Cox (1986) presented a grade and tonnage model for porphyry copper-gold deposits, and Cox (1986) published an accompanying descriptive model that emphasized coeval volcanic rocks, an oxidized ore fluid, and the presence of magnetite in alteration assemblages. In a later paper (Cox and Singer, 1992) that further analyzes a subset of the deposits included in the grade and tonnage model, a relatively shallow depth of emplacement is postulated as the factor primarily responsible for geochemical differences between the gold-rich deposits and other porphyry copper deposits. Ratios among Cu, Mo, and Au remained the basis for classification.

Barr and others (1976) apparently originated the idea that porphyry copper deposits associated with alkaline rocks are different. Their data suggest gold enrichment, but they took no note of it. Later, Mutschler and others (1985, 1991) speculated that porphyry copper deposits associated with alkaline rocks would be rich in precious metals, but presented little numerical data. They, like Cox and Singer (1992), also emphasized the role of an oxidized ore fluid. McMillan and Pantaleyev (1988) acknowledge alkaline as a subdivision of their volcanic type of porphyry copper deposit. Lowell (1989) states his opinion that gold content of porphyry copper deposits can be grouped according to their whole-rock geochemistry.

While Singer and Cox find both calc-alkaline and alkaline magma chemistries in their class of gold-rich porphyry copper deposits, all 6 of the deposits that they classified as alkaline, without exception, displayed high Au:Mo ratios. This observation leads us to believe that porphyry deposits associated with alkaline rocks can be appropriately represented by the grade and tonnage model published by Singer and Cox (1986). Grade and tonnage information in Schroeter and others (1989) seems to confirm that, whereas not all gold-rich porphyry copper deposits are alkaline, all alkaline porphyry copper deposits seem to be gold-rich. An important exception may be the Laramide Allard stock, in southwestern Colorado (Werle and others, 1984).

A belt of alkaline rocks, which contains known porphyry Cu-Au deposits and prospects in New Mexico, extends north into Colorado. Although no porphyry copper deposits or prospects of this type and age are known in Colorado, the team judged it necessary to consider the potential for undiscovered deposits. We note in passing that the Canadian examples of alkaline porphyry copper deposits that are described in the literature formed in island arcs, and not on the continent, so some caution is exercised in application of this model to Colorado. There are several known porphyry copper prospects related to alkaline rocks in nearby New Mexico, but their gold grades are not known.

Rationale for Tract Delineation

The permissive tract is based on the sufficient, but not necessary evidence of a belt of middle Tertiary alkaline rocks in southern Colorado that encompasses the Cripple Creek and Rosita

Hills areas. The tract is contiguous with a belt of alkaline rocks in New Mexico that contains known porphyry Cu-Au deposits and prospects.

Important Examples of Deposit Type

No deposits or prospects of this deposit type are known.

Rationale for Numerical Estimate

Although gold-rich deposits are known in this tract, the team knew of little evidence for copper-rich deposits associated with alkaline rocks. Therefore, the estimate is based largely on the presence of alkaline igneous rocks similar to those in New Mexico that have associated copper-gold deposits. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, and 1 or more deposits consistent with the porphyry copper-gold grade and tonnage model (Singer and Cox, 1986).

References

- Barr, D.A., Fox, P.E., Northcote, K.E., and Preto, V.A., 1976, The alkaline suite porphyry deposits—A summary: Special volume of the Canadian Institution for Mining and Metallurgy, v. 15, p. 359–367.
- Cox, D.P., 1986, Descriptive model of porphyry Cu-Au, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 110.
- Cox, D.P., and Singer, D.A., 1992, Gold—Distribution of gold in porphyry copper deposits, *in* DeYoung, J.H., Jr., and Hammarstrom, J.M., eds., Contributions to commodity geology research: U.S. Geological Survey Bulletin 1877, p. C1–C14.
- Lowell, J.D., 1989, Gold mineralization in porphyry copper deposits discussed: Mining Engineering, v. 41, no. 4, p. 227–231.
- McMillan, W.J., and Pantaleyev, A., 1988, Porphyry copper deposits, *in* Roberts, R.G., and Sheahan, P.A., eds., Ore deposit models: Geoscience Canada Reprint Series 3, p. 45–58.
- Mutschler, F.E., Griffen, M.E., Stevens, D.S., and Shannon, S.S. Jr., 1985, Precious metal deposits related to alkaline rocks in the North American Cordillera; an interpretive review: Transactions of the Geological Society of South Africa, v. 88, p. 355–377.
- Mutschler, F.E., Mooney, T.C., and Johnson, D.C., 1991, Precious metal deposits related to alkaline igneous rocks—A space-time trip through the Cordillera: Mining Engineering, v. 43, no. 3, p. 304–309.
- Schroeter, T.G., Lund, C., and Carter, G., 1989, Gold production and reserves in British Columbia: B.C. Ministry of Energy, Mines and Petroleum Resources, Open File 1989–22, 86 p.
- Singer, D.A., and Cox, D.P., 1986, Grade and tonnage model of porphyry Cu-Au, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 110–114.
- Werle, J.L., Ikramuddin, M., and Mutschler, F.E., 1984, Allard stock, La Plata Mountains, Colorado — An alkaline rock-hosted porphyry copper-precious metal deposit: Canadian Journal of Earth Sciences, v. 21, p. 630–641.

CR13**Porphyry Cu-Au Deposits****New Mexico****Descriptive Model 20c • Mark3 Index 34****Area = 45,600 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Steve Ludington**Rationale for Model Choice**

In assessing this deposit type in New Mexico, we knew that the copper prospects about which we had information were somewhat different, especially in igneous rock chemistry, than those defined by the general porphyry copper model. Singer and Cox (1986) presented a grade and tonnage model for porphyry copper-gold deposits, and Cox (1986) published an accompanying descriptive model that emphasized coeval volcanic rocks, an oxidized ore fluid, and the presence of magnetite in alteration assemblages. In a later paper (Cox and Singer, 1992) that further analyzes a subset of the deposits included in the grade and tonnage model, a relatively shallow depth of emplacement is postulated as the factor primarily responsible for geochemical differences between the gold-rich deposits and other porphyry copper deposits. Ratios among Cu, Mo, and Au remained the basis for classification.

Barr and others (1976) apparently originated the idea that porphyry copper deposits associated with alkaline rocks are different. Their data suggest gold enrichment, but they took no note of it. Later, Mutschler and others (1985, 1991) speculated that porphyry copper deposits associated with alkaline rocks would be rich in precious metals, but presented little numerical data. They, like Cox and Singer (1992), also emphasized the role of an oxidized ore fluid. McMillan and Pantaleyev (1988) acknowledge alkaline as a subdivision of their volcanic type of porphyry copper deposit. Lowell (1989) states his opinion that gold content of porphyry copper deposits can be grouped according to their whole-rock geochemistry.

While Singer and Cox find both calc-alkaline and alkaline magma chemistries in their class of gold-rich porphyry copper deposits, all 6 of the deposits that they classified as alkaline, without exception, displayed high Au:Mo ratios. This observation leads us to believe that porphyry deposits associated with alkaline rocks can be appropriately represented by the grade and tonnage model published by Singer and Cox (1986). Grade and tonnage information in Schroeter and others (1989) seems to confirm that, whereas not all gold-rich porphyry copper deposits are alkaline, all alkaline porphyry copper deposits seem to be gold-rich. We note in passing that the Canadian examples of alkaline porphyry copper deposits that are described in the literature formed in island arcs, and not on the continent, so some caution is exercised in application of this model in New Mexico. There there are several known porphyry copper prospects related to alkaline rocks, but their gold grades are not known.

Rationale for Tract Delineation

The permissive area in New Mexico is based on the presence of an alkaline rock province that stretches north from Trans-Pecos Texas, through eastern New Mexico, and into southern Colorado. This tract contains numerous prospects that contain evidence for middle Tertiary alkaline copper-gold porphyry deposits.

Important Examples of Deposit Type

New Mexico has eighteen districts that bear characteristics of porphyry Cu-Au deposits. They are Folsom, Laughlin, Cimmaroncito, Elizabethtown-Baldy, Cerrillos, Old Placer, New Placer,

Gallinas, Tecolote, Jicarilla, White Oaks, Veracruz, Nogal, Schelerville, Capitan, Jarilla (Orogrande), Organ, and Cornudas. In southern New Mexico, in addition to the SOL prospect (Seager, 1981), evidence for middle Tertiary alkaline copper-gold porphyry deposits is present at the Vera Cruz mine and at the Mudpuppy-Waterdog prospect, both in the Nogal district (Ryberg, 1991; Fulp and Woodward, 1991). Gold- and copper-bearing skarns and disseminated copper, as well as potassic alteration in the Orogrande district, are indicative of possible porphyry copper deposits (Beane and others, 1975). Further north in New Mexico, the deposit described by Wargo (1964) at Cerrillos matches the models of both those who emphasize alkaline magma chemistry and those who emphasize shallow emplacement to explain gold-rich porphyry copper deposits.

Rationale for Numerical Estimate

Although there are no demonstrable known deposits, and the overall level of exploration is judged to be relatively low, considerable information about mineralized districts is available, including that several have been drilled with encouraging results, although details of the exploration have never been made public. The team evaluated eighteen districts individually, then extrapolated those judgments to the entire permissive area, allowing for the intensity of exploration and the amount of area covered by thin surficial deposits, which was judged to be about 20 percent. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 3, 5, 9, 15, and 20 or more deposits consistent with the porphyry copper-gold grade and tonnage model (Singer and Cox, 1986).

References

- Barr, D.A., Fox, P.E., Northcote, K.E., and Preto, V.A., 1976, The alkaline suite porphyry deposits—A summary: Special volume of the Canadian Institution for Mining and Metallurgy, v. 15, p. 359–367.
- Beane, R.E., Jaramillo C., L.E., and Bloom, M.S., 1975, Geology and base metal mineralization of the southern Jarilla Mountains, Otero County, New Mexico, *in* Seager, W.R., Clemons, R.E., and Callender, J.F., eds., Guidebook to the Las Cruces country: New Mexico Geological Society, Twenty-second Annual Field Conference, p. 151–156.
- Cox, D.P., 1986, Descriptive model of porphyry Cu-Au, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 110.
- Cox, D.P., and Singer, D.A., 1992, Gold—Distribution of gold in porphyry copper deposits, *in* DeYoung, J.H., Jr., and Hammarstrom, J.M., eds., Contributions to commodity geology research: U.S. Geological Survey Bulletin 1877, p. C1–C14.
- Fulp, M.S., and Woodward, L.A., 1991, The Mudpuppy-Waterdog prospect, an alkalic copper-gold porphyry system in the Nogal-Bonito mining district, Lincoln County, New Mexico, *in* Barker, J.M., Kues, B.S., Austin, G.S., and Lucas, S.G., eds., Geology of the Sierra Blanca, Sacramento and Capitan Ranges, New Mexico: Guidebook of the New Mexico Geological Society, Forty-second Annual Field Conference, October 9–12, 1991, p. 327–328.
- Lowell, J.D., 1989, Gold mineralization in porphyry copper deposits discussed: Mining Engineering, v. 41, no. 4, p. 227–231.
- McMillan, W.J., and Pantaleyev, A., 1988, Porphyry copper deposits, *in* Roberts, R.G., and Sheahan, P.A., eds., Ore deposit models: Geoscience Canada Reprint Series 3, p. 45–58.
- Mutschler, F.E., Griffen, M.E., Stevens, D.S., and Shannon, S.S., Jr., 1985, Precious metal deposits related to alkaline rocks in the North American Cordillera; an interpretive review: Transactions of the Geological Society of South Africa, v. 88, p. 355–377.
- Mutschler, F.E., Mooney, T.C., and Johnson, D.C., 1991, Precious metal deposits related to alkaline igneous rocks—A space-time trip through the Cordillera: Mining Engineering, v. 43, no. 3, p. 304–309.

- Ryberg, G.E., 1991, Geology of the Vera Cruz mine and breccia pipe, Lincoln County, New Mexico, *in* Barker, J.M., Kues, B.S., Austin, G.S., and Lucas, S.G., eds., Geology of the Sierra Blanca, Sacramento and Capitan Ranges, New Mexico: Guidebook of the New Mexico Geological Society, Forty-second Annual Field Conference, October 9-12, 1991, p. 329-332.
- Schroeter, T.G., Lund, C., and Carter, G., 1989, Gold production and reserves in British Columbia: B.C. Ministry of Energy, Mines and Petroleum Resources Open File Report 1989-22, 86 p.
- Seager, W.R., 1981, Geology of Organ Mountains and southern San Andres Mountains, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Memoir 36, 97 p.
- Singer, D.A., and Cox, D.P., 1986, Grade and tonnage model of porphyry Cu-Au, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 110-114.
- Wargo, J.G., 1964, Geology of a disseminated copper deposit near Cerrillos, New Mexico: Economic Geology, v. 59, no. 8, p. 1525-1538.

CR14**Porphyry Cu-Au Deposits****Texas****Descriptive Model 20c • Mark3 Index 34****Area = 25,400 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Steve Ludington**Rationale for Model Choice**

The petrochemical characteristics of the Trans-Pecos Texas volcanic field are similar to those of the contiguous belt of alkaline intrusions in New Mexico that contain porphyry copper-gold deposits and prospects.

Rationale for Tract Delineation

The permissive tract is delineated on the basis of the extent of the alkaline Trans-Pecos Texas volcanic field, using the criteria used for porphyry copper-gold deposits in New Mexico.

Important Examples of Deposit Type

Two prospects that resemble porphyry copper deposits are associated with the Oligocene West Chinati caldera (Price and others, 1983), and the group assigned them to the porphyry copper-gold model. Gold assays from the prospects are not available, but the setting is very similar to the SOL porphyry prospect in New Mexico which is associated with the Organ caldera (Seager, 1981), where the alkaline volcanic and intrusive rocks are also of Oligocene age.

Rationale for Numerical Estimate

The numerical estimate is based upon the presence of alkaline igneous rocks and two known prospects. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 1, and 2 or more deposits consistent with the porphyry copper-gold grade and tonnage model (Singer and Cox, 1986).

References

- Seager, W.R., 1981, Geology of Organ Mountains and southern San Andres Mountains, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Memoir 36, 97 p.
- Singer, D.A., and Cox, D.P., 1986, Grade and tonnage model of porphyry Cu-Au, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 110-114.
- Price, J.G., Henry, C.D., and Standen, A.R., 1983, Annotated bibliography of mineral deposits in Trans-Pecos Texas: Bureau of Economic Geology, Mineral Resource Circular, no. 73, 108 p.

CR15**Polymetallic replacement Deposits (Laramide)**

Colorado

Descriptive Model 19a • Mark3 Index 47

Area = 4,450 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* Steve Ludington**Rationale for Model Choice**

Polymetallic replacement deposits consist of hydrothermal, epigenetic, Ag, Pb, Zn, and Cu sulfide minerals in massive lenses, pipes, and veins in limestone, dolomite, or other reactive rocks near contacts with intrusions. Colorado contains some of the classic examples of polymetallic replacement deposits.

Rationale for Tract Delineation

Polymetallic replacement deposits form where intermediate to felsic intrusive rocks, which are the principal sources of the metals, are emplaced into or near carbonate rocks, which, in Colorado, are principally of Paleozoic age. The permissive tract for Laramide polymetallic replacement deposits is that broad area where Laramide intrusive rocks are coincident with Paleozoic carbonate units. Data were taken from the State map (Tweto, 1979) and from Mutschler and others (1988). This tract generally coincides with the northeast-trending Colorado mineral belt.

Important Examples of Deposit Type

Laramide polymetallic replacement deposits are relatively rare, perhaps due to the relatively great depth of erosion and small area of carbonate rock outcrops; many Laramide intrusions in Colorado are emplaced into Proterozoic basement. There is only one deposit, Aspen, which is a significant exception to the generalization, as it produced more than 3,000 metric tons of silver (Stegen and others, 1990). Other small mineralized areas exist at Fulford, Lenado, and La Plata.

Rationale for Numerical Estimate

The relative dearth of known deposits and prospects and the small area of permissive outcrops produced a relatively small assessment. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, and 1 or more districts consistent with the grade and tonnage model for polymetallic replacement deposits of Mosier, Morris, and Singer (1986).

References

- Mosier, D.L., Morris, H.T., and Singer, D.A., 1986, Grade and tonnage model of polymetallic replacement deposits, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 101-104.
- Mutschler, R.E., Larson, E.E., and Bruce, R.M., 1988, Laramide and younger magmatism in Colorado — New petrologic and tectonic variations on old themes: *Golden, Colorado School of Mines Quarterly*, v. 82, p. 1-47.
- Stegen, R.J., Beaty, D.W., and Thompson, T.B., 1990, The origin of the Ag-Pb-Zn-Ba deposits at Aspen, Colorado, based on geologic and geochemical studies of the Smuggler orebody, *in* Beaty, D.W., Landis, G.W., and Thompson, T.B., eds., *Carbonate-hosted sulfide deposits of the central Colorado mineral belt: Economic Geology Monograph 7*, p. 266-300.
- Tweto, Ogden, 1979, Geologic map of Colorado: U.S. Geological Survey Map, scale 1:500,000.

CR16 **Polymetallic replacement Deposits (Middle Tertiary)** **Colorado**
Descriptive Model 19a • Mark3 Index 47
Area = 7,490 km²

[Cumulative Distribution](#)

[Histogram](#)

[Table](#)

[Model](#)

[Mineral Deposits](#)

by Steve Ludington

Rationale for Model Choice

Polymetallic replacement deposits consist of hydrothermal, epigenetic, Ag, Pb, Zn, and Cu sulfide minerals in massive lenses, pipes, and veins in limestone, dolomite, or other reactive rocks near contacts with intrusions. Colorado contains some of the classic examples of polymetallic replacement deposits.

Rationale for Tract Delineation

Polymetallic replacement deposits form where intermediate to felsic intrusive rocks, which are the principal sources of the metals, are emplaced into or near carbonate rocks, which, in Colorado, are principally of Paleozoic age. The permissive tract for middle Tertiary polymetallic replacement deposits is that broad area where middle Tertiary intrusive rocks are coincident with Paleozoic carbonate units. Data were taken from the State map (Tweto, 1979), and from Mutschler and others (1988). The area assigned to the middle Tertiary (older than about 24 Ma) is the largest of the three polymetallic replacement tracts in Colorado.

Important Examples of Deposit Type

Some of the largest mineral deposits in Colorado are polymetallic replacement deposits that formed during middle Tertiary time. Included in this group are the world-class deposits at Leadville and Gilman (Beatty and others, 1990), somewhat smaller but nevertheless significant deposits in the Alma, Tenmile, Tarryall Creek, and the Monarch-Garfield districts, and numerous prospected areas that contain polymetallic replacement occurrences. Leadville has produced ore nearly continuously for more than 130 years, and significant resources surely remain. Several districts also contain related polymetallic vein deposits that were mined along with the replacement deposits.

Rationale for Numerical Estimate

Much of Colorado has been heavily prospected for more than 100 years, and the chances of there being numerous exposed undiscovered districts are judged to be negligible. The most favorable place to explore for further resources is near the known districts and prospects. However, we identified eight areas that could, with further exploration, become districts consistent with the grade and tonnage model for polymetallic replacement deposits of Mosier, Morris, and Singer (1986). In addition to individual evaluation of those eight areas, and consideration of covered areas, the team was guided by our belief that there is at least a 50 percent chance that there is at least one more undiscovered deposit in Colorado. The deposit at Gilman was cited as an example of locally fortuitous erosion that exposed an otherwise blind ore body. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 1, 2, 3, and 4 or more districts consistent with the grade and tonnage model for polymetallic replacement deposits of Mosier, Morris, and Singer (1986).

References

- Beaty, D.W., Landis, G.P., and Thompson, T.B., eds., 1990, Carbonate-hosted sulfide deposits of the central Colorado mineral belt: Economic Geology Monograph 7, 424 p.
- Mosier, D.L., Morris, H.T., and Singer, D.A., 1986, Grade and tonnage model of polymetallic replacement deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 101-104.
- Mutschler, R.E., Larson, E.E., and Bruce, R.M., 1988, Laramide and younger magmatism in Colorado — New petrologic and tectonic variations on old themes: Colorado School of Mines Quarterly, v. 82, p. 1-47.
- Tweto, Ogden, 1979, Geologic map of Colorado: U.S. Geological Survey Map, scale 1:500,000.

CR17 **Polymetallic replacement Deposits (Late Tertiary)** **Colorado**
Descriptive Model 19a • Mark3 Index 47
Area = 6,640 km²

[Cumulative Distribution](#)

[Histogram](#)

[Table](#)

[Model](#)

[Mineral Deposits](#)

by Steve Ludington

Rationale for Model Choice

Polymetallic replacement deposits consist of hydrothermal, epigenetic, Ag, Pb, Zn, and Cu sulfide minerals in massive lenses, pipes, and veins in limestone, dolomite, or other reactive rocks near contacts with intrusions. Colorado contains some of the classic examples of polymetallic replacement deposits.

Rationale for Tract Delineation

Polymetallic replacement deposits form where intermediate to felsic intrusive rocks, which are the principal sources of the metals, are emplaced into or near carbonate rocks, which, in Colorado, are principally of Paleozoic age. Whereas, the permissive tract for middle Tertiary polymetallic replacement deposits is a broad area where middle Tertiary intrusive rocks are coincident with Paleozoic carbonate units. The area delineated for the late Tertiary (younger than about 24 Ma) is more restricted, as igneous rocks this young generally do not occur to the east of the Rio Grande rift. Data were taken from the State map (Tweto, 1979) and from Mutschler and others (1988).

Important Examples of Deposit Type

No unequivocal late Tertiary replacement deposits are known, although replacement ores are present at Redwell Basin, related to the Mt. Emmons-Redwell Climax Mo system, and at least part of the significant Rico district may consist of replacement ores related to Pliocene magmatism.

Rationale for numerical estimate

The potential for late Tertiary polymetallic replacement deposits is related primarily to suspected replacement ores associated with and below the large polymetallic vein districts in the western San Juan Mountains, such as Telluride and Red Mountain-Sneffels (Fisher, 1990). In addition, replacement ores could be associated with late Tertiary Climax-type molybdenite deposits. The group evaluated seven target areas individually, and then gave consideration to covered areas. Although the absolute number of late Tertiary magmatic systems is fewer than those with middle Tertiary ages, they are less likely to be eroded deeply enough to have destroyed related replacement deposits. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 1, 2, and 4 or more districts consistent with the grade and tonnage model for polymetallic replacement deposits of Mosier, Morris, and Singer (1986).

References

- Fisher, F.S., 1990, Gold deposits in the Sneffels-Telluride and Camp Bird mining districts, San Juan Mountains, Colorado, *in* Shawe, D.R., and Ashley, R.P., eds., *Geology and resources of gold in the United States: U.S. Geological Survey Bulletin 1857*, Chap. F, p. F12-F18.
- Mosier, D.L., Morris, H.T., and Singer, D.A., 1986, Grade and tonnage model of polymetallic replacement deposits, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models: U.S. Geological Survey Bulletin 1693*, p. 101-104.

Mutschler, R.E., Larson, E.E., and Bruce, R.M., 1988, Laramide and younger magmatism in Colorado — New petrologic and tectonic variations on old themes: *Golden, Colorado School of Mines Quarterly*, v. 82, p. 1-47.

Tweto, Ogden, 1979, Geologic map of Colorado: U.S. Geological Survey Map, scale 1:500,000.

CR18**Polymetallic replacement Deposits****New Mexico****Descriptive Model 19a • Mark3 Index 47****Area = 81,100 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* Alan R. Wallace and Virginia McLemore**Rationale for Model Choice**

Polymetallic replacement deposits consist of hydrothermal, epigenetic, Ag, Pb, Zn, and Cu sulfide minerals in massive lenses, pipes, and veins in limestone, dolomite, or other reactive rocks near contacts with intrusive rocks. New Mexico contains some of the classic examples of polymetallic replacement deposits.

Rationale for Tract Delineation

These deposits form where intermediate to felsic intrusive rocks, which are the principal sources of the metals, are emplaced into or near carbonate rocks. Therefore, the permissive tract for polymetallic replacement deposits in New Mexico, exclusive of the southwestern part of the State, is that area where carbonate rocks are present at or within a kilometer of the surface and middle Tertiary and younger igneous rocks are also present. Areas of exposed carbonate rocks outside of the area of igneous activity were judged to have no potential for a polymetallic replacement deposit because they are beyond the thermal and chemical influence of middle Tertiary and younger igneous systems. Undiscovered districts postulated in this tract are only those associated with calc-alkaline intrusions. Areas characterized by alkaline rocks were assessed for alkaline Au-Te deposits, which may include some replacement ore.

Important Examples of Deposit Type

New Mexico hosts an impressive number of middle Tertiary polymetallic replacement deposits and prospects. Magdalena (Loughlin and Koschman, 1935) is a known polymetallic replacement deposit, and we identified 4 incompletely-explored areas (Hermosa, Organ, Chloride, Water Canyon) where rocks mineralized in this style are known, but where recorded production is unknown, incomplete, or small, and further exploration could lead to discovery of a significant district.

Rationale for Numerical Estimate

We believe that the known prospects are not fully explored, and further exploration could result in at least one of them advancing to the status of known districts consistent with the grade and tonnage model for polymetallic replacement deposits of Mosier, Morris, and Singer (1986). The team evaluated the four known prospects and arrived at an expected value of about 1.25 deposits consistent with the grade and tonnage model for polymetallic replacement deposits of Mosier, Morris, and Singer (1986). This estimate was then combined with consideration of a large covered area to arrive at the overall assessment. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 2, 4, 6, 8, and 11 or more districts consistent with the grade and tonnage model for polymetallic replacement deposits of Mosier, Morris, and Singer (1986).

References

Loughlin, G.F., and Koschman, A.H., 1935, Geology and ore deposits of the Magdalena mining district, New Mexico: U.S. Geological Survey Professional Paper 200, 168 p.

Mosier, D.L., Morris, H.T., and Singer, D.A., 1986, Grade and tonnage model of polymetallic replacement deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 101-104.

CR19**Polymetallic replacement Deposits****Texas****Descriptive Model 19a • Mark3 Index 47****Area = 36,900 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* Steve Ludington and Gregory T. Spanski**Rationale for Model Choice**

Polymetallic replacement deposits consist of hydrothermal, epigenetic, Ag, Pb, Zn, and Cu sulfide minerals in massive lenses, pipes, and veins in limestone, dolomite, or other reactive rocks near contacts with intrusions.

Rationale for Tract Delineation

These deposits form where intermediate to felsic intrusive rocks, which are the principal sources of the metals, are emplaced into or near carbonate rocks. Therefore, the permissive tract for polymetallic replacement deposits in Texas is that area where carbonate rocks are present at or within a kilometer of the surface in the area where middle Tertiary and younger igneous rocks are also found. Undiscovered districts postulated in this tract are only those associated with calc-alkaline intrusions. Areas characterized by alkaline rocks were assessed for alkaline Au-Te deposits, which may include some replacement ore.

Important Examples of Deposit Type

The Shafter district was an important polymetallic replacement deposit in the past, and other areas (Altuda, Loma Plata) seem to conform to the descriptive model (Price and others, 1983). Very important polymetallic replacement deposits are found just to the west of trans-Pecos Texas in the Sierra Madre Oriental of Mexico, at Santa Eulalia (Megaw, 1990) and Naica (Querol and Vallejo, 1990).

Rationale for Numerical Estimate

The team judged that, even though the known occurrences are not impressive, the permissive area is large and the level of exploration probably has not been very intense. The Mexican deposits appear to be related to calc-alkaline intrusions, whereas trans-Pecos Texas east of this tract features primarily alkaline magmatic systems. For the 90th, 50th, and 10th percentiles, the team estimated 0, 1, and 2 or more deposits consistent with the grade and tonnage model for polymetallic replacement deposits of Mosier, Morris, and Singer (1986).

References

- Megaw, P.K.M., 1990, Mineralization in the Santa Eulalia mining district, Chihuahua, Mexico, *in* Clark, K.F., ed., Mexican silver deposits: Society of Economic Geologists Guidebook Series, v. 6, p. 27-39.
- Mosier, D.L., Morris, H.T., and Singer, D.A., 1986, Grade and tonnage model of polymetallic replacement deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 101-104.
- Querol, F., and Vallejo, A., 1990, Geology and genesis of Naica ore deposits, Chihuahua, *in* Clark, K.F., ed., Mexican silver deposits: Society of Economic Geologists, Guidebook series, v. 6, p. 47-58.
- Price, J.G., Henry, C.D., and Standen, A.R., 1983, Annotated bibliography of mineral deposits in Trans-Pecos Texas: Bureau of Economic Geology, Mineral Resource Circular, no. 73, 108 p.

CR20**Alkaline Au-Te Deposits (Laramide)****Colorado****Descriptive Model 22b • Mark3 Index 80****Area = 9,690 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* Steve Ludington**Rationale for Model Choice**

The alkaline Au-Te model (Cox and Bagby, 1986; Bliss and others, 1992) was chosen because of the presence of Laramide alkaline igneous rocks with associated Au-Ag-Te vein deposits. The model is roughly comparable to the deposits termed “alkaline rock-related, gold-only epithermal systems” by Mutschler and Mooney (1994), although we note that many of these deposits are not epithermal using classic definitions. Deposits of Laramide age are distinguished from middle Tertiary deposits of this type. By the term “Laramide”, we include deposits as young as 45 Ma.

Rationale for Tract Delineation

Some of the well-studied examples (Cripple Creek and Boulder County, Colorado and Vatukoula, Fiji) are characterized by great abundance of precious-metal tellurides and the presence of vanadium-bearing mica (roscoelite) in the alteration assemblage. These features are sufficient to characterize deposits, but, because they are easily destroyed by oxidation, and often not noted or overlooked when mining is by bulk methods, they were not useful in tract delineation.

The assessment team decided that the most useful general rule for delineating permissive areas for alkaline Au-Te deposits is the same as that developed for porphyry copper-gold deposits in the southern Rocky Mountains; areas that are the site of Laramide alkaline igneous activity, evidenced by mesozonal and epizonal intrusions and minor volcanic rocks, are permissive for the occurrence of Laramide alkaline Au-Te deposits. Alkaline rocks of Laramide age evidence permissive areas at the northeastern and southwestern ends of the Colorado mineral belt.

Important Examples of Deposit Type

The northeastern area is the site of many important districts that produced large amounts of gold from veins related to Laramide-age alkaline intrusions. The most important of these are Gold Hill-Sugarloaf, Jamestown, Magnolia, and Ward, all in Boulder County (Saunders, 1991), and part of Central City (Wallace, 1989), in Clear Creek County. To the southwest, precious-metal deposits in the La Plata Mountains are closely associated with a Laramide alkaline igneous complex (Werle and others, 1984).

Rationale for Numerical Estimate

The permissive area is relatively deeply eroded, well exposed, and well explored, and the team thought it unlikely that there are any undiscovered deposits, although important amounts of metal remain to be discovered in known districts. However, the presence of Laramide alkaline igneous rocks and related deposits and prospects makes the area permissive. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, and 1 or more districts consistent with the grade and tonnage model of Bliss and others (1992).

References

- Bliss, J.D., Sutphin, D.M., Mosier, D.L., and Allen, M.S., 1992, Grade-tonnage and target-area models of Au-Ag-Te veins associated with alkaline rocks: U.S. Geological Survey Open-File Report 92-208, 15 p.
- Cox, D.C., and Bagby, W.C., 1986, Descriptive model of Au-Ag-Te veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 124.
- Mutschler, F.E., and Mooney, T.C., in press, Precious metal deposits related to alkaline igneous rocks—Provisional classification, grade-tonnage data, and exploration frontiers: IAGOD symposium.
- Saunders, J.A., 1991, Gold deposits of the Boulder County gold district, Colorado: U.S. Geological Survey Bulletin 1857-H, p. 37-48.
- Wallace, A.R., 1989, Gold in the Central City mining district, Colorado, *in* Shawe, D.R., Ashley, R.P., and Carter, L.M.H., eds., Geology and resources of gold in the United States: U.S. Geological Survey Bulletin 1857-C, p. C38-C47.
- Werle, J.L., Ikramuddin, M., and Mutschler, F.E., 1984, Allard stock, La Plata Mountains, Colorado — An alkaline rock-hosted porphyry copper-precious metal deposit: Canadian Journal of Earth Sciences, v. 21, p. 630-641.

CR21**Alkaline Au-Te Deposits (Middle Tertiary)****Colorado****Descriptive Model 22B • Mark3 Index 80****Area = 12,900 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* Steve Ludington**Rationale for Model Choice**

The alkaline Au-Te model was chosen because of the presence of middle Tertiary alkaline igneous rocks with associated Au-Ag-(Te) vein deposits. The model is roughly comparable to the deposits termed “alkaline rock-related, gold-only epithermal systems” by Mutschler and Mooney (1994), although we note that many of these deposits are not epithermal using classic definitions. The descriptive model of Cox and Bagby (1986) and the grade-tonnage and target area model of Bliss and others (1992) were deemed to be the most appropriate models available for this class of deposits.

Rationale for Tract Delineation

Some of the well-studied examples (Cripple Creek and Boulder County, Colorado and Vatukoula, Fiji) are characterized by great abundance of precious-metal tellurides and the presence of vanadium-bearing mica (roscoelite) in the alteration assemblage. These features are sufficient to characterize deposits, but, because they are easily destroyed by oxidation and often not noted or overlooked when mining is by bulk methods, they were not useful in tract delineation.

The assessment team decided that the most useful general rule for delineating permissive areas for alkaline Au-Te deposits is the same as that developed for porphyry copper-gold deposits in the southern and central Rocky Mountains; areas that are the site of middle Tertiary alkaline igneous activity, evidenced by mesozonal and epizonal intrusions and minor volcanic rocks, are permissive for the occurrence of alkaline Au-Te deposits. The tract also contains large areas that might conceal alkaline intrusive rocks, but that do not display any direct evidence of concealed alkaline centers. Alkaline rocks of this age are part of a sinuous north-trending belt that extends from the Big Bend area of Texas into central Colorado, in the easternmost part of the Rocky Mountains, along the margin of the Great Plains.

Important Examples of Deposit Type

The permissive area includes the giant Cripple Creek deposit, hosted in Oligocene mafic alkaline volcanic and intrusive rocks, that is a continuing exploration target where reserves continue to be discovered (Thompson and others, 1985). Other alkaline centers, like those in the Rosita Hills and at Spanish Peaks, have associated precious metal prospects and deposits, but have been poorly explored.

Rationale for Numerical Estimate

Although the exposed alkaline rocks are not extensive, the general lack of exploration in some of them increases the possibility of finding an undiscovered deposit. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 1, and 2 or more districts consistent with the grade and tonnage model of Bliss and others (1992) (Mark3 index 80).

In addition, three small mineralized areas in the San Juan Mountains — Beartown, Cave Basin, and early mineralization at Lake City — are reported to contain telluride minerals (Van Loenen

and others, in press). The team judged that there was too little information about the associated igneous rocks and tectonic setting to delineate a permissive area or make an estimate of numbers of deposits.

References

- Bliss, J.D., Sutphin, D.M., Mosier, D.L., and Allen, M.S., 1992, Grade-tonnage and target-area models of Au-Ag-Te veins associated with alkalic rocks: U.S. Geological Survey Open-File Report 92-208, 15 p.
- Cox, D.P., and Bagby, W.C., 1986, Descriptive model of Au-Ag-Te veins *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 124.
- Van Loenen, R.E., Nash, J.T., Foley, N. K., and Gibbons, A.B., in press, Locatable mineral resources, *in* Van Loenen, R.E. and Gibbons, A.B., eds., Mineral resource potential and geology of the San Juan National Forest, Colorado: U.S. Geological Survey Bulletin, p. ?.
- Mutschler, F.E., and Mooney, T.C., in press, Precious metal deposits related to alkaline igneous rocks—provisional classification, grade-tonnage data, and exploration frontiers: IAGOD symposium.
- Thompson, T.B., Trippel, A.D., and Dwelley, P.C., 1985, Mineralized veins and breccias of the Cripple Creek district, Colorado: *Economic Geology*, v. 80, no.6, p. 1669-1688.

CR22**Alkaline Au-Te Deposits****New Mexico****Descriptive Model 22B • Mark3 Index 80****Texas****Area = 70,900 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* Alan R. Wallace, Virginia McLemore, and Steve Ludington**Rationale for Model Choice**

The alkaline Au-Te model was chosen because of the presence of middle Tertiary alkaline igneous rocks with associated Au-Ag-(Te) vein deposits. The descriptive model of Cox and Bagby (1986) and the grade-tonnage and target area model of Bliss and others (1992) were deemed to be the most appropriate models available for this class of deposits. The model is roughly comparable to the deposits termed “alkaline rock-related, gold-only epithermal systems” by Mutschler and Mooney (1994), although we note that many of these deposits are not epithermal using classic definitions. These deposits are also described by McLemore (1991).

Rationale for Tract Delineation

Some of the well-studied examples (Cripple Creek and Boulder County, Colorado and Vatukoula, Fiji) are characterized by great abundance of precious-metal tellurides and the presence of vanadium-bearing mica (roscoelite) in the alteration assemblage. These features are sufficient to characterize deposits, but, because they are easily destroyed by oxidation and often not noted or overlooked when mining is by bulk methods, they were not useful in tract delineation.

The assessment team decided that the most useful general rule for delineating permissive areas for alkaline Au-Te deposits is the same as that developed for porphyry copper-gold deposits in the southern and central Rocky Mountains; areas that are the site of middle Tertiary alkaline igneous activity, evidenced by mesozonal and epizonal intrusions and minor volcanic rocks, are permissive for the occurrence of alkaline Au-Te deposits. Alkaline rocks of this age are part of a sinuous north-trending belt that extends from the Big Bend area of Texas into central Colorado, in the easternmost part of the Rocky Mountains, along the margin of the Great Plains. The tract includes large areas between known alkaline igneous centers that show no direct evidence of concealed intrusions. If these areas were excluded from the tract, the apparent density of undiscovered deposits would be substantially higher.

Important Examples of Deposit Type

There are at least 5 known deposits: Ortiz (Maynard and others, 1990), Carache Canyon, Lukas Canyon, White Oaks, and the Nogal district (Fulp and Woodward, 1991), which had formerly been called Creede-type epithermal (Mosier, Sato, and Singer, 1986; Mosier and others, 1986). In total, there are eighteen areas that bear characteristics of alkaline gold deposits. They are Folsom, Laughlin, Cimarroncito, Elizabethtown-Baldy, Cerrillos, Old Placer, New Placer, Gallinas, Tecolote, Jicarilla, White Oaks, Veracruz, Nogal, Schelerville, Capitan, Jarilla (Orogrande), Organ, and Cornudas.

Rationale for Numerical Estimate

The team evaluated eighteen alkaline igneous centers in New Mexico individually, and then extrapolated those judgments to the entire permissive area, allowing for the intensity of exploration and the amount of area covered by thin surficial deposits. A relatively small amount of erosion has left many areas in this tract as attractive targets. For the 90th, 50th,

10th, 5th, and 1st percentiles, the team estimated 2, 5, 8, 12, and 20 or more districts consistent with the grade and tonnage model of Bliss and others (1992).

References

- Bliss, J.D., Sutphin, D.M., Mosier, D.L., and Allen, M.S., 1992, Grade-tonnage and target-area models of Au-Ag-Te veins associated with alkaline rocks: U.S. Geological Survey Open-File Report 92-208, 15 p.
- Fulp, M.S., and Woodward, L.A., 1991, The Mudpuppy-Waterdog prospect, an alkalic copper-gold porphyry system in the Nogal-Bonito mining district, Lincoln County, New Mexico, *in* Barker, J.M., Kues, B.S., Austin, G.S., and Lucas, S.G., eds., *Geology of the Sierra Blanca, Sacramento and Capitan Ranges, New Mexico: Guidebook of the New Mexico Geological Society, Forty-second Annual Field Conference*, October 9–12, 1991, p. 327–328.
- McLemore, V.T., 1991, Base- and precious-metal deposits in Lincoln and Otero counties, New Mexico, *in* Barker, J.M., Kues, B.S., Austin, G.S., and Lucas, S.G., eds., *Geology of the Sierra Blanca, Sacramento and Capitan Ranges, New Mexico: Guidebook of the New Mexico Geological Society, Forty-second Annual Field Conference*, October 9–12, 1991, p. 305–309.
- Maynard, S.R., Nelson, C.J., Martin, K.W., and Schultz, J.L., 1990, Geology and gold mineralization of the Ortiz Mountains, Santa Fe County, New Mexico: *Mining Engineering*, v. 42, no. 8, p. 1007-1011.
- Mosier, D.L., Singer, D.A., Sato, T., and Page N.J., 1986, Relationship of grade, tonnage, and basement lithology in volcanic-hosted epithermal precious- and base-metal quartz-adularia-type districts: *Mining Geology*, v. 36, p. 245-264.
- Mosier, D.L., Sato, T., and Singer, D.A., 1986, Grade and tonnage model of Creede epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models: U.S. Geological Survey Bulletin 1693*, p. 146–149.
- Mutschler, F.E., and Mooney, T.C., in press, Precious metal deposits related to alkaline igneous rocks—provisional classification, grade-tonnage data, and exploration frontiers: IAGOD symposium.

CR23**Massive Sulfide Deposits, Besshi Type****Wyoming
Colorado****Descriptive Model 24b • Mark3 Index 30****Area = 2,220 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Warren Day**Rationale for Model Choice**

In southernmost Wyoming and northern Colorado, the Proterozoic rocks exposed in the Medicine Bow, Park, and Sierra Madre Mountains contain several small massive sulfide deposits and occurrences that have characteristics similar to Besshi-type massive sulfide deposits. The descriptive model of Cox (1986) and the grade and tonnage model of Singer (1986), based on examples from Japan, were selected and used for assessment.

Rationale for Tract Delineation

Besshi-type volcanic-hosted massive sulfide deposits produce copper and zinc, with gold and silver as common byproducts. These deposits form thin, sheetlike stratiform bodies of massive to well-laminated pyrite, pyrrhotite, and chalcopyrite with interlayers of clastic sedimentary rocks and mafic tuffs and flows (Cox, 1986). The genesis of this deposit type is uncertain due to the amount of regional deformation and metamorphism of the deposits in the type locality in Japan. However, the general exploration criteria for these deposits include: (1) clastic terrigenous marine sedimentary rocks and mafic volcanic tuffs and breccia host rocks; (2), locally are associated with black shale, oxide-facies iron formation and red chert; (3) and, form from submarine hot springs related to basaltic magmatism in rifted basins in island-arc or back-arc tectonic settings.

Klipfel (1992) suggested that the massive sulfide deposits of the Encampment district of the Sierra Madre Mountains, which extends into northern Colorado, are of Besshi type. In the western part of this district, Cu ± Zn Besshi-type deposits form in dominantly mafic volcanic host rock terrane, whereas in the eastern part, Pb - Zn ± Ag deposits occur in metamorphosed metasedimentary rocks and may be more like sedimentary exhalative deposits (Klipfel, 1992). Several of the ore deposits and occurrences are locally associated with iron-formation, ferruginous chert, and volcanic rocks, indicating synvolcanic hot-spring activity conducive for formation of Besshi-type massive sulfide deposits.

Important Examples of Deposit Type

Several small massive sulfide deposits are exposed and have been exploited in the Encampment district of the Sierra Madre Mountains and in the Centennial Ridge area of the Medicine Bow Mountains.

Rationale for Numerical Estimate

The assessment team estimated that the package of rocks in the Encampment district has the highest potential for hosting an undiscovered Besshi-type massive sulfide deposit. We estimated that there is a 1 percent chance of the presence of an undiscovered Besshi-type massive sulfide deposit in the Encampment district in the Sierra Madre Mountains. In the Medicine Bow Mountains, which are adjacent to this area to the east, there are two areas that may host similar types of deposits. In the Centennial Ridge area, smaller massive sulfide deposits and occurrences in rocks of similar age and grossly similar tectonic setting. Therefore, we judged that there was a lesser chance for the presence of a deposit in this area.

For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, and 1 or more deposits consistent with the grade and tonnage model of Singer (1986).

References

- Cox, D.P., 1986, Descriptive model of Besshi massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 136.
- Klipfel, P.D., 1992, Geology and metallogeny of the southern portion of the Encampment district, Colorado and Wyoming: Golden, Colorado School of Mines, Unpublished Ph.D. dissertation, 244 p.
- Singer, D.A., 1986, Grade and tonnage model of Besshi massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 136-138.

CR24**Massive Sulfide Deposits, Kuroko Type**Wyoming
Colorado

Descriptive Model 28a • Mark3 Index 93

Area = 11,700 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Alan R. Wallace

Rationale for Model Choice

Small mines and prospects of this type occur in Early Proterozoic bimodal metavolcanic rocks in an east-trending belt in south-central Colorado, in northern Colorado and southern Wyoming, and in several small areas in the Front Range. Although these deposits have been studied to some degree, many of the descriptions are inadequate to permit a definitive assignment to a particular model. The association with metavolcanic rocks, coupled with descriptions of the Sedalia deposit near Salida (Sheridan and Raymond, 1984), indicate that it is most likely a kuroko-type deposit, and are the key criteria for choosing this model. The criteria used for this assessment followed those outlined by Eckstrand (1984) and Singer (1986) for regional evaluations of Precambrian terranes similar to those of Colorado and southern Wyoming.

Rationale for Tract Delineation

The assessment criteria include: (1) submarine volcanic host rocks of felsic composition; (2) an island-arc tectonic setting, with local extensional deformation at the time of mineralization; and, (3) exhalative horizons within the supracrustal sequence associated with the volcanic rocks (for example, iron-formations or cherty horizons) that indicate the evidence for submarine hydrothermal hot-spring activity during volcanism. The Early Proterozoic basement of Colorado and southern Wyoming is composed of metasedimentary and bimodal metavolcanic rocks that formed in a complex back-arc setting south of a suture zone with the Archean Wyoming Province near the Colorado-Wyoming border (Reed and others, 1987). The kuroko-type massive sulfide deposits in Colorado and southern Wyoming are associated with the Early Proterozoic bimodal metavolcanic rocks. These largely are exposed in (1) an east-west elongate belt in the south-central part of the State, (2) an area along the Wyoming-Colorado border in the Park Range and Sierra Madre Mountains, and (3) several small tracts in the central Front Range (Lovering and Goddard, 1950). Those in Colorado are all within unit Xfh (felsic and hornblende gneisses) on the State map of Colorado (Tweto, 1979). The overall proportion of volcanic rocks in these areas is small, although they may be dominant locally. These rocks are predominantly mafic flows with associated felsic intrusive rocks and tuffs (Sheridan and others, 1990), typical of bimodal volcanic rocks associated with kuroko-type massive sulfide deposits. The massive sulfide deposits associated with metavolcanic rocks in southern Wyoming were classified by Klipfel (1992) as Besshi-type and sedimentary exhalative massive sulfide deposits, but the area is nevertheless permissive for kuroko massive sulfide deposits.

Important Examples of Deposit Type

The east-trending belt in south-central Colorado contains scattered small prospects and mines, including the Sedalia deposit near Salida from which nearly 100,000 metric tons of Cu-Zn ore was produced (Sheridan and others, 1990). Very minor amounts of ore came from the Front Range deposits. Lovering and Goddard (1950) and Sheridan and others (1990) describe small sulfide deposits and occurrences in Proterozoic metamorphic rocks of a variety of compositions, but the descriptions are inadequate to confidently assign deposits to specific models. Production from those deposits either was trivial or not reported. The Encampment

district in the Sierra Madre Mountains of southern Wyoming has produced nearly 1,000 metric tons of copper, with some zinc, lead, silver, and gold, from deposits in a metamorphosed sequence of Proterozoic volcanic and sedimentary rocks (Hausel, 1989), although how much of this came from kuroko, as opposed to Besshi, deposits is unknown.

Rationale for Numerical Estimate

The permissive tract has a few small deposits, including that at the Sedalia mine near Salida. However, the rest of the occurrences are very small, and production of zinc, lead, copper, silver, and gold at the Sedalia deposit, the largest in Colorado, was less than for the smallest deposit on the grade-tonnage curves for kuroko-type deposits (Sheridan and others, 1990; Singer and Mosier, 1986). The area thought to have highest probability was the Encampment district in Wyoming, with an estimated 25 percent chance of hosting such a deposit. All of the assessed areas have received scrutiny by industry and USGS mappers, so the geology is fairly well known. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 4, and 5 or more deposits consistent with the grade and tonnage model of Singer and Mosier (1986).

References

- Eckstrand, O.R., Canadian mineral deposit types—A geological synopsis: Geological Survey of Canada Economic Geology Report 36, 86 p.
- Hausel, W.D., 1989, The geology of Wyoming's precious metal lode and placer deposits: Geological Survey of Wyoming Bulletin 68, 248 p.
- Lovering, T.S., and Goddard, E.N., 1950, Geology and ore deposits of the Front Range, Colorado: U.S. Geological Survey Professional Paper 223, 319 p.
- Reed, J.C., Jr., Bickford, M.E., Premo, W.R., Aleinikoff, J.N., and Pallister, J.S., 1987, Evolution of the Early Proterozoic Colorado province—Constraints from U-Pb geochronology: *Geology*, v. 15, p. 861-865.
- Sheridan, D.M., and Raymond, W.H., 1984, Precambrian deposits of zinc-copper-lead sulfides and zinc spinel (gahnite) in Colorado: U.S. Geological Survey Bulletin 1550, 31 p.
- Sheridan, D.M., Raymond, W.H., Taylor, R.B., and Hasler, J.W., 1990, Metallogenic map of stratabound exhalative and related occurrences in Colorado: U.S. Geological Survey Miscellaneous Investigations Series Map I-1971, scale 1:1,000,000.
- Singer, D.A., 1986, Descriptive model of kuroko massive sulfide deposits, *in* Cox and Singer, eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 189-190.
- Singer, D.A., and Mosier, D.L., 1986, Grade and tonnage model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 190-197.
- Tweto, Ogden, 1979, Geologic map of Colorado: U.S. Geological Survey Map, scale 1:500,000.

CR25**Massive Sulfide Deposits, Kuroko Type****New Mexico****Descriptive Model 28a • Mark3 Index 93****Texas****Area = 10,800 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* Miles Silberman**Rationale for Model Choice**

Metamorphosed Proterozoic volcanic rocks, especially felsic volcanic rocks in greenstone terranes show an association of stratabound polymetallic massive sulfide deposits.

Rationale for Tract Delineation

The assessment criteria include: (1) submarine volcanic host rocks of felsic composition; (2) an island-arc tectonic setting, with local extensional deformation at the time of mineralization; and, (3) exhalative horizons within the supracrustal sequence associated with the volcanic rocks (for example, iron-formations or cherty horizons) that indicate the evidence for submarine hydrothermal hot-spring activity during volcanism. Mafic-dominant greenstone belts make up a significant part of Proterozoic terranes in New Mexico. These greenstones consist of metamorphosed submarine basalts and locally important felsic rocks which are the host rocks for volcanic massive sulfide deposits (Silberman, 1994). Robertson and others (1986) indicate where felsic- and mafic-dominant greenstone belts occur within the Precambrian outcrop areas of New Mexico, thus defining the permissive tract for kuroko massive sulfide deposits.

Important Examples of Deposit Type

Significant production has come only from the Pecos deposit, a kuroko-type massive sulfide deposit hosted in metarhyolite in the Pecos greenstone belt (Silberman, 1994). Significant reserves have been drilled out at one other deposit, Jones Hill, hosted in similar rocks and only a few kilometers distant from the Pecos mine. Although no other significant deposits are known, there are large numbers of small mines and prospects in New Mexico, some of which produced minor amounts of Ag, Au, Cu, and other base metals.

Rationale for Numerical Estimate

Kuroko-type massive sulfide deposits small and tend to form in clusters, so the presence of several large deposits and numerous smaller deposits indicates that this process took place in New Mexico. Although the permissive tract is not large, it could contain a significant number of deposits of various sizes. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 1, 2, 4, and 6 or more deposits consistent with the grade and tonnage model for kuroko massive sulfide deposits (Singer and Mosier, 1986).

References

- Robertson, J.M., Fulp, M.S., and Daggett, M.D., III, 1986, Metallogenic map of volcanogenic massive sulfide deposit occurrences in New Mexico: U.S. Geological Survey Miscellaneous Field Studies Map MF-1853-A, scale 1:1,000,000.
- Silberman, M.L., 1994, Submarine exhalative and related Precambrian deposits of New Mexico: U.S. Geological Survey Administrative Report, 9 p.
- Singer, D.A., and Mosier, D.L., 1986, Grade and tonnage model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 190-197.

CR26 **Epithermal Vein Deposits, Quartz-adularia Type** **Colorado**
Descriptive Model 25C + 25D • Mark3 Index 25
Area = 20,400 km²

[Cumulative Distribution](#) [Histogram](#) [Table](#) [Model](#) [Mineral Deposits](#)

by Steve Ludington

Rationale for Model Choice

Although Colorado contains the namesake for Creede-type epithermal vein deposits, and many of the examples (Mosier and others, 1986a), recent reexamination of these Colorado deposits suggests that most (though not all) of them may be best considered to be polymetallic vein deposits (Cox, 1986) emplaced in a volcanic host. Many deposits in the western San Juan Mountains (Animas, Eureka, Ophir, Red Mountain, Sneffels, and Telluride districts) were formed 5–15 m.y. after the cessation of volcanism, were emplaced at paleodepths as great as 2 kilometers or more, contain abundant base metals and minor amounts of W, Bi, and Mo, and are associated at depth with skarn mineralization. As with other Tertiary vein deposits in Colorado, these volcanic-hosted districts do not conform to the polymetallic vein grade and tonnage models of Cox (1986) and accordingly were not assessed, despite a feeling on the part of the team that there is significant potential for undiscovered deposits of this type in Colorado.

Many other volcanic-hosted quartz-adularia epithermal vein deposits, prospects, and occurrences are known in Colorado. Although production data for these deposits are largely unavailable, the team's general knowledge of them suggests that the deposits have a relatively lower Ag:Au ratio and few base metals, fitting more closely the characteristics of the Comstock (Mosier, Singer, and Berger, 1986) and Sado (Mosier, Berger, and Singer, 1986) epithermal vein deposits. As a result, the team assessed the Colorado tract with a composite model of Comstock and Sado vein deposits (Mark3 index 25).

Rationale for Tract Delineation

The permissive tract for quartz-adularia deposits in Colorado encompasses volcanic fields of felsic to intermediate composition. The largest such terrane is the San Juan volcanic field, which hosts most of the known volcanic-hosted quartz-adularia vein deposits in the State. Virtually any part of a volcanic field such as the San Juan Mountains is permissive for the occurrence of this type of deposit, so long as there was concurrent magmatic activity to provide metals and drive the hydrothermal systems and extensional faulting to provide a path for the fluids.

Important Examples of Deposit Type

Creede is the largest deposit in the tract, although it contains proportionately more base metals than other deposits in the tract. Lake City (Slack, 1980) and Crystal Hill (Pansze, 1987) are other significant deposits. Other known prospects include Equity, Bondholder, San Luis Hills, Platoro, Stunner, Axtell, Crater Creek, Lincoln Gulch, and Independence.

Rationale for Numerical Estimate

The assessment team made separate assessments for nine districts in the State that contain known quartz-adularia deposits, prospects, and occurrences, and the total expected value obtained was about 1.3 deposits consistent with the combined Comstock-Sado epithermal vein grade and tonnage model (Mark3 index 25). The team also believed that large volcanic areas without known prospects within the San Juan volcanic field could host deposits, due to the

interlayered piles of volcanic rocks that could conceal older deposits. The general feeling of the team was that there was a high degree of certainty that there is at least one more deposit out there somewhere. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 1, 3, 5, 7, and 10 or more districts consistent with the combined Comstock-Sado epithermal vein grade and tonnage model.

References

- Cox, D.P., 1986, Descriptive model of polymetallic veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 125.
- Mosier, D.L., Sato, T., and Singer, D.A., 1986, Grade and tonnage model of Creede epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 146-149.
- Mosier, D.L., Singer, D.A., Sato, T., and Page N.J., 1986, Relationship of grade, tonnage, and basement lithology in volcanic-hosted epithermal precious- and base-metal quartz-adularia-type districts: *Mining Geology*, v. 36, p. 245-264.
- Pansze, Arthur J., 1987, Geologic sketch of the Crystal Hill breccia pipe, Saguache County, Colorado: DREGS field trip guide.
- Slack, J.F., 1980, Multistage vein ores of the Lake City district, western San Juan Mountains, Colorado: *Economic Geology*, v. 75, no. 7, p. 963-991.

CR27 **Epithermal Vein Deposits, Quartz-adularia Type**
Descriptive Model 25C + 25D • Mark3 Index 25New Mexico
Area = 43,600 km²
[Cumulative Distribution](#)
[Histogram](#)
[Table](#)
[Model](#)
[Mineral Deposits](#)
by Alan R. Wallace and Virginia McLemore

Rationale for Model Choice

Known quartz-adularia precious-metal veins occur in felsic to intermediate volcanic rocks in this area. The general lack of information on grades and tonnages precluded classifying known deposits and potential undiscovered deposits into separate Creede, Comstock, and Sado deposit models. Base metals are not prominent in the known examples, and, as a result, the team assessed the New Mexico quartz-adularia veins using a composite model of Comstock and Sado vein deposits (Mark3 index 25).

Rationale for Tract Delineation

Extensive felsic to intermediate Tertiary volcanic fields in the area contain known quartz-adularia deposits, prospects, and occurrences. These volcanic fields are variably cut by younger intrusive rocks, and faults and caldera ring fractures are common. Therefore, permissive tracts were delineated to consist of areas of volcanic rocks of intermediate to felsic composition. The absence of faults or other fluid-focusing structures on the maps we used was not considered a negative criterion for assessment. This tract is exclusive of southwestern New Mexico, which is part of the Southern Basin and Range Province.

Important Examples of Deposit Type

Cochiti (about 1.3 metric tons Au, 6.5 metric tons Ag) and Chloride are significant districts. In addition, 22 other districts and prospects were identified that are small or did not have adequate grade and tonnage information.

Rationale for Numerical Estimate

The team assessed each of the 22 prospects and arrived at a total expected value of about 0.7 deposits consistent with the combined Comstock-Sado grade and tonnage model. Additional estimates for the Black Range and for the covered area in the Jemez caldera area added 0.7 deposits. After reviewing the size of the known deposits and prospects, the extent of volcanic rocks, and the extent of covered areas, the team decided that the first estimates were uniformly between 50 and 100 percent too low. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 2, 5, 6, and 7 or more districts consistent with the combined Comstock-Sado grade and tonnage model.

CR28**Epithermal Vein Deposits, Quartz-adularia Type****Texas****Descriptive Model 25C + 25D • Mark3 Index 25****Area = 9,730 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Gregory T. Spanski**Rationale for Deposit Model**

In western Texas, a few precious- and base-metal quartz veins are hosted in Tertiary alkali-calcic intrusive rocks in volcanic centers occurring in the trans-Pecos back-arc volcanic field. At the assessment scale, we could not distinguish among the quartz-adularia submodels, and, as a result, the team assessed the Texas quartz-adularia vein tract with a composite model of Comstock and Sado vein deposits (Mark3 index 25).

Rationale for Tract Delineation

The Trans-Pecos volcanic province is a dominantly alkaline system becoming increasingly alkalic from west to east. Barker (1977) and Price and others (1987) divide the province along a north-northwest trending boundary into an alkalic eastern belt and a western alkali-calcic belt. Magmatic activity, lasting from about 48 Ma until 32 Ma, occurred under compressive tectonic conditions after the Laramide orogeny. The broad compositional range demonstrated in eruptive units from this period suggest that the magma chambers at depth had achieved a high degree of differentiation. Epithermal quartz veins are primarily spatially associated with late stage intrusive events that resulted in resurgent doming at many of the known volcanic centers in the western alkali-calcic belt. The permissive tract therefore includes all of the area in the Trans-Pecos volcanic province lying west of the alkalic/alkali-calcic boundary and extending to a depth of one kilometer.

Important Examples of Deposit Type

No examples of significant size are known in the permissive tract. However, small, low-grade prospects and occurrences that may be epithermal in character are known to exist in association with late-stage intrusive phases in the Infiernito, Chinati Mountains, and Quitman Mountains calderas (Price and others, 1983).

Rationale for Numerical Estimates

The Trans-Pecos region of Texas has been prospected since the middle of the 19th century without the discovery of a major deposit. The known calderas within the permissive tract have been well exposed by erosion, lessening the probability for the existence of concealed late-stage intrusions. The apparent absence of often-associated placer gold deposits is not meaningful because the known prospects are very silver-rich. Finally, the volcanic rocks in the permissive tract are compositionally enriched in potassium, compared with the calc-alkaline rocks with which the deposit type is most commonly associated. However, because of the favorable shows in the Chinati and Infiernito calderas and the potential for discovery of an early volcanic center concealed beneath the volcanic cover produced by later events, we made a small estimate. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, and 1 or more districts consistent with the combined Comstock-Sado grade and tonnage model.

References

- Barker, D.S., 1979, Magmatic Evolution in the Trans-Pecos Province, *in* Walton, A.W., and Henry, C.D., eds., *Cenozoic geology of the Trans-Pecos Volcanic Field of Texas*: Texas Bureau of Economic Geology Guidebook 19, p. 4-9.
- Price, J.G., Henry, C.D., and Standen, A.R., 1983, Annotated bibliography of mineral deposits in Trans-Pecos Texas: Bureau of Economic Geology, Mineral Resource Circular, no. 73, 108 p.
- Price, J.G., Henry, C.D., Barker, D.S., and Parker, D.F., 1987, Alkaline Rocks of Contrasting Tectonic Settings, *in* Morris, E.M. and Pasteris, J.D., eds., *Trans-Pecos Texas—Mantle metasomatism and alkaline magmatism*: Geological Society of America Special Paper 215, p. 335-346.

CR29**Epithermal Vein Deposits, Quartz-alunite Type****Colorado****Descriptive Model 25e • Mark3 Index 38****Area = 20,400 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* Alan R. Wallace**Rationale for Model Choice**

Quartz-alunite gold deposits are related to felsic volcanic and subvolcanic rocks, which are found in several volcanic fields in the State. The existence of the deposit at Summitville, an archetypal, if infamous, example led us to use the descriptive model of Berger (1986) and the grade and tonnage model of Mosier and Menzie (1986).

Rationale for Tract Delineation

Quartz-alunite gold deposits are associated with felsic volcanic and subvolcanic rocks, which in Colorado are of Tertiary age. The permissive tract encompasses Tertiary felsic volcanic rocks as shown on the State map. The principal area is the San Juan volcanic field in southwestern Colorado.

Important Examples of Deposit Type

Summitville is a large known quartz-alunite gold deposit (Steven and Ratté, 1960; Perkins and Nieman, 1982). Within the San Juan Mountains, known prospects include Red Mountain near Lake City, Crater Lake-Quartz Creek near Summitville, Piedra Peak-Red Mountain south of Creede, and Calico Peak near Rico; the San Juan National Forest assessment (VFoley and others, in press) also identified seven additional areas that had potential for undiscovered quartz-alunite gold deposits. Minor alunite alteration has been reported at other areas in the State, such as the San Luis Hills southwest of Alamosa (Bartlett, 1984).

Rationale for Numerical Estimate

The state of knowledge about volcanic-hosted precious-metal deposits in Colorado is fairly good, and many areas have been prospected for this and other types of volcanic-hosted mineral deposits. Some deposits could be concealed by younger volcanic rocks in areas such as the San Juan Mountains. Very few, if any, occurrences of quartz-alunite alteration are known outside of the San Juan volcanic field, so, although felsic volcanic rocks are present outside of that area, they appear not to be as favorable as those in the San Juans. In making our estimates, we drew, in part on those made for the San Juan National Forest assessment (Foley and others, in press). For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 1, 3, and 5 or more deposits consistent with the grade and tonnage model for quartz-alunite gold deposits of Mosier and Menzie (1986).

References

- Bartlett, R.D., 1984, Geology of an Oligocene-age acid hot spring, San Luis Hills, Conejos and Costilla Counties, Colorado: Fort Collins, Colorado State University, unpublished Master's thesis, 111 p.
- Berger, B.R., 1986, Descriptive model of epithermal quartz-alunite Au, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 158.
- Foley, N. K., Van Loenen, R.E., Nash, J.T., and Gibbons, A.B., in press, Mineral resource potential—locatable minerals, *in* Van Loenen, R.E. and Gibbons, A.B., eds., Mineral resource potential and geology of the San Juan National Forest, Colorado: U.S. Geological Survey Bulletin, p. ?.

- Mosier, D.L., and Menzie, W.D., 1986, Grade and tonnage model of epithermal quartz-alunite Au, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 159-161.
- Perkins, M., and Nieman, G.W., 1982, Epithermal gold mineralization in the South Mountain Dome, Summitville, Colorado: Denver Region Exploration Geologists Society Symposium on the Genesis of Rocky Mountain Ore Deposits—Changes with time and tectonics, Denver, Colorado, Proceedings, p. 165–172.
- Steven, T.A., and Ratté, J.C., 1960, Geology and ore deposits of the Summitville district, San Juan Mountains, Colorado: U.S. Geological Survey Professional Paper 343, 70 p.

CR30**Epithermal Vein Deposits, Quartz-alunite Type****New Mexico****Descriptive Model 25e • Mark3 Index 38****Area = 43,600 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Alan R. Wallace and Virginia McLemore**Rationale for Model Choice**

Quartz-alunite gold deposits are related to felsic volcanic and subvolcanic rocks, which are found in several volcanic fields in the State. We used the descriptive model of Berger (1986) and the grade-tonnage model of Mosier and Menzie (1986).

Rationale for Tract Delineation

Areas of felsic volcanic rocks, such as the Mogollon volcanic field, are extensive in New Mexico, and several occurrences of hypogene alunite and acid-sulfate alteration have been reported in these rocks. Therefore, all areas of felsic volcanic rocks are considered permissive for this deposit type.

Important Examples of Deposit Type

Acid-sulfate alteration is present in the San Jose district, west of Truth or Consequences, and at Kline Mountain in the Black Range (V.T. McLemore, written commun., 1993). Native sulfur is present in the Valles caldera area, but an associated quartz-alunite assemblage is not reported.

Rationale for Numerical Estimate

The permissive tract of volcanic rocks is extensive, and acid-sulfate alteration is evident in at least two areas. Most districts in New Mexico have not been adequately explored at depth, and drilling and other exploration programs are needed to better evaluate the potential for undiscovered deposits (V.T. McLemore, written commun., 1993). For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 2, and 4 or more deposits consistent with the grade and tonnage model for epithermal quartz-alunite gold deposits of Mosier and Menzie (1986).

References

- Berger, B.R., 1986, Descriptive model of epithermal quartz-alunite Au, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 158.
- Mosier, D.L., and Menzie, W.D., 1986, Grade and tonnage model of epithermal quartz-alunite Au, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 159-161.

CR31**Hot-spring Au-Ag Deposits****Colorado****Descriptive Model 25a • Mark3 Index 45****Area = 65,900 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Alan R. Wallace**Rationale for Model Choice**

Modern hot springs are common in Colorado, and geothermal activity was undoubtedly associated with the many Tertiary volcanic centers in Colorado. Erosion has probably stripped away many potential deposits, which form at or near the surface, but others many be concealed in volcanic piles such as the San Juan volcanic field or still preserved due to their relative youth. We used the descriptive model of Berger (1986) and the grade and tonnage model of Berger and Singer (1992).

Rationale for Tract Delineation

Two areas were deemed permissive for hot-spring gold-silver deposits: (1) thick volcanic piles, such as the Flat Tops, Thirtynine Mile, and San Juan volcanic fields, where hot-spring deposits related to volcanic activity could have been concealed by subsequent eruptions, and (2) areas of modern geothermal activity (Pearl, 1980), some of which may be generating or have already generated a gold deposit.

Important Examples of Deposit Type

No true hot-spring gold-silver deposits are known in the State. Possible examples of partially eroded deposits may include the Golden Wonder mine, in the Lake City district (Kalliokoski and Rehn, 1987), the San Luis gold deposit near San Luis, prospects along the west side of the Sangre de Cristo Mountains between Crestone and the Great Sand Dunes, and Poncha Hot Springs, where one sample of fluorspar ore contained 100 ppb Au (A. Wallace, unpub. data, 1993).

Rationale for Numerical Estimate

Colorado is known for its past and present high heat flow, and the permissive tracts easily could conceal a geothermal center, although very few such centers produce gold-silver deposits of the size consistent with the grade and tonnage model. Nevertheless, the amount of concealed volcanic rocks in the various volcanic fields and the presence of modern geothermal activity permits some chance for the existence of a hot-spring gold-silver deposit in the permissive areas. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 1, and 2 or more deposits consistent with the grade and tonnage model for hot-spring gold-silver deposits (Berger and Singer, 1992).

References

- Berger, B.R., 1986, Descriptive model of hot-spring Au-Ag deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 143.
- Berger, B.R., and Singer, D.A., 1992, Grade and tonnage model for hot-spring Au-Ag, *in* Bliss, J.D., ed., Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, p. 23-25.
- Kalliokoski, J., and Rehn, Patty, 1987, Geology of the veins and vein sediments of the Golden Wonder Mine, Lake City Colorado; an epithermal hot springs gold-alunite deposit: U.S. Geological Survey Open-File Report 87-344, 47 p.

Pearl, R.H., 1980, Geothermal resources of Colorado: Colorado Geological Survey Map Series MS-14, scale 1:500,000.

CR32**Hot-spring Au-Ag Deposits****New Mexico****Descriptive Model 25a • Mark3 Index 45****Area = 93,200 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Alan R. Wallace**Rationale for Model Choice**

Modern hot springs are common in New Mexico, and geothermal activity was undoubtedly associated with the many Tertiary volcanic centers in New Mexico. Erosion has probably stripped away many potential deposits, but others may be concealed in volcanic piles such as the Mogollon volcanic field or still preserved due to their relative youth. We used the descriptive model of Berger (1986) and the grade and tonnage model of Berger and Singer (1992).

Rationale for Tract Delineation

Two broad areas were deemed permissive for hot-spring gold-silver deposits: (1) thick volcanic piles, such as the Mogollon and Jemez volcanic fields, where hot-spring deposits related to volcanic activity could have been concealed by subsequent eruptions, and (2) areas of modern geothermal activity, principally along the Rio Grande rift but also in the Jemez volcanic field, some of which may be generating or have already generated a gold deposit.

Important Examples of Deposit Type

No true hot-springs gold-silver deposits have been reported in the State. Possible examples may include parts of the Wilcox, Mogollon, and Gila districts.

Rationale for Numerical Estimate

Parts of New Mexico are known for their past and present high heat flow, and the permissive tracts easily could conceal a geothermal center, although very few such centers produce gold-silver deposits of the size consistent with the grade and tonnage model. Nevertheless, the presence of concealed volcanic rocks in the various volcanic fields and the presence of modern geothermal activity permits some chance for the existence of a hot-spring gold-silver deposit in the permissive areas. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 1, and 2 or more deposits consistent with the grade and tonnage model for hot-spring gold-silver deposits (Berger and Singer, 1992).

References

- Berger, B.R., 1986, Descriptive model of hot-spring Au-Ag deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 143.
- Berger, B.R., and Singer, D.A., 1992, Grade and tonnage model of hot-spring Au-Ag, *in* Bliss, J.D., ed., Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, p 23-25.

CR33**Sediment-hosted Cu Deposits, Red-bed Type**

Descriptive Model 30b.2 • Mark3 Index 97

Area = 26,800 km²Colorado
New Mexico
Texas[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* David A. Lindsey**Rationale for Model Choice**

Deposits in this tract are small, lenticular bodies of reduced permeable sandstone, siltstone, and shale, within a larger red-bed sequence. Most host rocks contain organic plant remains and some contain pyrite. The small mineralized bodies occur in reduced zones preserved in red beds. Anomalous concentrations of uranium are commonly present. These features match those of other red-bed-type copper deposits.

Rationale for Tract Delineation

Deposits occur in Middle Pennsylvanian (DesMoinesian) through Lower Permian (Wolfcampian) clastic rocks derived from erosion of the Ancestral Rocky Mountains. Stratigraphic units include Minturn, Madera, Bursum, Naco, Sangre de Cristo, Abo, Yeso, Supai, and Cutler Formations, and these rocks constitute the permissive tract. Within these, the red bed-over-gray bed transition (Sangre de Cristo to Minturn or Madera; Abo to Bursum; Supai to Naco) is the best target.

Important Examples of Deposit Type

The Scholle district, in New Mexico (Hatchell and others, 1982) is the best example.

Rationale for Numerical Estimate

Although more than a dozen districts and occurrences are known (Soule, 1956), the largest production of any district (Scholle, New Mexico) has been 12,340 metric tons of ore (Hatchell and others, 1982); reserves in most districts are almost nil. Because production and reserves are much smaller than the median red-bed deposit tonnage, an estimate of 0, 1, 2, 4, and 5 or more deposits was made for the 90th, 50th, 10th, 5th, and 1st percentiles, consistent with the grade and tonnage model (Mark 3 no. 97).

References

- Hatchell, W.O., Blagbrough, J.W., and Hill, J.M., 1982, Stratigraphy and copper deposits of the Abo Formation, Abo Canyon area, central New Mexico, *in* Grambling, J.A., and Wells, S.G., eds., Albuquerque Country II, New Mexico Geological Society Guidebook, 33rd Annual Field Conference, p. 249-260.
- Soule, J.H., 1956, Reconnaissance of the "Red Bed" copper deposits in southeastern Colorado and New Mexico: U.S. Bureau of Mines Information Circular 7740, 74 p.

CR34**Sediment-hosted Cu Deposits, Red-bed Type**

New Mexico

Descriptive Model 30b.2 • Mark3 Index 97

Colorado

Area = 4,440 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by David A. Lindsey

Rationale for Model Choice

Sediment-hosted Cu deposits in Upper Triassic rocks are generally associated with concentrations of organic plant remains (logs, leaves, etc.) in permeable sandstone. The host rock and mechanism of precipitation matches the red-bed model. Deposits in this tract span the entire range of tonnage and grade for red-bed copper deposits, and the worldwide red-bed model is appropriate.

Rationale for Tract Delineation

The permissive tract includes the permeable sandstones of the lower part of the Upper Triassic Chinle Formation (including the Shinarump and Agua Zarca Sandstone Members) and the approximately equivalent Triassic Dockum Group (Santa Rosa Formation).

Important Examples of Deposit Type

Nacimiento, New Mexico (more than 10 million metric tons at 0.67 percent Cu) is the largest known deposit in the tract, and is found in the Agua Zarca Sandstone Member of the Chinle Formation (Talbot, 1974; Woodward and others, 1974).

Rationale for Numerical Estimate

Most undiscovered deposits are expected to be in the known districts and, although these have been extensively explored, each may contain concealed deposits. At least one deposit probably exists (90th percentile) among the three districts. For the 90th, 50th, 10th, and 5th percentiles, respectively, the team estimated 1, 3, 5, and 6 or more red-bed copper deposits of Triassic age, consistent with the grade and tonnage model.

References

- Talbot, L.W., 1947, Nacimiento pit, a Triassic strata-bound copper deposit, *in* Ghost Range, New Mexico Geological Society Guidebook, 25th Annual Field Conference, p. 301-303.
- Woodward, L.A., Kaufman, W.H., Schumacher, O.L., and Talbot, L.W., 1974, Strata-bound copper deposits in Triassic sandstone of Sierra Nacimiento, New Mexico: *Economic Geology*, v. 69, no. 1, p. 108-120.

CR35**Sedimentary Exhalative Zn-Pb Deposits**Wyoming
Colorado

Descriptive Model 31a • Mark3 Index 13

Area = 11,300 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Alan R. Wallace**Rationale for Model Choice**

Small stratiform sulfide deposits are present in Early Proterozoic metasedimentary rocks in Colorado. These may be sedimentary exhalative deposits related to contemporaneous submarine volcanism. The descriptions of many massive sulfide deposits in Colorado, such as in south-central Colorado and the Front Range, are generally inadequate to definitively assign those deposits to a particular model. Only in the northern Park Range (Klipfel, 1992) and the northern Sawatch Range (Tweto, 1974) have the deposits been studied in sufficient detail to make an assignment to this deposit type.

Rationale for Tract Delineation

The Early Proterozoic basement of Colorado, south of a suture zone with the Archean Wyoming Province near the Colorado-Wyoming border, is composed of metasedimentary and metavolcanic rocks that formed in a complex back-arc setting (Reed and others, 1987). Sediments deposited during submarine volcanism could have included exhalative products from the volcanic systems. Areas underlain by unit Xb (biotite schist) on the State geologic map (Tweto, 1979) in proximity to metavolcanic rocks are designated permissive for sedimentary exhalative deposits; these rocks are in the northern Sawatch Range, the Gore Range, and the central Front Range. Sulfide deposits are known to be associated with some of these rocks. The permissive tract also includes areas in southern Wyoming described by Klipfel (1992).

Important Examples of Deposit Type

Occurrences of stratabound sulfides are scattered through the Early Proterozoic metasedimentary and metavolcanic rocks of Colorado (Sheridan and others, 1990; Lovering and Goddard, 1950). Most occurrences, such as the broad belt of disseminated sulfides in the northern Sawatch Range near Homestake Reservoir (Tweto, 1974), are semiconformable with the enclosing gneisses, but some contain minor crosscutting veins. Due to the degree of metamorphism and deformation, these veins may contain sulfides that were remobilized locally from the stratabound sulfides. Lovering and Goddard (1950) and Sheridan and others (1990) describe small sulfide deposits and occurrences in Proterozoic metasedimentary rocks, but the descriptions were either inadequate to confidently assign deposits to specific models or the authors of those reports concluded that such assignments could not be made due to conditions such as extreme metamorphic grade and deformation. Production from those deposits was either trivial or not reported.

Rationale for Numerical Estimate

Although Klipfel (1992) concluded that some stratabound sulfide deposits in the northern Park Range were sedimentary exhalative deposits related to volcanism that produced nearby Besshi-type and mixed Besshi-sedex deposits; we do not agree with this view, and include undiscovered deposits from the northern Park Range in the assessment of Besshi-type deposits of southern Wyoming and northernmost Colorado.

Production from known zones of stratabound sulfides has been very small (less than a few thousand tons) to nonexistent (Sheridan and others, 1990), and none of the known occurrences are as large as the deposits in the grade and tonnage model of Menzie and Mosier (1986) for sedimentary exhalative lead-zinc deposits. Considering the relatively high degree of knowledge about the geology of the Proterozoic basement, especially in the permissive area, and the very small sizes of known occurrences, the team judged that there was only a small chance of there being an undiscovered deposit, and, for the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, and 1 or more sedimentary exhalative Zn-Pb deposits consistent with the grade and tonnage model of Menzie and Mosier (1986).

References

- Klipfel, P.D., 1992, Geology and metallogeny of the southern portion of the Encampment district, Colorado and Wyoming: Golden, Colorado School of Mines, unpub. Ph.D. dissertation, 244 p.
- Lovering, T.S., and Goddard, E.N., 1950, Geology and ore deposits of the Front Range, Colorado: U.S. Geological Survey Professional Paper 223, 319 p.
- Menzie, W.D., and Mosier, D.L., 1986, Grade and tonnage model of sedimentary exhalative Zn-Pb, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 212-215.
- Reed, J.C., Jr., Bickford, M.E., Premo, W.R., Aleinikoff, J.N., and Pallister, J.S., 1987, Evolution of the Early Proterozoic Colorado province—Constraints from U-Pb geochronology: *Geology*, v. 15, p. 861-865.
- Sheridan, D.M., Raymond, W.H., Taylor, R.B., and Hasler, J.W., 1990, Metallogenic map of stratabound exhalative and related occurrences in Colorado: U.S. Geological Survey Miscellaneous Investigations Series Map I-1971, scale 1:1,000,000.
- Tweto, Ogden, 1974, Geologic map and sections of the Holy Cross quadrangle, Eagle, Lake, and Pitkin Counties, Colorado: U.S. Geological Survey Miscellaneous Investigations Map I-830, scale 1:24,000.
- Tweto, Ogden, 1979, Geologic map of Colorado: U.S. Geological Survey Map, scale 1:500,000.

CR36**Low-sulfide Au-quartz Vein Deposits**Wyoming
Colorado

Descriptive Model 36a • Mark3 Index 27

Area = 11,400 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* Alan R. Wallace**Rationale for Model Choice**

Proterozoic medium-grade (upper greenschist to amphibolite grades) metamorphic rocks are cut by shear zones and faults that are demonstrably of Proterozoic age.

Rationale for Tract Delineation

The criteria for inclusion included: (1) the presence of supracrustal (volcanic or sedimentary) host rocks of Proterozoic age; (2) medium-grade (greenschist to lower-amphibolite facies) regional metamorphism; (3) the presence of gold deposits, placers, prospects, and occurrences; (4) evidence of large-scale shearing and faulting; and (5) alteration mineral assemblages within and adjacent to faults and shear zones containing quartz and carbonate veining, phyllosilicate minerals sericite, chlorite, and (or) biotite, and the sulfide minerals pyrite, arsenopyrite, and (or) pyrrhotite. Areas underlain principally by granitoids or gneisses were excluded. The most favorable areas are in Wyoming, in the Medicine Bow and Sierra Madre Mountains and in the Laramie Range.

Important Examples of Deposit Type

No vein deposits in Colorado are demonstrably of Proterozoic age. Small deposits occur along faults that cut syngenetic massive sulfide and sedimentary exhalative deposits, such as in the Gunnison gold belt and at the Homestake mine west of Tennessee Pass, but the ages of these deposits are unknown and may be as young as Tertiary. In Wyoming, roughly 4,500 oz of gold were produced in the late 1860s from the Centennial Ridge district in the Medicine Bow Mountains (Hausel, 1989).

Rationale for Numerical Estimate

Although the Proterozoic basement of Colorado contains low- to medium-grade metamorphic rocks and is cut by various faults and shear zones, none of the gold deposits along those faults are of the appropriate mineralogy nor of demonstrably Proterozoic age, unlike similar deposits in Wyoming and South Dakota. We estimated that there may be two low-sulfide Au-quartz vein deposits in the area of Centennial Ridge district in the Medicine Bow Mountains. Although the total amount of gold ore recovered in the district is relatively low, there are numerous gold occurrences throughout the district indicating that widespread mineralization occurred along faults and in shear zones. The bedrock of this region is poorly exposed, and, therefore, we believe that the potential for concealed gold-quartz vein deposits remains relatively high. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 1, 2, 3, 4, and 5 or more deposits consistent with the low-sulfide Au-quartz grade and tonnage model of Berger (1986) (Mark3 index 27); most of them are believed to be in the part of the tract in southern Wyoming.

References

Berger, B.R., 1986, Descriptive model of epithermal quartz-alunite Au, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 158.

Hausel, W.D., 1989, The geology of Wyoming's precious metal lode and placer deposits: Geological Survey of Wyoming Bulletin 68, 248 p.

EC01**Descriptive Model 30a****Area = 71,000 km²****Sandstone-hosted Pb-Zn Deposits****New York****Pennsylvania****New Jersey, Maryland****Virginia, West Virginia****North Carolina, Tennessee****Georgia, Alabama**[Model](#)*by* John F. Slack, Sandra H.B. Clark, John D. Peper, and Howard A. Pohn**Rationale for Model Choice**

No major sandstone-hosted lead-zinc deposits are known in the United States, and deposits of this type are of relatively minor economic importance by world standards. The only significant deposit in the United States was developed at the Goose Creek mine in the Indian Creek district of southeast Missouri (Kyle and Gutierrez, 1988). The importance of some deposits, such as the large (80 million metric tons) Laisvall lead-zinc deposit in northern Sweden, shows that potential must be considered for the occurrence of similar deposits in geologically analogous settings. Sandstone-hosted lead-zinc deposits are stratabound concentrations of galena and generally minor sphalerite that occur within quartz-rich sandstone and quartzite overlying feldspathic basement rocks (Rickard and others, 1979; Bjørlykke and Sangster, 1981). The origin of sandstone-hosted lead-zinc deposits by transport of metals through permeable channels to an environment with sufficiently high H₂S content to precipitate sulfides from groundwater or basinal brines resembles that of sediment-hosted copper and Mississippi Valley deposits.

Clastic sedimentary sequences that occur near underlying basement rocks are potential hosts for lead-zinc deposits in which metals were concentrated by groundwater leaching from feldspar-rich basement rocks. Although no deposits are known in the United States Appalachians, several occurrences have been described from the Quebec Appalachians to the north (Schrijver and Beaudoin, 1987), suggesting potential for mineralization of the Cheshire Quartzite and correlative units of Early Cambrian age that overlie feldspathic basement rocks. Galena samples from the Rossie veins of western New York have lead isotope compositions and fluid inclusions (Ayuso and others, 1987) that are compatible with an origin from a Paleozoic basinal brine that migrated into fractures during tectonism. The migration of base-metals in brines suggests the possibility for the formation of sandstone-hosted lead-zinc deposits in favorable host rocks such as the Upper Cambrian Potsdam Sandstone that forms a basal unit overlying the Grenvillian basement of the Adirondacks.

For sandstone-hosted lead-zinc deposits that form as a result of the tectonically driven flow of metal-bearing brines, proximity to basement rocks may not be a critical factor, and all clastic sequences that were present at the time of the Alleghenian deformation are potential host rocks. An occurrence of this deposit type has been recognized in Silurian rocks of the Tuscarora Quartzite in southwestern Virginia (J.R. Craig, oral commun., 1980). This occurrence was discovered by A. Hayes during construction of the I-77 highway tunnel under Walker Mountain, 10 km north-northwest of Wytheville. Representative parts of the galena-cemented samples were given to J.E. Gair, USGS, by J.R., Craig in 1980. Ore samples from the Laisvall mine (see Rickard and others, 1979; Lindblom, 1986) collected by J.E. Gair and J.F. Slack in 1979, are nearly identical in texture and mineralogy to the samples collected by Hayes from the I-77 tunnel.

Other occurrences of lead or zinc in Silurian to Devonian sandstone or quartzite are known in Pennsylvania, Virginia, and West Virginia (Martens, 1964; Smith, 1977; Clark, 1987; Cannon and others, 1994), and sandstone hosts the galena-sphalerite veins of the Shawangunk district of New York (Crawford and Beales, 1983). Occurrences of lead are known also in sandstones of the Upper Devonian and Lower Mississippian Pocono Group in Pennsylvania and West Virginia (Smith, 1977; Clark, 1987; Cannon and others, in press). These occurrences, along with the major base-metal deposits in Appalachian Zn deposits, record the passage of metal-bearing fluids through sedimentary rocks of the Appalachian basin and show that conditions were favorable for precipitation locally in clastic host rocks ranging in age from Cambrian through Mississippian.

Rationale for Tract Delineation

The permissive tract includes the Lower Cambrian and Lower Cambrian(?) basal clastic sequences, the Silurian clastic sequence (Shawangunk Formation, Bloomsburg Formation, Tuscarora Quartzite, and stratigraphically equivalent clastic units) and the Upper Devonian and Lower Mississippian Pocono Group (sandstone) and its stratigraphic equivalents that are predominantly sandstone. The Cambrian basal clastic sequences, including the Cheshire Quartzite in Vermont, the Potsdam Sandstone in New York, and other stratigraphically equivalent units, are considered permissive for the occurrence of sandstone-hosted lead-zinc deposits because of their predominantly clastic composition and position overlying feldspathic basement rocks.

Boundaries for this tract, where exposed at the surface, were derived from contacts on the map showing the generalized geologic setting for metal deposits in the Appalachians (J.D. Peper, written commun.; see Gair and others, 1987) and from State geologic maps. Contacts were projected to 1 km beneath the surface by structural interpretation by John Peper and Howard Pohn and by interpretation of stratigraphic sections and lithofacies maps of the Mississippian System (Dally, 1956; deWitt and others, 1979; Craig and Conner, 1979) by Antoinette Geoly. The western limit of the permissive tract was drawn where sedimentary rocks of the Osage Series of the Mississippian System that are composed of greater than 80 percent detrital components have sandstone:shale ratios of less than 1:1.

Rationale for Numerical Estimate

No estimates of undiscovered deposits were made for this tract because, while occurrences of galena are known in the region, large sandstone-hosted lead-zinc deposits are uncommon on a worldwide basis. The lack of any known large deposits in the eastern United States or other indications beyond appropriate geologic settings over broad areas were not considered an adequate basis for estimating undiscovered resources of this deposit type.

References

- Ayuso, R.A., Foley, N.K., and Brown, C.E., 1987, Source of lead and mineralizing brines for Rossie-type Pb-Zn veins in the Frontenac axis area, New York: *Economic Geology*, v. 82, no. 2, p. 489-496.
- Bjørlykke, A., and Sangster, D.F., 1981, An overview of sandstone lead deposits and their relation to red-bed copper and carbonate-hosted lead-zinc deposits, *in* Skinner, B.J., ed., *Economic Geology Seventy-Fifth Anniversary Volume, 1905-1980*: Lancaster, Pennsylvania, Economic Geology Publishing Company, p. 179-213.
- Cannon, W.F., Clark, S.H.B., Lesure, F.G., Hinkle, M.E., Paylor, R.L., King, H.M., Simard, C.M., Ashton, K.C., and Kite, J.S., 1994, Mineral resources of West Virginia: U.S. Geological Survey Miscellaneous Investigations Series Map I-2364-A, scale 1:500,000, with pamphlet, 14 p.

- Clark, S.H.B., 1987, Metallogenic map of zinc, lead, and barium deposits and occurrences in Paleozoic sedimentary rocks, east-central United States: U.S. Geological Survey Miscellaneous Investigations Series Map I-1773, scale 1:2,500,000 with pamphlet, 77 p.
- Craig, L.C., and Connor, C.W., coordinators, 1979, Paleotectonic investigations of the Mississippian System in the United States: U.S. Geological Survey Professional Paper 1001, pt. III., plates 4-B and 9-B.
- Crawford, M.J., and Beales, F.W., 1983, The Shawangunk mine—A possible sandstone-hosted Mississippi Valley-type ore deposit in New York, *in* Kisvarsanyi, Geza, Grant, S.K., Pratt, W.P., and Koenig, J.W., eds., International conference on Mississippi Valley type lead-zinc deposits: Rolla, University of Missouri, p. 436-445.
- deWitt, Wallace, Jr., and McGrew, L.W., 1979, The Appalachian basin region, *in* Craig, L.C., and Connor, C.W., coordinators, Paleotectonic investigations of the Mississippian System in the United States: U.S. Geological Survey Professional Paper 1001, pt. I, p. 13-48.
- Dally, J.L., 1956, The stratigraphy and paleontology of the Pocono Group in West Virginia: New York, Columbia University, unpub. Ph.D. dissertation, 248 p.
- Gair, J.F., Cannon, W.F., Peper, J.D., Cannon, S.S., and Martin, B., 1987, Appalachian metallogenic map (abs.), *in* Sachs, J.S., ed., USGS research on mineral resources—1987, Third Annual V.E. McKelvey Forum on Mineral and Energy Resources: U.S. Geological Survey Circular 995, p. 22-23.
- Kyle, J.R., and Gutierrez, G.N., 1988, Origin of the Indian Creek sandstone-hosted lead deposits, southeast Missouri, USA, *in* Zachrisson, Ebbe, ed., Proceedings of the Seventh Quadrennial IAGOD Symposium, Luleå, Sweden, 1986: Stuttgart, E. Schweizerbart'sche Verlagsbuchhandlung, p. 669-684.
- Lindblom, Sten, 1986, Textural and fluid inclusion evidence for ore deposition in the Pb-Zn deposit at Laisvall, Sweden: *Economic Geology*, v. 81, no. 1, p. 46-64.
- Martens, J.H.C., 1964, Minerals of West Virginia: West Virginia Geological and Economic Survey, Educational Series 8, 41 p.
- Peper, J.D., in prep., Map showing the generalized geologic setting for metal deposits in the Appalachians: U.S. Geological Survey Miscellaneous Investigations Series Map, 2 sheets, scale 1:1,000,000.
- Rickard, D.T., Willdén, M.Y., Marinder, N.-E., and Donnelly, T.H., 1979, Studies on the genesis of the Laisvall sandstone lead-zinc deposit, Sweden: *Economic Geology*, v. 74, no. 5, p. 1255-1285.
- Schrijver, K., and Beaudoin, G., 1987, Diverse occurrences of galena-cemented sandstones in the Paleozoic, northern Appalachians, Quebec: *Canadian Institute of Mining and Metallurgy Bulletin*, v. 80, no. 908, p. 54-62.
- Smith, R.C., II, 1977, Zinc and lead occurrences in Pennsylvania: Pennsylvania Geological Survey, Mineral Resources Report 72, 318 p.

EC02**Descriptive Model 31a****Area = 220,100 km²****Sedimentary exhalative Zn-Pb Deposits**

New York
Pennsylvania, Maryland
Ohio, West Virginia
Virginia, Kentucky
Tennessee

[Model](#)*by* Sandra H.B. Clark**Rationale for Model Choice**

Although no sedimentary-exhalative Zn-Pb deposits are known in the east-central region, the probability for undiscovered deposits of this type was evaluated because conditions in some parts of the Appalachian basin are geologically analogous to the settings of known deposits elsewhere (Goodfellow and others, 1993). The analogous setting was recognized and resulted in some exploration interest in the late 1970s and early 1980s. (Wedow, 1983; Nuelle and Shelton, 1988). Wedow (1983) redesigned an empirical model for sedimentary-exhalative deposits that had been developed by Large (1980) to apply to a computer-assisted search for exploration targets in Appalachian Devonian rocks. Occurrences of barite in the Appalachian basin were studied to determine resource potential because of their similarity in geologic setting to large, economically important sedimentary-exhalative Zn-Pb and barite deposits in other areas such as Meggen, Germany (Nuelle and Shelton, 1986, 1988; Clark, 1988; Clark and Mosier, 1989). An assessment of the mineral resources of West Virginia (Cannon and others, 1994) suggests potential for sedimentary-exhalative Zn-Pb deposits based on geological characteristics and stream-sediment geochemistry. These studies were reevaluated in the light of more recent work about the nature and characteristics of sedimentary-exhalative Zn-Pb deposits to determine if parts of the Appalachian basin sedimentary sequence are permissive for the occurrence of undiscovered deposits.

Rationale for Tract Delineation

Examination of the metallogenic map for zinc, lead, and barite in the east-central United States (Clark, 1987) shows some occurrences in shale of Ordovician through Pennsylvanian age in Appalachian basin rocks. However, most occurrences are in shale of Middle to Late Devonian age. The Devonian black shale sequence was considered by Wedow (1983) to be the most likely sequence for hosting sedimentary-exhalative Pb-Zn deposits because major known deposits (Meggen and Rammelsburg, Germany and deposits in the Selwyn basin in Canada) are Devonian. Wedow's analysis (1983) consisted of maps showing the occurrence of nine attributes or parameters that were observed to be associated with known deposits and the areas of coincidence of more than one attribute within a 7.5-minute cell. The attributes were: (1) epicenter density of modern seismic activity; (2) extent of Silurian salt; (3) zone of Devonian volcanic activity, based on the distribution of the Tioga Ash Bed and heavy development of chert in Middle Devonian (Onesquethaw Group) rocks; (4) high-angle faults; (5) possible geosuture (the Alabama-New York lineament); (6) possible Silurian to Devonian hingeline based on isopach maps of the Silurian to Devonian carbonate sequence; (7) possible Middle to Late Devonian hingeline based on maps of the cumulative thickness of Devonian black shale; (8) occurrence of anomalously high amounts of supergene Mn-Fe; and (9) occurrence of the pteropod, *Styliolina fissurella*, which indicates favorable sedimentary environments. Maps showing the coincidence of attributes (both unweighted and weighted) led to identification of

the following four areas as possible exploration targets needing further study: (1) lowermost Upper Devonian rocks straddling the Clarendon-Linden fault in western and central New York; (2) an area in western Virginia and eastern West Virginia, generally coincident with the "Oriskany" Mn-Fe ores; (3) an area in West Virginia, Maryland, and Virginia along and near the trend of the Alabama-New York lineament between 38° and 40° N. latitude; and (4) an area in northeastern Ohio overlying and coincident with a significant thickness of Silurian salt and modern seismic activity.

Studies of barite occurrences in the Appalachians suggest that they can be interpreted as indicating the introduction of submarine-hydrothermal fluids (Nuelle and Shelton, 1986, 1988). However, because the barite nodules in the Appalachians are sparse, they can also be interpreted as resulting from biogenic processes at redox boundaries without the involvement of submarine-exhalative fluids that could have produced Zn-Pb deposits (Clark, 1988; Clark and Mosier, 1989).

The lack of evidence for strong Devonian tectonic activity was discussed by the assessment team and considered to be a basis for doubting the existence of undiscovered sedex deposits in the Appalachian basin. However, the thick sequences of black shale in the basin and indications that later tectonic activity may represent reactivation of pre-existing structures leaves open the possibility for Devonian synsedimentary-tectonic activity. Because black shale normally contains anomalously high base-metal contents, base-metal anomalies in themselves were not considered sufficient evidence for mineralization, but base-metal or barite anomalies and occurrences in combination with possible synsedimentary tectonism led to the conclusion that the presence of undiscovered sedimentary-exhalative Pb-Zn deposits could not be ruled out. The team concluded that the thick sequences of Middle Devonian to Lower Mississippian black shale and clastic sedimentary rocks are permissive for the occurrence of sedimentary-exhalative Pb-Zn deposits. The lower contact for the tract is derived from the map of generalized geologic setting for metal deposits in the eastern United States (J.D. Peper, written commun.; see Gair and others, 1987). The extension of the tract to depths of one kilometer or less is based on analysis of stratigraphic cross sections, structure contours, drilling depths, and lithofacies maps (deWitt and others, 1993; Oliver and others, 1971). Shale units less than 100 ft thick, such as the Chattanooga Shale, are excluded from the tract.

Rationale for Numerical Estimate

Although a large permissive tract was defined, the team estimated less than a one percent chance for an undiscovered deposit. This was because of the lack of known deposits and the lack of strong evidence of syndepositional tectonic activity or other indicators of the existence of undiscovered sedimentary-exhalative deposits.

References

- Cannon, W.F., Clark, S.H.B., Lesure, F.G., Hinkle, M.E., Paylor, R.L., King, H.M., Simard, C.M., Ashton, K.C., and Kite, J.S., 1994, Mineral resources of West Virginia: U.S. Geological Survey Miscellaneous Investigations Series Map I-2364-A, scale 1:500,000, with pamphlet, 14 p.
- Clark, S.H.B., 1987, Metallogenic map of zinc, lead, and barium deposits and occurrences in Paleozoic sedimentary rocks, east-central United States: U.S. Geological Survey, Miscellaneous Investigations Series Map I-1773, scale 1:2,500,000, with pamphlet, 77 p.
- _____, 1988, Origin of some shale-hosted barite nodules of the Appalachian basin of the eastern United States, *in* Zachrisson, Ebbe, ed., Proceedings of the seventh Quadrennial International Association on the Genesis of Ore Deposits Symposium, Luleå, Sweden, 1986: Stuttgart, Germany, E. Schweizerbart'sche Verlagsbuchhandlung, p. 259-268.

- Clark, S.H.B., and Mosier, E.L., 1989, Barite nodules in Devonian shale and mudstone of western Virginia: U.S. Geological Survey Bulletin 1880, 30 p.
- deWitt, Wallace, Jr., Roen, J.B., and Wallace, L.G., 1993, Stratigraphy of Devonian black shale and associated rocks in the Appalachian basin, *in* Roen, J.B., and Kepferle, R.C., eds., Stratigraphy of Devonian black shales and associated rocks in the Appalachian basin: U.S. Geological Survey Bulletin 1909-B, 57 p.
- Gair, J.F., Cannon, W.F., Peper, J.D., Cannon, S.S., and Martin, B., 1987, Appalachian metallogenic map (abs.), *in* Sachs, J.S., ed., USGS research on mineral resources—1987, Third Annual V.E. McKelvey Forum on Mineral and Energy Resources: U.S. Geological Survey Circular 995, p. 22–23.
- Goodfellow, W.D., Lydon, J.W., and Turner, R.J.W., 1993, Geology and genesis of stratiform sediment-hosted (SEDEX) Zn-Pb-Ag sulphide deposits, *in* Kirkham, R.V., Sinclair, W.D., Thorpe, R.I., and Duke, J.M., eds., Mineral deposit modeling: Geological Association of Canada Special Paper 40, p. 201–251.
- Large, Duncan, 1980, Geological parameters associated with sediment-hosted, submarine exhalative Pb-Zn deposits: *Geologisches Jahrbuch*, Riehe D, Heft 40, p. 59-129.
- Nuelle, L.M., and Shelton, K.L., 1986, Geologic and geochemical evidence of possible bedded barite deposits in Devonian rocks of the Valley and Ridge province, Appalachian Mountains: *Economic Geology*, v. 81, no. 6, p. 1408-1430.
- _____, 1988, Sediment-hosted barite of the Appalachian-basin Valley and Ridge Province: A product of tectonic influence on sedimentation, *in* Kisvarsanyi, Geza and Grant, S.K., eds., North American Conference on Tectonic Control of Ore Deposits and the Vertical and Horizontal Extent of Ore Systems, p. 501-511.
- Oliver, W.A., Jr., deWitt, Wallace, Jr., Dennison, J.M., Hoskins, D.M., and Huddle, J.W., 1971, Isopach and lithofacies maps of the Devonian in the Appalachian basin: Pennsylvania Topographic and Geologic Survey, Progress Report 182, 6 sheets.
- Peper, J.D., in prep., Map showing the U.S. generalized geologic setting for metal deposits in the eastern USA: U.S. Geological Survey Investigations Series Map, 2 sheets, scale 1,100,000.
- Wedow, Helmuth, Jr., 1983, A search for stratiform massive-sulfide exploration targets in Appalachian Devonian rocks—A case study using computer assisted attribute-coincidence mapping: U.S. Geological Survey Open-File Report 83-352, 38 p.

EC03**Mississippi Valley Deposits (Appalachian Zinc)**

New York

Descriptive Model 32b • Mark3 Index 109

Ohio, Michigan, Indiana

Area = 233,200 km²

Illinois, Kentucky

Tennessee, Mississippi

Alabama

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Sandra H.B. Clark, Joseph A. Briskey, Jr., and Dennis P. Cox

Rationale for Model Choice

Large resources of zinc occur in the Central Tennessee district in deposits like Elmwood and Gordonsville that have many similarities to major stratabound Appalachian Zn or Mississippi Valley (MVT) districts that extend from Tennessee to Newfoundland. Because of the distinctive geological features and importance of the Eastern United States deposits, they are the basis for definition of the world-wide Appalachian Zn model (Briskey, 1986a). This differentiation of Appalachian Zn as a subtype of MVT is supported by recent studies of lead isotopes, which indicate that the Appalachian sulfides have unusually homogeneous compositions, distinctly different from the arrays typical of MVT deposits in the mid-continent of the United States (Kesler and others, 1994; Carlson, 1994). Known Appalachian Zn districts in east-central United States are stratabound within Lower Cambrian to Lower Ordovician dolostones and limestones that formed as platform carbonate deposits in the Appalachian basin sedimentary sequence. Host rocks for known deposits are the Upper Cambrian and Lower Ordovician Knox Group and the Lower and Middle Ordovician Beekmantown Group (East and Central Tennessee, Shenandoah Valley, and Friedensville districts) and the Lower and Middle Cambrian Shady Dolomite (Austinville-Ivanhoe district).

The grade and tonnage model currently in use combines Appalachian Zn (Briskey, 1986a) with southeast Missouri Pb-Zn (Briskey, 1986b). Although MVT deposits have heterogeneous characteristics, the southeast Missouri Pb-Zn district differs from other major MVT districts in several significant ways (Sangster, 1983). The southeast Missouri deposits formed in a stable interior platform sequence separated from the underlying Middle Proterozoic craton by a major erosional surface and lie closer to cratonic basement than any other major MVT district. The proximity to granitic basement rocks may account for the Pb-dominant ores in southeast and central Missouri where Zn/(Zn+Pb) ratios are less than 0.3 (Sangster, 1983). Sorby Hills, Australia, has both geology and Zn/(Zn+Pb) ratio that are similar to southeast and central Missouri, but other major MVT deposits have Zn/(Zn+Pb) ratios between 0.5 and 1.0. Sangster (1983) suggested that a progression from Pb-rich to Zn-rich MVT deposits might reflect decreasing "communication" with metal sources within the craton. The silver content of southeast Missouri ores is higher than other MVT ores, and also may be related to proximity to the craton. Although no further work has been published to test Sangster's (1983) suggested classification, the anomalous nature of southeast and central Missouri ores relative to those formed in platform carbonate rocks of the Appalachian basin is clear.

Because of the anomalous nature of the southeast and central Missouri districts, we have deleted them from the grade and tonnage model (Mark3 index 109) to better represent undiscovered districts in this tract. The results for zinc are similar using both modified and unmodified versions and are considered to be realistic estimates based on the known deposits in the tract. However, the estimates for lead and silver endowment are much lower when

southeast and central Missouri are deleted and are considered to be a more realistic estimate of the expected lead endowment for the platform deposits not close to cratonic basement.

Rationale for Tract Delineation

The tract is defined by the distribution of Cambrian and Ordovician dolostones and limestones that are: (1) below the Middle Ordovician unconformity; (2) west and north of the Appalachian basin; and (3) less than one kilometer below the surface. These rocks contain the Central Tennessee district. The tract is bounded to the west by the Great Plains Region, and to the north by the Adirondack Region, both of which contain tracts permissive for MVT districts. On the east are other MVT tracts in the East Central Region. MVT mineralization may be localized near basement highs, facies changes, karst features, broad crestral areas of regional domes and local structural highs, joints, and faults—features that concentrated porosity and permeability, focused the flow of regional hydrothermal brines, and permitted introduced brines to mix with local fluids of different compositions. The most important districts in Tennessee are hosted in breccias and other structures resulting from dissolution and collapse of limestones and dolostones below the Middle Ordovician unconformity. Mixing of fluids with different chemical composition, hydrocarbon contents, and redox potential are among the possible causes of mineral precipitation.

The age of MVT mineralization in central Tennessee is uncertain, but a Mississippian or younger age has been proposed by Gaylord and Briskey (1983), based on similarities between stratabound deposits in the Knox Group and veins that cut overlying Middle Ordovician to Mississippian beds.

Rationale for Numerical Estimate

The area occupied by the Central Tennessee district was considered, and estimates in part were guided by how many undiscovered districts of approximately the same size as this district would fit into the permissive tract extended to a depth of 1 km. The team also considered vein deposits of the Central Kentucky district (Anderson, 1982), numerous exposures of non-economic MVT mineralized areas in northwestern Ohio and parts of adjacent States, especially the occurrences in Cambrian to Lower Ordovician host rocks (Botoman and Stieglitz, 1978; Carlson, 1983, 1994; Clark, 1987). The identification of brines with compositions of MVT fluids in Rossie vein deposits (Ayuso and others, 1987) also was considered of importance as a possible indication of undiscovered MVT districts in the carbonate sequences of western New York. Because MVT ore-forming processes in this region appear to have been concentrated in the broad crestral areas of domes and arches (Gaylord and Briskey, 1983; Briskey and others, 1986), these areas are considered to be more favorable than elsewhere. From a consideration of the sizes of the tract and favorable crestral areas of domes and arches, the size of the Central Tennessee district, and the number and distribution of non-economic MVT mineralized areas, to a depth of one km, the assessment team estimated that the probability of more than five undiscovered MVT districts occurring in the tract is less than one percent. The team had a high degree of confidence that one undiscovered MVT district exists near or below the Central Kentucky fluorspar district. For the 90th, 50th, 10th, 5th and 1st percentiles, the team estimated, respectively, 1, 2, 3, 4, and 5 or more Appalachian Zn districts consistent with the grade and tonnage model of Mosier and Briskey (1986), but with the southeast and central Missouri districts deleted.

References

Anderson, W.H., 1982, Barite deposits of Kentucky: Kentucky Geologic Survey Bulletin, Series II, no. 1, 56 p.

- Botoman, George, and Stieglitz, R.D., 1978, The occurrence of sulfide and associated minerals in Ohio: Ohio Department of Natural Resources, Division of Geological Survey, Report of Investigations No. 104, 11 p.
- Ayuso, R.A., Foley, N.K., and Brown, C.E., 1987, Source of lead and mineralizing brines for Rossie-type Pb-Zn Veins in the Frontenac axis area, New York: *Economic Geology*, v. 82, no. 2, p. 489-496.
- Briskey, J.A., 1986a, Descriptive model of Appalachian Zn, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models: U.S. Geological Survey Bulletin 1693*, p. 222.
- Briskey, J.A., 1986b, Descriptive model of southeast Missouri Pb-Zn, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models: U.S. Geological Survey Bulletin 1693*, p. 220.
- Briskey, J.A., Dingess, P.R., Smith, Fred, Gilbert, R.C., Armstrong, A.K., and Cole G.P., 1986, Localization and source of Mississippi Valley-type zinc deposits in Tennessee, USA, and comparisons with Lower Carboniferous rocks of Ireland, *in* Andrew, C.J., Crowe, S.F., Pennell, W.M., and Pyne, J.F., eds., *Geology and genesis of mineral deposits in Ireland: Dublin, Irish Association for Economic Geology*, p. 635-661.
- Carlson, E.H., 1983, The occurrence of Mississippi Valley-type mineralization in northwestern Ohio, *in* Kisvarsanyi, Geza, Grant, S.K., Pratt, W.P., and Koenig, J.W., ed., *International conference on Mississippi Valley type lead-zinc deposits: Rolla, University of Missouri*, p. 424-435.
- Carlson, E.H., 1994, Geologic, fluid inclusion, and isotopic studies of the Findlay Arch district, northwestern Ohio: *Economic Geology*, v. 89, no. 1, p. 67-90.
- Clark, S.H.B., 1987, Metallogenic map of zinc, lead, and barium deposits and occurrences in Paleozoic sedimentary rocks, east-central United States: U.S. Geological Survey Miscellaneous Investigations Series Map, scale 1:2,500,000 and pamphlet, 77 p.
- Gaylord, W.B., and Briskey, J.A., 1983, Tennessee zinc deposits field trip guidebook: Blacksburg, Virginia Polytechnic and State University, Guidebook No. 9, p. 116-151.
- Kesler, S.E., Cumming, G.L., Kristic, Dragan, and Appold, M.S., 1994, Lead isotopic geochemistry of Mississippi Valley-type deposits of the southern Appalachians: *Economic Geology*, v. 89, no. 2, p. 307-321.
- Mosier, D.L., and Briskey, J.A., 1986, Grade and tonnage model of southeast Missouri lead-zinc and Appalachian Zinc, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models: U.S. Geological Survey Bulletin 1693*, p. 211.
- Sangster, D.F., 1983, Mississippi Valley-type lead-zinc deposits—A geological melange, *in* Kisvarsanyi, Geza, Grant, S.K., Pratt, W.P., and Koenig, J.W., ed., *International conference on Mississippi Valley type lead-zinc deposits: Rolla, University of Missouri*, p. 7-9.

EC04**Descriptive Model 32b****Area = 145,400 km²****Mississippi Valley Deposits (Appalachian Zinc)**

New York
Pennsylvania, New Jersey, Maryland
Virginia, West Virginia
Ohio, Kentucky
Tennessee, Georgia
Alabama

[Model](#)

by Sandra H.B. Clark, Joseph A. Briskey, Jr., and Dennis P. Cox

Rationale for Model Choice

Carbonate sequences permissive for the occurrence of Appalachian Zn deposits occur in the Lower and Middle Devonian Onondaga Limestone and stratigraphically equivalent formations below Middle to Upper Devonian shale sequences, and in Middle Ordovician to Lower Devonian dolostones and limestones. Some small occurrences of zinc or lead have been reported in these rocks, but no deposits clearly representative of the Appalachian Zn type are known (Clark, 1987).

Rationale for Tract Delineation

The tract includes Middle Ordovician to Middle Devonian dolostone and limestone exposed or covered by less than 1 km of younger rocks. This tract is permissive for the occurrence of Appalachian Zn deposits but has a low probability for the occurrence of undiscovered districts.

Rationale for Numerical Estimate

Most Appalachian Zn districts are in, or spatially associated with, dissolution collapse breccias formed in the paleoaquifer below the Middle Ordovician section. However, in the Burkesville, Kentucky, deposit in the Central Tennessee district, large areas of porous and permeable primary carbonate depositional textures and structures in the Knox Group also are mineralized (Briskey and others, 1986). Although the relationship between these features and associated mineralized collapse breccias is debatable, the existence of this deposit suggests that porous and permeable zones other than those associated with the paleoaquifer might host Appalachian Zn districts. Consequently, carbonate rocks in this tract might be potential host rocks providing that the age of mineralization is Acadian or younger. Nonetheless, because the carbonate rocks that comprise the tract are above the paleoaquifer, and contain no known districts or deposits of this type, the study team estimated the probability for the occurrence of an undiscovered district to be less than one percent.

References

- Briskey, J.A., Dingess, P.R., Smith, Fred, Gilbert, R.C., Armstrong, A.K., and Cole G.P., 1986, Localization and source of Mississippi Valley-type zinc deposits in Tennessee, USA, and comparisons with Lower Carboniferous rocks of Ireland, *in* Andrew, C.J., Crowe, S.F., Pennell, W.M., and Pyne, J.F., eds., *Geology and genesis of mineral deposits in Ireland*: Dublin, Irish Association for Economic Geology, p. 635-661.
- Clark, S.H.B., 1987, Metallogenic map of zinc, lead, and barium deposits and occurrences in Paleozoic sedimentary rocks, east-central United States: U.S. Geological Survey Miscellaneous Investigations Series Map I-1773, scale 1:2,500,000 and pamphlet, 77 p.

EC05**Mississippi Valley Deposits (Appalachian Zinc)**

New York

Descriptive Model 32b • Mark3 Index 109

Pennsylvania, New Jersey, Maryland

Area = 42,300 km²

Virginia, West Virginia

North Carolina, Tennessee

Georgia, Alabama

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Sandra H.B. Clark, Joseph A. Briskey, Jr., and Dennis P. Cox

Rationale for Model Choice

Large resources of zinc occur in major stratabound Appalachian Zn or Mississippi Valley (MVT) districts from Tennessee to Newfoundland including the deposits at Friedensville, Austinville-Ivanhoe, Mascot-Jefferson City, Copper Ridge, and Newfoundland zinc. Because of the distinctive geological features and importance of the Eastern United States deposits, they are the basis for definition of the worldwide Appalachian Zn model (Briskey, 1986a). This differentiation of Appalachian Zn from MVT is supported by recent studies showing that the Appalachian sulfides have unusually homogeneous lead-isotope compositions, distinctly different from the typical leads of MVT deposits in the mid-continent of the United States (Kesler and others, 1994; Carlson, 1994). Known Appalachian Zn districts in the east-central United States are stratabound within Lower Cambrian to Lower Ordovician dolostones and limestones that formed as platform carbonate deposits in the Appalachian basin sedimentary sequence. Host rocks for known deposits are the Lower and Middle Cambrian Shady Dolomite (Austinville-Ivanhoe district), the Upper Cambrian and Lower Ordovician Knox Group and the Lower and Middle Ordovician Beekmantown Group, and stratigraphically equivalent carbonate units (East and Central Tennessee, Shenandoah Valley, and Friedensville districts).

The grade and tonnage model currently in use combines Appalachian Zn (Briskey, 1986a) with southeast Missouri Pb-Zn (Briskey, 1986b). Although MVT deposits have heterogeneous characteristics, the southeast Missouri Pb-Zn district differs from other major MVT districts in several significant ways (Sangster, 1983). The southeast Missouri deposits formed in a stable interior platform sequence separated from the underlying Middle Proterozoic craton by a major erosional surface and lie closer to cratonic basement than any other major MVT district. The close proximity to granitic basement rocks may account for the Pb-dominant ores in southeast and central Missouri where Zn/(Zn+Pb) ratios are less than 0.3 (Sangster, 1983). Sorby Hills, Australia, has geology and Zn/(Zn+Pb) ratio that are similar to southeast and central Missouri, but other major MVT deposits have Zn/(Zn+Pb) ratios between 0.5 and 1.0. Sangster (1983) suggested that a progression from Pb-rich to Zn-rich MVT deposits might reflect decreasing "communication" with metal sources within the craton. The silver content of southeast Missouri ores is higher than other MVT ores, and also may be related to proximity to the craton. Although no further work has been published to test Sangster's (1983) suggested classification, the anomalous nature of southeast and central Missouri ores relative to those formed in platform carbonate rocks of the Appalachian basin is clear.

Because of the anomalous nature of the southeast and central Missouri districts, we have deleted them from the grade and tonnage model (Mark3 index 109) to better represent undiscovered districts in the tract. The results for zinc are similar using both modified and unmodified versions and are considered to be realistic estimates based on the known deposits in the tract. However, the estimates for lead and silver endowment are much lower when

southeast and central Missouri are deleted and are considered to be a more realistic estimate of the expected lead endowment for the platform deposits not close to cratonic basement.

Rationale for Tract Delineation

This tract, to a depth of one kilometer, includes the exposed part of the Cambrian and Ordovician dolostones and limestones below the Middle Ordovician unconformity on the east side of the Appalachian basin, and includes the host rocks for four major known Appalachian Zn districts, Friedensville, Austinville-Ivanhoe, Mascot-Jefferson City, and Copper Ridge. On its north end, the tract borders the Northern Appalachian and Adirondacks Regions, both of which contain tracts permissive for the occurrence of undiscovered MVT districts.

MVT mineralization may be localized near basement highs, facies changes, karst features, broad crestral areas of regional domes and local structural highs, joints, and faults—features that concentrated porosity and permeability, focused the flow of regional hydrothermal brines, and permitted introduced caused the brines to mix with local fluids of different compositions. The most important districts in Tennessee are hosted in breccias and other structures resulting from dissolution and collapse of limestones and dolostones below the Middle Ordovician unconformity. Mixing of fluids with different chemical composition, hydrocarbon contents, and redox potential are among the possible causes of mineral precipitation.

The age of MVT mineralization in the Appalachian area is uncertain. Some investigators suggest that mineralization may be as young as late Paleozoic and be associated with the Alleghenian orogeny (Hearn and others, 1987), which took place from about 330 Ma to 230 Ma in the central and southern Appalachians (Glover and others, 1983). Other investigators have summarized evidence for a pre-Alleghenian age for mineralization, which may have been associated with the Taconic or Acadian orogenies, or perhaps the earliest part of the Alleghenian event (e.g., Briskey and others, 1986; Kesler and others, 1990, 1994).

Rationale for Numerical Estimate

Exploration in this tract has been intensive, especially in Tennessee near the major known districts. However, the tract is large, and much of the geology is obscured by soil and vegetation. The team believed that it was probable that one undiscovered district exists in the tract. For the 90th, 50th, 10th 5th, and 1st percentiles, the team estimated respectively 0, 1, 3, 3, and 4 or more undiscovered Appalachian Zn districts consistent with the grade and tonnage model of Mosier and Briskey (1986) with the southeast and central Missouri districts deleted (Mark3 index 109). The density of known districts relative to surface area in this tract is higher than in the largely subsurface tracts to the west. Among the probable causes for this higher density are: (1) the presence of at least two, rather than one, major stratigraphic horizons containing MVT districts; (2) aerial concentration of these horizons in steeply dipping, tectonically repeated sections in narrow, elongate bands of rock; and (3) their exposure in mountains and ridges, which prevents accumulations of thick covering rocks and sediments. These features also have contributed to a relatively high proportion of districts discovered to total districts discovered and estimated in the tract. It also is possible that the Appalachian tracts have a naturally higher density of MVT districts for geologic reasons unknown today.

References

- Briskey, J.A., 1986a, Descriptive model of Appalachian Zn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 222.
- Briskey, J.A., 1986b, Descriptive model of southeast Missouri Pb-Zn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 220.

- Briskey, J.A., Dingess, P.R., Smith, Fred, Gilbert, R.C., Armstrong, A.K., and Cole G.P., 1986, Localization and source of Mississippi Valley-type zinc deposits in Tennessee, USA, and comparisons with Lower Carboniferous rocks of Ireland, *in* Andrew, C.J., Crowe, S.F., Pennell, W.M., and Pyne, J.F., eds., *Geology and genesis of mineral deposits in Ireland*: Dublin, Irish Association for Economic Geology, p. 635-661.
- Carlson, E.H., 1994, Geologic, fluid, inclusion, and isotopic studies of the Findlay Arch district, northwestern Ohio: *Economic Geology*, v. 89, no. 1, p 67-90.
- Glover, L., Speer, J.A., Russell, G.S., and Farrar, S.S., 1983, Ages of regional metamorphism and ductile deformation in the central and southern Appalachians: *Lithos*, v. 16, p. 223-245.
- Hearn, P.P., Jr., Sutter, J.F., and Belkin, H.E., 1987, Evidence for Late-Paleozoic brine migration in Cambrian carbonate rocks of the central and southern Appalachians—Implications for Mississippi Valley-type sulfide mineralization: *Geochimica et Cosmochimica Acta*, v. 51, no. 5m p. 1323-1334.
- Kesler, S.E., and van der Pluijm, D.A., 1990, Timing of Mississippi Valley-type mineralization—Relations to Appalachian orogenic events: *Geology*, v. 18, p. 1115-1118.
- Kesler, S.E., Cumming, G.L., Kristic, Dragan, and Appold, M.S., 1994, Lead isotopic geochemistry of Mississippi Valley-type deposits of the southern Appalachians: *Economic Geology*, v. 89, no. 2, p. 307-321.
- Mosier, D.L., and Briskey, J.A., 1986, Grade and tonnage model of southeast Missouri lead-zinc and Appalachian Zinc *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 211.
- Sangster, D.F., 1983, Mississippi Valley-type lead-zinc deposits: a geological melange, *in* Kisvarsanyi, Geza, Grant, S.K., Pratt, W.P., and Koenig, J.W., ed., *International conference on Mississippi Valley type lead-zinc deposits*: Rolla, University of Missouri, p. 7-9.

EC06**Mississippi Valley Deposits (Appalachian Zinc)**

Pennsylvania

Descriptive Model 32b • Mark3 Index 109

New Jersey, Maryland, Virginia

Area = 44,500 km²

West Virginia, Tennessee

Georgia, Alabama

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Sandra H.B. Clark, Joseph A. Briskey, Jr. and Dennis P. Cox

Rationale for Model Choice

Large resources of zinc occur in major stratabound Appalachian Zn or Mississippi Valley (MVT) districts from Tennessee to Newfoundland including the deposits at Friedensville, Austinville-Ivanhoe, Mascot-Jefferson City, Copper Ridge, and Newfoundland zinc. Because of the distinctive geological features and importance of the eastern United States deposits, they are the basis for definition of the worldwide Appalachian Zn model (Briskey, 1986a). This differentiation of Appalachian Zn from MTV is supported by recent studies showing that the Appalachian sulfides have unusually homogeneous lead-isotope compositions, distinctly different from the typical leads of MVT deposits in the mid-continent of the United States (Kesler and others, 1994; Carlson, 1994). Known Appalachian Zn districts in the east-central United States are stratabound within Lower Cambrian to Lower Ordovician dolostones and limestones that formed as platform carbonate deposits in the Appalachian basin sedimentary sequence. Host rocks for known deposits are the Lower and Middle Cambrian Shady Dolomite (Austinville-Ivanhoe district), the Upper Cambrian and Lower Ordovician Knox Group and the Lower and Middle Ordovician Beekmantown Group, and stratigraphically equivalent carbonate units (East and Central Tennessee, Shenandoah Valley, and Friedensville districts).

The grade and tonnage model currently in use combines Appalachian Zn (Briskey, 1986a) with southeast Missouri Pb-Zn (Briskey, 1986b). Although MVT deposits have heterogeneous characteristics, the southeast Missouri Pb-Zn district differs from other major MVT districts in several significant ways (Sangster, 1983). The southeast Missouri deposits formed in a stable interior platform sequence separated from the underlying Middle Proterozoic craton by a major erosional surface and lie closer to cratonic basement than any other major MVT district. The proximity to granitic basement rocks may account for the Pb-dominant ores in southeast and central Missouri where Zn/(Zn+Pb) ratios are less than 0.3 (Sangster, 1983). Sorby Hills, Australia, has geology and a Zn/(Zn+Pb) ratio that is similar to southeast and central Missouri, but other major MVT deposits have Zn/(Zn+Pb) ratios between 0.5 and 1.0. Sangster (1983) suggested that a progression from Pb-rich to Zn-rich MVT deposits might reflect decreasing "communication" with metal sources within the craton. The silver content of southeast Missouri ores is higher than other MVT ores, and also may be related to proximity to the craton. Although no further work has been published to test Sangster's (1983) suggested classification, the anomalous nature of southeast and central Missouri ores relative to those formed in platform carbonate rocks of the Appalachian basin is clear.

Because of the anomalous nature of the southeast and central Missouri districts, we have deleted them from the grade and tonnage model (Mark3 index 109) to better represent undiscovered districts in the tract. The results for zinc are similar using both modified and unmodified versions and are considered to be realistic estimates based on the known deposits in other tracts. However, the estimates for lead and silver endowment are much lower when southeast and central Missouri are deleted and are considered to be a more realistic estimate of the expected lead endowment for the platform deposits not close to cratonic basement.

Rationale for Tract Delineation

This tract is the concealed counterpart of Tract EC05. It is defined by the presence, in the subsurface, of Cambrian to Ordovician dolostones and limestones beneath the Middle Ordovician unconformity on the east side of the Appalachian basin, and includes the host rocks for the major known Appalachian Zn districts. These rocks do not crop out within the tract but are covered by no more than one kilometer of younger Paleozoic sedimentary rocks, commonly in the troughs of synclines. MVT mineralization may be localized near basement highs, facies changes, karst features, broad crestal areas of regional domes and local structural highs, joints, and faults—features that concentrated porosity and permeability, focused the flow of regional hydrothermal brines, and permitted introduced brines to mix with local fluids of different compositions. The most important districts in Tennessee are hosted in breccias and other structures resulting from dissolution and collapse of limestones and dolostones below the Middle Ordovician unconformity. Mixing of fluids with different chemical composition, hydrocarbon contents, and redox potential are among the possible causes of mineral precipitation.

The age of MVT mineralization in the Appalachian area is uncertain. Some investigators suggest that mineralization may be as young as late Paleozoic and be associated with the Alleghenian orogeny (Hearn and others, 1987), which took place from about 330 Ma to 230 Ma in the central and southern Appalachians (Glover and others, 1983). Other investigators have summarized evidence for a pre-Alleghenian age for mineralization, which may have been associated with the Taconic or Acadian orogenies, or perhaps the earliest part of the Alleghenian event (e.g., Briskey and others, 1986; Kesler and others, 1990, 1994).

Rationale for Numerical Estimate

Because the rocks in this tract are the concealed equivalents of exposed, well-explored rocks in the adjacent tract, the study team decided that the best way to estimate the number of undiscovered districts was to assume this tract also has the same areal density of Appalachian Zn districts as does the exposed tract. Although there are no known districts in this concealed tract, there also are no known geologic reasons why these two tracts would have different densities of districts. The exposed tract contains four known and one expected (50th percentile) undiscovered districts in an area of 42,300 km². Consequently, this concealed tract, which has a somewhat larger area of 46,200 km² is expected (at the 50th percentile) proportionally to contain about 6 undiscovered districts. For the 90th, 50th, 10th, 5th and 1st percentiles, the team estimated 3, 6, 8, 11 and 14 or more Appalachian Zn districts consistent with the grade and tonnage model of Mosier and Briskey (1986) but with the southeast and central Missouri districts deleted (Mark3 index 109).

The density of known districts relative to surface area in this tract, like the exposed tract, is higher than in the largely subsurface tracts to the west. Among the probable causes for a higher density are: (1) the presence of at least two, rather than one, major stratigraphic horizons containing MVT districts; (2) aerial concentration of these horizons in steeply dipping, tectonically repeated sections in narrow, elongate bands of rock; and (3) their exposure in mountains and ridges, which prevents accumulations of thick covering rocks and sediments. It also is possible that the Appalachian tracts have a naturally higher density of MVT districts for geologic reasons unknown today.

References

- Briskey, J.A., 1986a, Descriptive model of Appalachian Zn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 222.
- Briskey, J.A., 1986b, Descriptive model of southeast Missouri Pb-Zn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 220.

- Briskey, J.A., Dingess, P.R., Smith, Fred, Gilbert, R.C., Armstrong, A.K., and Cole G.P., 1986, Localization and source of Mississippi Valley-type zinc deposits in Tennessee, USA, and comparisons with Lower Carboniferous rocks of Ireland, *in* Andrew, C.J., Crowe, S.F., Pennell, W.M., and Pyne, J.F., eds., *Geology and genesis of mineral deposits in Ireland*: Dublin, Irish Association for Economic Geology, p. 635-661.
- Carlson, E.H., 1994, Geologic, fluid, inclusion, and isotopic studies of the Findlay Arch district, northwestern Ohio: *Economic Geology*, v. 89, no. 1, p. 67-90.
- Glover, L., Speer, J.A., Russell, G.S., and Farrar, S.S., 1983, Ages of regional metamorphism and ductile deformation in the central and southern Appalachians: *Lithos*, v. 16, p. 223-245.
- Hearn, P.P., Jr., Sutter, J.F., and Belkin, H.E., 1987, Evidence for Late-Paleozoic brine migration in Cambrian carbonate rocks of the central and southern Appalachians—Implications for Mississippi Valley-type sulfide mineralization: *Geochimica et Cosmochimica Acta*, v. 51, no. 5, p. 1323-1334.
- Kesler, S.E., and van der Pluijm, D.A., 1990, Timing of Mississippi Valley-type mineralization—Relations to Appalachian orogenic events: *Geology*, v. 18, p. 1115-1118.
- Kesler, S.E., Cumming, G.L., Kristic, Dragan, and Appold, M.S., 1994, Lead isotopic geochemistry of Mississippi Valley-type deposits of the southern Appalachians: *Economic Geology*, v. 89, no. 2, p. 307-321.
- Mosier, D.L., and Briskey, J.A., 1986, Grade and tonnage model of southeast Missouri lead-zinc and Appalachian Zinc, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 211.
- Sangster, D.F., 1983, Mississippi Valley-type lead-zinc deposits: a geological melange, *in* Kisvarsanyi, Geza, Grant, S.K., Pratt, W.P., and Koenig, J.W., ed., *International conference on Mississippi Valley type lead-zinc deposits*: Rolla, University of Missouri, p. 7-9.

GB01**Skarn Cu Deposits****California****Descriptive Model 18b • Mark3 Index 8****Area = 17,700 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Dennis P. Cox**Rationale for Model Choice**

Although copper skarn deposits are much less common in this tract than lead-zinc dominated systems, widespread igneous intrusions into carbonate rocks represent permissive conditions for copper skarn formation. Copper skarn mineral assemblages were observed in ores from the Gold Bottom-Copper Queen mine (D.P. Cox, unpub. data).

Rationale for Tract Delineation

The permissive tract is defined to be that part of the area that is underlain by Proterozoic and Paleozoic carbonate rocks, and that is near Mesozoic plutons. Small areas of basin fill more than 1 km in depth are excluded.

Rationale for Numerical Estimate

For the 90th, 50th, 10th, and 5th percentiles, the team estimated 0, 1, 1, and 2 or more copper skarn deposits consistent with the grade and tonnage model of Jones and Menzie (1986).

Reference

Jones, G.W., and Menzie, W.D., 1986, Grade-tonnage model of Cu skarns, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 86-89.

GB02**Skarn Cu Deposits****Nevada****Descriptive Model 18b • Mark3 Index 8****Oregon, Idaho****Area = 111,900 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by D.P. Cox, Steve Ludington, B.R. Berger, M.G. Sherlock, and D.A. Singer, (USGS); and J.V. Tingley (Nevada Bureau of Mines and Geology).

Important Examples and Rationale for Model Choice

Copper skarns are numerous in Nevada with more than 50 occurrences listed in 20 localities. The seven deposits from Nevada included in the copper skarn grade and tonnage model of Jones and Menzie (1986) are significantly lower in tonnage and higher in grade than the other deposits in the model. However, because these seven deposits are all located in the same general area near Yerington, and because we believe that undiscovered copper skarn deposits are, for the most part, located elsewhere in Nevada, we have relied on the original unmodified model. Copper skarns in the Copper Canyon and Robinson districts are included with the porphyry copper deposits.

Most of the known deposits are in the Yerington district and are of Jurassic age. The Victoria deposit and other skarns in the Dolly Varden district are also Jurassic. The Contact district in northeastern Nevada contains many occurrences of unrecorded grade and tonnage associated with Jurassic plutons. Two deposits associated with Cretaceous plutons are in the Adelaide and Santa Fe districts. Tertiary copper skarn deposits occur in the Battle Mountain district. Other copper skarn occurrences near Tertiary plutons are numerous.

Rationale for Tract Delineation

The tract permissive for copper skarn deposits is defined as an area extending 10 km outward from the outcrop of a pluton, or, in the case that the pluton has a geophysical expression as discussed by Grauch and others (1988), from the inferred subsurface boundary of the pluton, based on its geophysical expression. It also includes areas around plutons whose presence is inferred from geophysics or from the occurrence of skarn mineralization. The tract covers about 40 percent of the area of the State. Carbonate-bearing and calcareous sedimentary rocks are present in all sedimentary assemblages in Nevada (Stewart, 1980), hence, no areas were excluded from the permissive tract on the basis of age or composition of intruded country rock. Those parts of the tract that do contain assemblages rich in carbonate rocks, however, are considered favorable.

About 72 percent of the permissive tract is covered by 1 km or less of upper Tertiary and Quaternary rocks and sediments. Areas covered by more than 1 km (Blakely and Jachens, 1991) are excluded as are areas that are within a Tertiary caldera. In these latter areas, permissive pre-Tertiary host rocks are likely to be covered by more than 1 km of volcanic rock.

Rationale for Numerical Estimate

Our estimate was based on the belief that the number of concealed undiscovered deposits within 1 km of the surface is at least as large as the number of known deposits. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 6, 10, 14, 16, and 18 or more undiscovered deposits in the delineated area that are consistent with the grade and tonnage model for copper skarn of Jones and Menzie (1986a).

References

- Blakely, R.J., and Jachens, R.C., 1991, Concealed ore deposits in Nevada: insights from three-dimensional analysis of gravity and magnetic anomalies, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., *Geology and ore deposits of the Great Basin—Symposium proceedings*: Reno, Geological Society of Nevada, v. 1, April 1990, p. 185-192.
- Grauch, V.J.S., Blakely, R.J., Blank, H.R., Oliver, H.W., Plouff, Donald, and Ponce, D.A., 1988, Geophysical delineation of granitic plutons in Nevada: U.S. Geological Survey Open-File Report 88-11, 7 p.
- Jones, G.W., and Menzie, W.D., 1986, Grade-tonnage model of Cu skarns, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 86-89.
- Stewart, J.H., 1980, *Geology of Nevada*: Nevada Bureau of Mines and Geology Special Pub. 4, 136 p.

GB03**Skarn Cu Deposits**Utah
Idaho

Descriptive Model 18b • Mark3 Index 8

Area = 43,400 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Douglas B. Stoesser

Rationale for Model Choice

The model used here follows Einaudi and others (1981) and Cox and Singer (1986) that distinguish two types of copper skarns, those related to porphyry copper deposits and those related to other intrusions. Here the latter model type is considered.

Rationale for Tract Delineation

The basis for the tract delineation is areas where epizonal calc-alkaline granitic stocks intrude carbonate rocks. Thus, the permissive tract has the same geographic boundaries as the one for skarn-related porphyry copper deposits and other types of skarns.

Important Examples of Deposit Type

There are no significant examples of this type of deposit in Utah. Seven minor occurrences of this type are listed in Reid (1991) for western Utah, but most are part of polymetallic replacement districts, and it is not clear whether all are actually copper skarns.

Rationale for Numerical Estimate

Although no significant deposits of this type are known for Utah, minor deposits occur in western Utah and the region is permissive in terms of the overall geological environment. Large parts of the permissive tract are covered, and, for the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 1, 2, 4, and 6 deposits consistent with the grade and tonnage model for Cu skarn deposits of Cox and Theodore (1968).

References

- Cox, D.P., and Theodore, T.G., 1986, Descriptive model of Cu skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 86-89.
- Einaudi, M.T., Meinert, L.D., and Newberry, R.J., 1981, Skarn deposits, *in* Skinner, B.J., ed., Economic Geology Seventy-Fifth Anniversary Volume, 1905-1980: Lancaster, Pennsylvania, Economic Geology Publishing Company, p. 317-392.
- Reid, J.E., 1991, Skarn occurrences in Utah and the potential for associated gold mineralization: Utah Geological Survey Contract Report 91-13, 49 p.

GB04**Skarn Zn-Pb Deposits**Utah
Idaho

Descriptive Model 18c • Mark3 Index 22

Area = 43,400 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* Douglas B. Stoeser**Rationale for Model Choice**

Tertiary felsic to intermediate intrusive rocks emplaced into predominantly Paleozoic carbonate rocks have produced some zinc-lead skarn deposits in western Utah.

Rationale for Tract Delineation

The permissive tract for this deposit type is defined primarily by the distribution of intrusive rocks and suitable reactive host rocks, especially carbonate-bearing sedimentary rocks. Because of the extensive occurrence of carbonate sedimentary rocks in western Utah, and the genetic association with porphyry copper-type deposits, we used the same geographic areas as for porphyry copper deposits. The tract consists of three east-trending belts in western Utah. The southernmost of the three is less deeply eroded than the other two, and any undiscovered skarn deposits would most likely be concealed by the volcanic and alluvial cover. Aeromagnetic surveys were employed to define areas of high magnetics that might indicate a buried intrusive body adjacent to which might be concealed skarn deposits.

Important Examples of Deposit Type

Although a relatively rare deposit worldwide, western Utah has two deposits of this type, Ophir and Crypto (Fish Springs District). Of interest is that Crypto was a blind orebody. There are no known prospects. Other minor prospects and deposits are listed in Reid, 1991.

Rationale for Numerical Estimate

In making our estimates, the team considered the broad permissive terrane, coupled with the presence of two examples of this relatively rare deposit type. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 2, 3, 4, and 7 districts consistent with the grade and tonnage model for skarn Zn-Pb deposits (Mosier, 1986).

References

- Mosier, D.L., 1986, Grade and tonnage model of Zn-Pb skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 90-93.
- Reid, J.E., 1991, Skarn occurrences in Utah and the potential for associated gold mineralization: Utah Geological Survey Contract Report 91-13, 49 p.

GB05**Skarn Au Deposits**

Nevada

Descriptive Model Bull. 1930 • Mark3 Index 105

Oregon, Idaho

Area = 112,100 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by D.P. Cox, Steve Ludington, B.R. Berger, M.G. Sherlock, and D.A. Singer, (USGS); and J.V. Tingley (Nevada Bureau of Mines and Geology)

Important Examples and Rationale for Model Choice

Skarn deposits with gold as the principal product are important in Nevada, as illustrated by the gold production from the Copper Canyon and McCoy areas. Theodore and others (1991) found that the presence of gold is the only consistent difference between gold-bearing and non gold-bearing base-metal skarns. Deposits in which gold is the major product are included in this model. Seven of these are in the Battle Mountain district; all are above the median tonnage; but only one deposit, Fortitude, is richer than the median gold grade (8.6 g/mt).

Rationale for Tract Delineation

The tract permissive for gold skarn deposits is defined as an area extending 10 km outward from the outcrop of a pluton, or, in the case that the pluton has a geophysical expression as discussed by Grauch and others (1988), from the inferred subsurface boundary of the pluton, based on its geophysical expression. It also includes areas around plutons whose presence is inferred from geophysics or from the occurrence of skarn mineralization. The tract covers about 40 percent of the area of the State. Carbonate-bearing and calcareous sedimentary rocks are present in all sedimentary assemblages in Nevada (Stewart, 1980), hence, no areas were excluded from the permissive tract on the basis of age or composition of intruded country rock.

About 72 percent of the permissive tract is covered by 1 km or less of upper Tertiary and Quaternary rocks and sediments. Areas covered by more than 1 km (Blakely and Jachens, 1991) are excluded as are areas that are within a Tertiary caldera. In these latter areas, permissive pre-Tertiary host rocks are likely to be covered by more than 1 km of volcanic rock.

Meinert (1989) suggested that host rocks for gold skarns are typically carbonate-bearing sequences with an important clastic or volcanoclastic component. These rocks commonly represent parts of accreted terranes. Because the known examples in Nevada are related to Tertiary plutons, a favorable area for gold skarns might be based on the intersection of Tertiary plutons and accreted terranes of the Black Rock, Paradise, Pine Nut, Golconda, and Roberts Mountains assemblages and the overlying Mesozoic carbonate assemblage. Undiscovered deposits are believed to exist mainly in concealed parts of the permissive tract.

Rationale for Numerical Estimate

About 2.5 times as much of the permissive tract is concealed as is exposed, and we estimated an expected value of undiscovered deposits of about three to four. Because the grade and tonnage model of Theodore and others (1991) includes some very small deposits, we felt we could estimate more accurately using a model that is truncated to include only those deposits with more than 25,000 metric tons of mineralized rock. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 1, 3, 6, 8, and 12 or more deposits that are comparable in grade and tonnage to the gold skarn grade and tonnage model (truncated) of Theodore and others (1991).

References

- Blakely, R.J., and Jachens, R.C., 1991, Concealed ore deposits in Nevada: insights from three-dimensional analysis of gravity and magnetic anomalies, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., *Geology and ore deposits of the Great Basin—Symposium proceedings*: Reno, Geological Society of Nevada, v. 1, April 1990, p. 185-192.
- Grauch, V.J.S., Blakely, R.J., Blank, H.R., Oliver, H.W., Plouff, Donald, and Ponce, D.A., 1988, *Geophysical delineation of granitic plutons in Nevada*: U.S. Geological Survey Open-File Report 88-11, 7 p.
- Meinert, L.D., 1989, Gold skarn deposits—Geology and exploration criteria, *in* Keays, R.R., Ramsay, W.R.H., and Groves D.I., eds., *The geology of gold deposits—The perspective in 1988*: Economic Geology Monograph 6, p. 537-552.
- Stewart, J.H., 1980, *Geology of Nevada*: Nevada Bureau of Mines and Geology Special Pub. 4, 136 p.
- Theodore, T.G., Orris, G.J., Hammarstrom, J.M., and Bliss, J.D., 1991, *Gold-bearing skarns*: U.S. Geological Survey Bulletin 1930, 61 p.

GB06**Skarn Au Deposits**Utah
Idaho

Descriptive Model Bull. 1930 • Mark3 Index 105

Area = 43,400 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by Douglas B. Stoeser***Rationale for Model Choice**

Theodore and others (1991) recognize a class of skarn deposits as gold-bearing skarn if they have an average gold grade of at least 1 g/t and typical skarn mineralogy. They recognize two subtypes of gold-bearing skarns: gold-skarn and byproduct gold-skarn. They define gold-skarns as skarn deposits where gold is the principal commodity, and byproduct gold-skarns as deposits where gold had been or is being recovered as a byproduct. Only the gold-skarn subtype is considered here, because byproduct gold-skarns are primarily Cu skarn and Pb-Zn skarn and these deposit types are considered elsewhere in the present study. Western Utah has been judged to be permissive for this deposit type by (Reid, 1991).

Rationale for Tract Delineation

Gold skarns are found in the same areas as skarns enriched in other metals, where epizonal calc-alkaline granitoid stocks intrude carbonate rocks. Theodore and others (1991) indicated that the associated intrusions are typically "compositionally expanded I-type felsic and intermediate plutons, dikes, sills, or stocks that may or may not be porphyritic." They also state that host rocks include a wide variety of sedimentary and igneous rocks, including limestone, dolomite, clastic sedimentary rocks, volcanic rocks, and granitoids, with a calcareous component typically being present. The Tertiary magmatic belts of western Utah contain appropriate intrusions, and because of the approximately seventy percent alluvial cover within the magmatic belts, the unknown distribution of rock types beneath that cover, and the fact that the bulk of these terranes are underlain by a sedimentary shelf sequence dominated by carbonate sedimentary rocks, we use the same permissive terranes for gold skarns as for porphyry copper deposits.

Important Examples of Deposit Type

There are no significant gold skarn deposits in Utah and the only known occurrence is the Midas deposit in the Gold Hill district that produced 600 metric tons of ore with a grade of 25 g/t Au (Theodore and others, 1991).

Rationale for Numerical Estimate

This deposit type has not been vigorously sought in Utah until recently. The median deposit for this model (Theodore and others, 1991) is quite small (213,000 metric tons at 8.6 g/t equaling 59,000 oz Au). We judged ourselves unable to estimate numbers of deposits as small as some of those in the grade and tonnage model, and we made our estimate with reference to a truncated model consisting only of those deposits that are larger than 25,000 metric tons. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 1, 2, and 4 or more deposits consistent with the grade and tonnage model of Theodore and others (1991), truncated as described above.

References

- Reid, J.E., 1991, Skarn occurrences in Utah and the potential for associated gold mineralization: Utah Geological Survey Contract Report 91-13, 49 p.
- Theodore, T.G., Orris, G.J., Hammarstrom, J.M., and Bliss, J.D., 1991, Gold-bearing skarns: U.S. Geological Survey Bulletin 1930, 61 p.

GB07**Porphyry Cu Deposits**

California

Descriptive Model 17 • Mark3 Index 4

Area = 24,500 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Dennis P. Cox

Rationale for Model Choice

Plutons, mainly of Jurassic age, are closely associated with copper- and lead-zinc skarns and polymetallic replacement and vein deposits in the Great Basin of California. It is possible that one or more of these plutons could have given rise to a porphyry copper system, although few examples are known. Outcrops of felsic porphyry with an aplitic groundmass and pervasive sericitic alteration was observed at the Copper Queen mine east of Trona (D.P. Cox, unpub. data) suggesting that favorable conditions for porphyry mineralization might have occurred, at least, locally. In addition, records in the Bureau of Land Management office in Ridgecrest, Calif., indicate that there is a deposit believed to be a porphyry copper deposit being explored in the El Paso Mountains.

Rationale for Tract Delineation

The permissive tract is a nearly continuous area that encompasses many small plutons that intrude Precambrian metamorphic rocks and Precambrian and Paleozoic sedimentary rocks in a highly faulted part of the Mesozoic continental margin. Small areas of basin fill more than 1 km in depth are excluded.

Rationale for Numerical Estimate

Porphyry systems that are well exposed at the surface are marked by highly visible alteration patterns. Since no such alteration has been observed, it is likely that any deposits awaiting discovery would be largely concealed by alluvium or Tertiary sedimentary or volcanic rocks.

For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 1, and 2 or more porphyry copper deposits consistent with the grade and tonnage model of Singer and others (1986).

Reference

Singer, D.A., Mosier, D.L., and Cox, D.P., 1986, Grade-tonnage model of porphyry copper, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 77-81.

GB08**Porphyry Cu Deposits**

Nevada

Descriptive Model 17 • Mark3 Index 4

Oregon, Idaho

Area = 111,300 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by D.P. Cox, Steve Ludington, B.R. Berger, M.G. Sherlock, and D.A. Singer, (USGS); and J.V. Tingley (Nevada Bureau of Mines and Geology)

Important Examples and Rationale for Model Choice

Porphyry copper deposits are characterized by stockworks and disseminations of chalcopyrite, molybdenite, and gold in porphyritic stocks and in nearby country rocks. They are commonly surrounded by concentric zones of potassic, phyllic, and propylitic hydrothermal alteration. Nevada examples of porphyry copper deposits appear to be well-represented by the worldwide general porphyry copper model of Singer and others (1986) (Mark3 index 4).

Porphyry copper, skarn-related deposits, an important variant of this model characterized by chalcopyrite-bearing quartz-sulfide stockwork veinlets in porphyritic intrusive rock and adjacent skarn are formed where porphyry systems are emplaced in carbonate rocks or other reactive wall rocks. Examples in Nevada are in the Cretaceous Robinson district, where several deposits form a linear belt extending 10 km west from Ely. Deposits in the Robinson district were the first in Nevada to produce copper from low-grade ores by open pit mining. Production began in 1908 on a reserve of 26 million metric tons of 2 percent ore (Joralemon, 1973). The district produced more than 3 million metric tons of copper from five open pits before closing in the late 1970s. Drilling in the 1990s has identified reserves of about 183 million metric tons containing 0.61 percent copper and 0.38 g/mt gold (Mining Magazine, Oct. 1992).

Carbonate rocks are widespread in Nevada and it was not possible to delineate separate tracts or make separate estimates for these two types of deposits, therefore the general porphyry copper model was used. Tonnages and grades of the known deposits in Nevada are well represented by this model.

Rationale for Tract Delineation

The tract permissive for porphyry copper deposits is defined as an area extending 10 km outward from the outcrop of a pluton, or, in the case that the pluton has a geophysical expression as discussed by Grauch and others (1988), from the inferred subsurface boundary of the pluton based on its geophysical expression. It also includes areas around plutons whose presence is inferred from geophysics or from the occurrence of skarn mineralization. The tract covers about 40 percent of the area of the State.

Porphyry copper deposits tend to form in and around epizonal plutons rather than deep-seated batholiths, but, because we have only very general paleodepth information for many plutons in Nevada (Barton and others, 1988), no part of the tract could be excluded on this basis. Because of a lack of unequivocal knowledge of the age of all Nevada plutons, the tract for all three ages has the same physical boundaries. The most favorable area for deposits of Early Cretaceous age is a belt including the Eureka, White Pine, and Robinson districts. An area of Late Cretaceous plutons and associated copper skarn deposits near Luning is also favorable for porphyry copper deposits.

About 72 percent of the permissive tract is covered by 1 km or less of upper Tertiary and Quaternary rocks and sediments. Areas covered by more than 1 km (Blakely and Jachens, 1991)

are excluded as are areas that are within a Tertiary caldera. In these latter areas, permissive pre-Tertiary host rocks are likely to be covered by more than 1 km of volcanic rock.

Rationale for Numerical Estimate

In our estimate of undiscovered deposits, we were guided by the fact that the area of concealed permissive bedrock that is unexplored, is about 2.5 times larger than the area of exposed permissive rock. On the negative side, we noted that during the period of intensive exploration for porphyry copper deposits in the 1960s and 70s, only a small number of deposits were found in Nevada, and that most of these were in the Yerington area.

We made separate estimates for undiscovered deposits of different ages because of the differences in their favorable areas and because we believe that their probabilities of occurrence are different. The estimate given for Cretaceous deposits is relatively low because we believe that, although Cretaceous plutons are numerous in Nevada, those of Early Cretaceous age are rare, and consequently, undiscovered systems like Robinson district (110 Ma) are less likely to exist. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 1, 2, 2, 3, and 5 or more Cretaceous deposits consistent with the grade and tonnage model of Singer and others (1986).

References

- Barton, M.D., Battles, D.A., Debout, G.E., Capo, R.C., Christensen, J.N., Davis, S.R., Hanson, R.B., Michelsen, C.J., and Trim, H.E., 1988, Mesozoic contact metamorphism in the western United States, p. 110-178, *in* Ernst, W.G., ed., *Metamorphism and crustal evolution of the western United States*, Rubey Volume VII: Prentice Hall, New Jersey, 1153 p.
- Blakely, R.J., and Jachens, R.C., 1991, Concealed ore deposits in Nevada—Insights from three-dimensional analysis of gravity and magnetic anomalies *in* Raines, G. L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., *Geology and ore deposits of the Great Basin—Symposium proceedings*: Reno, Geological Society of Nevada, v. 1, April 1990, p. 185-192.
- Cox, D.P., Ludington, Steve, Sherlock, M.G., Singer, D.A., Berger, B.R., and Tingley, J.V., 1991, Mineralization patterns in time and space in the Great basin of Nevada *in* Raines, G. L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., *Geology and ore deposits of the Great Basin—Symposium proceedings*: Reno, Geological Society of Nevada, v. 2, April 1990, p. 193-198.
- Grauch, V.J.S., Blakely, R.J., Blank, H.R., Oliver, H.W., Plouff, Donald, and Ponce, D.A., 1988, Geophysical delineation of granitic plutons in Nevada: U.S. Geological Survey Open-File Report 88-11, 7 p.
- Hudson, D.M., 1983, Alteration and geochemical characteristics of the upper parts of selected porphyry systems, western Nevada: Reno, University of Nevada, unpub. Ph.D. dissertation, 229 p.
- Joralemon, I.B., 1973, *Copper, the encompassing story of mankind's first metal*: Berkeley, California, Howell-North Books, 407 p.
- Singer, D.A., Mosier, D.L., and Cox, D.P., 1986, Grade-tonnage model of porphyry copper, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 77-81.
- Stewart, J.H., 1980, *Geology of Nevada*: Nevada Bureau of Mines and Geology Special Pub. 4, 136 p.
- Wallace, A.B. , 1979, Possible signatures of buried porphyry copper deposits in middle to late Tertiary volcanic rocks of Western Nevada *in* Ridge, J.D., ed., *Proceedings of the Fifth Quadrennial IAGOD Symposium*: Reno, University of Nevada, Mackay School of Mines, v. 2, p. 69-76.

GB09**Porphyry Cu Deposits****Nevada****Descriptive Model 17 • Mark3 Index 4****Oregon, Idaho****Area = 111,300 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by D.P. Cox, Steve Ludington, B.R. Berger, M.G. Sherlock, and D.A. Singer, (USGS); and J.V. Tingley (Nevada Bureau of Mines and Geology)

Important Examples and Rationale for Model Choice

Porphyry copper deposits are characterized by stockworks and disseminations of chalcopyrite, molybdenite, and gold in porphyritic stocks and in nearby country rocks. They are commonly surrounded by concentric zones of potassic, phyllic, and propylitic hydrothermal alteration. Nevada examples of porphyry copper deposits appear to be well-represented by the worldwide general porphyry copper model of Singer and others (1986) (Mark3 index 4).

Porphyry copper skarn-related deposits, an important variant of this model characterized by chalcopyrite-bearing quartz-sulfide stockwork veinlets in porphyritic intrusive rock and adjacent skarn are formed where porphyry systems are emplaced in carbonate rocks or other reactive wall rocks. Examples in Nevada include the Tertiary Battle Mountain district. The Copper Canyon deposits are small by porphyry copper standards, containing about 18 million metric tons of 0.8 percent copper ore. The ore bodies produced byproduct metals, especially gold and silver, and satellite deposits to these are now being mined for gold (Theodore and Blake, 1975).

Carbonate rocks are widespread in Nevada and it was not possible to delineate separate tracts or make separate estimates for these two types of deposits, therefore the general porphyry copper model was used. Tonnages and grades of the known deposits in Nevada are well represented by this model.

Rationale for Tract Delineation

The tract permissive for porphyry copper deposits is defined as an area extending 10 km outward from the outcrop of a pluton, or, in the case that the pluton has a geophysical expression as discussed by Grauch and others (1988), from the inferred subsurface boundary of the pluton based on its geophysical expression. It also includes areas around plutons whose presence is inferred from geophysics or from the occurrence of skarn mineralization. The tract covers about 40 percent of the area of the State.

Porphyry copper deposits tend to form in and around epizonal plutons rather than deep-seated batholiths, but, because we have only very general paleodepth information for many plutons in Nevada (Barton and others, 1988), no part of the tract could be excluded on this basis. The three known districts in the State contain deposits of three distinct ages: Yerington, Jurassic; Robinson, Cretaceous; and Copper Canyon, Tertiary. The favorable area for Tertiary deposits is very broad because many the small epizonal plutons of Tertiary age scattered across northern and eastern Nevada are associated with small base- and precious-metal deposits and are favorable for porphyry copper systems. In addition, Tertiary plutons accompanied by areas of widespread alunite alteration (Wallace, 1979; Hudson, 1983) within the western andesite belt are also favorable for porphyry copper deposits. It is possible, however, that some alunite alteration areas are associated with porphyry molybdenum or porphyry gold systems. Because

of a lack of equivocal knowledge of the age of all Nevada plutons, the tract for all three ages has the same physical boundaries.

About 72 percent of the permissive tract is covered by 1 km or less of upper Tertiary and Quaternary rocks and sediments. Areas covered by more than 1 km (Blakely and Jachens, 1991) are excluded as are areas that are within a Tertiary caldera. In these latter areas, permissive pre-Tertiary host rocks are likely to be covered by more than 1 km of volcanic rock. Where the pluton is Tertiary in age, however, the enclosing Tertiary volcanic rocks are delineated as permissive.

Rationale for Numerical Estimate

In our estimate of undiscovered deposits, we were guided by the fact that the area of concealed permissive bedrock that is unexplored, is about 2.5 times larger than the area of exposed permissive rock. On the negative side, we noted that during the period of intensive exploration for porphyry copper deposits in the 1960s and 1970s, only a small number of deposits were found in Nevada, and that most of these were in the Yerington area.

We made separate estimates for undiscovered deposits of different ages because of the differences in their favorable areas and because we believe that their probabilities of occurrence are different. The estimate for Tertiary deposits was partly influenced by the large number of alunite alteration areas in western Nevada. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 1, 3, 4, 6, and 8 or more Tertiary deposits consistent with the grade and tonnage model of Singer and others (1986).

References

- Barton, M.D., Battles, D.A., Debout, G.E., Capo, R.C., Christensen, J.N., Davis, S.R., Hanson, R.B., Michelsen, C.J., and Trim, H.E., 1988, Mesozoic contact metamorphism in the western United States, *in* Ernst, W.G., ed., *Metamorphism and crustal evolution of the western United States*, Rubey Volume VII: New Jersey, Prentice Hall, p. 110–178.
- Blakely, R.J., and Jachens, R.C., 1991, Concealed ore deposits in Nevada—Insights from three-dimensional analysis of gravity and magnetic anomalies, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., *Geology and ore deposits of the Great Basin—Symposium proceedings*: Reno, Geological Society of Nevada, v. 1, April 1990, p. 185–192.
- Cox, D.P., Ludington, Steve, Sherlock, M.G., Singer, D.A., Berger, B.R., and Tingley, J.V., 1991, Mineralization patterns in time and space in the Great basin of Nevada, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., *Geology and ore deposits of the Great Basin—Symposium proceedings*: Reno, Geological Society of Nevada, v. 2, April 1990, p. 193–198.
- Grauch, V.J.S., Blakely, R.J., Blank, H.R., Oliver, H.W., Plouff, Donald, and Ponce, D.A., 1988, Geophysical delineation of granitic plutons in Nevada: U.S. Geological Survey Open-File Report 88-11, 7 p.
- Hudson, D.M., 1983, Alteration and geochemical characteristics of the upper parts of selected porphyry systems, western Nevada: Reno, University of Nevada, unpub. PhD. dissertation, 229 p.
- Singer, D.A., Mosier, D.L., and Cox, D.P., 1986, Grade-tonnage model of porphyry copper, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 77–81.
- Stewart, J.H., 1980, *Geology of Nevada*: Nevada Bureau of Mines and Geology Special Pub. 4, 136 p.
- Theodore, T.G., and Blake, D.W., 1975, Geology and geochemistry of the west orebody and associated skarns, Copper Canyon porphyry copper deposits, Lander County, Nevada, with a section on Electron microprobe analysis of andradite and diopside by N.G. Banks: U.S. Geological Survey Professional Paper, 798-C, 85 p.

Wallace, A.B. 1979, Possible signatures of buried porphyry copper deposits in middle to late Tertiary volcanic rocks of western Nevada, *in* Ridge, J.D., ed., Proceedings of the Fifth Quadrennial IAGOD Symposium: Reno, University of Nevada, Mackay School of Mines, v. 2, p. 69-76.

GB10**Porphyry Cu Deposits**

Nevada

Descriptive Model 17 • Mark3 Index 4

Oregon, Idaho

Area = 111,300 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by D.P. Cox, Steve Ludington, B.R. Berger, M.G. Sherlock, and D.A. Singer, (USGS); and J.V. Tingley (Nevada Bureau of Mines and Geology)

Important Examples and Rationale for Model Choice

Porphyry copper deposits are characterized by stockworks and disseminations of chalcopyrite, molybdenite, and gold in porphyritic stocks and in nearby country rocks. They are commonly surrounded by concentric zones of potassic, phyllic, and propylitic hydrothermal alteration. Nevada examples of porphyry copper deposits appear to be well-represented by the worldwide general porphyry copper model of Singer and others (1986) (Mark3 index 4), and this general model was used for assessment. Yerington, Macarthur, Bear, and Anne Mason deposits are the main examples in Nevada.

Rationale for Tract Delineation

The tract permissive for porphyry copper deposits is defined as an area extending 10 km outward from the outcrop of a pluton, or, in the case that the pluton has a geophysical expression as discussed by Grauch and others (1988), from the inferred subsurface boundary of the pluton based on its geophysical expression. It also includes areas around plutons whose presence is inferred from geophysics or from the occurrence of skarn mineralization. The tract covers about 40 percent of the area of the State.

Porphyry copper deposits tend to form in and around epizonal plutons rather than deep-seated batholiths, but, because we have only very general paleodepth information for many plutons in Nevada (Barton and others, 1988), no part of the tract could be excluded on this basis. The three known districts in the State contain deposits of three distinct ages: Yerington, Jurassic; Robinson, Cretaceous; and Copper Canyon, Tertiary. Deposits of Jurassic age are most likely to occur in a discontinuous belt extending from Yerington northeast to the Contact and Dolly Varden districts (Cox and others, 1991). Because of a lack of unequivocal knowledge of the age of all Nevada plutons, the tract for all three ages has the same physical boundaries.

About 72 percent of the permissive tract is covered by 1 km or less of upper Tertiary and Quaternary rocks and sediments. Areas covered by more than 1 km (Blakely and Jachens, 1991) are excluded as are areas that are within a Tertiary caldera. In these latter areas, permissive pre-Tertiary host rocks are likely to be covered by more than 1 km of volcanic rock.

Rationale for Numerical Estimate

In our estimate of undiscovered deposits, we were guided by the fact that the area of concealed permissive bedrock that is unexplored, is about 2.5 times larger than the area of exposed permissive rock. Two concealed deposits have already been discovered (Bear and Ann Mason). On the negative side, we noted that during the period of intensive exploration for porphyry copper deposits in the 1960s and 1970s, only a small number of deposits were found in Nevada, and that most of these were in the Yerington area.

We made separate estimates for undiscovered deposits of different ages because of the differences in their favorable areas and because we believe that their probabilities of occurrence are different. The estimate for Jurassic deposits (including the possibility of undiscovered Late

Triassic to Early Jurassic deposits) is the largest because of the large number of known Jurassic copper skarn deposits. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 1, 3, 6, 9, and 12 or more Jurassic deposits consistent with the grade and tonnage model of Singer and others (1986).

References

- Barton, M.D., Battles, D.A., Debout, G.E., Capo, R.C., Christensen, J.N., Davis, S.R., Hanson, R.B., Michelsen, C.J., and Trim, H.E., 1988, Mesozoic contact metamorphism in the western United States, *in* Ernst, W.G., ed., *Metamorphism and crustal evolution of the western United States*, Rubey Volume VII: Prentice Hall, New Jersey, p. 110–178.
- Blakely, R.J., and Jachens, R.C., 1991, Concealed ore deposits in Nevada—Insights from three-dimensional analysis of gravity and magnetic anomalies *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., *Geology and ore deposits of the Great Basin—Symposium proceedings*: Reno, Geological Society of Nevada, v. 2, April 1990, p. 185–192.
- Cox, D.P., Ludington, Steve, Sherlock, M.G., Singer, D.A., Berger, B.R., and Tingley, J.V., 1991, Mineralization patterns in time and space in the Great basin of Nevada, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., *Geology and ore deposits of the Great Basin—Symposium proceedings*: Reno, Geological Society of Nevada, v. 2, April 1990, p. 193–198.
- Dilles, J.H., and Wright, J.E., 1988, The chronology of early Mesozoic arc magmatism in the Yerington district of western Nevada and its regional implications: *Geological Society of America Bulletin*, v. 100, no. 5, p. 644–652.
- Einaudi, M.T., 1982, Descriptions of skarns associated with porphyry copper plutons: Southwestern North America, *in* S.R. Titley, ed., *Advances in geology of the porphyry copper deposits, southwestern North America*: Tucson, University of Arizona Press, p. 139–184.
- Grauch, V.J.S., Blakely, R.J., Blank, H.R., Oliver, H.W., Plouff, Donald, and Ponce, D.A., 1988, Geophysical delineation of granitic plutons in Nevada: U.S. Geological Survey Open-File Report 88-11, 7 p.
- Hudson, D.M., 1983, Alteration and geochemical characteristics of the upper parts of selected porphyry systems, western Nevada: Reno, University of Nevada, unpub. Ph.D. dissertation, 229 p.
- Singer, D.A., Mosier, D.L., and Cox, D.P., 1986, Grade-tonnage model of porphyry copper, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 77–81.
- Stewart, J.H., 1980, *Geology of Nevada*: Nevada Bureau of Mines and Geology Special Pub. 4, 136 p.
- Wallace, A.B., 1979, Possible signatures of buried porphyry copper deposits in middle to late Tertiary volcanic rocks of Western Nevada, *in* Ridge, J.D., ed., *Proceedings of the fifth quadrennial IAGOD symposium*: Reno, University of Nevada, Mackay School of Mines, v. 2, p. 69–76.

GB11**Porphyry Cu Deposits**Utah
Idaho

Descriptive Model 17 • Mark3 Index 81

Area = 19,300 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Douglas B. Stoeser

Rationale for Model Choice

Several belts of Tertiary calc-alkaline igneous rocks, including plutons and associated volcanic rocks, with related porphyry copper, polymetallic vein and replacement, and skarn deposits are exposed in western Utah. The North American subset of the worldwide grade and tonnage model (Mark3 index 81) was used for the quantitative assessment.

Rationale for Tract Delineation

Two permissive tracts were recognized for porphyry copper deposits in Utah. The basis for delineating these tracts are the occurrence of Tertiary calc-alkaline intermediate to silicic intrusive rocks, associated volcanic rocks, and intrusive-related mineral deposits (porphyry copper, polymetallic vein and replacement, and skarn). The two tracts are defined by east-west-trending Tertiary dominantly calc-alkaline magmatic belts in the western part of the State, and they contain most of the significant base and precious metal deposits of Utah (Shawe and Stewart, 1976; Seedorff, 1991). In the north, two adjacent belts, the Oquirrh-Uinta belt and the Tintic-Deep Creek belt, combine to form the permissive tract. The igneous rocks here range in age from approximately 43 to 32 Ma, and range from intermediate to silicic. The silicic volcanic rocks are mainly associated with ash-flow calderas (Steven and Rowley, 1984; Best, 1989; Stoeser, 1993). These igneous rocks are relatively deeply eroded, such that the majority of the once extensive volcanic rocks of the area have been removed. Because of the deep erosion level, the area has significant amounts of exposed plutonic rocks, and is characterized by mineral deposits related directly to intrusive centers. The northernmost part of this tract, in the extreme northwest corner of Utah, contains local volcanic rocks with minor intrusive rocks. It should be noted that the tract is approximately 70 percent covered by alluvium. Aeromagnetic surveys were used to define areas of high magnetics that might indicate intrusions at depth. A few minor base and precious metal occurrences associated with small intrusions are located in the eastern Uinta Mountains, but this area was considered to have insignificant mineral potential for intrusive-related deposits and was not considered in the estimates for this tract.

Important Examples of Deposit Type

Utah contains one of the largest and richest porphyry copper deposits in the world at Bingham Canyon (Lanier and others, 1978). This, however, is the only porphyry copper deposit that has been exploited in the State. Six other prospects occur in the northern permissive tract, (Park Premier, Southwest Tintic, West Tintic, Detroit, Dugway, and Gold Hill), and some of them could become significant deposits if they were fully explored.

Rationale for Numerical Estimate

Estimates of numbers of undiscovered deposits took into account the distribution of known deposits and prospects, beliefs about the extent and efficiency of past mineral exploration, and the large proportion of the permissive tract that is covered by alluvium. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 1, 3, 6, 8, and 11 deposits consistent with the grade and tonnage model for the North American subset of porphyry copper deposits.

References

- Best, M.G., Christiansen, E.H., Deino, A.L., Grommé, C.S., McKee, E.H., and Noble, D.C., 1989, Excursion 3A—Eocene through Miocene volcanism in the Great Basin of the western United States, *in* Chapin, C.E. and Zidek, Jiri, eds., Field excursion to volcanic terranes in the western United States, Volume II—Cascades and Intermountain West: New Mexico Bureau of Mines and Mineral Resources Memoir 47, p. 91-133.
- Lanier, George, John, E.C., Swenson, A.J., Reid, Julia, Bard, C.E., Caddy, S.W., and Wilson, J.C., 1978, General geology of the Bingham mine, Bingham Canyon, Utah: *Economic Geology*, v. 73, no. 7, p. 1228-1241.
- Seedorff, Eric, 1991, Magmatism, extension, and ore deposits of Eocene to Holocene age in the Great Basin—Mutual effects and preliminary proposed genetic relationships, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., *Geology and ore deposits of the Great Basin—Symposium proceedings*: Reno, Geological Society of Nevada, p. 133-178.
- Shawe, D.R., and Stewart, J.H., 1976, Ore deposits as related to tectonics and magmatism, Nevada and Utah: *Transactions of Society of Mining Engineers*, v. 260, p. 225-231.
- Steven, T.A., and Rowley, P.D., 1984, Calderas of the Marysvale volcanic field, west central Utah: *Journal of Geophysical Research*, v. 89, p. 8751-8764.
- Stoeser, D.B., 1993, Tertiary calderas and regional extension of the east-central part of the Tintic-Deep Creek Mineral Belt, eastern Great Basin, *in* Scott, R.W., Jr., Detra, T.S., and Berger, B.R., eds., *Advances related to United States and international mineral resources—Developing frameworks and exploration technologies*: U.S. Geological Survey Bulletin 2039, Chap. A, p. 5-23.

GB12**Porphyry Cu Deposits****Utah****Descriptive Model 17 • Mark3 Index 81****Area = 24,600 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by Douglas B. Stoeser***Rationale for Model Choice**

Several belts of Tertiary calc-alkaline igneous rocks, including plutons and associated volcanic rocks, with related porphyry copper, polymetallic vein and replacement, and skarn deposits are exposed in western Utah. The North American subset of the worldwide grade and tonnage model (Mark3 index 81) was used for the quantitative assessment.

Rationale for Tract Delineation

Two permissive tracts were recognized for porphyry copper deposits in Utah. The basis for delineating these tracts are the occurrence of Tertiary calc-alkaline intermediate to silicic intrusive rocks, associated volcanic rocks, and intrusive-related mineral deposits (porphyry copper, polymetallic vein and replacement, and skarn). The two tracts are defined by east-west-trending Tertiary dominantly calc-alkaline magmatic belts in the western part of the State, and they contain most of the significant base and precious metal deposits of Utah (Shawe and Stewart, 1976; Seedorff, 1991). The southern permissive tract is defined by the combination of the Pioche-Marysville (or Wah Wah-Tushar) and Delamar-Iron Springs mineral belts. Ages of emplacement for the volcanic and intrusive rocks are mainly 34 to 18 Ma. The tract contains intermediate to silicic volcanic rocks, which are primarily associated with ash-flow calderas (Steven and Rowley, 1984; Best, 1989; Stoeser, 1993). The erosion level is such that extensive areas of volcanic rocks are still preserved, although more deeply eroded plutons are exposed near Milford. The southern permissive tract is more favorable for epithermal-type deposits, with possible associated intrusive-related systems at depths below 1 kilometer, the depth to which this assessment was conducted. It should be noted that the tract is approximately 70 percent covered by alluvium. Aeromagnetic surveys were used to define areas of high magnetics that might indicate intrusions at depth. Outside of the three permissive terranes defined above, a few minor base and precious metal occurrences associated with small intrusions are located in the nearby Colorado Plateau, but these areas were considered to have insignificant mineral potential for intrusive-related deposits and were not considered in the estimates for this tract.

Important Examples of Deposit Type

Utah contains one of the largest and richest porphyry copper deposits in the world at Bingham Canyon. This, however, is the only porphyry copper deposit to have been exploited in the State. Three porphyry copper prospects are known in the southern area (Cactus, OK, and Rocky). It should be noted that the Cactus and OK prospects are pipe-like bodies and the classification of them as porphyry copper type is questionable.

Rationale for Numerical Estimate

Estimates of numbers of undiscovered deposits took into account the distribution of known deposits and prospects, beliefs about the extent and efficiency of past mineral exploration, and the large proportion of the permissive tract that is covered by alluvium. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 2, 3, and 4 deposits consistent with the grade and tonnage model for the North American subset of porphyry copper deposits.

References

- Best, M.G., Christiansen, E.H., Deino, A.L., Gromme, C.S., McKee, E.H., and Noble, D.C., 1989, Excursion 3A—Eocene through Miocene volcanism in the Great Basin of the western United States, *in* Chapin, C.E., and Zidek, Jiri, eds., Field excursion to volcanic terranes in the western United States, Volume II: Cascades and Intermountain West: New Mexico Bureau of Mines and Mineral Resources Memoir 47, p. 91-133.
- Seedorff, Eric, 1991, Magmatism, extension, and ore deposits of Eocene to Holocene age in the Great Basin —Mutual effects and preliminary proposed genetic relationships *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., Geology and ore deposits of the Great Basin: Reno, Symposium proceedings, Geological Society of Nevada, p. 133-178.
- Shawe, D.R. and Stewart, J.H., 1976, Ore deposits as related to tectonics and magmatism, Nevada and Utah: Transactions of Society of Mining Engineers, v. 260, p. 225-231.
- Steven, T.A., and Rowley, P.D., 1984, Calderas of the Marysvale volcanic field, west central Utah: Journal of Geophysical Research, v. 89, p. 8751-8764.
- Stoeser, D.B., 1993, Tertiary calderas and regional extension of the east-central part of the Tintic-Deep Creek Mineral Belt, eastern Great Basin, *in* Scott, R.W., Jr., Detra, T.S., and Berger, B.R., eds., Advances related to United States and international mineral resources—Developing frameworks and exploration technologies: U.S. Geological Survey Bulletin 2039, Chap. A, p. 5-23.

GB13**Porphyry Cu Deposits, Skarn-related**Utah
Idaho

Descriptive Model 18a • Mark3 Index 9

Area = 43,400 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Douglas B. Stoesser

Rationale for Model Choice

The model used here follows Einaudi and others (1981); Cox (1986); and Cox and Theodore (1986) who distinguish two types of copper skarns, those related to intrusions that host porphyry copper deposits and those related to other intrusions. The latter class of copper skarns is relatively small, typically containing 1–50 million metric tons of ore, whereas, porphyry-related copper skarns commonly contain 50–600 million metric tons of ore (Einaudi and others, 1981). Many of the world's largest porphyry-related copper skarns occur in the southwestern United States. Porphyry-related copper skarns are associated with Mesozoic to Tertiary calc-alkaline granodiorite to granitic porphyry-textured hypabyssal stocks emplaced in continental-margin orogenic belts (Einaudi and others, 1981).

Rationale for Tract Delineation

Because western Utah contains calc-alkaline magmatic belts superimposed over the continental marginal Sevier orogenic belt (Armstrong, 1968; Shawe and Stewart, 1976), the region is favorable for the occurrence of copper skarns. The primary criteria for the occurrence of porphyry-related copper skarn are the presence of porphyry copper deposits, and carbonate host rocks found proximal to the porphyry copper intrusions. Thus, the permissive terranes for porphyry copper, skarn-related deposits are defined where the porphyry copper permissive terranes are underlain by carbonate sedimentary rocks. Because the detailed distribution of carbonate rocks beneath the approximately seventy percent alluvial cover in the area is not known, we used the same permissive tract for skarn-related porphyry copper deposits as for general porphyry copper deposits.

Important Examples of Deposit Type

In Utah, there is one significant deposit of this type, the Carr Fork copper skarn associated with the Bingham porphyry copper deposit (Atkinson and Einaudi, 1978; Tooker, 1990; Reid, 1991), and a few more in the Bingham district and in other areas.

Rationale for Numerical Estimate

Einaudi and others (1981, p. 341) state that for the southwestern United States: "Large copper skarn deposits are associated with all porphyry copper plutons emplaced in carbonate rocks". Therefore, the estimated number of porphyry-related copper skarns should be approximately the same as for copper porphyry deposits, with perhaps a somewhat lower number allowing for roughly 10–20 percent non-carbonate rocks underlying the permissive terranes. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 2, 5, 6, and 8 or more deposits consistent with the grade and tonnage curve for skarn-related porphyry copper deposits of Cox (1986).

References

Armstrong, R.L., 1968, Sevier orogenic belt in Nevada and Utah: Geological Society of America Bulletin, v. 79, p. 429-458.

- Atkinson, W.W., Jr., and Einaudi, M.T., 1978, Skarn formation and mineralization in the contact aureole at Carr Fork, Bingham, Utah: *Economic Geology*, v. 73, no. 7, p. 1326–1365.
- Cox, D.P., 1986, Descriptive model of Cu skarn Deposits, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 82-85.
- Cox, D.P., and Theodore, T.G., 1986, Descriptive model of Cu skarn Deposits, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 86-89.
- Einaudi, M.T., Meinert, L.D., and R.J. Newberry, 1981, Skarn deposits, *in* Skinner, B.J., ed., *Economic Geology Seventy-Fifth Anniversary Volume, 1905–1980*: Lancaster, Pennsylvania, Economic Geology Publishing Company, p. 317-392.
- Reid, J.E., 1991, Skarn occurrences in Utah and the potential for associated gold mineralization: Utah Geological Survey Contract Report 91-13, 49 p.
- Shawe, D.R., and Stewart, J.H., 1976, Ore deposits as related to tectonics and magmatism, Nevada and Utah: Las Vegas, American Institute Mining Engineers Transactions, 1977 Annual Meeting, v. 260, p. 225-232.
- Tooker, E.W., 1990, Gold in the Bingham District, Utah, *in* Shawe, D.R., Ashley, R.P., and Carter, L.M.H., eds., *Gold in porphyry copper systems*: U.S. Geological Survey Bulletin 1857-E, p. E1-E-16.

GB14 **Polymetallic Replacement and Skarn Zn-Pb Deposits** **California**
Descriptive Model 19a + 18c • Mark3 Index 92
Area = 17,700 km²

[Cumulative Distribution](#)

[Histogram](#)

[Table](#)

[Model](#)

[Mineral Deposits](#)

by Dennis P. Cox

Rationale for Model Choice and Important Examples

Mesozoic plutons on the southeast flank of the Sierra Nevada batholith show a consistent association with numerous zinc-lead skarn and polymetallic replacement districts where they intrude Paleozoic carbonate rocks. These districts include Darwin, Cerro Gordo, Modoc, Santa Rosa (MacKevett, 1953), and Ubehebe districts (McAllister, 1955). Darwin, the largest, produced more than a million metric tons of ore containing about 6 percent lead, 6 percent zinc, 0.2 percent copper, 200 g/t silver and recoverable gold (Hall and MacKevett, 1962; Newberry and others, 1991).

The Shoshone (Tecopa) district (Carlisle and others, 1954, p. 46-47) produced about 600,000 metric tons of lead-zinc-silver ore and is the largest of a group of similar districts that includes Queen of Sheba, Honolulu, Ashford, Paddy's Pride, and Blackwater. These districts are all localized within the Late Proterozoic Noonday Dolomite, and have no consistent relation with igneous rocks of any specific age. They also have much lower pyrite contents compared to the ores related to Jurassic plutons. They may be incorrectly classified here as polymetallic replacement districts, however more work needs to be done to establish this.

Zinc-lead skarn deposits are possible in the same environment as polymetallic replacement deposits, therefore, a new model that combines the zinc-lead skarn (Mosier, 1986) and polymetallic replacement (Mosier and others, 1986) was used to represent the undiscovered districts (Mark 3, no. 92).

Rationale for Tract Delineation

The permissive tract is defined to be that part of the area that is underlain by Proterozoic and Paleozoic carbonate rocks, and that is near Mesozoic plutons. Small areas of basin fill more than 1 km in depth are excluded.

Rationale for Numerical Estimate

For the 90th, 50th, 10th, and 5th percentiles, the team estimated 0, 3, 5, and 8 or more districts consistent with the combined grade and tonnage model for zinc-lead skarn and polymetallic replacement districts of Singer (Mark3 index 92). This estimate was based on the belief that approximately three known districts have grades and tonnages close to the median of the combined model. An equal number of undiscovered districts probably exist under cover, or in old districts that are, as presently known, too small to fit the tonnage model distribution.

References

- Carlisle, Donald, Davis, D.L., Kildale, M.B., and Stewart, R.M., 1954, Base metal and iron deposits of southern California: California Division of Mines and Geology Bulletin 170, Chap. 8, p. 41-49.
- Mosier, D.L., 1986, Grade-tonnage model of Zn-Pb skarns, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 90-93.

- Mosier, D.L., Morris, H.T., and Singer, D.A., 1986, Grade-tonnage model of polymetallic replacement deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 101-104.
- Hall, W.E., and MacKevett, E.M., Jr., 1962, Geology and ore deposits of the Darwin quadrangle, Inyo County California: U.S. Geological Survey Professional Paper 368, 87 p.
- MacKevett, E.M., Jr., 1953 Geology of the Santa Rosa lead mine, Inyo County California: California Division of Mines and Geology Special Report 34, 9 p.
- McAllister, J.F., 1955, Geology and mineral deposits of the Ubehebe Peak quadrangle: California Division of Mines and Geology Special Report 42, 63 p.
- Newberry, R.J., Einaudi, M.T., and Eastman, H.S., 1991, Zoning and genesis of the Darwin Pb-Zn-Ag skarn deposit, California—A reinterpretation based on new data: *Economic Geology*, v. 86, no. 5, p. 960–982.

GB15 **Polymetallic Replacement and Skarn Zn-Pb Deposits** Nevada
Descriptive Model 19a + 18c • Mark3 Index 92 Oregon, Idaho
Area = 111,800 km²

[Cumulative Distribution](#) [Histogram](#) [Table](#) [Model](#) [Mineral Deposits](#)

by D.P. Cox, Steve Ludington, B.R. Berger, M.G. Sherlock, and D.A. Singer, (USGS); and J.V. Tingley (Nevada Bureau of Mines and Geology)

Important Examples and Rationale for Model Choice

Zinc-lead skarn deposits are found where carbonate rocks are intruded by granitoids and typically are formed farther from the mineralizing intrusive rock than are copper and iron skarns. Their geologic environment of formation and geographic distribution is similar to the more numerous polymetallic replacement deposits. We recognize 16 zinc-lead skarn deposits and occurrences in Nevada, the Ward district being the most important.

Polymetallic replacement deposits typically form tabular, podlike, and pipelike ore bodies which are localized by faults or sedimentary strata. The deposits are in sedimentary rocks, chiefly carbonate rocks, which are intruded by porphyritic calc-alkaline plutons. Massive carbonate beds which fracture during intrusion and deformation are the preferred host rock. Polymetallic replacement ores contain galena, sphalerite, tetrahedrite, and silver sulfosalts. Mineral zoning is common with inner zones rich in chalcopyrite or enargite and outer zones containing only sphalerite and rhodochrosite. Jasperoid is frequently found near ore bodies.

Two significant clusters of polymetallic replacement deposits in Nevada are Pioche-Bristol-Highland, associated with Cretaceous or, more likely, Tertiary plutons; and Eureka, associated with Cretaceous intrusions. A large gold deposit has recently (1994) been announced that is part of the Eureka district. Overall, more than 80 percent of known deposits and occurrences are near plutons of Cretaceous or Tertiary age.

Zinc-lead skarn deposits are possible in the same environment as polymetallic replacement deposits, therefore, a new model that combines the zinc-lead skarn (Mosier, 1986) and polymetallic replacement (Mosier and others, 1986) was used to represent the undiscovered districts (Mark3 index 92). The known districts in Nevada are well represented by this model, with three districts, Pioche, Eureka, and Ward, above the median in tonnage.

Rationale for Tract Delineation

The tract permissive for zinc-lead skarns and polymetallic replacement deposits is defined as an area extending 10 km outward from the outcrop of a pluton, or, in the case that the pluton has a geophysical expression as discussed by Grauch and others (1988), from the inferred subsurface boundary of the pluton, based on its geophysical expression. It also includes areas around plutons whose presence is inferred from geophysics or from the occurrence of skarn mineralization. The tract covers about 40 percent of the area of the State. Carbonate-bearing and calcareous sedimentary rocks are present in all sedimentary assemblages in Nevada (Stewart, 1980), hence, no areas were excluded from the permissive tract on the basis of age or composition of intruded country rock.

About 72 percent of the permissive tract is covered by 1 km or less of upper Tertiary and Quaternary rocks and sediments. Areas covered by more than 1 km (Blakely and Jachens, 1991) are excluded as are areas that are within a Tertiary caldera. In these latter areas, permissive pre-Tertiary host rocks are likely to be covered by more than 1 km of volcanic rock.

Most major zinc-lead skarn and polymetallic replacement districts tend to be associated with plutons of Cretaceous age, but a few major districts and a large number of occurrences are known around Tertiary intrusive centers. A few occurrences are associated with Jurassic plutons in northeast and southwest Nevada. Most of the deposits and occurrences are situated in the part of Nevada underlain by Precambrian continental crust, and the host-rocks for most deposits belong to the lower Paleozoic carbonate assemblage. The first carbonate beds above or within the thick Precambrian and Lower Cambrian quartzite sequences have long been known to be the most productive (Woodward, 1972; Ivosevic, 1978). Some deposits are known in upper Paleozoic rocks and a few are found in the Luning Formation of Triassic age.

Rationale for Numerical Estimate

Zinc-lead skarn and polymetallic replacement districts are abundant in Nevada; at least eight districts are large enough to be on the grade-tonnage distribution. Many of the 25 smaller occurrences may be insufficiently explored, and little or no exploration has been carried out in covered areas. Of the eight known districts, four have tonnages distributed around the median (two above and two below) and are situated in the exposed part of the permissive tract. The covered part of the tract is 2.5 times greater in size, so the expected value of undiscovered deposits should about 10. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 9, 14, 18, 20, and 22 or more undiscovered districts in the delineated area that are comparable in grade and tonnage to the combined zinc-lead skarn and polymetallic replacement grade-tonnage model of Singer.

References

- Blakely, R.J., and Jachens, R.C., 1991, Concealed ore deposits in Nevada—Insights from three-dimensional analysis of gravity and magnetic anomalies, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., *Geology and ore deposits of the Great Basin—Symposium proceedings*: Reno, Geological Society of Nevada, v. 1, April 1990, p. 185-192
- Grauch, V.J.S., Blakely, R.J., Blank, H.R., Oliver, H.W., Plouff, Donald, and Ponce, D.A., 1988, *Geophysical delineation of granitic plutons in Nevada*: U.S. Geological Survey Open-File Report 88-11, 7 p.
- Ivosevic, S.W., 1978, Johnnie gold district, Nevada, and implications on regional stratigraphic controls: *Economic Geology*, v. 73, no. 1, p. 100-105.
- Mosier, D.L., 1986, Grade-tonnage model of Zn-Pb skarns, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 90-93.
- Mosier, D.L., Morris, H.T., and Singer, D.A., 1986, Grade-tonnage model of polymetallic replacement deposits, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 101-104.
- Stewart, J.H., 1980, *Geology of Nevada*: Nevada Bureau of Mines and Geology Special Pub. 4, 136 p.
- Woodward, L.A., 1972, Upper Precambrian strata of the eastern Great Basin as potential host rocks for mineralization: *Economic Geology*, v. 67, no. 5, p. 677-681.

GB16**Polymetallic Replacement Deposits**Utah
Idaho

Descriptive Model 19a • Mark3 Index 47

Area = 43,400 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by Douglas B. Stoesser***Rationale for Model Choice**

Polymetallic replacement deposits are common in western Utah, and are found where Tertiary felsic to intermediate intrusive rocks were emplaced into predominantly Paleozoic carbonate rocks.

Rationale for Tract Delineation

The permissive tract for this deposit type is defined primarily by the distribution of intrusive rocks and suitable reactive host rocks, especially carbonate-bearing sedimentary rocks. It is made up of three east-trending belts in western Utah. The southernmost of the three is less deeply eroded than the other two, and any undiscovered replacement deposits in the south would most likely be concealed by the volcanic cover and alluvial cover. Aeromagnetic maps were employed to define areas of buried intrusive bodies.

Important Examples of Deposit Type

Other than the Bingham Canyon porphyry copper deposit, polymetallic replacement (and associated vein deposits) comprise by far the most important type of metallic mineral deposits in Utah. Major districts are all in the north-central area of the permissive tract and are Park City, Little and Big Cottonwood, Bingham Canyon (Lark and U.S. mines), Ophir, American Fork, Stockton (Rush Valley), Tintic and East Tintic. Minor deposits within the north-central area include West Tintic, Detroit, Fish Springs, Lucin, Silver Island, and Gold Hill, and in the southern area, Preuss, Deer Trail, Bradshaw, Pine Grove, and Star.

Many polymetallic replacement districts contained polymetallic veins as well, and production figures for some, if not most, of these districts reflects combined production from replacement and vein orebodies.

Rationale for Numerical Estimate

Although there has been extensive exploration for this deposit type since the late 1880s, major discoveries within the exposed parts of the permissive areas are unlikely. However, because of the extensive cover within the permissive areas, the widespread and numerous examples of this deposit type, the certainty of many concealed plutons within the covered areas, and the fact that the permissive tract is extensively underlain by carbonate sedimentary rocks, it seems likely that a number of undiscovered replacement deposits are present. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 3, 7, 11, 13, and 20 or more deposits consistent with the grade and tonnage model of Mosier, Morris and Singer (1986) (Mark3 index 47). The group noted that the estimate requires a somewhat anomalous distribution with probability falling off rapidly above 11 deposits, but felt the size of polymetallic replacement districts restricts their maximum numbers.

Reference

Mosier, D.L., Morris, H.T., and Singer, D.A., 1986, Grade and tonnage model of polymetallic replacement deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 101-104.

GB17**Distal Disseminated Ag-Au Deposits**Utah
Idaho

Descriptive Model Bull. 2004

Area = 43,400 km²[Model](#)*by* Dennis P. Cox and Steve Ludington**Rationale for Model Choice**

Distal disseminated Ag-Au deposits (Cox and Singer, 1992) are commonly associated with polymetallic replacement deposits which are common in western Utah. Areas where Tertiary felsic to intermediate intrusive rocks were emplaced into predominantly Paleozoic carbonate rocks are permissive for this deposit type.

Rationale for Tract Delineation

The permissive tract for this deposit type is defined primarily by the distribution of intrusive rocks and suitable reactive host rocks, especially carbonate-bearing sedimentary rocks. It is made up of three east-trending belts in western Utah. The southernmost of the three is less deeply eroded than the other two, and any undiscovered replacement deposits in the south would most likely be concealed by the volcanic cover and alluvial cover. Aeromagnetic maps were employed to define areas of buried intrusive bodies.

Important Examples of Deposit Type

The only deposit of this type is Tecoma, in northwest Utah near the Nevada border.

Rationale for Numerical Estimate

Because of the rarity of distal disseminated deposits in this tract the team estimated that the probability of an undiscovered deposit was less than 0.01

Reference

Cox, D.P., and Singer, D.A., 1992, Descriptive and grade and tonnage model of distal-disseminated Ag-Au, *in* Bliss, J.D., ed., Developments in deposit modeling: U.S. Geological Survey Bulletin 2004, p. 20-22.

GB18**Distal Disseminated Ag-Au Deposits****Nevada****Descriptive Model Bull. 2004 • Mark3 Index 18****Area = 111,800 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by D.P. Cox, Steve Ludington, B.R. Berger, M.G. Sherlock, and D.A. Singer, (USGS) and J.V. Tingley (Nevada Bureau of Mines and Geology)

Important Examples and Rationale for Model Choice

Distal disseminated silver-gold deposits (Cox and Singer, 1992) are low-grade, sediment-hosted, precious-metal deposits found in the same districts as copper- and zinc-lead-skarn and polymetallic replacement deposits. They occur in a wide variety of favorable host rocks including clastic sedimentary rocks. They show no apparent preference for plutons of any specific age, but they probably require the presence of a large, productive intrusive system. Deposits of this type are numerous in Nevada; Candelaria, Cove, and Taylor are the most important.

Rationale for Tract Delineation

The tract permissive for zinc-lead skarns and polymetallic replacement deposits is defined as an area extending 10 km outward from the outcrop of a pluton, or, in the case that the pluton has a geophysical expression as discussed by Grauch and others (1988), from the inferred subsurface boundary of the pluton, based on its geophysical expression. It also includes areas around plutons whose presence is inferred from geophysics or from the occurrence of skarn mineralization. The tract covers about 40 percent of the area of the State. Carbonate-bearing and calcareous sedimentary rocks are present in all sedimentary assemblages in Nevada (Stewart, 1980), hence, no areas were excluded from the permissive tract on the basis of age or composition of intruded country rock.

About 72 percent of the permissive tract is covered by 1 km or less of upper Tertiary and Quaternary rocks and sediments. Areas covered by more than 1 km (Blakely and Jachens, 1991) are excluded as are areas that are within a Tertiary caldera. In these latter areas, permissive pre-Tertiary host rocks are likely to be covered by more than 1 km of volcanic rock.

Rationale for Numerical Estimate

There are at least ten deposits known in Nevada, six of which belong to the grade-tonnage model (Cox and Singer, 1992). Because they are low in metallic mineral content and thus difficult to detect by traditional prospecting methods, we believe that the number of undiscovered deposits is approximately equal to the number of known deposits. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 6, 10, 14, 15, and 17 deposits in the permissive tract that are comparable in grade and tonnage to the distal disseminated silver-gold model of Cox and Singer (1992).

References

Blakely, R.J., and Jachens, R.C., 1991, Concealed ore deposits in Nevada—Insights from three-dimensional analysis of gravity and magnetic anomalies *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., *Geology and ore deposits of the Great Basin—Symposium proceedings*: Reno, Geological Society of Nevada, v. 1, April 1990, p. 185-192.

- Cox, D.P., and Singer, D.A., 1992, Descriptive and grade and tonnage model of distal-disseminated Ag-Au, *in* Bliss, J.D., ed., *Developments in deposit modeling*: U.S. Geological Survey Bulletin 2004, p. 20-22.
- Grauch, V.J.S., Blakely, R.J., Blank, H.R., Oliver, H.W., Plouff, Donald, and Ponce, D.A., 1988, Geophysical delineation of granitic plutons in Nevada: U.S. Geological Survey Open-File Report 88-11, 7 p.
- Stewart, J.H., 1980, *Geology of Nevada*: Nevada Bureau of Mines and Geology Special Pub. 4, 136 p.

GB19**Massive Sulfide Deposits, Cyprus Type****Nevada****Descriptive Model 24a • Mark3 Index 11****Area = 37,500 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by D.P. Cox, Steve Ludington, B.R. Berger, M.G. Sherlock, and D.A. Singer, (USGS); and J.V. Tingley (Nevada Bureau of Mines and Geology)

Important Examples and Rationale for Model Choice

Cyprus-type deposits contain mainly iron, copper, and minor zinc sulfides and occur in basinal oceanic or back-arc basalts. Rye and others (1984) conclude from textural and isotopic studies that the Big Mike copper deposit, which occurs in basalt of the Golconda assemblage, is probably a Cyprus-type deposit formed near a sea-floor spreading center.

Rationale for Tract Delineation

The Roberts Mountains and Golconda allochthons are believed to contain remnants of closed oceanic basins. Parts of these assemblages that contain volcanic rocks form a tract permissive for Cyprus massive sulfide deposits. Parts of the Golconda allochthon include thick pillow basalt units, chert, and turbidite, as well as scattered bodies of serpentine indicating an oceanic depositional environment (Jones and Jones, 1990). The Roberts Mountains assemblage contains chert, argillite, and greenstone that also suggest an oceanic environment permissive for Cyprus-type deposits, but the eastern part of the Roberts Mountains allochthon that is composed chiefly of shales of the Vinini Formation is considered less favorable.

Rationale for Numerical Estimates

Our estimate is based on the broad extent of the permissive area, and on the presence of one known deposit and one occurrence that might belong to this model. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 1, 2, 5, 7, and 8 or more deposits that are comparable in grade and tonnage to the Cyprus massive sulfide model of Singer and Mosier (1986).

References

- Jones, A.E., and Jones, D.L., 1991, Paleogeographic significance of subterranean of the Golconda allochthon, northern Nevada, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., *Geology and ore deposits of the Great Basin—Symposium proceedings*: Reno, Geological Society of Nevada, p. 21–23.
- Rye, R.O., Roberts, R.J., Snyder, W.S., Lahusen, G.L., and Motica, J.E., 1984, Textural and isotopic studies of the Big Mike cupriferous volcanogenic massive sulfide deposit, Pershing County, Nevada: *Economic Geology*, v. 79, no. 1, p. 124–140.
- Singer, D.A., and Mosier, D.L., 1986, Grade-tonnage model of Cyprus massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p.131–135.

GB20**Massive Sulfide Deposits, Besshi Type****Nevada****Descriptive Model 24b • Mark3 Index 30****Area = 28,800 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by D.P. Cox, Steve Ludington, B.R. Berger, M.G. Sherlock, and D.A. Singer, (USGS); and J.V. Tingley (Nevada Bureau of Mines and Geology)

Rationale for Model Choice and an Important Example

Besshi deposits are stratabound, tabular bodies of massive iron, copper, and minor zinc sulfides found in sedimentary rocks in volcanic environments (Fox, 1984). The Rio Tinto copper deposit at Mountain City (Coats and Stephens, 1968) occurs in graphitic shale of the Valmy Formation in the Roberts Mountains allochthon and has some similarity to Besshi deposits worldwide. It lacks a close association with mafic flow rocks, which are present in the best examples of the Besshi model in Japan, the eastern United States, and Norway.

Rationale for Tract Delineation

The permissive tract is based on the distribution of rocks of the Ordovician Roberts Mountains assemblage, which include seafloor basalts, and represent a deep-water assemblage.

Rationale for Numerical Estimate

Because of uncertainties about the classification of Rio Tinto, and the geologic controls of this deposit type, we made a low estimate of the number of undiscovered deposits. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 1, 2, 2, and 3 or more deposits in the delineated area that are comparable in grade and tonnage to the Besshi massive sulfide model of Singer (1986).

References

- Coats, R.R., and Stephens, E.C., 1968, Mountain City Copper Mine, Elko County, Nevada, *in* Ridge, J.D., ed., *Ore deposits of the United States, 1933-1967 (Graton Sales Volume)*: New York, American Institute of Mining, Metallurgical, and Petroleum Engineers, v. 2, p. 1074-1101.
- Fox, J.S., 1984, Besshi-type volcanogenic sulphide deposits—a review: *Canadian Mining and Metallurgical Bulletin*, v. 77, p. 57-68.
- Singer, D.A., 1986, Grade-tonnage model of Besshi massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models: U.S. Geological Survey Bulletin 1693*, p. 136.

GB21 **Massive Sulfide Deposits, Sierran Kuroko Type** **Nevada**
Descriptive Model 28a.1 • Mark3 Index 44 **Oregon, California**
Area = 13,500 km²

[Cumulative Distribution](#)

[Histogram](#)

[Table](#)

[Model](#)

by D.P. Cox, Steve Ludington, B.R. Berger, M.G. Sherlock, and D.A. Singer, (USGS); and J.V. Tingley (Nevada Bureau of Mines and Geology)

Rationale for Model Choice and an Example

Examples of kuroko deposits are rare and not well documented in Nevada. Sorensen and others (1987, p. B12) briefly described the Red Boy and other prospects that probably belong to this type in the South Jackson Mountains. Singer (1992) has shown that Mesozoic kuroko deposits, typified by deposits in the western foothills of the Sierra Nevada, tend to have lower tonnage than other kuroko deposits. Since the permissive rocks for kuroko deposits in Nevada are of Triassic and Jurassic age, the Sierran kuroko grade and tonnage model is believed to best represent undiscovered deposits in Nevada.

Rationale for Tract Delineation

The Jurassic Black Rock and Triassic Koipato assemblages are delineated as permissive for kuroko massive sulfide deposits because they contain intermediate to felsic marine volcanic rocks in many localities.

Rationale for Numerical Estimates

For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 1, 3, 6, 7, and 8 undiscovered kuroko deposits, comparable in grade and tonnage to the Sierran kuroko massive sulfide model of Singer (1992) (Mark3 index 44), based primarily on the size of the permissive tract.

References

- Singer, D.A., 1992, Grade and tonnage model of Sierran kuroko deposits, *in* Bliss, J.D., ed., *Developments in deposit modeling: U.S. Geological Survey Bulletin 2004*, p. 29-32.
- Sorensen, M.L., Plouff, Donald, and Turner, R.L., 1987, Mineral resources of the South Jackson Mountains Wilderness Study Area, Humboldt County, Nevada: U.S. Geological Survey Bulletin 1726, 12 p.

GB22**Epithermal Vein Deposits, Comstock Type**

California

Descriptive Model 25c • Mark3 Index 16

Area = 13,400 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* Roger P. Ashley**Rationale for Model Choice**

Calc-alkaline volcanic centers of Tertiary age are widespread in the western Great Basin. Most are part of the ancestral Cascade volcanic arc. Several Comstock-type deposits occur in these centers, and many more occur immediately to the east in the same geologic environment in western Nevada. In addition, alkaline volcanic rocks belonging to the bimodal suite of the Basin and Range Province occur in this area.

Rationale for Tract Delineation

All areas of volcanic rocks in this tract are considered permissive for Comstock-type deposits. Because these deposits usually have limited vertical extent (about 1000 m maximum), they could be present within the 1-km depth limit and have little surface manifestation.

The tract boundaries are drawn to include all areas underlain predominantly by Cenozoic volcanic rocks between the Sierra Nevada front and the Nevada border, to the southern edge of the Great Basin. Where volcanic areas are covered by non-volcanic basin deposits of Tertiary or Quaternary age, the boundary is delineated where the cover is inferred to be 1 km thick, as derived from gravity models of the intermontane basins.

Important Examples of Deposit Type

The most prominent example is the Bodie district, which produced about 46 metric tons of gold and 31 metric tons of silver (Chesterman and others, 1986; Mosier, Menzie, and Kleinhampl, 1986). The Comstock and Aurora districts lie immediately adjacent to the tract, in western Nevada.

Rationale for Numerical Estimate

The volcanic centers in this tract have been relatively well explored for precious metal deposits, and some Comstock-type prospects are known. Bedrock areas in the tract are generally well exposed, and many parts of the tract are covered by detailed geologic mapping. Geophysical and geochemical data are also extensive. The estimators felt that continued exploration of the known prospects could yield one, or less likely two, deposits of size and tonnage appropriate to the Comstock model. For the 90th, 50th, and 10th percentiles, the team estimated 0, 1, and 2 or more districts consistent with the grade and tonnage models of Mosier, Sato, and Singer (1986) (Mark3 index 16).

The probability of large numbers of deposits is considered extremely low because the area has been relatively thoroughly explored, so no completely new prospects are likely to be discovered. Therefore the 5th and 1st percentile estimates show no additional deposits.

References

Chesterman, C.W., Chapman, R.H., and Gray, C.H., Jr., 1986, Geology and ore deposits of the Bodie mining district, Mono County, California: California Division of Mines and Geology Bulletin 206, 36 p.

Mosier, D.L., Menzie, W. D., and Kleinhampl, F.J., 1986, Geologic and grade-tonnage information on Tertiary epithermal precious- and base-metal vein districts associated with volcanic rocks: U.S. Geological Survey Bulletin 1666, 39 p.

Mosier, D.L., Sato, Takeo, and Singer, D.A., 1986, Grade-tonnage model of Comstock epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 151-153.

GB23**Epithermal Vein Deposits, Comstock Type****Nevada****Descriptive Model 25c • Mark3 Index 16****Oregon, Idaho****Area = 161,500 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by D.P. Cox, Steve Ludington, B.R. Berger, M.G. Sherlock, and D.A. Singer, (USGS); and J.V. Tingley (Nevada Bureau of Mines and Geology)

Rationale for Model Choice

Quartz-adularia veins have been subdivided into three subtypes, Comstock, Sado, and Creede, based on their metal grades and the presumed character of the basement underlying the volcanic sequence in which they are found (Mosier, Singer, and others 1986). The Comstock subtype, rich in silver and low in base metals, is generally found in volcanic rocks overlying low-grade metasedimentary basement rocks, and is, by far, the most abundant subtype in Nevada. The Creede type, rich in base metals, is not found in Nevada, and the Sado type, with low silver to gold ratio, makes up a very small proportion of the known deposits. Therefore the Comstock grade-tonnage model was applied to undiscovered quartz-adularia districts.

Rationale for Tract Delineation

The known Comstock-type deposits are distributed in a crescent-shaped area, concave to the east, that corresponds poorly with the overall distribution of Tertiary volcanic rocks (Silberman and others, 1976; Stewart and others, 1977; Seedorff, 1991; Cox and others, 1991; Ludington and others, in press). This distribution of volcanic-hosted epithermal deposits cannot be explained by the absence of volcanic rocks inward from the crescent. On the contrary, eastern Nevada contains extensive outcrops of older interior andesite-rhyolite assemblage rocks (older than 27 Ma) in which epithermal vein deposits are virtually unknown.

In addition to active volcanism, faulting and fracture permeability are important in controlling the distribution of epithermal deposits. The crescent-shaped area described above corresponds closely to those areas which were undergoing faulting in an extensional tectonic regime during active volcanism. The synvolcanic deformation is important because it provides fracture permeability at the same time that hydrothermal systems related to volcanism are active and circulating, thus facilitating the formation of veins and stockworks. Where Miocene volcanic rocks are relatively unfaulted, for example in the Sierra Nevada of California and in the Cascade Range of Oregon and Washington, Comstock deposits are rare or absent.

The Walker Lane area contains well-developed normal faults, and is probably the best studied region of epithermal mineralization in Nevada (Stewart, 1988). Northwest-striking high-angle faults that predominate in this area have been shown by John and others (1989) to be at least as old as the earliest volcanic activity (22 Ma) in the Paradise Range suggesting that faulting and volcanism were synchronous throughout the period of andesite volcanism. This region is shown by Blakely (1988) to be characterized by a northwest-trending grain in the pattern of magnetic anomalies that can be recognized about 50 km to the northeast of traditional boundaries of the Walker Lane that are based on topography and structure. This expanded area of characteristic magnetic fabric encompasses all of the volcanic-hosted epithermal districts in southwestern Nevada. The northeastern boundary of this magnetic anomaly pattern coincides with a line separating calderas younger and older than 27 Ma. (Best and others, 1989); the eastern boundary is the magnetic quiet zone (Blakely, 1988). Walker Lane deformation began locally at 27 Ma, and continued during succeeding volcanic episodes until the beginning of Basin and

Range deformation at about 11 Ma, thus controlling the distribution of epithermal precious-metal deposits in this part of Nevada. A strong negative correlation exists between the magnetic quiet zone and the distribution of volcanic-hosted epithermal deposits. This is especially clear in the southern arm of the crescent where a gap exists between the deposits in the Walker Lane and the Atlanta and Stateline districts to the east in Lincoln County.

The permissive tract for quartz-adularia districts is based on the distribution of volcanic rocks, of epithermal mineral deposits, prospects, and occurrences, on the distribution of synvolcanic faults, and on the magnetic anomaly patterns described above. This tract covers about 55 percent of Nevada; about 47 percent of the tract is covered by superficial deposits younger than the mineralized rocks. Because some epithermal deposits occur in sedimentary rocks close to volcanic centers (Willard, Atlanta, Florida Canyon), sedimentary rocks within and between the volcanic rock areas are included in the tract.

Important Examples of Deposit Type

The Comstock and Tonopah districts, the largest in Nevada, are associated with volcanic rocks of the western andesite assemblage. The Jarbidge and National districts are related to the bimodal assemblage, and Tuscarora, to the andesite-rhyolite assemblage.

Rationale for Numerical Estimate

Our estimate of the number of undiscovered districts of the quartz-adularia type was based on the following considerations:

- (1) A district is defined by the grade-tonnage model for Comstock epithermal veins (Mosier and others, 1986b). Roughly 30 such districts are known in Nevada.
- (2) An additional 8 districts are known that are too small to fit the definition. Some of these may be incompletely explored and present opportunities for the discovery of new districts.
- (3) Quartz-adularia vein systems will probably be found in the vicinity of some hot-spring gold deposits as exploration near these deposits proceeds. Where the hot-spring deposit is isolated from other known epithermal districts, these systems are considered to be evidence for undiscovered quartz-adularia districts.
- (4) Quartz-adularia vein deposits can be detected by prospecting methods that have been employed in Nevada since the 1850s. Thus exploration for them in exposed permissive areas can be considered to be well advanced.
- (5) Known deposits and prospects are mainly in areas of exposed permissive rock. Only one deposit, Sleeper, has been found beneath alluvium. Thus, the 47 percent of the permissive area under cover is likely to contain many undiscovered deposits.

For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 14, 18, 24, 26, and 29 districts consistent with the Comstock grade and tonnage model (Mosier and others, 1986).

References

- Best, M.G., Christiansen, E.H., Deino, A.L., Grommé, C.S., McKee, E.H., and Noble, D.C. 1989, Excursion 3A: Eocene through Miocene volcanism in the Great Basin of the western United States: New Mexico Bureau of Mines and Mineral Resources Memoir 47, p. 91-133.
- Blakely, R. J., 1988, Curie temperature isotherm analysis and tectonic implications of aeromagnetic data from Nevada: *Journal of Geophysical Research*, v. 93, p. 11, 817-11, 832.
- Cox, D.P., Ludington, Steve, Sherlock, M.G., Singer, D.A., Berger, B.R., and Tingley, J.V., 1991, Mineralization patterns in time and space in the Great basin of Nevada, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., *Geology and ore deposits of the Great Basin—Symposium proceedings*: Reno, Geological Society of Nevada, v. 2, April 1990, p. 193-198.

- John, D.A., Thomason, R.E., and McKee, E.H., 1989, Geology and geochronology of the Paradise Peak Mine and the relationship of pre-Basin and Range extension to early Miocene precious metal mineralization in west-central Nevada: *Economic Geology*, v. 84, no. 3, p. 631-649.
- Ludington, Steve, Cox, D.P., Sherlock, M.G., Singer, D.A., Berger, B.R., and Tingley, Joe, in press, Spatial and temporal analysis of precious-metal deposits for a mineral resource assessment of Nevada: Ottawa, Canada, Transactions IAGOD/IUGS Symposium, 15 p.
- Mosier, D.L., Singer, D.A., Sato, T., and Page, N.J., 1986, Relationship of grade, tonnage, and basement lithology in volcanic-hosted epithermal precious- and base-metal quartz-adularia-type districts: *Mining Geology*, v. 36, no. 4, p. 245-264.
- Mosier, D.L., Sato, Takeo, and Singer, D.A., 1986, Grade-tonnage model of Comstock epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 151-153.
- Seedorff, Eric, 1991, Magmatism, extension, and ore deposition of Eocene to Holocene age in the Great Basin—Mutual effects and preliminary proposed genetic relationships, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., *Geology and ore deposits of the Great Basin—Symposium proceedings*: Reno, Geological Society of Nevada, v. 1, April 1990, p. 133-178.
- Silberman, M.L., Stewart, J.H., and McKee, E.H., 1976, Igneous activity, tectonics and precious metal mineralization in the Great Basin during Cenozoic time: *Society of Mining Engineers, AIME Transactions*, v. 260, p. 253-263.
- Stewart, J.H., 1988, Tectonics of the Walker lane belt, western Great Basin—Mesozoic and Cenozoic deformation in a shear zone, *in* Ernst, W.G., ed., *Metamorphism and crustal evolution of the western United States (Rubey Volume VII)*: Englewood Cliffs, New Jersey, Prentice Hall, p. 683-713.
- Stewart, J.H., Moore, W.J., and Zietz, Isidore, 1977, East-west patterns of Cenozoic igneous rocks, aeromagnetic anomalies, and mineral deposits, Nevada and Utah: *Geological Society of America Bulletin*, v. 88, p. 67-77.

GB24 Epithermal Vein Deposits, Quartz-adularia Type

Descriptive Model 25c + 25d • Mark3 Index 25

Utah
IdahoArea = 41,600 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Douglas B. Stoeser

Rationale for Model Choice

Western Utah contains extensive areas of felsic volcanic rocks that contain known quartz-adularia epithermal deposits. Although production data are meager, the team's general knowledge of the deposits and prospects in the area suggests that they have a relatively small Ag:Au ratio and very low base metals, fitting more closely the characteristics of the Comstock (Mosier, Singer, and Berger, 1986) and Sado (Mosier, Berger, and Singer, 1986) epithermal vein deposits. As a result, the team compared the Utah quartz-adularia veins with a composite model of Comstock and Sado vein deposits (Mark3 index 25).

Rationale for Tract Delineation

Quartz-adularia gold deposits belong to the epithermal class of mineral deposits, and are typically localized within a few hundred meters of the Earth's surface. They occur mainly in or adjacent to volcanic vent areas. Permissive rocks for this type of deposit consist of intermediate to silicic volcanic fields which have undergone minimal erosion. These are present in three east-trending belts in western Utah and southernmost Idaho. In addition to the Miocene and older calc-alkaline belts which also have porphyry copper potential, the younger (20 Ma to present) extension-related, evolved, silicic systems are also prospective for epithermal gold deposits. Most of the silicic extensional magmatism also occurs within the three same areas that contain intrusion-related deposits (porphyry copper, polymetallic replacement, and skarn).

Important Examples of Deposit Type

All significant quartz-adularia gold deposits occur within the southern area and include Gold Mountain (Marysvale District), Stateline, Escalante, and possibly Goldstrike (although the Goldstrike District is generally considered to be of the sediment-hosted gold deposit type). Prospects in the southern area include Gold Springs, Modena, Fortuna, Rob Roy, and the Belknap area of the Marysvale District, and in the north-central area, Erickson (Indian Canyon), and possibly the Desert Mountain (Coyote Knoll prospect) and Gold Hills districts.

Rationale for Numerical Estimate

The presence of a large permissive tract, coupled with the fact that about 70 percent of the area is covered by alluvium, led the team to believe that the chances for the existence of undiscovered deposits are fairly good. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 1, 2, 4, 6, and 9 or more deposits consistent with the composite grade and tonnage model.

References

Mosier, D.L., Singer, D.A., and Berger, B.R., 1986, Grade and tonnage model of Comstock epithermal veins, in Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 151-153.

Mosier, D.L., Berger, B.R., and Singer, D.A., 1986, Grade and tonnage model of Sado epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 155-157.

GB25**Epithermal Vein Deposits, Quartz-alunite Type**

California

Descriptive Model 25e • Mark3 Index 38

Area = 13,400 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Roger P. Ashley**Rationale for Model Choice**

Both Comstock-type epithermal deposits and quartz-alunite gold deposits are shallow-level products of hydrothermal systems associated with volcanism. Systems that produce quartz-alunite Au-Cu deposits are distinguished from those that produce Comstock deposits by higher thermal gradients and abundant, oxidized sulfur. Quartz-alunite deposits show an even stronger preference for calc-alkaline volcanic centers than do Comstock deposits, because shallow sub-volcanic intrusions are required to supply heat and sulfur to the near-surface environment. Calc-alkaline centers of Tertiary age are widespread in the western Great Basin; most are related to the ancestral Cascade volcanic arc. Some of these centers host quartz-alunite-type epithermal deposits, here and to the east in western Nevada.

Rationale for Tract Delineation

The geologic environment for quartz-alunite deposits is volcanic rocks with associated subvolcanic intrusions. The existence of subvolcanic intrusions can be inferred using geologic criteria (presence of hydrothermal alteration, intermediate to silicic domes) or geophysical criteria (magnetic patterns or anomalies). Because published geologic and geophysical maps do not provide the information necessary to apply these criteria everywhere, the permissive tract consists of all areas of volcanic rocks in the area. Also, since these deposits are limited in vertical extent (a few hundred meters), they could be present within the 1-km depth limit, yet have little surface manifestation.

The tract boundaries are the same as for Comstock-type epithermal deposits. They are drawn to include all areas underlain predominantly by Cenozoic volcanic rocks between the Sierra Nevada front and the Nevada border, to the southern edge of the Great Basin. Where volcanic areas are covered by non-volcanic basin deposits of Tertiary or Quaternary age, the boundary is delineated where the cover is inferred to be 1 km thick, as derived from gravity models of the intermontane basins.

Important Examples of Deposit Type

The most important known deposit in the tract is the Masonic district, with production of just over 1 metric ton of gold (Mosier and others, 1986). Other deposits of this type occur in similar volcanic host rocks in western Nevada; the most prominent example is Goldfield, having a production of more than 120 metric tons of gold (Ashley, 1990).

Rationale for Numerical Estimate

The individual prospects considered likely to yield new quartz-alunite type deposits are not the same as those expected to yield new Comstock-type deposits, but the rationale for the two deposit types is similar in the Great Basin of California. Bedrock areas in the tract are generally well exposed, and many parts of the tract are covered by detailed geologic maps. Geophysical and geochemical data are also extensive. The estimators felt that continued exploration of the known prospects could yield one, or less likely two, deposits of size and tonnage appropriate to the quartz-alunite model. For the 90th, 50th, and 10th percentiles, the team estimated 0, 1,

and 2 or more districts consistent with the grade and tonnage models of Mosier and Menzie (1986) (Mark3 index 38).

The probability of large numbers of deposits is considered extremely low because the area has been relatively thoroughly explored, therefore the 5th and 1st percentile estimates show no additional deposits.

References

- Ashley, R.P., 1990, The Goldfield gold district, Esmeralda and Nye Counties, Nevada, *in* Shawe, D.R., and Ashley, R.P., eds., *Geology and resources of gold in the United States, Epithermal gold deposits—Part 1: U.S. Geological Survey Bulletin 1857-H*, p. H1-H7.
- Mosier, D.L., and Menzie, W.D., 1986, Grade-tonnage model of epithermal quartz-alunite veins, in Cox, D.P., and Singer, D.A., eds., *Mineral deposit models: U.S. Geological Survey Bulletin 1693*, p. 159-161.
- Mosier, D.L., Menzie, W.D., and Kleinhampl, F.J., 1986, Geologic and grade-tonnage information on Tertiary epithermal precious- and base-metal vein districts associated with volcanic rocks: U.S. Geological Survey Bulletin 1666, 39 p.

GB26**Epithermal Vein Deposits, Quartz-alunite Type****Nevada****Descriptive Model 25e • Mark3 Index 38****Area = 161,600 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by D.P. Cox, Steve Ludington, B.R. Berger, M.G. Sherlock, and D.A. Singer, (USGS); and J.V. Tingley (Nevada Bureau of Mines and Geology)

Rationale for Model Choice

The quartz-alunite deposit type requires the presence of extensive hypogene acid-sulfate alteration. In addition to the Goldfield district, at least six additional occurrences of hypogene alunite are known in western Nevada, mainly in rocks of the western andesite assemblage. Alunite alteration locally affects pre-Miocene rocks but can be shown to be genetically related to western andesite assemblage volcanism (D. John, written comm., 1993).

Rationale for Tract Delineation

The known epithermal deposits are distributed in a crescent-shaped area, concave to the east, that corresponds poorly with the overall distribution of Tertiary volcanic rocks (Silberman and others, 1976; Stewart and others, 1977; Seedorff, 1991; Cox and others, 1991; Ludington and others, in press). This distribution of volcanic-hosted epithermal deposits cannot be explained by the absence of volcanic rocks inward from the crescent. On the contrary, eastern Nevada contains extensive outcrops of older interior andesite-rhyolite assemblage rocks (older than 27 Ma) in which epithermal vein deposits are virtually unknown.

In addition to active volcanism, faulting and fracture permeability are important in controlling the distribution of epithermal deposits. The crescent-shaped area described above corresponds closely to those areas which were undergoing faulting in an extensional tectonic regime during active volcanism. The synvolcanic deformation is important because it provides fracture permeability at the same time that hydrothermal systems related to volcanism are active and circulating, thus facilitating the formation of veins and stockworks. Where Miocene volcanic rocks are relatively unfaulted, for example in the Sierra Nevada of California and in the Cascade Range of Oregon and Washington, Comstock deposits are rare or absent.

The Walker Lane area contains well-developed normal faults, and is probably the best studied region of epithermal mineralization in Nevada (Stewart, 1988). Northwest-striking high-angle faults that predominate in this area have been shown by John and others (1989) to be at least as old as the earliest volcanic activity (22 Ma) in the Paradise Range suggesting that faulting and volcanism were synchronous throughout the period of andesite volcanism. This region is shown by Blakely (1988) to be characterized by a northwest-trending grain in the pattern of magnetic anomalies that can be recognized about 50 km to the northeast of traditional boundaries of the Walker Lane that are based on topography and structure. This expanded area of characteristic magnetic fabric encompasses all of the volcanic-hosted epithermal districts in southwestern Nevada. The northeastern boundary of this magnetic anomaly pattern coincides with a line separating calderas younger and older than 27 Ma (Best and others, 1989); the eastern boundary is the magnetic quiet zone (Blakely, 1988). Walker Lane deformation began locally at 27 Ma, and continued during succeeding volcanic episodes until the beginning of Basin and Range deformation at about 11 Ma, thus controlling the distribution of epithermal precious-metal deposits in this part of Nevada. A strong negative correlation exists between the magnetic quiet zone and the distribution of volcanic-hosted epithermal deposits. This is especially clear

in the southern arm of the crescent where a gap exists between the deposits in the Walker Lane and the Atlanta and Stateline districts to the east in Lincoln County.

The permissive tract for quartz-alunite districts is based on the distribution of volcanic rocks, of epithermal mineral deposits, prospects, and occurrences, on the distribution of synvolcanic faults, and on the magnetic anomaly patterns described above. This tract covers about 55 percent of Nevada; about 47 percent of the tract is covered by superficial deposits younger than the mineralized rocks. Because some epithermal deposits occur in sedimentary rocks close to volcanic centers (Willard, Atlanta, Florida Canyon), sedimentary rocks within and between the volcanic rock areas are included in the tract.

The area considered favorable for undiscovered quartz-alunite districts includes exposed and covered areas of western andesite assemblage rocks in the Walker Lane belt, because nearly all examples of alunite alteration in Nevada are in rocks of this assemblage.

Important Examples of Deposit Type

The Goldfield district is the premier example in Nevada, and one of the most important districts in the world (Ransome, 1909; Ashley, 1990).

Rationale for Numerical Estimate

In our estimate of undiscovered districts, we considered that the favorable area of andesitic rocks is small relative to the permissive area, and that quartz-alunite gold deposits form under special conditions of intense sulfidation and are thus inherently less abundant than hot-spring and quartz-adularia deposits. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 2, 5, 9, 12, and 15 districts consistent with the epithermal quartz-alunite grade-tonnage model (Mosier and Menzie, 1986).

References

- Ashley, R.P., 1990, The Goldfield gold district, Esmeralda and Nye Counties, *in* Shawe, D.R., and Ashley, R.P., eds., *Geology and resources of gold in the United States, Epithermal gold deposits—Part 1: U.S. Geological Survey Bulletin 1857-H*, p. H1–H7.
- Mosier, D.L., and Menzie, W.D., 1986, Grade-tonnage model of epithermal quartz-alunite veins, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models: U.S. Geological Survey Bulletin 1693*, p. 159–161.
- Ransome, F.L., 1909, *Geology and ore deposits of Goldfield, Nevada: U.S. Geological Survey Professional Paper 66*, 258 p.

GB27**Epithermal Vein Deposits, Quartz-alunite Type**Utah
Idaho

Descriptive Model 25e • Mark3 Index 38

Area = 41,600 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Douglas B. Stoesser

Rationale for Model Choice

Quartz-alunite gold deposits are associated with felsic to intermediate volcanic centers with associated shallow intrusions. Although no deposits are known in the State, hydrothermal alunite is present in the Marysvale district, and volcanic rocks are abundant in western Utah. We used the descriptive model of Berger (1986) and the grade and tonnage model of Mosier and Menzie (1986).

Rationale for Tract Delineation

Quartz-alunite gold deposits belong to the epithermal class of mineral deposits, and typically form within a few hundred meters of the Earth's surface. They occur mainly within volcanic vent areas. Permissive rocks for this type of deposit consist of volcanic fields which have undergone minimal erosion. These are present in three east-trending belts in western Utah. In addition to the Miocene and older calc-alkaline belts that also have porphyry copper potential, the younger (20 Ma to present) extension-related, evolved, silicic systems are also prospective for epithermal gold deposits. Most of the silicic extensional magmatism also occurs within the three same areas that contain intrusion-related deposits (porphyry copper, polymetallic replacement, and skarn). Utah was considered permissive for this deposit type even though there was little direct evidence for its occurrence in western Utah.

Important Examples of Deposit Type

No known quartz-alunite gold deposits occur in Utah, but areas of hydrothermal alteration that include alunite deposits occur in the Tushar Mountains area of the Marysvale volcanic field.

Rationale for Numerical Estimate

Despite the paucity of deposits or prospects in the State, the team felt that the extent of volcanic rocks and the amount of alluvial cover permitted the possible occurrence of this type of deposit. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 1, and 2 or more deposits consistent with the grade and tonnage model for quartz-alunite gold deposits of Mosier and Menzie (1986).

References

- Berger, B.R., 1986, Descriptive model of epithermal quartz-alunite Au, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 158.
- Mosier, D.L., and Menzie, W.D., 1986, Grade and tonnage model of epithermal quartz-alunite Au *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 159-161.

GB28**Hot-spring Au-Ag Deposits****Nevada****Descriptive Model 25a • Mark3 Index 45****Oregon, Idaho****Area = 161,500 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by D.P. Cox, Steve Ludington, B.R. Berger, M.G. Sherlock, and D.A. Singer, (USGS); and J.V. Tingley (Nevada Bureau of Mines and Geology)

Rationale for Model Choice

Hot-spring Au-Ag deposits are disseminated or stockwork deposits that form near a paleosurface in volcanic rocks and, less commonly, in sedimentary rocks and alluvial sediments (Berger, 1985). They are closely related to quartz-adularia and quartz-alunite gold deposits but we have tried to classify them separately because they are distinctly larger in tonnage and lower in grade. Because they grade downward into fissure veins, they are, in some cases, difficult to distinguish from the other types of epithermal gold deposits. Moreover, some epithermal deposits, mined by open pit methods, are more appropriately placed in the hot-spring category because of their reported tonnage and grade, even though evidence for a paleosurface is lacking.

Rationale for Tract Delineation

In Nevada, known hot-spring gold-silver deposits are distributed in a crescent-shaped area, concave to the east, that corresponds poorly with the overall distribution of Tertiary volcanic rocks (Silberman and others, 1976; Stewart and others, 1977; Cox and others, 1991; Seedorff, 1991; Cox and others, 1991; Ludington and others, in press). This distribution of hot-spring gold deposits cannot be explained by the absence of volcanic rocks inward from the crescent. On the contrary, eastern Nevada contains extensive outcrops of older interior andesite-rhyolite assemblage rocks (older than 27 Ma) in which epithermal vein deposits are virtually unknown.

In addition to active volcanism, faulting and fracture permeability are important in controlling the distribution of epithermal deposits. The crescent-shaped area described above corresponds closely to those areas which were undergoing faulting in an extensional tectonic regime during active volcanism. The synvolcanic deformation is important because it provides fracture permeability at the same time that hydrothermal systems related to volcanism are active and circulating, thus facilitating the formation of veins and stockworks. Where Miocene volcanic rocks are relatively unfaulted, for example in the Sierra Nevada of California and in the Cascade Range of Oregon and Washington, epithermal mineral deposits are rare or absent.

The Walker Lane area contains well-developed normal faults, and is probably the best studied region of epithermal mineralization in Nevada (Stewart, 1988). Northwest-striking high-angle faults that predominate in this area have been shown by John and others (1989) to be at least as old as the earliest volcanic activity (22 Ma) in the Paradise Range suggesting that faulting and volcanism were synchronous throughout the period of andesite volcanism.

This region is shown by Blakely (1988) to be characterized by a northwest-trending grain in the pattern of magnetic anomalies that can be recognized about 50 km to the northeast of traditional boundaries of the Walker Lane that are based on topography and structure. This expanded area of characteristic magnetic fabric encompasses all of the volcanic-hosted epithermal districts in southwestern Nevada. The northeastern boundary of this magnetic anomaly pattern coincides with a line separating calderas younger and older than 27 Ma (Best and others, 1989), the eastern boundary is the magnetic quiet zone (Blakely, 1988). We believe

that the Walker Lane deformation began locally at 27 Ma, and continued during succeeding volcanic episodes until the beginning of Basin and Range deformation at about 11 Ma, thus controlling the distribution of hot-spring precious-metal deposits in this part of Nevada.

Two northwest-striking linear permissive areas in central Nevada were drawn to enclose basalt flows, dike swarms, and linear magnetic anomalies associated with the northern Nevada rift (Blakely, 1988). The northern segment of this area contains the Fire Creek and Buckhorn hot-spring gold deposits. Basalt outcrops and magnetic anomalies die out at the southern end of this segment near Eureka, but shallow magnetic sources indicate a southern continuation that is slightly offset, but parallel to the northern one.

The permissive tract is based on the distribution of volcanic rocks, of epithermal mineral deposits, prospects, and occurrences, on the distribution of synvolcanic faults, and on the magnetic anomaly patterns described above. This tract covers 55 percent of Nevada; 47 percent of the tract is covered by superficial deposits younger than the mineralized rocks. The high-level environments permissive for hot-spring deposits are difficult to separate from those for other epithermal deposits using published geologic data.

Important Examples of Deposit Type

Of the 15 deposits classified as hot-spring gold-silver deposits in Nevada, Round Mountain, the largest, is related to the interior andesite-rhyolite volcanic assemblage, and lies near the inner, eastern edge of the expanded Walker Lane belt. Borealis and Paradise Peak are associated with western andesite assemblage rocks, and the rest are in rocks of the bimodal basalt-rhyolite assemblage (e.g., Sleeper and Hog Ranch) and nearby sedimentary rocks or sedimentary deposits (e.g., Lewis). Seven deposits are located within 5 km of a rhyolite intrusion close in age to the time of mineralization. Buckhorn and Fire Creek are hosted in basaltic andesite and presumably lie above mafic dikes related to the Northern Nevada magnetic anomaly described by Blakely (1988).

Rationale for Numerical Estimate

Our estimate of the number of undiscovered deposits in these areas was influenced by the following considerations:

- (1) About 15 deposits are known and prospecting was in progress in at 7 or more additional localities at the time of preparing the estimate (1989-92).
- (2) MRDS records contain 19 additional occurrences that have descriptions suggestive of hot-spring gold-silver mineralization.
- (3) There is a common association of gold and hot-spring mercury deposits. Roughly 75 hot-spring mercury deposits and occurrences are described in the MRDS records for Nevada.
- (4) Most of these deposits and occurrences are in areas of exposed permissive rock. Additional permissive area, roughly equal to the exposed area, is covered by younger sediments, and could conceal undiscovered deposits.
- (5) Because of their low grade and fine grain size of contained gold, hot-spring gold deposits are more difficult to detect by traditional exploration methods than vein deposits and most of the known deposits have been discovered since 1960. There has been no exploration during this period in the large part of the permissive area within the Nevada Test Site.

For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 13, 18, 21, 25, and 29 deposits comparable in grade and tonnage to the hot-spring gold grade and tonnage model (Berger and Singer, 1992).

References

- Berger, B.R., 1985, Geologic-geochemical features of hot-spring precious metal deposits, *in* Tooker, E.W., Ed., Geologic characteristics of sediment- and volcanic-hosted disseminated gold deposits—Search for an occurrence model: U.S. Geological Survey Bulletin 1646, p. 47-48.
- Berger, B.R., and Singer, D.A., 1992, Grade and tonnage model of hot-spring Au-Ag, *in* Bliss, J.D., ed., Developments in deposit modeling: U.S. Geological Survey Bulletin 2004, p. 23-25.
- Best, M.G., Christiansen, E.H., Deino, A.L., Grommé, C.S., McKee, E. H., and Noble, D.C. 1989, Excursion 3A—Eocene through Miocene volcanism in the Great Basin of the western United States: New Mexico Bureau of Mines and Mineral Resources Memoir 47, p. 91-133.
- Blakely, R. J., 1988, Curie temperature isotherm analysis and tectonic implications of aeromagnetic data from Nevada, *Journal of Geophysical Research*, v. 93, p. 11,817-11,832.
- Cox, D.P., Ludington, Steve, Sherlock, M.G., Singer, D.A., Berger, B.R., and Tingley, J.V., 1991, Mineralization patterns in time and space in the Great Basin of Nevada, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., *Geology and ore deposits of the Great Basin—Symposium proceedings*: Reno, Geological Society of Nevada, v. 2, April 1990, p. 193-198.
- John, D.A., Thomason, R.E., and McKee, E.H., 1989, Geology and geochronology of the Paradise Peak mine and the relationship of pre-Basin and Range extension to early Miocene precious metal mineralization in west-central Nevada: *Economic Geology*, v. 84, no. 3, p. 631-649.
- Ludington, Steve, Cox, D.P., Sherlock, M.G., Singer, D.A., Berger, B.R., and Tingley, Joe, in press, Spatial and Temporal analysis of precious-metal deposits for a mineral resource assessment of Nevada: Ottawa, Canada, Transactions IAGOD/IUGS Symposium, 15 p.
- Seedorff, Eric, 1991, Magmatism, extension, and ore deposition of Eocene to Holocene age in the Great Basin—Mutual effects and preliminary proposed genetic relationships, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., *Geology and ore deposits of the Great Basin, Symposium proceedings*: Reno, Geological Society of Nevada, v. 1, April 1990, p. 133-178.
- Silberman, M.L., Stewart, J.H., and McKee, E.H., 1976, Igneous activity, tectonics and precious metal mineralization in the Great Basin during Cenozoic time: Society of Mining Engineers, AIME, Transactions, v. 260, p. 253-263.
- Stewart, J.H., 1988, Tectonics of the Walker lane belt, western Great Basin—Mesozoic and Cenozoic deformation in a shear zone, *in* Ernst, W.G., ed., *Metamorphism and crustal evolution of the western United States (Rubey Volume VII)*: Englewood Cliffs, New Jersey, Prentice Hall, p. 683-713.
- Stewart, J.H., Moore, W.J., and Zietz, Isidore, 1977, East-west patterns of Cenozoic igneous rocks, aeromagnetic anomalies, and mineral deposits, Nevada and Utah: *Geological Society of America Bulletin*, v. 88, p. 67-77.

GB29**Hot-spring Au-Ag Deposits**Utah
Idaho

Descriptive Model 25a • Mark3 Index 45

Area = 41,600 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Douglas B. Stoesser

Rationale for Model Choice

Although no hot-spring Au-Ag deposits are known in the State, this type of deposit is commonly related to volcanic activity, evidence for which is abundant in Utah.

Rationale for Tract Delineation

Three areas make up the permissive tract for hot-spring Au-Ag deposits. The two most important areas are defined by east-trending, dominantly calc-alkaline, Tertiary magmatic belts in the western part of the State which contain most of the significant base- and precious-metal deposits of Utah (Shawe and Stewart, 1976; Seedorff, 1991). Two adjacent belts, the Oquirrh-Uinta belt and the Tintic-Deep Creek belt, combine to form the north-central area. The southern area is collectively defined by the Pioche-Marysville (or Wah Wah-Tushar) and Delamar-Iron Springs belts. The erosional level on the north-central area is deeper than the southern area, such that much of the once-extensive volcanic rocks have been removed, whereas to the south, extensive areas of volcanic rocks are still preserved. Thus, the southern area is more favorable for hot-spring Au-Ag deposits, which form near the paleosurface. In addition to the two areas identified above, a third area in the northwest is also recognized. The northwestern area is underlain by local volcanic and minor intrusive rocks, and is also permissive for hot-spring Au-Ag deposits. The three permissive terranes have approximately 70 percent alluvial cover less than 1 km thick.

Important Examples of Deposit Type

There are no known hot-spring Au-Ag deposits in Utah, nor are there any significant prospects.

Rationale for Numerical Estimate

Although no hot-spring Au-Ag deposits are known from the area, the presence of felsic volcanic rocks suggests that they could have formed. Deposits may be concealed beneath younger volcanic units or beneath the extensive alluvial cover. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 1, and 2 or more deposits consistent with the grade and tonnage model for hot-spring Au-Ag deposits of Berger and Singer (1992).

References

- Berger, B.R., and Singer, D.A., 1992, Grade and tonnage model of hot-spring Au-Ag, *in* Bliss, J.D., ed., *Developments in deposit modeling: U.S. Geological Survey Bulletin 2004*, p. 23-25.
- Seedorff, Eric, 1991, Magmatism, extension, and ore deposition of Eocene to Holocene age in the Great Basin—Mutual effects and preliminary proposed genetic relationships, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., *Geology and ore deposits of the Great Basin—Symposium proceedings: Reno, Geological Society of Nevada*, v. 1, April 1990, p. 133-178.
- Shawe, D.R. and Stewart, J.H., 1976, Ore deposits as related to tectonics and magmatism, Nevada and Utah: *Transactions of Society of Mining Engineers*, v. 260, p. 225-231.

GB30**Sediment-hosted Au Deposits****Nevada****Descriptive Model 26a • Mark3 Index 17****California, Idaho****Area = 195,100 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by D.P. Cox, S. D. Ludington, B.R. Berger, M.G. Sherlock, and D.A. Singer, (USGS); and J.V. Tingley (Nevada Bureau of Mines and Geology)

Rationale for Model Choice

Nevada contains 50 known sediment-hosted gold deposits, which comprise the bulk of deposits on which the grade and tonnage model of Mosier and others (1992) is based.

Rationale for tract Delineation

Delineation of tracts permissive for sediment-hosted gold deposits is difficult because: (1) the deposits occur in a wide variety of types and ages of host rock; (2) structures believed to control the distribution of deposits are too subtle to be shown on published geologic maps; (3) direct determination of mineralization age by isotopic analysis is restricted by the lack of suitable minerals in the deposits; and (4) the genetic association of mineralization with igneous rocks is uncertain, primarily because of the lack of age constraints.

During the last two decades of intensive exploration for gold, sediment-hosted gold deposits have not been found in significant numbers outside of the Great Basin. If these deposits are unique to the Great Basin, then, as pointed out by Seedorff (1991), their origin must be related to some unique feature of the region. Speed and others (1988) showed that this region is distinctive among other forelands in its great width, lack of extensive uplift and unroofing, and absence, on the oceanward side, of a colliding basement-terrane. Berger and Henley (1989) point to the overthickening of the crust by thrust faulting as an important characteristic of the part of the Great Basin occupied by known sediment-hosted gold deposits, adding that tectonic stacking of marine sedimentary deposits could have created large reservoirs of connate water. Existence of such a fluid reservoir is suggested (Rose and Kuehn, 1987; Hofstra and others, 1988) by the geochemistry and isotopic composition of ore-stage fluid inclusions (elevated $\delta^{18}\text{O}$, CO_2 , H_2S , and Cl) from sediment-hosted gold deposits.

Large parts of the crust in Nevada have been overthickened by crustal shortening along the active western margin of North America from during the late Paleozoic and Mesozoic (Speed and others, 1988). The Roberts Mountains and Golconda assemblages were thrust eastward during the late Paleozoic Antler and Triassic Sonoma orogenies, respectively. In the Cretaceous, several allochthons within the Paradise volcanic assemblage were thrust southeastward and stacked east of the Pine Nut fault and behind and atop the Golconda assemblage; thrust faulting resulted in thickening of Triassic rocks of the Jungo assemblage; eastern assemblage rocks were thickened by east-directed thrusting during the Elko and Sevier orogenies in much of northeastern Nevada (Thorman and others, 1991).

Based on the assumed relationship between crustal thickening and sediment-hosted gold deposits, all sedimentary and metasedimentary rocks within the area of tectonically thickened crust are delineated as permissive for sediment-hosted gold deposits. Tract delineation was based on distribution of the allochthons mentioned above, and, in the Sevier orogenic belt in eastern Nevada by patterns of folding and thrust faulting shown on the geologic map of Stewart and Carlson (1978). The permissive tract encompasses 62 percent of the area of Nevada; 77

percent of the tract is covered by Tertiary and Quaternary rocks and sedimentary deposits less than 1 km thick.

Important Examples of Deposit Type

Sediment-hosted gold deposits are distributed in three groups which reflect differences in host rocks, structures, and possibly, age of formation. The central group is represented by deposits in the Jerritt Canyon (Burns Basin) district; the Carlin trend; Marigold; deposits around Cortez; Tonkin Springs; and Northumberland. Many of these districts are situated on or close to the Roberts Mountains Thrust. Ages of some of these gold deposits have been indirectly estimated at between 36 and 39 Ma (Bonham, 1989; Berger and Bagby, 1991). The western group of sediment-hosted gold deposits is represented by deposits in the Getchell trend, Standard, and Fondaway Canyon. The Getchell trend deposits are hosted by siliceous shale and phyllite of Cambrian age. The eastern group of deposits is represented by the Bald Mountain, Golden Butte, Alligator Ridge, Illipah, Night Hawk, and Green Springs, mainly hosted in Cambrian, Devonian, and Mississippian carbonate rocks and shales.

Rationale for Numerical Estimates

Our estimate was influenced mainly by the high density of known deposits in the exposed part of the permissive tract and the large proportion of the tract that is concealed by less than 1 km of cover. Significant recent discoveries have been made beneath varying depths of cover. Also, recent exploration of known deposits has shown that their vertical extent can be great, suggesting that undiscovered deposits can exist over a wide range of depths within the permissive tract. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 15, 21, 27, 30, and 33 deposits that are consistent with the grade and tonnage model of Mosier and others (1992).

References

- Berger, B.R., and Henley, R.W., 1989, Advances in the understanding of epithermal gold-silver deposits, with special reference to the western United States, *in* Keays, R.R., Ramsay, W.R.H., and Groves, D.I., eds., *The geology of gold deposits—The perspective in 1988: Economic Geology Monograph 6*, p. 405-423.
- Berger, B.R., and Bagby, W.C., 1991, The geology and origin of Carlin type deposits, *in* Foster, R.P., ed., *Gold exploration and metallogeny: London, Blackie and Sons*, p. 210-248.
- Hofstra, A.H., Landis, G.P., Leventhal, J.S., Northrop, H.R., Rye, R.O., Doe, T.C., and Dahl, A.R., 1991, Genesis of sediment-hosted, disseminated gold deposits by fluid mixing and sulfidation of iron in the host rocks—Chemical reaction path modeling of ore depositional processes at Jerritt Canyon, Nevada, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., *Geology and ore deposits of the Great Basin—Symposium proceedings: Reno, Geological Society of Nevada*, v. 1, April 1990, p. 235-238.
- Mosier, D.L., Singer D.A., Bagby, W.C., and Menzie, W. D., 1992, Grade and tonnage model of sediment-hosted Au, *in* Bliss, J.D., ed., *Developments in deposit modeling: U.S. Geological Survey Bulletin 2004*, p. 26-28.
- Rose, A.W., and Kuehn, C.A., 1987, Ore deposition from highly acidic CO₂-enriched solutions at the Carlin gold deposit, Eureka County, Nevada [abs.]: *Geological Society of America, Abstracts with Programs*, v. 19, no. 7, p. 824.
- Seedorff, Eric, 1991, Magmatism, extension, and ore deposition of Eocene to Holocene age in the Great Basin—Mutual effects and preliminary proposed genetic relationships, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., *Geology and ore deposits of the Great Basin, Symposium proceedings: Reno, Geological Society of Nevada*, v. 1, April 1990, p. 133-178.

- Speed, R.C., Elison, M.W., and Heck, F.R., 1988, Phanerozoic tectonic evolution of the Great Basin, *in* Ernst, W.G., ed., *Metamorphism and crustal evolution of the western United States (Rubey Volume VII)*: Englewood Cliffs, New Jersey, Prentice Hall, p. 572-605.
- Stewart, J.H., and Carlson, J.E., 1978, *Geologic map of Nevada*: U.S. Geological Survey, scale 1:500,000.
- Thorman, C.H., Ketner, K.B., Brooks, W.E., Snee, L.W., and Zimmermann, R.A., 1991, Late Mesozoic-Cenozoic tectonics in northeastern Nevada, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., *Geology and ore deposits of the Great Basin—Symposium proceedings*: Reno, Geological Society of Nevada, v. 1, April 1990, p. 25–46.

GB31**Sediment-hosted Au Deposits**Utah
Idaho

Descriptive Model 26a • Mark3 Index 17

Area = 87,400 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Douglas B. Stoesser

Rationale for Model Choice

Western Utah is characterized by suitable host rocks, such as silty or argillaceous carbonaceous limestone and dolomite, and known sediment-hosted gold deposits. The descriptive model of Berger (1986) and the grade and tonnage model of Mosier and others (1992) were used for the assessment.

Rationale for Tract Delineation

The criteria used to define the permissive tract for sediment-hosted gold are broad; the basic requirement is the presence of suitable host rocks and an intrusive heat source in the underlying crust. Suitable host rocks are primarily silty or argillaceous carbonaceous limestone and dolomite. Since such rocks underlie western Utah, it was agreed that the most of the Great Basin province of Utah and southernmost Idaho was permissive.

Important Examples of Deposit Type

One large (Mercur) and four small sediment-hosted gold deposits (Barney's Canyon, Melco, Tecoma and possibly Goldstrike) occur in Utah. Another possibly relevant occurrence is King's Canyon, which is difficult to classify. In Idaho, the Black Pine deposit is another example.

Rationale for Numerical Estimate

The group felt positive about the potential for further discoveries. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 1, 2, 6, 9, and 16 or more deposits consistent with the grade and tonnage model of Mosier and others (1992).

References

- Berger, B.R., 1986, Descriptive model of carbonate-hosted Au-Ag, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 175.
- Mosier, D.L., Singer, D.A., Bagby, W.C., and Menzie, W.D., 1992, Grade and tonnage model of sediment-hosted Au, *in* Bliss, J.D., ed., Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, p. 26-28.

GB32**Sediment-hosted Cu Deposits, Red-bed Type**Utah
Arizona

Descriptive Model 30b.2 • Mark3 Index 97

Area = 2,310 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* David A. Lindsey**Rationale for Model Choice**

Deposits in Upper Triassic rocks are generally associated with concentrations of organic plant remains (e.g., logs, leaves) in permeable sandstone. The host rock and mechanism of precipitation matches the red-bed model. Deposits in this environment span the entire range of tonnages and grade for red-bed copper deposits. Thus the world red-bed model is appropriate.

Rationale for Tract Delineation

Deposits occur in permeable sandstone of the lower part of the Upper Triassic Chinle Formation (including the Shinarump and Agua Zarca Sandstone Members), and these rocks constitute the permissive tract.

Important Examples of Deposit Type

White Canyon, Utah (530,000 metric tons at 0.75 percent Cu, in the Shinarump Member of the Chinle Formation) (Finch, 1959) is the most important district. The Silver Reef (Harrisburg) district of southwest Utah may or may not belong to the Upper Triassic tract, but was included here for purposes of estimation. Although copper and uranium minerals are associated with plant matter at Silver Reef, silver (as halides) is the principal metal (Proctor, 1953).

Rationale for Numerical Estimate

Although the most important district has been extensively explored, it could contain concealed deposits. For the 90th, 50th, and 10th percentiles, the team estimated 0, 0, and 1 or more deposits consistent with the grade and tonnage model.

References

- Finch, W.I., 1959, Geology of uranium deposits in Triassic rocks of the Colorado Plateau region: U.S. Geological Survey Bulletin 1074-D, p. 125-164.
- Proctor, P.D., 1953, Geology of the Silver Reef (Harrisburg) District, Washington County, Utah: Utah Geological and Mineralogical Survey Bulletin 44, 169 p.

GB33**Sedimentary Exhalative Zn-Pb Deposits****Nevada****Descriptive Model 31a • Mark3 Index 13****Area = 27,500 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by D.P. Cox, Steve Ludington, B.R. Berger, M.G. Sherlock, and D.A. Singer, (USGS); and J.V. Tingley (Nevada Bureau of Mines and Geology)

Rationale for Model Choice

Sedimentary exhalative zinc-lead deposits, more conveniently referred to as sedex deposits, are stratabound tabular bodies of massive zinc and lead sulfides in black shales, siltstones, or carbonate rocks (Large, 1980). There are no known examples of this type in Nevada, however Turner and others (1989) noted similarities between the Roberts Mountains assemblage and lower Paleozoic strata in the northern Canadian Cordillera that host numerous large sedex deposits. Bedded barite deposits, which occur in close association with sedex deposits in some areas, are widespread in the Roberts Mountains assemblage. Ketner (1991) described stratabound gossans containing high values of lead, zinc, and silver in lower Middle Ordovician and Lower Silurian rocks in northeastern Nevada that are strongly suggestive of sedex deposits.

Rationale for Tract Delineation

The permissive tract consists of the Roberts Mountains assemblage. The eastern part of the tract, underlain by shale and chert of the Vinini Formation, probably has a higher probability of deposits because these rocks are most similar to the host rocks typical of sedex deposits.

Rationale for Numerical Estimate

Because of the absence of known examples of sedex deposits in Nevada, our estimate of undiscovered deposits is relatively low. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 1, 3, and 5 deposits in the delineated area that are comparable in grade and tonnage to the sedimentary exhalative Zn-Pb deposits of Menzie and Mosier (1986).

References

- Ketner, K.B., 1991, Stratigraphy and strata-bound, lead-zinc-barium mineralization of lower Paleozoic rocks in northeastern Nevada, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., *Geology and ore deposits of the Great Basin—Symposium proceedings*: Reno, Geological Society of Nevada, v. 2, April 1990, p. 539-551.
- Large, D.E., 1980, Geologic parameters associated with sediment-hosted, submarine exhalative Pb-Zn deposits—An empirical model for mineral exploration, *in* *Stratiform Cu-Pb-Zn deposits*: Geologisches Jahrbuch, Series D, v. 40, p. 59-129.
- Menzie, W.D., and Mosier, D.L., 1986, Grade-tonnage model of sedimentary exhalative Zn-Pb, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 212-215.
- Turner, R.J.W., Madrid, R.J., and Miller, E.L., 1989, Roberts Mountains allochthon—Comparison with lower Paleozoic outer continental margin strata from the northern Canadian Cordillera: *Geology*, v. 17, p. 341-344.

GP01**Sediment-hosted Cu Deposits, Red-bed Type**

Descriptive Model 30b.2 • Mark3 Index 97

Area = 476 km²Colorado
New Mexico
Oklahoma[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* David A. Lindsey**Rationale for Model Choice**

Structurally controlled copper deposits in sedimentary rocks are no different than other red-bed-type sediment-hosted copper deposits in that their mechanism of metal transport (oxidizing chloride brines in equilibrium with hematite) and precipitation (reduction by sulfides or organic matter) is the same. However, the path of mineralizing fluids was determined at least in part by structures that cut across stratigraphic horizons, as well as by permeable beds. In addition to mineralized rock in a structure, mineralized beds and lenses (mantos) may extend into favorable formations adjacent to a structure.

Deposits in this tract span the general range of tonnages and grade for red-bed copper deposits. Thus the worldwide red-bed model is appropriate (Mark3 index 97).

Rationale for Tract Delineation

Structurally-controlled red-bed deposits occur where faults and solution-collapse pipes allow basin fluids to ascend through reducing environments. Because existing geologic maps do not show all of the possible structures in which deposits could occur, to delineate a true permissive tract is beyond the scope of this study. The tract portrayed was delineated by the distribution of the sediment-hosted copper occurrences that appear to have structural control, and is much smaller than the permissive tract would be.

Important Examples of Deposit Type

The Panhandle area of Oklahoma contains a group of small mines and occurrences of which one mine produced an estimated 4,000 metric tons of ore (Fay, 1983). The host-rock is sandstone of the Triassic Dockum Group.

Rationale for Numerical Estimate

Estimates are based entirely on one area of mineral occurrences. For the 90th, 50th, and 10th percentiles, the team estimated, respectively, 0, 0, and 1 or more red-bed-type sediment-hosted copper deposits consistent with the grade and tonnage model.

Reference

Fay, R.O., 1983, Copper deposits in Sheep Pen Sandstone (Triassic) in Cimarron County, Oklahoma, and adjacent parts of Colorado and New Mexico: Oklahoma Geological Survey Circular 86, 24 p.

GP02**Sediment-hosted Cu Deposits, Red-bed Type**

Colorado

Descriptive Model 30b.2 • Mark3 Index 97

New Mexico

Area = 33,100 km²

Oklahoma, Texas

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* David A. Lindsey**Rationale for Model Choice**

Red-bed-type sediment-hosted copper deposits in Upper Triassic rocks are generally associated with concentrations of organic plant remains (logs, leaves, etc.) in permeable sandstone. The host rock and mechanism of precipitation matches the red-bed model. The Pastura (Stauber mine), New Mexico produced about 240,000 metric tons at 2.57 percent Cu (Holmquist, 1947). Thus the worldwide red-bed sediment-hosted copper model is appropriate.

Rationale for Tract Delineation

The permissive tract includes permeable sandstone of the Upper Triassic Dockum Group (Santa Rosa Formation).

Rationale for Numerical Estimate

For the 90th, 50th, 10th, and 5th percentiles, respectively, the team estimated 1,3, 5, and 6 or more red-bed copper deposits of Triassic age, consistent with the grade and tonnage model.

Reference

Holmquist, R.J., 1947, Stauber copper mine, Guadalupe County, New Mexico: U.S. Bureau of Mines Report of Investigations 4026, 7 p.

GP03**Sediment-hosted Cu Deposits, Red-bed Type**

Descriptive Model 30b.2 • Mark3 Index 97

Area = 114,200 km²Kansas
Oklahoma
Texas[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* David A. Lindsey**Rationale for Model Choice**

Red-bed-type sediment-hosted copper deposits are lenticular, sandstone- and shale-hosted, and are associated with accumulations of plant and other organic matter in red-bed sequences. These characteristics are widespread in this tract and indicate classification as red-bed type. No information is available on tonnage and grade, but at least one deposit (Paoli, Oklahoma) was explored by drilling (Shockey and others, 1974); grade and tonnage curves for the worldwide red-bed-type sediment-hosted copper model were used.

Rationale for Tract Delineation

The tract encompasses the Lower Permian (Leonardian) mixed continental-marine strata of Kansas, Oklahoma, and northern Texas (Fischer, 1937) and includes the Ninnescah Shale and Wellington Formation.

Important Examples of Deposit Type

Occurrences in the Ninnescah Shale and Wellington Formation, south-central Kansas, and north-central Oklahoma are typical of this tract and are the best-studied (Berendsen and Lambert, 1981; Waugh and Brady, 1976). The sandstone-hosted copper-silver deposit at Paoli, Oklahoma (Shockey and others, 1974) is probably the largest example assigned to this tract.

Rationale for Numerical Estimate

Only the Paoli deposit (Thomas and others, 1991) is known to have presented an attractive exploration target. However, numerous other occurrences are known, and at least two stratigraphic horizons are mineralized in southern Oklahoma and north Texas (Fischer, 1937). Many occurrences probably have not been sufficiently explored to determine whether median-size deposits exist. Probabilities of 1, 3, and 20 or more undiscovered deposits were assigned to the 90th, 50th, and 10th percentiles, respectively, consistent with the grade and tonnage model (Mark3 index 97), but more work is needed to determine the number and possible size of occurrences in north Texas.

References

- Berendsen, P., and Lambert, M.W., 1981, Copper sulfides in the lower Permian red beds of south-central Kansas—Stratigraphy and host rocks lithology: Kansas Geological Survey Bulletin 223, pt. 1, 86 p.
- Fischer, R.P., 1937, Sedimentary deposits of copper, vanadium-uranium, and silver in southwestern United States: Economic Geology, v. 32, no. 7, p. 906-951.
- Shockey, P.N., Renfro, A.A., and Peterson, R.J., 1974, Copper-silver solution fronts at Paoli, Oklahoma: Economic Geology, v. 69, no. 2, p. 266-268.
- Thomas, C.A., Hagni, R.D., and Berendsen, P., 1991, Ore microscopy of the Paoli silver-copper deposit, Oklahoma: Ore Geology Reviews, no. 6, p. 229-244.
- Waugh, T.C., and Brady, L.L., 1976, Copper occurrences associated with Permian rocks in south-central Kansas, in Johnson, K.S., and Croy, R.L., eds., Stratiform copper deposits of the Midcontinent region, a symposium: Oklahoma Geological Survey Circular 77, p. 76-79.

GP04	Sediment-hosted Cu Deposits, Reduced-facies Type	New Mexico
Descriptive Model 30b.1 • Mark3 Index 96		Kansas
Area = 215,200 km²		Oklahoma, Texas
Cumulative Distribution	Histogram	Table
		Model
		Mineral Deposits

by David A. Lindsey

Rationale for Model Choice

Copper deposits in this tract, characterized by the Flowerpot Shale, were assigned to the reduced-facies (shale-hosted or Kupferschiefer-type) model. The Flowerpot copper deposits are hosted by thin (10-50 cm), laterally continuous (as much as 20 km²) reduced shale beds associated with evaporites and red beds (Johnson, 1976). Although not as extensive or as organic-rich (0.09–0.56 percent organic carbon) as the Kupferschiefer, the copper-mineralized beds in the Flowerpot Shale resemble the reduced-facies model more than the red-bed model.

Rationale for Tract Delineation

Deposits occur in shale beds of the Permian (Guadalupian) Flowerpot Shale and stratigraphically equivalent beds of the El Reno Group and San Angelo Formation of Oklahoma and north Texas (Johnson, 1976; Smith, 1976). Favorable shale beds were deposited in the shallow margins of the Midcontinent Permian basin. The tract extends in outcrop from central Oklahoma to central Texas and throughout the subsurface of Panhandle Oklahoma and Texas at a depth of less than 1 km.

Important Examples of Deposit Type

The Creta and Mangum, Oklahoma, deposits (Dingess, 1976; Johnson, 1976) have production plus reserves of more than 7 million metric tons each at 1.9 and 1.0 percent Cu, respectively. Two other deposits (Crowell and McClellan mines) in north Texas may contain more than 1.5 million metric tons each of 1 percent Cu (the Crowell deposit is described by Schoenike and Zeballos, 1976).

There is some confusion about the size of the Mangum deposit, MRDS records show a tonnage of 36 million metric tons, which is near the median for world shale-hosted tonnage. However, the Oklahoma Geological Survey (R.O. Fay, written commun., 1993) estimates both Mangum and Creta at slightly more than 7 million metric tons. In conducting estimates of undiscovered copper for the Flowerpot tract, the lower estimate of Mangum tonnage was accepted. Calculations show that the higher estimate can only be reached by assuming a uniform grade of 1 percent copper for the entire thickness and entire known extent of the mineralized bed; this assumption has not been substantiated (Johnson, 1976, p. 13).

Rationale for Numerical Estimate

Mineralized localities in outcrop probably number about 10 (Johnson, 1976, lists six; others are described by Stroud and others, 1970). Of these, two 7-million-metric ton deposits have been found (Mangum and Creta). Considering that 10 mineralized localities are represented in outcrop, there may be 30-50 mineralized localities at a depth of less than 1 km in the subsurface of Panhandle Oklahoma and Texas. Of these perhaps two in ten contain Mangum-size deposits, for a total of 6-10 deposits in the subsurface. These hypothetical (undiscovered) deposits will be difficult to find because they are completely concealed; however, our estimate concerns probability of existence, not discovery. There is a good (90th percentile) chance for

existence of another Mangum size deposit, in outcrop and probably one or two in the subsurface.

Because the Mangum-size deposit of more than 7 million metric tons is approximately 25 percent as large as the median-size (32 million metric tons) reduced-facies copper deposit, probably (90th percentile) less than one deposit (0.25 times 3 Mangum-size deposits) of the median-size world model could exist in the Flowerpot tract. There may be at least an even chance (50th percentile) of 2 to 3 deposits (0.25 times 0.20 deposits per locality times 40 to 60 localities) and only a 10 percent chance of 10 or more, including deposits that might exist in the subsurface.

For the 90th, 50th, and 10th percentiles, the team estimated, respectively, 0, 3, and 10 or more reduced-facies copper deposits consistent with the grade and tonnage model.

References

- Dingess, P.A., 1976, Geology and mining operations at the Creta copper deposit of Eagle-Picher Industries, Inc., *in* Johnson, K.S., and Croy, R.L., eds., Stratiform copper deposits of the Midcontinent region, a symposium: Oklahoma Geological Survey Circular 77, p. 15-24.
- Johnson, K.S., 1976, Permian copper shales of southwestern Oklahoma, *in* Johnson, K.S., and Croy, R.L., eds., Stratiform copper deposits of the Midcontinent region, a symposium: Oklahoma Geological Survey Circular 77, p. 3-14.
- Schoenike, H.G., and Zeballos, R.A., 1967, The geology, exploration, and development of stratiform copper deposit located northwest of Crowell, Texas, *in* Johnson, K.S., and Croy, R.L., eds., Stratiform copper deposits of the Midcontinent region, a symposium: Oklahoma Geological Survey Circular 77, p. 99.
- Smith, G.E., 1976, Sabkha and tidal-flat facies control of stratiform copper deposits in north Texas, *in* Johnson, K.S., and Croy, R.L., eds., Stratiform copper deposits of the Midcontinent region, a symposium: Oklahoma Geological Survey Circular 77, p. 25-39.
- Stroud, R.B., McMahan, A.B., Stroup, R.K., and Hibpsman, M.H., 1976, Production potential of copper deposits associated with Permian red bed formations in Texas, Oklahoma, and Kansas: U.S. Bureau of Mines Report of Investigations 7422, 103 p.

GP05**Mississippi Valley Deposits, S.E. Missouri Pb-Zn**

Wisconsin

Descriptive Model 32a • Mark3 Index 108

Michigan

Area = 702,400 km²

Minnesota, Illinois

Indiana, Ohio

Kansas, Nebraska

Missouri, Kentucky

Oklahoma, Arkansas

Tennessee, Texas

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Walden P. Pratt, Martin B. Goldhaber, David L. Leach, Gregory T. Spanski, and John G. Viets

Rationale for Model Choice

The midcontinent region of the United States contains four known world-class Mississippi Valley districts and several smaller ones, and large areas of permissive host rocks—i.e., Paleozoic sedimentary carbonate rocks. General descriptions of the Mississippi Valley deposit type are in Heyl (1982); Heyl and others (1959); Pratt (1982); Sangster (1983); and Briskey (1986).

Rationale for Tract Delineation

The permissive tract is defined simply by the known or inferred presence of significant sections of sedimentary carbonate rock of Cambrian through Mississippian age occurring within 1 km of the surface. The permissive tract is bounded on the east by a common boundary with tract EC03, positioned over the western flanks of the Cincinnati Arch and Nashville dome. The southern and western boundaries are defined by burial of permissive carbonate rocks beneath 1 km of cover. The northern boundary is defined by the boundary between the Great Plains and Lake Superior Provinces and, in the region of the Michigan Basin, by burial. A small area of permissive terrane is also found surrounding the Llano uplift in central Texas. Enclaves of non-permissive terrane occur in the central Illinois Basin due to burial and in the vicinity of St. Francois Mountains and center of the Llano uplift due to absence of host carbonate rocks.

Important Examples of Deposit Type

The principal Mississippi Valley districts in the Mid-continent are the Southeast Missouri lead-zinc-silver-copper district (subdivided into the Old Lead Belt and the Viburnum Trend), the Tri-State zinc-lead district (Kansas-Oklahoma-Missouri), the Upper Mississippi Valley zinc-lead district (Wisconsin-Iowa-Illinois), and the Illinois-Kentucky fluorspar-lead-zinc district (in which the fluorspar had a magmatic source and is atypical of Mississippi Valley mineralization; thus the district is a hybrid). Less important are the Northern Arkansas zinc district and the Central Missouri lead-zinc-barite district. In this assessment the potential for districts is considered rather than individual deposits, because the important Mississippi Valley deposits in the Central Region are the products of broad, pervasive hydrothermal mineralizing systems, and the mineralized areas are so interconnected that their designation as individual "deposits" may be only a matter of the location of property lines. The Mississippi Valley grade and tonnage models are themselves based on data for entire districts and not individual deposits.

Rationale for Numerical Estimates

Two basically different approaches were used in this step of the assessment. These are referred to here for convenience as the Pratt method and the Goldhaber-Leach-Viets method.

Pratt Method

This method is limited in geographic extent to only a part of the Central Region, and uses a more restricted model than the other approach—a simple Mississippi Valley occurrence model in which the critical features are: (1) proximity to the limestone-dolostone interface (and preferably on the dolostone side thereof); (2) "windows," edges, or other gaps in underlying shales; (3) presence of overlying shale caps; and (4) additional data such as favorable structure or known mineral shows. (These data on limestone-dolostone ratios, shales, etc., were obtained from maps recently compiled by Pratt for the Mid-continent Strategic and Critical Minerals (MSCM) project, specifically for the purpose of identifying prospective areas for Mississippi Valley deposits.) This regional analysis led Pratt to identify some 16 prospective areas with various combinations of the model criteria. To these 16 areas were then added 8 other areas that had been assigned at least a "high potential" for undiscovered Mississippi Valley deposits in the five recent CUSMAP studies in this region (Rolla quadrangle—Pratt and others, 1984; Springfield quadrangle—Erickson and Chazin, 1991; Joplin quadrangle—Pratt and others, 1993(a); Harrison quadrangle—Pratt and others, 1993(b); Paducah quadrangle—Goldhaber and others, 1992).

In the present assessment, Pratt assigned probabilistic estimates to the existence of a new median-size district in each of the identified prospective areas within the MSCM quadrangle, excluding those that would be considered extensions of known districts; Goldhaber did the same for the two prospective areas in the Paducah 1° x 2° quadrangle. The results of the probabilistic estimates when summed give an expected mean value of about 0.2 of a district. At the 90th, 50th, 10th, 5th, and 1st percentile, this mean is consistent with estimated values, respectively, of 0, 0, 0, 2, and 4 undiscovered Mississippi Valley districts in the MSCM quadrangle consistent with the grade and tonnage model for Southeast Missouri Pb-Zn districts as defined by Mosier and Briskey (1986) (Mark3 index 42). Areas of permissive terrane outside the MSCM quadrangle are not assessed in this method.

Goldhaber-Leach-Viets Method

In this approach the three proponents, applying their combined general knowledge of Mississippi Valley deposits and their processes of formation, both in the Mid-continent region and worldwide, examined the permissive tract, and outlined areas believed to be favorable on the basis of four factors: (1) known presence of typical sulfide and gangue minerals, (2) known extent of a typical hydrothermal system, (3) proximity to fold belts and arches, and (4) bleaching of underlying basal (originally red) sandstone. The assessment team specifically opted not to attempt the analogue type of estimate—i.e., how many districts of size x would fit into permissive tract—because of the insufficiency of data.

The group reached consensus for the 90th, 50th, 10th, 5th, and 1st percentiles, respectively, of 2, 3, 3, 6, and 8 undiscovered deposits. This estimate was anchored at the 90th percentile, on a subjective agreement that at least one undiscovered lead-dominant district and one undiscovered zinc-dominant district, consistent with the revised grade and tonnage model for Southeast Missouri Pb-Zn districts as defined by Mosier and Briskey (1986), exist somewhere in the region; and that the availability of favorable areas limits the range to a maximum of 8 districts at the 1st percentile. The mean expected district value for this distribution range is about 3 undiscovered districts consistent with the grade and tonnage model for Southeast

Missouri Pb-Zn and Appalachian Zn districts as defined by Mosier and Briskey (1986) (Mark3 index 108).

Non-reconciliation of the Two Assessments

No attempt is made to reconcile the two assessments because the areas considered are not directly comparable and because different assessment methods were used, one considerably more restrictive, detailed, and site-specific (Pratt Method) than the other. For purposes of consistency with the assessment philosophy followed in other assessments the editors have adopted the results of the Goldhaber-Leach-Viets Method for calculation of commodity endowments as they reflect consideration of the entire permissive tract.

References

- Briskey, J.A., 1986, Descriptive model of Southeast Missouri Pb-Zn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 220-221.
- Erickson, R.L., and Chazin, Barbara, 1991, Resource assessment for Mississippi Valley-type base-metal deposits, *in* Martin, J.A., and Pratt, W.P., Geology and mineral-resource assessment of the Springfield 1° x 2° quadrangle, Missouri: U.S. Geological Survey Bulletin 1942, p. 90-94, plate 2, scale 1:250,000.
- Goldhaber, M.B., Hayes, T.S., Eidel, J.J., LaRock, E.J., and Sargent, M.L., 1992, Assessment of Mississippi Valley-type mineralization, examples from the Middle Ordovician Dutchtown Formation, *in* Goldhaber, M.B., and Eidel, J.J., eds., Mineral resources of the Illinois Basin in the context of basin evolution, Program and Abstracts, St. Louis, Missouri, January 22-23, 1992: U.S. Geological Survey Open-File Report 92-1, p. 16-18.
- Heyl, A.V. 1982, Mineral deposit occurrence model for the Viburnum trend subregion of the southeast Missouri base metal and barite district, *in* Erickson, R.L., ed., Characteristics of mineral deposit occurrences: U.S. Geological Survey Open-File Report 82-795, p. 158-171.
- Heyl, A.V., Jr., Agnew, A.F., Lyons, E.J., and Behre, C.H., Jr., 1959, The geology of the Upper Mississippi Valley zinc-lead district: U.S. Geological Survey Professional Paper 309, 310 p.
- Mosier, D.L., and Briskey, J.A., 1986, Grade and tonnage model of Southeast Missouri Pb-Zn and Appalachian Zn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 224-226.
- Pratt, W.P., 1982, A prospecting model for stratabound lead-zinc(-barite-fluorite) deposits ("Mississippi Valley-type" deposits), *in* Erickson, R.L., ed., Characteristics of mineral deposit occurrences: U.S. Geological Survey Open-File Report 82-795, p. 155-157.
- Pratt, W.P., Erickson, R.L., Kisvarsanyi, E.B., and Wharton, H.M., 1984, Maps showing areas of significant metallic mineral-resource potential in the Rolla 1° x 2° quadrangle, Missouri: U.S. Geological Survey Miscellaneous Field Studies Map MF-1005-A, scale 1:250,000.
- Pratt, W.P., Hayes, T.S., Erickson, R.L., Berendsen, Pieter, and Kisvarsanyi, E.B., 1993a, Assessment of the Joplin 1° x 2° quadrangle, Kansas and Missouri, for Mississippi Valley-type deposits and other minerals: U.S. Geological Survey Miscellaneous Field Studies Map MF-2125-E, scale 1:250,000.
- Pratt, W.P., Hayes, T.S., Erickson, R.L., Kisvarsanyi, E.B., McFarland, M.C., Rueff, Ardel, Bush, W.V., Colton, G.W., and McFarland, J.D. III, 1993b, Mineral-resource assessment maps of the Harrison 1° x 2° quadrangle, Missouri and Arkansas: U.S. Geological Survey Miscellaneous Field Studies Map MF-1994-D, scale 1:250,000.
- Sangster, D.F., 1983, Mississippi Valley-type deposits: a geological mélange, *in* Kisvarsanyi, Geza, Grant, S.K., Pratt, W.P., and Koenig, J.W., eds., International conference on Mississippi Valley type lead-zinc deposits: Rolla, University of Missouri, Proceedings, p. 7-19.

LS01**Descriptive Model 5a****Area = 17,500 km²****Duluth Cu-Ni-PGE Deposits****Minnesota****Wisconsin****Iowa**[Mineral Deposits](#)*by* Michael P. Foose and William F. Cannon**Rationale for Model Choice**

A number of large magmatic sulfide deposits are known in the Duluth Complex in Minnesota. The copper sulfide deposits occur as irregular disseminations near the base of various mafic intrusions. Deposit grades range up to about 0.6 percent Cu and 0.2 percent Ni; Cu/Ni ratios typically are between 2.5 and 3.0 and cutoff grades used for resource estimation are typically about 0.25 percent combined Cu and Ni. Similar mineralization is known on a smaller scale in the Mellen Intrusive Complex in northern Wisconsin.

Rationale for Tract Delineation

Known deposits in Minnesota occur along the basal (northwestern) edge of the Duluth Complex, a Middle Proterozoic intrusive complex composed predominantly of mafic to anorthositic intrusive bodies. The complex extends for about 250 km along a northeast trend and dips gently to the southeast. Footwall rocks of granite and metasedimentary rocks are exposed along the northern and western edge of the complex, whereas flood basalts form the roof of the complex along its southeastern margin.

Isotopic studies have shown that a significant part of the sulfur in these deposits was assimilated from adjacent sedimentary footwall rocks. Conversely, there are no known deposits in locations removed from this footwall where country rock sulfides would not have been available for assimilation. For this reason, the permissive tract within the Duluth Complex has been limited to the basal parts of the complex along the northwestern footwall. It encompasses the lower troctolitic series of the complex which is host to all known deposits.

The permissive tract is extended to eastern Iowa and southern Minnesota where aeromagnetic and gravity data define anomalies interpreted by Sims (1990) as a large mafic to ultramafic body, probably correlative with the Duluth Complex. Recent geophysical studies suggest that the anomalies represent a series of individual intrusions, rather than a single body (Raymond Anderson, personal commun., 1995). These bodies intrude granitic rocks of the Early Proterozoic terranes which form the eastern and southern margins of the permissive tract. Middle Proterozoic clastic sedimentary rocks unconformably overlie the intrusions on their western margin. No drill data or other evidence relating to lithology, age, or possible mineralization are available, and correlation with the Duluth Complex must be viewed as highly speculative at this time. If the intrusions are similar to the Duluth Complex, a critical factor for evaluating potential for Cu-Ni sulfides would be whether the country rocks contain a source of sulfur that could have been assimilated during emplacement.

A third part of the tract encompasses the Mellen Intrusive Complex in northern Wisconsin. This intrusive complex ranges from peridotite to granite but is dominantly a variety of gabbroic and anorthositic rocks. It intrudes Middle Proterozoic basalts and Early Proterozoic metasedimentary rocks. Mineralization has been identified at several localities and is very similar to that in the Duluth Complex (Bakheit, 1981).

Rationale for Numerical Estimate

The lack of a grade-tonnage model for this type of deposit precludes making a quantitative estimate of undiscovered resources. Estimates, controlled by drilling, of known Cu resources made for part of the Duluth Complex indicate approximately 4 billion tons of mineralized rock grading 0.6 percent Cu and 0.2 percent Ni (Listerud and Meineke, 1977). These estimates make the Duluth Complex the largest Ni resource in the United States. At least equally large Ni-Cu resources can be inferred for the remaining permissive tract in the Duluth Complex for which no estimates have been published.

No resources are known in the part of the tract in Iowa and Minnesota but it is virtually unexplored. If parts of the country rock contain abundant sulfur which could have been assimilated during intrusion of the complex, very substantial mineralization could be expected. If not, then the potential for mineralization is much less.

The Mellen Complex is known to be mineralized but insufficient exploration has been done to outline and measure deposits. It is likely, however, to contain at least one, and possibly several small deposits with grades comparable to the Duluth Complex.

References

- Bakheit, A.K., 1981, Petrography of Cu-Ni mineralization in Mineral Lake area, Ashland County, Wisconsin: Madison, University of Wisconsin, M.S. thesis, 104 p.
- Listerud, W.H., and Meineke, D.G., 1977, Mineral resources of a portion of the Duluth Complex and adjacent rocks in St. Louis and Lake Counties, northern Minnesota: Minnesota Department of Natural Resources, Division of Minerals Report 93, 74 p.
- Sims, P.K., 1990, Precambrian basement map of the northern Midcontinent, USA: U.S. Geological Survey Miscellaneous Investigations Map I-1853-A, scale 1:1,000,000.

LS02**Massive Sulfide Deposits, Kuroko Type**

Minnesota

Descriptive Model 28a

North Dakota

Area = 153,800 km²

South Dakota

[Model](#)*by* K.J. Schulz, W.F. Cannon, P.K. Sims, and G.L. LaBerge**Rationale for Model Choice**

Exploration has been extensive and is continuing in the Late Archean greenstone-granite terrane, particularly in northern Minnesota, but so far as known, no potentially minable deposits have been discovered. Massive sulfide deposits of the kuroko type are known in the Canadian part of the Late Archean terrane (Franklin and others, 1981).

Rationale for Tract Delineation

The permissive tract is delineated based on: (1) its general geologic similarity to other Precambrian terranes that are known to host volcanogenic massive sulfide deposits; (2) the known presence of suitable host rocks and deposit environments; and (3) the known occurrence of massive sulfide deposits in extensions of the area in Canada. The tract encompasses the Late Archean volcanic belts in the Lake Superior region where the rocks are within one km of the surface. Excluded from the permissive area is a region of biotite schist, gneiss and granite, termed the Quetico subprovince (Card, 1990), that lacks both known volcanogenic massive sulfide deposits and suitable host rocks.

Rationale for Numerical Estimate

No estimate of undiscovered deposits was made for this tract because: (1) the lack of known exploration success at finding minable deposits in exposed parts of this terrane, and (2) the apparent paucity of known volcanogenic massive sulfide deposits in the western part of the Superior province (Fyon and others, 1992).

References

- Franklin, J.M., Lydon, J.W., and Sangster, D.F., 1981, Volcanic-associated massive sulfide deposits, *in* Skinner, B.J., ed., Economic Geology Seventy-Fifth Anniversary Volume, 1905-1980: Lancaster, Pennsylvania, Economic Geology Publishing Company, p. 485-627.
- Fyon, J.A., Breaks, F.W., Heather, K.B., Jackson, S.L., Muir, G.M., Stott, G.M., and Thurston, P.C., 1992, Metallogeny of metallic mineral deposits in the Superior Province of Ontario, *in* Geology of Ontario, Ontario Geological Survey, Special Volume 4, pt. 2, p. 1091-1174.

LS03**Massive Sulfide Deposits, Kuroko Type****Minnesota****Descriptive Model 28a • Mark3 Index 103****Area = 3,000 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* K.J. Schulz, W.F. Cannon, P.K. Sims, and G.L. LaBerge**Rationale for Model Choice**

Exploration has been extensive and is continuing in the Late Archean greenstone-granite terrane, particularly in northern Minnesota, but so far as is known, no potentially minable deposits have been discovered. Massive sulfide deposits of the kuroko type are known in the Canadian part of the Late Archean terrane (Franklin and others, 1981). It should be noted that most of the Late Archean greenstone-granite terrane in the Lake Superior region is covered by Pleistocene glacial deposits to depths locally exceeding 200 m. This widespread glacial cover has restricted the effectiveness of the geophysical exploration methods used in the region.

Franklin and others (1981) have shown that Precambrian massive sulfide deposits typically contain mainly copper and zinc and little lead. This conclusion is supported by the grade information available for the Early Proterozoic massive sulfide deposits in the northern part of the Wisconsin magmatic terranes, where only the recently discovered Lynne deposit contains significant lead values. In contrast, Paleozoic massive sulfide deposits typically contain higher lead contents. The kuroko grade and tonnage model given in Singer and Mosier (1986) contains data for massive sulfide deposits of all ages and, as a result, has a higher mean lead grade than would be true for Precambrian deposits only. A modified grade and tonnage model with Phanerozoic deposits deleted (Mark3 index 103) is believed to better represent undiscovered deposits in the permissive tract.

Rationale for Tract Delineation

The permissive tract is delineated based on: (1) its general geologic similarity to other Precambrian terranes that are known to host volcanogenic massive sulfide deposits; (2) the known presence of suitable host rocks and deposit environments; (3) the known occurrence of massive sulfide deposits in extensions of the area in Canada; and (4) past exploration activity for this deposit type in the region. The tract includes the Rainy Lake area of Archean metavolcanic rocks in northern Minnesota and is considered favorable for volcanogenic massive sulfide deposits based on: (1) the presence of massive sulfide occurrences in the area and deposits directly to the east of the area in Canada (Klein, 1989) and (2) the occurrence of felsic volcanic rocks similar compositionally to the distinctive tholeiitic rhyolites recognized to host many Archean massive sulfide deposits in the Superior province (Leshner and others, 1986).

Rationale for Numerical Estimate

The estimate of undiscovered deposits for this tract reflects: (1) the lack of known exploration success at finding deposits in this terrane, and (2) the apparent paucity of known volcanogenic massive sulfide deposits in the western part of the Superior province (Fyon and others, 1992). For the 90th, 50th, and 10th percentiles, the team estimated 1, 2, and 3, or more kuroko massive sulfide deposits consistent with the grade and tonnage model of Singer and Mosier (1991) with Phanerozoic deposits deleted.

References

- Franklin, J.M., Lydon, J.W., and Sangster, D.F., 1981, Volcanic-associated massive sulfide deposits, *in* Skinner, B.J., ed., Economic Geology Seventy-Fifth Anniversary Volume, 1905-1980: Lancaster, Pennsylvania, Economic Geology Publishing Company, p. 485-627.
- Fyon, J.A., Breaks, F.W., Heather, K.B., Jackson, S.L., Muir, G.M., Stott, G.M., and Thurston, P.C., 1992, Metallogeny of metallic mineral deposits in the Superior Province of Ontario, *in* Geology of Ontario, Ontario Geological Survey, Special Volume 4, pt. 2, p. 1091-1174.
- Klein, T.L., 1989, Mineral occurrence and drill-hole location map of the International Falls 1° x 2° quadrangle, Minnesota and Ontario: U.S. Geological Survey Miscellaneous Field Studies Map MF-2082, 1:250,000.
- Leshner, C.M., Goodwin, A.M., Campbell, I.H., and Gorton, M.P., 1986, Trace-element geochemistry of ore-associated and barren, felsic metavolcanic rocks in the Superior Province, Canada: Canadian Journal of Earth Sciences, v. 23, p. 222-237.
- Sangster, D.F., 1980, Quantitative characteristics of volcanogenic massive sulfide deposits: CIM Bulletin, v. 73, p. 74-81.
- Singer, D.A., and Mosier, D.L., 1986, Grade and tonnage model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 190-197.

LS04**Massive Sulfide Deposits, Kuroko Type**Michigan
Wisconsin

Descriptive Model 28a • Mark3 Index 103

Area = 22,900 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by K.J. Schulz, W.F. Cannon, P.K. Sims, and G.L. LaBerge

Rationale for Model Choice and Important Examples of Deposit Type

At least seven significant volcanogenic massive sulfide deposits (Flambeau, Pelican, Crandon, Bend, Lynne, Thornapple, and Catwillow) are known in the northern part of the Early Proterozoic magmatic terranes of Wisconsin. Other massive sulfide deposits have been discovered within the terrane, but grade and tonnage information for these occurrences are not generally available to the public. The general characteristics of the known deposits and occurrences in northern Wisconsin appear to fit those given for kuroko deposits (model 28a of Singer, 1986), although individual deposits have distinguishing characteristics when examined in detail (DeMatties, 1989, 1994). Like most Precambrian massive sulfide deposits, the Wisconsin deposits are Zn-Cu-rich and Pb-poor deposits. The Crandon deposit is by far the largest of the Wisconsin deposits and the most extensively studied (Lambe and Rowe, 1987). The Wisconsin massive sulfides are typically steeply dipping, tabular bodies conformably contained within a sequence of subaqueous calc-alkaline felsic pyroclastic rocks, lava flows and associated chemical sedimentary rocks. The ore bodies are composed of massive sulfide ore that contains abundant pyrite and lesser sphalerite, chalcopyrite, and galena, and an underlying zone of stringer ore composed largely of pyrite and chalcopyrite. The footwall stringer ore can make up about half of a deposit's reserves. To date, only the Flambeau deposit has been put into production, with mining of the high-grade gossan zone of the deposit beginning in May, 1993. However, efforts have recently begun to obtain permitting approval for mining of the Crandon deposit.

Franklin and others (1981) have shown that Precambrian massive sulfide deposits typically contain mainly copper and zinc and little lead. This conclusion is supported by the grade information available for the Early Proterozoic massive sulfide deposits in the northern part of the Wisconsin magmatic terranes, where only the recently discovered Lynne deposit contains significant lead values. In contrast, Phanerozoic massive sulfide deposits typically contain higher lead contents. The kuroko grade and tonnage model given in Singer and Mosier (1986) contains data for massive sulfide deposits of all ages and, as a result, has a higher mean lead grade than would be true for Precambrian deposits only. A modified grade and tonnage model with Phanerozoic deposits deleted (Mark3 index 103) is believed to better represent undiscovered deposits in the permissive tract.

Rationale for Tract Delineation

The permissive tract is delineated based on: (1) general geologic similarity to other Precambrian terranes that are known to host volcanogenic massive sulfide deposits; (2) the known presence of suitable host rocks and deposit environments; (3) the known occurrence of massive sulfide deposits within the designated area; and (4) past exploration activity for this deposit type in the region. The tract includes the Pembine-Wausau terrane which is considered as favorable for undiscovered volcanogenic massive sulfide deposits. The area encompasses the known massive sulfide deposits and most known occurrences, and also encloses the area of compositionally

distinct bimodal volcanic rocks that host at least some of the deposits in northern Wisconsin (Sims and others, 1989).

Rationale for Numerical Estimate

In contrast to the Archean terrane, the estimated massive sulfide resources of this tract are large and, if verified by future work, would establish this area as one of the principal base-metal massive sulfide regions of the world (Spooner and Barrie, 1993). This large resource estimate is based on the following factors: (1) Several massive sulfide deposits, including the world-class Crandon deposit, have already been discovered in the area. (2) Much of the area designated as favorable is blanketed by glacial deposits that have restricted the effectiveness of geophysical exploration methods to areas of relatively shallow cover, thus effectively leaving much of the area still unexplored. (3) Studies of other massive sulfide districts have shown that deposits tend to be clustered, with each cluster containing as many as about 20 geologically distinct orebodies and an "average" cluster containing about 12 (Sangster, 1980). Although the number of possible massive sulfide districts present within the area is not known, DeMatties (1989, 1994) has suggested the existence of at least three based on the observed clustering of known deposits. For the 90th, 50th, and 10th percentiles, the team estimated 30, 65, and 85, or more kuroko massive sulfide deposits consistent with the grade and tonnage model of Singer and Mosier (1991) with Phanerozoic deposits deleted.

References

- DeMatties, T.A., 1989, A proposed geologic framework for massive sulfide deposits in the Wisconsin Penokean volcanic belt: *Economic Geology*, v. 84, no. 4, p. 946-952.
- DeMatties, T.A., 1994, Early Proterozoic volcanogenic sulfide deposits in Wisconsin—An overview: *Economic Geology*, v. 89, no. 5, p. 1122-1151.
- Franklin, J.M., Lyndon, J.W., and Sangster, D.F., 1981, Volcanic-associated massive sulfide deposits, *in* Skinner, B.J., ed., *Economic Geology Seventy-Fifth Anniversary Volume, 1905-1980*: Lancaster, Pennsylvania, Economic Geology Publishing Company, p. 485-627.
- Lambe, R.N., and Rowe, R.G., 1987, Volcanic history, mineralization, and alteration of the Crandon massive sulfide deposit, Wisconsin: *Economic Geology*, v. 82, no. 5, p. 1204-1238.
- Sangster, D.F., 1980, Quantitative characteristics of volcanogenic massive sulfide deposits: *CIM Bulletin*, v. 73, p. 74-81.
- Sims, P.K., VanSchmus, W.R., Schulz, K.J., and Peterman, Z.E., 1989, Tectono-stratigraphic evolution of the Early Proterozoic Wisconsin magmatic terranes of the Penokean Orogen: *Canadian Journal of Earth Sciences*, v. 26, p. 2145-2158.
- Singer, D.A., 1986, Descriptive model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 189-190.
- Singer, D.A., and Mosier, D.L., 1986, Grade and tonnage model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 190-197.
- Spooner, E.T.C., and Barrie, C.T., 1993, A special issue devoted to Abitibi ore deposits in a modern context: preface: *Economic Geology*, v. 88, no. 6, p. 1307-1322.

LS05**Massive Sulfide Deposits, Kuroko Type****Wisconsin****Descriptive Model 28a****Area = 51,300 km²**[Model](#)*by* K.J. Schulz, W.F. Cannon, P.K. Sims, and G.L. LaBerge**Rationale for Model Choice**

At least seven significant volcanogenic massive sulfide deposits (Flambeau, Pelican, Crandon, Bend, Lynne, Thornapple, and Catwillow) are known in the exposed northern part of the Early Proterozoic magmatic terranes of Wisconsin.

Rationale for Tract Delineation

The tract consists of that part of the Wisconsin magmatic terranes where the rocks are concealed, but lie within one km of the surface as projected by Sims (1990). This includes areas in northwestern Iowa and northeastern Nebraska, as well as areas in northern Wisconsin that are adjacent to the exposed part.

Rationale for Numerical Estimate

Because of lack of knowledge about covered parts of the Penokean orogen, the team did not make an estimate of undiscovered kuroko deposits for this tract.

Reference

Sims, P.K., 1990, Precambrian basement map of the northern midcontinent, USA: U.S. Geological Survey Miscellaneous Investigations Map I-1853-A.

LS06**Sediment-hosted Cu Deposits, Red-bed Type****Nebraska****Descriptive Model 30b.2****Kansas****Area = 24,300 km²**[Model](#)*by* David A. Lindsey**Rationale for Model Choice**

Deposits are lenticular, sandstone and shale-hosted, and are associated with accumulations of plant and other organic matter in red-bed sequences. These characteristics indicate classification as red-bed type. No information is available on tonnage and grade, but at least one nearby deposit (Paoli, Oklahoma) was explored by drilling (Shockey and others, 1974).

Rationale for Tract Delineation

The permissive tract encompasses the Lower Permian (Leonardian) mixed continental-marine strata of northern Kansas and southeast Nebraska (Fischer, 1937) and includes the Ninnescah Shale and Wellington Formation. It is largely in the subsurface.

Important Examples of Deposit Type

Occurrences in the Ninnescah Shale and Wellington Formation in south-central Kansas and north-central Oklahoma, though not in this tract, are typical of it and are the best-studied (Berendson and Lambert, 1981; Waugh and Brady, 1976). The sandstone-hosted copper-silver deposit at Paoli, Oklahoma (Shockey and others, 1974) is in the contiguous tract to the south.

Rationale for Numerical Estimate

There are no known deposits in Kansas, the permissive rocks are primarily in the subsurface, and no estimate of undiscovered deposits was made.

References

- Berendson, P., and Lambert, M.W., 1981, Copper sulfides in the lower Permian red beds of south-central Kansas: stratigraphy and host rocks lithology: Kansas Geological Survey Bulletin 223, pt. 1, 86 p.
- Fischer, R.P., 1937, Sedimentary deposits of copper, vanadium-uranium, and silver in southwestern United States: Economic Geology, v. 32, no. 7, p. 906-951.
- Shockey, P.N., Renfro, A.A., and Peterson, R.J., 1974, Copper-silver solution fronts at Paoli, Oklahoma: Economic Geology, v. 69, no. 2, p. 266-268.
- Waugh, T.C., and Brady, L.L., 1976, Copper occurrences associated with Permian rocks in south-central Kansas, in Johnson, K.S., and Croy, R.L., eds., Stratiform copper deposits of the Midcontinent region, a symposium: Oklahoma Geological Survey Circular 77, p. 76-79.

Rationale for Model Choice

The known mineralization is most like the sediment-hosted copper model (30b) of Mosier and others (1986). But for this quantitative assessment we have modified model 30b in two ways. First we have removed red-bed deposits which tend to be small compared to deposits hosted in reduced facies. Second we have excluded deposits from the Copper Belt of Zambia and Zaire. The Copper Belt accounts for roughly half of the known reduced-facies deposits of the world. The distribution of tonnages and grades for Copper Belt deposits is very different from those of deposits elsewhere. For instance, median tonnage about five times higher and median copper grades are about double the medians of the tonnage and grade distributions of all other reduced facies deposits. Moreover, the overall geology of the Copper Belt is markedly different from the midcontinent of the U.S. These differences suggest to us that Copper Belt mineralization is a special case in which, for reasons not yet fully understood, exceptionally numerous, large, and rich deposits were formed. We believe that a global model that does not include the Copper Belt (Mark3 index 102) is a better analogue for undiscovered deposits in the Midcontinent rift, where all known mineralization is of low grade.

The permissive tract consists of red clastic rocks with interbedded reduced-facies rocks approximately correlative with the mineralized rocks in northern Michigan. The tract includes areas where these rocks are at the surface in parts of northern Michigan and Wisconsin and direct extensions beneath Lake Superior, as well as areas where they are covered by less than 1 km of younger rocks in parts of Wisconsin, Minnesota, Iowa, Nebraska, and Kansas. The location of the covered part of the tract is determined by geophysical methods and drill holes (Sims, 1990). In the covered areas the character of the red-bed sequence and the amount and

location of interbedded reduced-facies rocks are very imperfectly known. Several deep petroleum test wells have intersected reduced-facies rocks at widely scattered locations (Newell and others, 1993), so the occurrence of favorable host rocks is judged to be possible throughout the tract. There is no evidence that mineralizing processes have occurred anywhere other than near the known mineralized areas in northern Michigan, but data is very fragmentary and substantial mineralization could be concealed. The two known deposits are around the sediment-covered flanks of a stratovolcano where stratigraphic thinning of paleoaquifers onto the volcanic edifice may have focused the flow of heated groundwater to produce the copper enrichment (White, 1971). If such focusing of flow was required to produce mineralization, only a small part of the permissive tract is likely to be mineralized.

Rationale for Numerical Estimate

At 90th, 50th, and 10th percentiles, the estimated numbers of undiscovered deposits in the tract are, respectively, 2, 5, and 10 or more deposits consistent with the grade and tonnage model (Mark3 index 102). The permissive tract is large and poorly explored except in part of the exposed belt in northern Michigan and Wisconsin closest to the known deposits. On the other hand, known deposits and their subeconomic fringes cover very large areas so that similar deposits could be detected with widely spaced drilling. Thus, a somewhat limited area exists in which very large deposits might still be found in the permissive tract. The two known deposits in the tract are very large compared to the global tonnage distribution of deposits of this type suggesting that even if no additional large deposits exist, there is likely to be a substantial number of moderate- to small-sized deposits.

References

- Brown, A.C., 1971, Zoning in the White Pine copper deposit, Ontonagon County, Michigan: *Economic Geology*, v. 66, no. 4, p. 543-573.
- Mauk, J.L., 1993, Geologic and geochemical investigations of the White Pine sediment-hosted stratiform copper deposit, Ontonagon County Michigan: Ann Arbor, University of Michigan, Ph.D. dissertation, 194 p.
- Mosier, D.L., Singer, D.A., and Cox, D.P., 1986, Grade and tonnage model of sediment-hosted copper, *in* Cox, D.P., and Singer, D.A., eds. 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 206-208.
- Newell, K.D., Burruss, R.C., and Palacas, J.G., 1993, Thermal maturation and organic richness of potential petroleum source rocks in Proterozoic Rice Formation, North American Midcontinent rift system, northeastern Kansas: *American Association of Petroleum Geologists*, v. 77, p. 1922-1941.
- Sims, P.K., 1990, Precambrian basement map of the northern midcontinent, USA: U.S. Geological Survey Miscellaneous Investigations Map I-1853-A, scale 1:1,000,000.
- White, W.S., 1971, A paleohydrologic model for the mineralization of the White Pine copper deposit, northern Michigan: *Economic Geology*, v. 66, no. 1, p. 1-13.

LS08**Native Cu Deposits****No Published Descriptive Model • Mark3 Index 99****Area = 45,300 km²****Minnesota
Wisconsin, Michigan
Iowa, Nebraska
Kansas**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* William F. Cannon, Suzanne W. Nicholson, and Laurel G. Woodruff**Rationale for Model Choice**

Copper in metallic form occurs in altered volcanic rocks deposited in the Midcontinent rift about 1.1 billion years ago (White, 1968). Production was from twelve principal deposits, and numerous smaller deposits, all in the Keweenaw Peninsula. No deposits have been in production since the 1960's but substantial known resources are left in the ground at marginally economic concentrations. The native copper deposits have few known analogues elsewhere in the world so the occurrence model and tonnage-grade model are developed solely on features in the Lake Superior region. The tonnage grade model (Mark3 index 99) was developed using the 12 deposits and is believed to represent the undiscovered deposits in the permissive tract.

Rationale for Tract Delineation

The permissive tract lies along the trend of the Midcontinent rift where rift-related basalts are within one kilometer of the surface. The tract includes the principal mining district in northern Michigan and extensions of the basalts along the rift trend as far south as northern Kansas. In northern Michigan, Wisconsin, and parts of Minnesota, these basalts form the bedrock surface but farther south are covered by Paleozoic strata (Sims, 1990). The tract also lies partly under Lake Superior. Even where buried, the distribution of the basalts is quite well constrained by geophysical data and drilling.

Rationale for Numerical Estimate

At 90th, 50th, and 10th percentiles, the estimated numbers of undiscovered deposits in the tract are 10, 20, and 40 or more, respectively consistent with the grade and tonnage model (Mark3 index 99). This assessment is based on the large size of the tract and very incomplete exploration. Except for the heart of the mining district, little or no modern exploration has been done. Even within the mining district, a large percentage of the ground is not adequately tested, and a major new deposit was discovered there only a few years before the district was closed. Occurrences of native copper are widespread and distinctive rock alteration related to native copper mineralization is common throughout the outcrop belts of the basalts. Within the outcrop belts, much favorable rock is covered by glacial deposits, so important mineralization could be concealed at the bedrock surface. Where the basalts are covered by Paleozoic strata their character is not well known, but there is no geologic reason to conclude that they are not significantly mineralized.

References

- Sims, P.K., 1990, Precambrian basement map of the northern midcontinent, USA: U.S. Geological Survey Miscellaneous Investigations Map I-1853-A.
- White, W.S., 1968, The native-copper deposits of northern Michigan, *in* Ridge, J.D., ed., Ore deposits of the United States, 1933-1967: American Institute of Mining, Metallurgical and Petroleum Engineers, p. 303-325.

LS09**Mississippi Valley Deposits, S.E. Missouri Pb-Zn****Minnesota****Descriptive Model 32a • Mark3 Index 108****Wisconsin, Michigan****Area = 381,200 km²****North Dakota, South Dakota****Iowa, Nebraska****Kansas, Missouri**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Martin B. Goldhaber, David L. Leach, Walden P. Pratt, Gregory T. Spanski, and John G. Viets

Rationale for Model Choice

The midcontinent region of the U.S contains four known world-class Mississippi Valley districts and several smaller ones, and large areas of permissive host rocks—i.e., Paleozoic sedimentary carbonate rocks. General descriptions of the Mississippi Valley deposit type are in Heyl (1982); Pratt (1982); Sangster (1983); and Briskey (1986).

Rationale for Tract Delineation

The permissive tract is defined simply by the known or inferred presence of significant sections of sedimentary carbonate rocks of Cambrian through Mississippian age occurring within 1 km of the surface. It is bounded on the south by the boundary between the Great Plains and Lake Superior regions. The western boundary in the Dakotas is defined by burial of permissive carbonate rocks of the Ordovician Red River Formation beneath 1 km of cover. On the north, in the absence of definitive control on the northernmost extent of carbonate rock in the Cambrian interval, all Cambrian rocks are included, which results in the inclusion of a marginal zone where the rocks are predominantly clastic. Minor enclaves of non-permissive terrane occur in eastern Kansas and Nebraska overlying the Nemaha Ridge due to absence of carbonate rocks.

Important Examples of Deposit Type

There are no known occurrences of Mississippi Valley-style mineralization in this tract. The nearest locality is the Upper Mississippi Valley zinc-lead district in Wisconsin, Iowa, and Illinois (Heyl and others, 1959) that produced 0.79 and 1.7 million metric tons of lead and zinc, respectively. In this assessment the potential for districts is considered rather than individual deposits, because the important Mississippi Valley deposits in the Central Region are the products of broad, pervasive hydrothermal mineralizing systems, and the mineralized areas are so interconnected that their designation as individual "deposits" may be only a matter of the location of property lines. The Mississippi Valley grade and tonnage curves given by Mosier and Briskey (1986) are themselves based on data for entire districts and not individual deposits.

Rationale for Numerical Estimate

For this part of the permissive terrane for Mississippi Valley deposits the assessors applied their combined general knowledge of the deposits and their processes of formation, both in the Mid-continent region and worldwide. They examined this permissive tract, and outlined areas believed to be favorable on the basis of four factors: (1) known presence of typical sulfide and gangue minerals, (2) known extent of a typical hydrothermal system, (3) proximity to foldbelts and arches, and (4) bleaching of underlying basal (originally red) sandstone. The tract is bordered on the west by the Williston and Salina Basins and on the south by the Forest City Basin. However, the abundance of carbonate host rocks in the stratigraphic interval is more highly restrictive. The assessment team specifically opted not to attempt the analogue type of

estimate—i.e., how many districts of size x would fit into permissive tract—because of the insufficiency of data.

The group reached consensus for the 90th, 50th, 10th, 5th, and 1st percentiles, respectively, of 0, 0, 0, 1, and 2 undiscovered deposits consistent with the revised grade and tonnage model of Mosier and Briskey (1986) (Mark3 index 108). This estimate was anchored on the belief that there is a small probability (less than 10 percent) that an undiscovered district exists somewhere in the tract; and that the availability of favorable areas limits the range to a maximum of 2 districts at the 1st percentile.

References

- Briskey, J.A., 1986, Descriptive model of Southeast Missouri Pb-Zn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 220-221.
- Heyl, A.V., Jr., Agnew, A.F., Lyons, E.J., and Behre, C.H., Jr., 1959, The geology of the Upper Mississippi Valley zinc-lead district: U.S. Geological Survey Professional Paper 309, 310 p.
- Mosier, D.L., and Briskey, J.A., 1986, Grade and tonnage model of Southeast Missouri Pb-Zn and Appalachian Zn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 224-226.
- Pratt, W.P., 1982, A prospecting model for stratabound lead-zinc(-barite-fluorite) deposits ("Mississippi Valley-type" deposits), *in* Erickson, R.L., ed., Characteristics of mineral deposit occurrences: U.S. Geological Survey Open-File Report 82-795, p. 155-157.
- Sangster, D.F., 1983, Mississippi Valley-type deposits—A geological mélange, *in* Kisvarsanyi, Geza, Grant, S.K., Pratt, W.P., and Koenig, J.W., eds., International conference on Mississippi Valley type lead-zinc deposits: Rolla, University of Missouri, Proceedings, p. 7-19.

LS10**Low-sulfide Au-quartz Vein Deposits****Wisconsin
Michigan****Descriptive Model 36a • Mark3 Index 27****Area = 39,600 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* T.L. Klein and K.J. Schulz**Rationale for Model Choice**

The southern part of the Early Proterozoic Penokean orogen (the Wisconsin magmatic terranes of Sims and others, 1989), exposed in northern Wisconsin, consists of volcano-sedimentary rocks and related granitoid intrusions that are similar in many respects to older Archean greenstone belts. Transpressive shear zones, some of which represent collisional suture zones, are also present. Au-quartz vein deposits are known within similar Early Proterozoic terranes of the Trans-Hudson orogen in Canada (Ansdell and Kyser, 1992).

The Proterozoic greenstone-dominated terranes of the Lake Superior region are thought to contain gold deposits that fit the descriptive model for low-sulfide Au-quartz veins (Berger, 1986) by analogy with the setting of deposits in other areas of Proterozoic age. These deposits have lower grades and tonnages than similar deposits of Archean age.

Rationale for Tract Delineation

The permissive tract encloses the Early Proterozoic magmatic terranes of the Penokean orogen. These terranes consist mainly of tholeiitic and calc-alkaline volcanic rocks, lesser volcanogenic sedimentary rocks, and a variety of granitoid intrusions. These terranes contain northeast to eastward-trending shear zones and faults. The tract is bounded on the north by the Niagara fault zone, a presumed suture zone, and the Archean rocks of the Superior Province. It is bounded on the south by Archean gneisses and Paleozoic sedimentary rocks, and is truncated on the east by the Middle Proterozoic Wolf River Batholith and on the west by rocks of the Middle Proterozoic Midcontinent Rift System. This tract is thought to be permissive for low-sulfide Au-quartz vein deposits based on lithologic and structural similarity to other Early Proterozoic terranes in Canada and elsewhere that host such gold deposits (e.g., Flin Flon domain of the Trans-Hudson orogen, Canada). Also, a number of occurrences of gold in quartz veins are known, and a small structurally controlled deposit, the Reef prospect, is reported to contain about 408,000 metric tons of mineralized rock that grades about 9 g/metric ton Au and 0.28 percent Cu (DeMatties, 1994).

Rationale for Numerical Estimate

For the 90th, 50th, and 10th percentiles, the team estimated, respectively, 1, 3, and 6 or more low-sulfide gold quartz vein deposits consistent with the grade and tonnage model for this deposit type. Small numbers of low-sulfide Au-quartz vein deposits were estimated for this tract because of the limited exploration success in the exposed parts of the tract. However, given the large proportion of covered, relatively unexplored bedrock in the Lake Superior region, we feel that there is a large degree of uncertainty in the numerical deposit estimate for this region.

References

Ansdell, K.M., and Kyser, T.K., 1992, Mesothermal gold mineralization in a Proterozoic greenstone belt: western Flin Flon domain, Saskatchewan, Canada: *Economic Geology*, v. 87, p. 1496-1524.

- Berger, B.R., 1986, Descriptive model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239.
- DeMatties, T.A., 1994, Early Proterozoic volcanogenic massive sulfide deposits in Wisconsin—an overview: *Economic Geology*, v. 89, p. 1122–1151.

LS11	Low-sulfide Au-quartz Vein Deposits, Archean type	Minnesota
Descriptive Model 36b • Mark3 Index 101		North Dakota
Area = 171,900 km²		South Dakota

[Cumulative Distribution](#)

[Histogram](#)

[Table](#)

[Model](#)

by T.L. Klein and K.J. Schulz

Rationale for Model Choice

Greenstone-dominated subprovinces of the Archean Superior Province of the Canadian Shield are host to most of the major gold districts in Canada, with gold produced principally from quartz vein deposits or sulfide-mineral disseminations found near major shear zones that are tens to hundreds of kilometers long. Most deposits are immediately adjacent to major, generally east-trending, dextral, transpressive fault zones in greenstone belts or along their boundaries. The largest districts or deposits appear to have been formed during early episodes of dominantly high-angle reverse movement along these typically transpressive zones. Most current models favor an epigenetic origin for Archean gold deposits (Colvine and others 1988; Groves and others, 1989; Groves and Foster, 1991). The gold-bearing veins and sulfide mineral disseminations were emplaced in a zone of brittle-ductile deformation after peak deformation and metamorphism which, in most of the Superior Province, occurred between 2700 and 2680 Ma. Gold production does not correlate with any lithologic or geochemical characteristics or with the age of the major rock units within the subprovinces. Rather, production has been greatest in those subprovinces (i.e., the Abitibi and Uchi subprovinces) that show the highest degree of preservation of volcano-sedimentary rocks, reflected in thick sections with low-grade metamorphism and a high ratio of volcanic to plutonic rocks (Card and others, 1989).

Rocks of the southern Superior Province underlie the Lake Superior region and are the southwestward extensions of, from north to south, the Archean Wabigoon, Quetico, and Wawa subprovinces. The Wabigoon and Wawa are greenstone-granite dominated subprovinces that contain important gold districts in Canada. The metasedimentary rock-dominated Quetico subprovince has no history of gold production in the U.S. or Canada. The greenstone-granite dominated Wawa subprovince is the southwestward extension of the highly-productive Abitibi subprovince, which ranks first in production of gold in the Superior Province, and accounts for 84 percent of the total production from the province (data from Card and others 1989). However, the only major gold camp in the Wawa subprovince in Canada is at Wawa, Ontario. Rocks of the Wawa subprovince are exposed in the Vermilion district in northeastern Minnesota (Sims, 1976) and in the Ishpeming greenstone belt of northern Michigan (Johnson and Bornhorst, 1991).

The descriptive model for low-sulfide Au-quartz vein deposits of Archean age of Klein and Day (1994) is thought to best describe most of the potential Archean Au-quartz vein deposits in the Lake Superior region. Formerly, the only model for the occurrence of Archean gold deposits in greenstone belts was that for Homestake type deposits (model 36b of Mosier, 1986). Upon re-examination of the descriptive model and grade and tonnage information of model 36b, Klein and Day (1994) found that only 10 percent of the deposits used for the grade and tonnage curves fit the descriptive criteria, i.e. that the deposits were related spatially or genetically to iron-formation or chemical sediments. The new model for Archean low-sulfide Au-quartz vein deposits (Klein and Day, 1994) does not require iron-formation as a diagnostic criteria in defining permissive tracts and it serves to emphasize the importance of structural control on the

formation of these deposits. Studies of Archean gold deposits elsewhere show that most deposits are epigenetic in character and not related genetically to chemical sediments. Several studies in the Superior Province of Canada and the Yilgarn Province of Western Australia (Colvine and others, 1988; Groves and others, 1989) have shown that the Archean gold deposits do not show any consistent lithologic control and occur in most of the rock types that make up Archean greenstone belts. The Archean low-sulfide Au-quartz vein deposits share most geologic characteristics with Proterozoic and Phanerozoic low-sulfide Au-quartz vein deposits, but have distinct grade and tonnage.

The tracts outlined for the Archean low-sulfide Au-quartz deposits in the Lake Superior region could also contain Homestake gold deposits. However, because Homestake deposits are relatively rare in greenstone belts, quantitative resources estimates were not made for these deposits in the Lake Superior region.

Rationale for Tract Delineation

Deeply buried rocks of the greenstone-dominated Wabigoon and Wawa subprovinces and the metasedimentary Quetico subprovince in Minnesota and North and South Dakota are included in this tract. The tract is bounded on the south by the high-grade Middle Archean gneisses of the Minnesota River Valley and by Early Proterozoic rocks of the Animikie Basin and is bounded on the north by the border with Canada. The tract extends westward to where Archean rocks are buried by more than 1 kilometer of Paleozoic sedimentary rocks. Much of this area is covered by glacial deposits from 20-100 m thick and most of it has not been explored for metal deposits. We consider the tract permissive for the occurrence of undiscovered low-sulfide Au-quartz vein deposits because of the inferred presence of Archean host rocks and structures and because such deposits occur in equivalent rocks elsewhere in the exposed parts of these subprovinces in Canada. The metasedimentary rocks and granites of the Quetico subprovince were included in this tract because, even though the terrain has not produced gold elsewhere, several gold-bearing shear zones are found along the subprovince boundaries or project into the subprovince. The rocks of this subprovince are in large part poorly explored.

Rationale for Numerical Estimate

For the 90th, 50th, and 10th percentiles, the team estimated, respectively, 2, 4, and 6 or more Archean low-sulfide gold quartz vein deposits consistent with the grade and tonnage model of Klein and Day (1994).

References

- Card, K.D., Poulsen, K.H., and Robert, Francios, 1989, The Archean Superior Province of the Canadian Shield and its lode gold deposits, *in* Keays, R.R., and Skinner, B.J., eds., *The geology of gold deposits-The perspective in 1988: Economic Geology Monograph 6*, p. 19-36.
- Colvine, A.C., Fyon, J.A., Heather, K.B., Marmont, S., Smith, P.M., and Troop, D.G., 1988, Archean lode gold deposits in Ontario: Ontario Geological Survey Miscellaneous Paper 139, 136 p.
- Groves, D.I., and Foster, R.P., 1991, Archaean lode gold deposits, *in* Foster, R.P., ed., *Gold Metallogeny and Exploration*, Blackie, London, p. 63-103.
- Groves, D.I., Barley, M.E., Ho, S.E., 1989, Nature, genesis, and tectonic setting of mesothermal gold mineralization in the Yilgarn Block, Western Australia, *in* Keays, R.R., Ramsay, W.R.H., and Groves, D.I., eds., *The Geology of Gold Deposits-The Perspective in 1988: Economic Geology Monograph 6*, p. 71-85.
- Johnson, R.C., and Bornhorst, T.J., 1991, Archean geology of the northern block of the Ishpeming greenstone belt, Marquette County Michigan: U.S. Geological Survey Bulletin 1904-F, 20 p.

- Klein, T.L., and Day, W.C., 1994, Descriptive and grade-tonnage models of Archean low-sulfide Au-quartz and a revised grade-tonnage model of Homestake Au: U.S. Geological Survey Open-File Report 94-250.
- Mosier, D.L., 1986, Grade-tonnage model of Homestake gold, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 245-247.
- Sims, P.K., 1976, Early Precambrian tectonic-igneous evolution in the Vermilion district, northeastern Minnesota: Geological Society of America Bulletin, v. 87, p. 379-389.

LS12**Low-sulfide Au-quartz Vein Deposits, Archean type**

Minnesota

Descriptive Model 36b • Mark3 Index 101

Michigan

Area = 4,860 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by T.L. Klein and K.J. Schulz

Rationale for Model Choice

Greenstone-dominated subprovinces of the Archean Superior Province are host to most of the major gold districts in Canada, with gold produced principally from quartz vein deposits or sulfide-mineral disseminations found near major shear zones tens to hundreds of kilometers long. Most deposits are immediately adjacent to major, generally east-trending, dextral, transpressive fault zones in greenstone belts or along their boundaries. The largest districts or deposits appear to have been formed during early episodes of dominantly high-angle reverse motion along these typically transpressive zones. Most current models favor an epigenetic origin for Archean gold deposits (Colvine and others, 1988; Groves and others, 1989; Groves and Foster, 1991). The gold-bearing veins and sulfide mineral disseminations were emplaced in a zone of brittle-ductile deformation after peak deformation and metamorphism which, in most of the Superior province, occurred between 2700 and 2680 Ma. Gold production does not correlate with any lithologic or geochemical characteristics or with the age of the major rock units within the subprovinces. Rather, production has been greatest in those subprovinces (i.e., the Abitibi and Uchi subprovinces) that show the highest degree of preservation of volcano-sedimentary rocks, reflected in thick sections with low-grade metamorphism and a high ratio of volcanic to plutonic rocks (Card and others, 1989).

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deposits are epigenetic in character and not related genetically to chemical sediments. Several studies in the Superior Province of Canada and the Yilgarn Province of Western Australia (Colvine and others, 1988; Groves and others, 1989) have shown that the Archean gold deposits do not show any consistent lithologic control and occur in most of the rock types that make up Archean greenstone belts. The Archean low-sulfide Au-quartz vein deposits share most geologic characteristics with Proterozoic and Phanerozoic low-sulfide Au-quartz vein deposits, but have distinct grade and tonnage.

The tracts outlined for the Archean low-sulfide Au-quartz deposits in the Lake Superior region could also contain Homestake gold deposits. However, because Homestake deposits are relatively rare in greenstone belts, quantitative resources estimates were not made for these deposits in the Lake Superior region.

Rationale for Tract Delineation

This tract includes three areas within northern Minnesota and northern Michigan that are thought to be favorable for the occurrence of undiscovered Archean low-sulfide Au-quartz vein deposits.

The westernmost of the three areas, composed of low- to medium-grade metavolcanic and plutonic rocks of the Wabigoon subprovince, is a triangular area in northern Minnesota bounded by the U.S.-Canadian border, the Vermilion fault, the Rainy Lake-Seine River fault and a segment of the Quetico fault. Gold deposits are present in this tract near International Falls (Little America mine) and in the extension of these rocks in Canada. Geochemical anomalies are present in soil, rock, and glacial drift, and hydrothermally-altered rocks and carbonate alteration typical of low-sulfide Au-quartz vein deposits are found along major and minor faults and shear zones located at the boundaries of this tract, as well as within it. Exploration in the central and western part of the tract is complicated by glacial drift up to 60 m thick. Some parts of the area have been moderately well explored, whereas others are virtually untested.

The central of the three areas contains the Vermilion district which contains metamorphosed volcanic and sedimentary rocks of the Wawa subprovince. The Vermilion district is bounded on the north by subprovince boundary faults, the Vermilion and Burntside Lake faults, and is bounded on the south by the Giants Range batholith. Several east-west trending dextral fault segments of the Vermilion fault and northwest-trending sinistral faults are located internal to the district. Several gold prospects, gold-bearing shear zones, and geochemical anomalies are present along both the bounding and internal faults (Sims and Day, 1992).

The mafic metavolcanic-dominated Ishpeming greenstone belt of the Wawa subprovince in northern Michigan defines the easternmost of the three areas. This greenstone belt is bounded on the north and south by high-grade gneissic rocks and is in part overlain by rocks of the Early Proterozoic Marquette Range Supergroup. Several internal dextral shear zones affect the Archean rocks in the belt (Johnson and Bornhorst, 1991). The Ishpeming greenstone belt hosts the Ropes gold mine, as well as several low-sulfide Au-quartz vein prospects.

Important Examples of Deposit Type

The Wabigoon subprovince extends into northern Minnesota and ranks third in gold production when compared with other Superior subprovinces. Total known production of gold in the Wabigoon subprovince accounts for about 3 percent of the total gold production in the Superior Province (data from Card and others 1989). In the U.S. part of the southern Wabigoon subprovince, the only gold production has come from quartz veins in the Little America mine located along the U.S.-Canadian border near International Falls, Minnesota (Klein, 1989). This deposit and several nearby prospects in the U.S. and many other small deposits found nearby

in Canada are located along the dextral Rainy Lake-Seine River fault. Small deposits also occur further north in Canada along the Quetico fault. Both of these major transcurrent faults can be traced into northern Minnesota beneath thick glacial cover using airborne magnetic data.

In the Ishpeming greenstone belt, in northern Michigan, gold has been produced only at the Ropes mine, a typical low-sulfide Au-quartz vein deposit (see Bornhorst and others, 1986; Brozdowski and others, 1986). Gold in this deposit is associated with finely disseminated pyrite in altered felsic volcanic rocks and in quartz-tetrahedrite veins in a ductile shear zone. In the Vermilion district in northeastern Minnesota, greenstones contain several gold prospects in hydrothermally altered rocks along the dextral Vermilion fault and related secondary shear zones (Sims and Day, 1992). Several areas along the Vermilion fault system contain soil geochemical anomalies typical of anomalies associated with low-sulfide Au-quartz vein deposits.

Rationale for Numerical Estimate

For the 90th, 50th, and 10th percentiles, the team estimated, respectively, 2, 3, and 6 or more Archean low-sulfide gold quartz vein deposits consistent with the grade and tonnage model of T.L. Klein and W.C. Day (1994).

References

- Card, K.D., Poulsen, K.H., and Robert, Francios, 1989, The Archean Superior Province of the Canadian Shield and its lode gold deposits, *in* Keays, R.R., and Skinner, B.J., eds., *The geology of gold deposits-The perspective in 1988: Economic Geology Monograph 6*, p. 19-36.
- Colvine, A.C., Fyon, J.A., Heather, K.B., Marmont, S., Smith, P.M., and Troop, D.G., 1988, Archean lode gold deposits in Ontario: Ontario Geological Survey Miscellaneous Paper 139, 136 p.
- Groves, D.I., and Foster, R.P., 1991, Archean lode gold deposits, *in* Foster, R.P., ed., *Gold Metallogeny and Exploration*, Blackie, London, p. 63-103.
- Groves, D.I., Barley, M.E., Ho, S.E., 1989, Nature, genesis, and tectonic setting of mesothermal gold mineralization in the Yilgarn Block, Western Australia, *in* Keays, R.R., Ramsay, W.R.H., and Groves, D.I., eds., *The Geology of Gold Deposits-The Perspective in 1988: Economic Geology Monograph 6*, p. 71-85.
- Johnson, R.C., and Bornhorst, T.J., 1991, Archean geology of the northern block of the Ishpeming greenstone belt, Marquette County, Michigan: U.S. Geological Survey Bulletin 1904-F, 20 p.
- Klein, T.L., and Day, W.C., 1994, Descriptive and grade-tonnage models of Archean low-sulfide Au-quartz and a revised grade-tonnage model of Homestake Au: U.S. Geological Survey Open-File Report 94-250.
- Klein, T.L., 1989, Mineral occurrence and drill-hole location map of the International Falls 1° x 2° quadrangle, Minnesota and Ontario: U.S. Geological Survey Miscellaneous Field Studies Map MF-2082, scale 1:250,000.
- Mosier, D.L., 1986, Grade-tonnage model of Homestake gold, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models: U.S. Geological Survey Bulletin 1693*, p. 245-247.
- Sims, P.K., 1976, Early Precambrian tectonic-igneous evolution in the Vermilion district, northeastern Minnesota: *Geological Society of America Bulletin*, v. 87, p. 379-389.
- Sims, P.K., and Day, W.C., 1992, A regional structural model for gold mineralization in the southern part of the Archean Superior province, United States: U.S. Geological Survey Bulletin 1904-M, 19 p.

NA01**Magmatic Cu Deposits****No Published Descriptive Model****Area = 2,690 km²***by Michael P. Foose*

Maine
New Hampshire
Massachusetts
Connecticut

Rationale for Model Choice

Magmatic copper deposits are part of a general class known as magmatic sulfides. Significant members of this deposit class are described in Cox and Singer (1986) *by* models 1, 2b, 5a, 5b, 6a, 6b, 7a. As a group, these deposits form by the separation of an immiscible sulfide liquid during the crystallization of mafic or ultramafic magmas. The partition coefficients for Cu, Ni, Co, and the platinum group elements (PGEs) between the sulfide liquid and the hosting silicate melt are generally large and cause the immiscible sulfides to be enriched in these elements. After separation, the dense sulfide liquid settles towards the bottom of the magma chamber where it may coalesce into large masses that, upon final cooling of the magma, form a sulfide mass that may contain economic concentrations of copper, nickel, and PGEs.

Within the United States, the identified magmatic copper deposits are of three types (Cox and Singer, 1986). The most important are those associated with continental rifting (model 5a) and occur within the Duluth Complex (Minnesota). Magmatic copper sulfides also occur in layered intrusions (models 1 and 2b) such as the Stillwater Complex (Montana), and in association with synorogenic intrusions (model 7a).

Within the Northern Appalachians, several magmatic sulfide occurrences have been identified in association with diverse mafic and ultramafic intrusions. Five of these sites are identified here and briefly described from north to south.

With the exception of the sulfides in the Moxie and Katahdin intrusions, these permissive areas contain only small amounts of identified sulfide mineralization within relatively small areas. Further, the genesis and setting of most of these sulfides bodies is unclear. The mineralization in the Alexander Area is probably associated with synorogenic intrusions; the mineralization associated with Moxie and Katahdin intrusions has been classified as synorogenic, but is still ambiguous; the mineralization in the other areas have been so extensively altered by subsequent events that a confident assignment of deposit type is not possible.

Rationale for Tract Delineation

Alexander Area—Copper-bearing magmatic sulfides have been prospected near the Town of Alexander, Maine. This occurrence, known as the Frost Prospect, is associated with coarse-grained pyroxene-rich gabbros or norites. The sulfides occur partly as magmatic segregations but also as fracture fillings. Although several drill holes have penetrated this copper-nickel sulfide, the details of their occurrence are poorly known (Young, 1963; 1968). However, their association with post-Silurian to pre-Devonian gabbro-norite intrusions which occur in this area, such as the Pocamoonshine Gabbro-Diorite (Larrabee and others, 1965; Amos, 1963), and the recognition of similar magmatic sulfide occurrences in associated rocks in adjacent parts of Canada, such as the St. Steven body in New Brunswick (Ruitenberg, 1968), suggests that these rocks are permissive for copper magmatic sulfide deposits. This mineralization is probably similar to that associated with synorogenic intrusions.

Moxie and Katahdin Plutons—A number of low grade copper-bearing sulfides have been identified within gabbroic rocks that form the Moxie and Katahdin plutons. These Devonian intrusions have been interpreted to be emplaced synorogenically during the Acadian orogeny. The Moxie intrusion is 2–8 km wide and 70 km long. Although sulfides are ubiquitous, three

higher grade sulfide occurrences have been identified and prospected. Study of sulfur isotopes and magma S/Se ratios show that the sulfur was derived from adjacent sedimentary rocks (Naldrett and others, 1984).

The gabbro of the Katahdin pluton is similar to, and probably related to, the Moxie intrusion. It is a 4.5 km by 1.5 km stock about 15 km south of the Moxie pluton. However, unlike the sparse disseminated mineralization that characterizes the Moxie, the Katahdin intrusion contains 200 million tons of nearly massive magmatic sulfide. Study of sulfur isotopes and S/Se ratios show that this intrusion assimilated a large amount of country-rock sulfur. This caused large amounts of iron-sulfides to form which diluted the Cu and Ni grades of the massive magmatic sulfides. As a result, the Katahdin deposit has low Ni and Cu grades.

Both the Moxie and Katahdin mineralization have been interpreted as being associated with synorogenic intrusions. However, recent field studies suggest that these intrusions might be associated with a previously unrecognized period of rifting, and that it may have more in common with rift-related magmatic sulfide deposits such as the Duluth Complex.

Warren Area—Two mafic intrusions (the Harriman and the Warren intrusion) in eastern Maine host magmatic copper sulfides. The Area 5 prospect within the gabbro of the Warren intrusion is the largest of these and represents the most significant concentration of Ni-Cu sulfides in Maine. Further, it is an area currently undergoing active exploration. Paleozoic metamorphism and deformation have extensively altered these areas so that the character and genesis of the host rocks are not known. Consequently classification of the deposit type for this mineralization is not certain.

Dracut—A small pyrrhotite-pentlandite-chalcopyrite body occurs within a Paleozoic noritic stock in central Massachusetts (Dennon, 1943). It has been periodically worked, but no significant development has occurred. Subsequent deformation and alteration obscures the deposit genesis and its deposit type.

Mount Prospect—Small amounts of nickel and copper sulfide occur near Mount Prospect in northwest Connecticut (Cameron, 1943). These sulfides occur in deformed norites and pyroxenites. Much of this mineralization has clearly been remobilized by later deformation and metamorphism. However, the most reasonable interpretation is that these were initially magmatic sulfides that have subsequently been remobilized. Little additional information exists about the age, setting, size, and grade of these sulfides and the classification of these prospects is uncertain.

Rationale for Numerical Estimate

No resource estimates were made for magmatic copper deposits in the northern Appalachian region because grade tonnage curves do not exist for rift-related (model 5a) mineralization. Although such data is available for synorogenic intrusions around the world, it is not clear how adequately these curves would apply to the possible synorogenic mineralization in this region. Without adequate grade-tonnage data or confidence that the available data is applicable to the known mineralized areas, a reliable quantitative mineral assessment of undiscovered magmatic copper resources for these areas cannot be made.

References

- Amos, D.H., 1963, Petrology and age of plutonic rocks in extreme southeastern Maine: Geological Society of America Bulletin, v. 74, p. 169-194.
- Cameron, E.N., 1943, Origin of sulphides in the nickel deposits of Mount Prospect, Connecticut: Geological Society of America Bulletin, v. 54, p. 651-686.

- Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, 379 p.
- Dennon, W.H., 1943, A nickel deposit near Dracut, Massachusetts: *Economic Geology*, v. 38, no. 1, p. 25 - 55.
- Larrabee, D.M., Spencer, C.W., and Swift, D.J.P., 1965, Bedrock geology of the Grand Lake area Aroostook, Hancock, Penobscot, and Washington Counties, Maine: U.S. Geological Survey Bulletin 1201-E, 38 p.
- Naldrett, A.J., Duke, J.M., Lightfoot, P.C., and Thompson, J.F.H., 1984, Quantitative modeling of the segregation of magmatic sulphides—An exploration guide: *Canadian Institute of Mining and Metallurgy Bulletin*, v. 77, no. 864, p. 46-56.
- Ruitenbergh, A.A., 1968, Geology and mineral deposits Passamquoddy Bay area: Report of Investigation no. 7, Department of Natural Resources, New Brunswick, 47 p.
- Young, R.S., 1963, Prospect evaluations, Washington County, Maine: Maine Geological Survey Special Economic Studies Series no. 3, 86 p.
- , 1968, Mineral exploration and development in Maine, *in* Ridge, J.D., ed., *Ore deposits in the United States 1933–1967*, v. I: New York, American Institute of Mining, Metallurgical, and Petroleum Engineers, p. 125-139.

NA02**Porphyry Cu Deposits****Descriptive Model 17 • Mark3 Index 4****Area = 26,500 km²****Maine
New Hampshire
Vermont**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* Robert A. Ayuso**Rationale for Model Choice**

Porphyry-type mineralization includes several types of deposits that have in common extensive and pervasive regional alteration zones, bulk mineable features, and chalcopyrite contained in hydrothermally altered intrusions and adjacent wallrocks. Thus, the general porphyry copper mineralization model (17) of Cox (1986) and Singer and others (1986) includes a number of variants that include porphyry copper-molybdenum (model 21a), porphyry copper-gold (model 20c), and porphyry copper, skarn-related deposits (model 18a). In fact, it is well known that a continuum of geological attributes exists between these types of deposits (see also, for example, discussion by Hammarstrom and others, 1993).

Although porphyry-type deposits were exploration targets in the northeastern United States in the 1970s, no porphyry copper deposits were brought into production. Moreover, intense exploration for all types of granitoid-associated deposits identified no major deposits or even subeconomic prospects of molybdenum, gold, tin, or tungsten. Several subeconomic porphyry prospects, however, have been found in northern Maine, northern New Hampshire, and northern Vermont.

Examples of Known Deposits

One of the first porphyry copper-molybdenum prospects to be recognized, and one of the best studied, is at Catheart Mountain (Schmidt, 1974; Ayuso, 1987, 1989; Ayuso and Foley, 1993a, b; Schmidt and Ayuso, 1993; Foley and Ayuso, 1992; Hollister, 1978). Together with the nearby Sally Mountain porphyry molybdenum-copper prospect in northwestern Maine, these Ordovician to Silurian stocks are characterized by intense alteration and fracturing. Other important prospects in this tract include the Devonian porphyry-copper-molybdenum (and gold?) Deboullie Mountain (Ayuso and Loferski, 1993; Loferski and Ayuso, 1993) and porphyry molybdenum-copper at Priestly Lake in northern Maine (Ayuso and Shank, 1983).

The potassic-altered Ordovician to Silurian Catheart Mountain prospect is the largest and best exposed porphyry copper-molybdenum deposit in New England, occupying a large area of intensely altered, red-yellow-brown rocks. Fine to medium grained biotite-bearing equigranular granodiorites were intruded by quartz porphyritic granodioritic dikes associated with copper and molybdenum mineralization at Catheart Mountain. Regional alteration zones resemble those typical of porphyry copper-molybdenum deposits in the western United States (Lowell and Guilbert, 1970; Gustafson and Hunt, 1975). From least to most altered, these zones include the propylitic, outer phyllic, phyllic, quartzose potassic, and potassic. Sulfides (chalcopyrite, pyrite, molybdenite, sphalerite, stannite, galena) constitute as much as 4 volume percent of the rocks, and are concentrated in quartz stockworks and are also disseminated in the host rocks. The highest amounts of Cu and Mo as well as the highest Cu/Mo ratio is found in rocks having potassic alteration. Extensive supergene ore metal enhancement at Catheart Mountain is absent. Intense metasomatic reactions controlled by the quartz porphyry dikes enhanced the potassium contents and produced major changes in the major-, trace-element, and isotopic (Sr, O, and Pb)

compositions of the hydrated and sulfur-rich host granodioritic rocks. Fluid inclusion studies have also shown that the fluids at Catheart Mountain were unusually rich in carbon dioxide, in contrast to fluid compositions in the majority of porphyry copper-molybdenum deposits in western United States.

The nearby Ordovician Sally Mountain porphyry molybdenum-copper (?) prospect is characterized by mineralization in highly fractured, altered, evolved, and silicified granitic quartz porphyry plugs. Sulfide minerals consist of chalcopyrite and molybdenite but the mineralization is clearly dominated by molybdenite. No reliable data for grade and tonnage are known for this prospect. Alteration zones are poorly developed (especially quartz-sericite alteration). The geochemical evolution, which was evaluated on the basis of isotopic compositions and incompatible element ratios and abundances, is opposite and distinct from that documented at the Catheart Mountain prospect. The total amount of sulfide minerals is low; thus, this also contrasts with the higher abundances at the Catheart Mountain prospect. Despite their proximity, it is unlikely that the Catheart Mountain and Sally Mountain prospects developed from the same mineralizing event.

A mafic hornblende-clinopyroxene-bearing syenitic unit (associated with shonkinite and gabbro) in the composite (hornblende-biotite-bearing granodiorite) Devonian Deboullie stock contains a small zone of disseminated and vein-filling pyrite and rare chalcopyrite and molybdenite (Loferski and Ayuso, 1993). Alteration and mineralization is associated with quartz porphyry dikes which intruded medium to coarse syenite. The syenitic half of the stock was extensively drilled in the 1970s. On the basis of drilling data (unreleased) and surface mapping, mineralization in the syenitic unit is thought to have many of the features of classic porphyry copper-molybdenum deposits. However, surface exposures lack well-developed, extensive alteration zones and intensely fractured areas containing abundant sulfide minerals.

Deposits associated with the intermontane belt of alkaline plutons in British Columbia, Allard stock (CO), and the Trans-Pecos alkaline province (TX) generally resemble the Deboullie stock; these alkaline plutons have copper, gold, silver, and platinum-group element mineralization and have been defined as the alkaline gabbro-syenite association (Zientek, 1993). Unlike this association, the alkaline Deboullie stock (mafic syenite) is not part of an extensive belt associated with an active margin. Instead, the stock contains a unique compositional range that distinguishes it from the predominant calc-alkaline Devonian granitic rocks in northern Maine, northern New Hampshire, and northern Vermont. Moreover, the Deboullie stock is associated with a continent-collision environment, and is not related to an active orogenic margin.

Field and geochemical information on porphyry copper-gold-molybdenum deposits in the northern Appalachians have been obtained for the most part from field work in remote areas characterized by poor exposures (glacial and vegetation cover), and from generally incomplete results obtained by drilling. In the northeastern United States, the continuum of porphyry deposits is expressed by a wide range of sulfide contents (Cu/Mo ratios) and sulfide minerals, and a broad spectrum of host rock compositions (mafic syenites, granodiorites, and granites).

The overall results of field studies, geochemical investigations, and drilling at Catheart Mountain show it to be generally similar to other calc-alkaline porphyry copper systems. The explored part of the Catheart Mountain prospect may in fact represent the lower part of an eroded porphyry copper deposit. This constitutes a negative feature against further exploration and development of this mineralized system and against the potential of this tract. No reliable geologic data exist to confidently estimate the size of the Sally and Deboullie prospects, but available field information is consistent with the conclusion that they resemble porphyry copper-molybdenum deposits.

The Catheart Mountain prospect is included in the generalized porphyry Cu model (17) of Singer and others (1986) and both the estimated tonnage (25 million metric tons) and copper grade (0.4 percent) are slightly above the 10th percentile of all deposits included in the model. The tonnage of the Catheart Mountain prospect falls below the deposits included in the porphyry Cu-Mo model (21a) of Singer and others (1986), which is a subset of the generalized porphyry copper model. The size of the Sally Mountain and Deboullie prospects are unknown, but there is no evidence that they are larger than Catheart Mountain. Therefore, even though molybdenum grades are not available, and molybdenum is an important constituent in all the known deposits, the porphyry Cu grade-tonnage model (17) is thought to be a more appropriate choice than the porphyry Cu-Mo model (21a) for estimating metal endowment of undiscovered deposits in New England.

Skarns are characteristically associated with the contact metamorphism of carbonate-bearing wallrocks by intrusion of shallow plutonic rocks associated with porphyry copper deposits. However, there are no known copper (or gold, iron, etc.) skarns deposits or major occurrences of this kind associated with the intrusion of porphyry copper deposits in northern (or coastal) Maine, northern New Hampshire, nor Vermont. In addition, the level of erosion in the northeastern United States is likely to be too deep for skarns deposits to be an important prospective target for exploration.

Rationale for Tract Delineation

The terrane that contains calc-alkaline Ordovician to Devonian alkaline plutonic rocks of northern Maine, northern New Hampshire and northern Vermont, also includes the Catheart Mountain, Sally Mountain, and Deboullie prospects, and is considered permissive for porphyry copper deposits, especially the porphyry copper-molybdenum subtype. Stocks thought to be potential hosts for porphyry copper-molybdenum deposits are generally structurally controlled and are known to occur within tectonic zones that were part of active margins (continental or island-arc margins). The features mentioned above favor the Ordovician granitic suite because tectonic models for this suite indicate that they were produced in an active margin. However, an unfavorable feature in this tract is that stocks in this area were not shallowly emplaced. Moreover, the most abundant stocks in the northeastern United States are Acadian, and they are thought to have formed in a continental-collision environment. This feature argues against such Acadian granitic rocks as important hosts of typical porphyry-type mineralization.

Rationale for Numerical Estimate

The team used the consensus method to make resource estimates for porphyry copper deposits in the permissive tract. The bulk of the geologic information suggests that the majority of the stocks that could have been associated as hosts of porphyry copper-gold-molybdenum mineralization lack key petrologic and mineralization features, including appropriate alteration and fracture intensities, and shallow emplacement depths resembling those known from mined deposits elsewhere. For the 90th, 50th, and 10th percentiles, the team estimated 1, 1, and 2 or more porphyry copper deposits consistent with the grade and tonnage model of Singer and others (1986).

References

- Ayuso, R.A., 1987, Mineralized rocks of the Catheart Mountain Cu-Mo porphyry, Maine: Aluminous white micas as indices of mineralization: U.S. Geological Survey Bulletin 1803, 16 p.
- Ayuso, R.A., 1989, Geochemistry of the Catheart Mountain porphyry copper deposit, Maine, *in* Tucker, R.D., and Marvinney, R.G., eds., *Studies in Maine geology*, v. 4—Igneous and metamorphic geology: Maine Geological Survey, p. 139-162.

- Ayuso, R.A., and Foley, N.K., 1993a, Rb-Sr isotopic redistribution and character of hydrothermal fluids in the Catheart Mountain Cu-Mo deposit, Maine, *in* Scott, R.W., Jr., Detra, P.S., and Berger, B.R., eds., *Advances related to United States and international mineral resources—Developing frameworks and exploration technologies*: U.S. Geological Survey Bulletin 2039, p. E45-E57.
- Ayuso, R.A., and Foley, N.K., 1993b, Porphyry Cu and Cu-Mo mineralization in the northern U.S. Appalachian Mountains, *in* Fenoll Hach Alli, P., Torres-Ruiz, J., and Gervilla, F., eds., *Current research in geology applied to ore deposits: Proceedings of the second biennial SGA (Society for Geology Applied to Mineral Deposits) meeting*, Granada, Spain, 9–11 Sep 93, p. 601-604.
- Ayuso, R.A., and Loferski, P.J., 1993, Trace element geochemistry of syenite and granodiorite in the Deboullie pluton, northern Maine: Geological Association of Canada, Program and Abstracts, v. 17, p. A5.
- Ayuso, R.A., and Shank, S.G., 1983, Quartz-molybdenite veins in the Priestly Lake granodiorite, north central Maine: U.S. Geological Survey Open-File Report 83-800, 12 p.
- Cox, D.P., 1986, Descriptive model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 76.
- Foley, N.K., and Ayuso, R.A., 1993, Character of hydrothermal fluids in the Catheart Mountain Cu-Mo deposit, Maine—Constraints on modeling a mineralizing system: Geological Association of Canada, Program and Abstracts, v. 17, p. A34.
- Gustafson, L.B., and Hunt, J.P., 1975, The porphyry copper deposits at El Salvador, Chile: *Economic Geology*, v. 70, no. 5, p. 857-912.
- Hammarstrom, J.M., Zientek, M.L., Elliott, J.E., Van Gosen, B.S., Carlson, R.R., Lee, G.K., and Kulik, D.M., 1993, Mineral resource assessment for locatable minerals (exclusive of the Stillwater Complex), *in* Hammarstrom, J.M., Zientek, M.L., and Elliott, J.E., eds., *Mineral resource assessment of the Absaroka-Beartooth study area, Custer and Gallatin National Forests, Montana*: U.S. Geological Survey Open-File Report 93-207, p. G1-G74.
- Hollister, V., 1978, *Geology of the porphyry copper deposits of the western hemisphere*: Society of Mining Engineers, American Institute of Mining, Metallurgical, and Petroleum Engineers, New York, 219 p.
- Loferski, P.J., and Ayuso, R.A., 1993, Mineral chemistry of biotite and apatite from syenitic rocks in the Deboullie pluton, northern Maine: Geological Association of Canada, Program and Abstracts, v. 17, p. A67.
- Schmidt, R.G., 1974, Preliminary study of rocks alteration in the Catheart Mountain molybdenum-copper deposit, Maine: U.S. Geological Survey Journal of Research, v. 2, p. 189-194.
- Schmidt, R.G., and Ayuso, R.A., 1993, Porphyry Cu and Cu-Mo mineralization in New England—Examples from Catheart Mountain and Deboullie plutons and implications for future exploration in the northern Appalachian Mountains, *in* Applications of recent geological concepts to exploration in the northern Appalachians, Third annual CIM geological field conference: *Exploration and Mining Geology*, v. 2, no. 4, p. 411-412.
- Singer, D.A., Mosier, D.L., and Cox, D.P., 1986, Grade and tonnage model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 77-81.
- Singer, D.A., Mosier, D.L., and Cox, D.P., 1986, Grade and tonnage model of porphyry Cu-Mo, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 116-119.
- U.S. Bureau of Mines, 1987, An appraisal of minerals availability for 34 commodities: U.S. Bureau of Mines Bulletin 692, 300 p.
- Zientek, M.L., 1993, Alkaline gabbro-syenite association, *in* Hammarstrom, J.M., Zientek, M.L., and Elliott, J.E., eds., *Mineral resource assessment of the Absaroka-Beartooth study area, Custer and Gallatin National Forests, Montana*: U.S. Geological Survey Open-File Report 93-207, p. G75-G78.

NA03**Descriptive Model 17****Area = 17,000 km²****Porphyry Cu Deposits****Maine
New Hampshire
Vermont****Model***by* Robert A. Ayuso**Rationale for Model Choice**

Areas containing fractured, altered rocks, and coarse molybdenite are known in the Mesozoic alkalic intrusive complex at Cuttingsville, Vermont. The Cuttingsville area also contains anomalously high gold contents (Robinson, 1990), but it is unclear whether the mineralization is associated with a regional hydrothermal system as expected from a porphyry-gold deposit. Minor gold occurrences have also been reported from other alkaline complexes, for example, at Ascutney (VT). However, as in the case of the intrusive complex at Cuttingsville, field examination of the Ascutney locality does not indicate the presence of an intense and extensive hydrothermal system.

Rationale for Tract Delineation

Based on these occurrences, a tract permissive for porphyry copper-gold is defined to include the area around Cuttingsville, Vermont and the alkaline igneous province that includes the Montereian Hills, and the White Mountain batholith in New Hampshire, coastal New Hampshire and Maine, and northern Vermont. The plutonic rocks range from undersaturated (e.g., pyroxenite, diorite, syenite, etc.) to metaluminous biotite-bearing alkaline granites. The alkaline igneous province consists of stocks, overlapping calderas, ring-dike complexes, and large granitic units emplaced from about 240 to 90 m.y. ago. The major periods of magmatism are in fact related to the opening of the North Atlantic Ocean (Eby, 1987).

Because of the lack of a clear example of porphyry mineralization or alteration in this tract, the team was unable to estimate undiscovered deposits.

References

- Eby, G.N., 1987, The Montereian Hills and White Mountain alkaline igneous provinces, North America, *in* Fitton, F.G., and Upton, B.G.J., eds., *Alkaline igneous rocks: Geological Society Special Publication no. 30*, p. 433-447.
- Robinson, G.R., Jr., 1990, Carbonate-hosted gold mineralization of hydrothermal-replacement origin adjacent to a syenitic stock at Cuttingsville, Vermont, and the potential for other syenite-related gold deposits in New England, *in* Slack, J.F., ed., *Summary results of the Glens Falls CUSMAP project, New York, Vermont, and New Hampshire: U.S. Geological Survey Bulletin 1887, Chapter O*, 18 p.

NA04**Massive Sulfide Deposits, Cyprus Type****Maine****Descriptive Model 24a****Area = 52 km²**[Model](#)*by* J.F. Slack**Rationale for Model Choice**

No Cyprus massive sulfide deposits are known in the northern United States Appalachians. However, several deposits of this type occur in the Canadian Appalachians to the north, at the Huntingdon mine in southeastern Quebec (Trottier and others, 1987) and at the Betts Cove, York Harbour, and Rambler mines in western Newfoundland (Stephens and others, 1984; Swinden, 1991). Cyprus massive sulfide deposits are restricted in their occurrence to sequences of submarine pillow lavas that overlie variously preserved ophiolite complexes, like those in the type area of Cyprus (Constantinou and Govett, 1973). The deposits, which have been mined chiefly for copper, consist of stratiform massive pyrite, with variable amounts of chalcopyrite and minor sphalerite and pyrrhotite, and locally some gold (Franklin and others, 1981).

Rationale for Tract Delineation

The only area that is considered permissive in the Northern Appalachians region is the Boil Mountain Complex (ophiolite) of west-central Maine (Boudette, 1982). This tract, which is near the border with southeastern Quebec, encompasses pillow lavas that overlie ophiolitic mafic and ultramafic intrusive rocks. No Cyprus massive sulfide deposits are known within this tract, but based on analogies with similar geologic terranes elsewhere that contain such deposits, the pillow lavas of the Boil Mountain Complex are judged to be permissive for the occurrence of volcanogenic massive sulfide deposits. No estimate was made for undiscovered deposits within this tract, however.

References

- Boudette, E.L., 1982, Ophiolite assemblage of early Paleozoic age in central western Maine, *in* St-Julien, P., and Béland, J., eds., Major structural zones and faults of the northern Appalachians: Geological Association of Canada, Special Paper 24, p. 209-230.
- Constantinou, G., and Govett, G.J.S., 1973, Geology, geochemistry and genesis of Cyprus sulphide deposits: *Economic Geology*, v. 68, no. 6, p. 843-858.
- Franklin, J.M., Lydon, J.W., and Sangster, D.F., 1981, Volcanic-associated massive sulfide deposits, *in* Skinner, B.J., ed., *Economic Geology Seventy-Fifth Anniversary Volume, 1905-1980*: Lancaster, Pennsylvania, Economic Geology Publishing Company, p. 485-627.
- Stephens, M.B., Swinden, H.S., and Slack, J.F., 1984, Correlation of massive sulfide deposits in the Appalachian-Caledonian orogen on the basis of paleotectonic setting: *Economic Geology*, v. 79, no. 7, p. 1442-1478.
- Swinden, H.S., 1991, Paleotectonic settings of volcanogenic massive sulphide deposits in the Dunnage Zone, Newfoundland Appalachians: *Canadian Institute of Mining and Metallurgy Bulletin*, v. 84, no. 946, p. 59-69.
- Trottier, Jacques, Gauthier, Michel, and Brown, A.C., 1987, Geology and lithogeochemistry of the Huntingdon deposit, Cyprus-type mineralization in the ophiolite belt of the southeastern Quebec Appalachians: *Economic Geology*, v. 82, no. 6, p. 1483-1504.

NA05**Massive Sulfide Deposits, Besshi Type**

Maine

Descriptive Model 24b

Area = 1,000 km²[Model](#)[Mineral Deposits](#)

by J.F. Slack

Rationale for Model Choice

A Besshi classification is tentatively assigned to the Black Hawk (Blue Hill) deposit on the coast of Maine. This deposit, in the Ellsworth Schist on the east side of Penobscot Bay, produced 900,000 metric tons of ore from stratabound and generally stratiform massive sulfides during the period 1972-1977 (Gair and Slack, 1980), which constitutes the most recent metal mining in New England. The mineralogy and geologic setting of the Black Hawk deposit (LaPierre, 1977; Stewart, in press) are similar to those of many Besshi deposits of the world, except for the presence of minor felsic metavolcanic rocks in the surrounding area and a local abundance of lead in the Black Hawk ores. Despite the presence of these features, the overall nature of the Black Hawk deposit seems to best fit a Besshi model, although a distal kuroko model might also be applicable.

The Besshi grade-tonnage model of Slack (1993) was used in the calculation of undiscovered metal resources. In contrast with the model 24b of Singer (1986), which only included data for Besshi deposits in Japan, this model (Mark3 index 98) incorporates grade and tonnage data for Besshi deposits throughout the world, including those in the United States Appalachians, and is therefore more comprehensive.

Rationale for Tract Delineation

The permissive tract consists of 3 areas along the central coast of Maine and encompasses the Ordovician(?) rocks of the Ellsworth Schist (east side of Penobscot Bay) and the lower Paleozoic rocks of the Penobscot Formation near the town of Appleton (west side of Penobscot Bay). It is assigned potential because of the occurrence of the Black Hawk deposit and several prospects in the Ellsworth Schist, and the presence of altered metabasalts and a copper-rich massive sulfide prospect in the Penobscot Formation. The tract is small because the permissive rocks have been largely destroyed by the intrusion of large plutons of Devonian age. No numerical estimates were made.

References

- Gair, J.E., and Slack, J.F., 1980, Stratabound massive sulfide deposits of the U.S. Appalachians, *in* Vokes, F.M., and Zachrisson, Ebbe, eds., *Review of Caledonian-Appalachian stratabound sulphides: Geological Survey of Ireland, Special Paper No. 5*, p. 68-81.
- LaPierre, P.T., 1977, The geology, zoning, and textural features of the Second Pond ore deposit, Blue Hill, Maine: Orono, University of Maine, unpublished M.S. thesis, 75 p.
- Singer, D.A., 1986, Grade and tonnage model of Besshi massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models: U.S. Geological Survey Bulletin 1693*, p. 136-138.
- Slack, J.F., 1993, Descriptive and grade-tonnage models for Besshi-type massive sulphide deposits, *in* Kirkham, R.V., Sinclair, W.D., Thorpe, R.I., and Duke, J.M., eds., *Mineral deposit modeling: Geological Association of Canada, Special Paper 40*, p. 343-371.
- Stewart, D.B., in press, Bedrock geologic map of northern Penobscot Bay, south-central Maine: U.S. Geological Survey Miscellaneous Investigations Series Map 2551, scale 1:62,500.

NA06**Massive Sulfide Deposits, Besshi Type**

Vermont

Descriptive Model 24b • Mark3 Index 98

Area = 1,600 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by J.F. Slack

Rationale for Model Choice

Besshi massive sulfide deposits occur in terrigenous clastic sedimentary rocks interbedded with tholeiitic to andesitic flows, tuffs and breccias (Fox, 1984). Similar rocks are present in this tract.

The Besshi grade-tonnage model of Slack (1993) was used in the calculation of undiscovered metal resources. In contrast with the model 24b of Singer (1986), which only included data for Besshi deposits in Japan, this model incorporates grade and tonnage data for Besshi deposits throughout the world, including those in the United States Appalachians, and is therefore more comprehensive.

Rationale for Tract Delineation

The permissive tract, to the west of the Vermont copper belt, consists of a sequence of Cambrian and (or) Ordovician clastic metasedimentary rocks and minor metabasalts that have associated geochemical anomalies (Watts, 1990), which Slack (1990) judged to be permissive for the occurrence of Besshi deposits.

Rationale for Numerical Estimate

For the 90th, 50th, and 10th percentiles, the team estimated 1, 2, and 2 or more Besshi massive sulfide deposits consistent with the grade and tonnage model of Slack (1993) (Mark3 index 98). The number of undiscovered deposits assigned to the favorable tract reflects: (1) the presence of several prospects and sulfide occurrences, and (2) geochemical anomalies in stream sediments and panned concentrates (Watts, 1990; Slack and others, 1990).

References

- Fox, J.S., 1984, Besshi-type volcanogenic sulphide deposits—A review: Canadian Institute of Mining and Metallurgy Bulletin, v. 77, no. 864, p. 57-68.
- Singer, D.A., 1986, Grade and tonnage model of Besshi massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 136-138.
- Slack, J.F., 1990, Preliminary assessment of metallic mineral resources in the Glens Falls 1° x 2° quadrangle, New York, Vermont, and New Hampshire, *in* Slack, J.F., ed., Summary results of the Glens Falls CUSMAP project, New York, Vermont, and New Hampshire: U.S. Geological Survey Bulletin 1887-R, 26 p.
- Slack, J.F., 1993, Descriptive and grade-tonnage models for Besshi-type massive sulphide deposits, *in* Kirkham, R.V., Sinclair, W.D., Thorpe, R.I., and Duke, J.M., eds., Mineral deposit modeling: Geological Association of Canada, Special Paper 40, p. 343-371.
- Slack, J.F., Atelsek, P.J., and Whitlow, J.W., 1990, Geochemistry of stream sediments and heavy-mineral concentrates from the Orange County copper district, east-central Vermont, *in* Slack, J.F., ed., Summary results of the Glens Falls CUSMAP project, New York, Vermont, and New Hampshire: U.S. Geological Survey Bulletin 1887-Q, 21 p.

Watts, K.C., Jr., 1990, Regional exploration geochemistry of the Glens Falls 1° x 2° quadrangle, New York, Vermont, and New Hampshire, *in* Slack, J.F., ed., Summary results of the Glens Falls CUSMAP project, New York, Vermont, and New Hampshire: U.S. Geological Survey Bulletin 1887-F, 70 p.

NA07**Massive Sulfide Deposits, Besshi Type**

Vermont

Descriptive Model 24b • Mark3 Index 98

Massachusetts

Area = 785 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by J.F. Slack

Rationale for Model Choice

The only well-documented Besshi massive sulfide deposits in the northern United States Appalachians occur in the Vermont copper belt of east-central Vermont (White and Eric, 1944; Slack and others, 1993). These deposits are part of a group of stratabound, and generally stratiform, sulfide deposits that form mainly by submarine hydrothermal processes within clastic metasedimentary rocks and variable amounts of metabasalt, (Franklin and others, 1981; Fox, 1984; Slack, 1993). The largest such deposit in the New England Appalachians is at the Elizabeth mine, Vermont (McKinstry and Mikkola, 1954; Howard, 1969; Annis and others, 1983; Slack and others, 1993). Production from the Elizabeth mine was approximately 2.9 million metric tons of massive sulfide ore containing an estimated 1.8 percent copper and 0.5 percent zinc, with recoverable silver and gold; pyrrhotite was mined locally for the production of sulfuric acid (Howard, 1969; Gair and Slack, 1980). On the Besshi grade-tonnage curves of Slack (1993), production from the Elizabeth mine falls slightly above the median tonnage (1.3 million metric tons) and copper grade (1.4 percent Cu).

The Besshi grade-tonnage model of Slack (1993) was used in the calculation of undiscovered metal resources. In contrast with the model 24b of Singer (1986), which only included data for Besshi deposits in Japan, this model (Mark3 index 98) incorporates grade and tonnage data for Besshi deposits throughout the world, including those in the United States Appalachians, and is therefore more comprehensive.

Rationale for Tract Delineation

This tract includes strike extensions of the Standing Pond Volcanics and related clastic metasedimentary rocks of the Vermont copper belt in areas without important known deposits.

Rationale for Numerical Estimate

For the 90th, 50th, and 10th percentiles, the team estimated 1, 2, and 2 or more Besshi massive sulfide deposits consistent with the grade and tonnage model of Slack (1993) (Mark3 index 98). The number of undiscovered deposits assigned to this tract reflects: (1) the presence of many prospects and sulfide occurrences in the copper belt (White and Eric, 1944; J.F. Slack, unpub. data); (2) known geochemical anomalies in stream sediments and panned concentrates of the district (Watts, 1990; Slack and others, 1990); and (3) airborne geophysical anomalies identified in the region by industry exploration during the 1980s.

References

- Annis, M.P., Slack, J.F., and Rolph, A.L., 1983, Stratabound massive sulphide deposits of the Elizabeth mine, Orange County, Vermont, *in* Sangster, D.F., ed., Field trip guidebook to stratabound sulphide deposits, Bathurst area, N.B., Canada and west-central New England, U.S.A.: Geological Survey of Canada, Miscellaneous Report 36, p. 41-51.
- Fox, J.S., 1984, Besshi-type volcanogenic sulphide deposits—A review: Canadian Institute of Mining and Metallurgy Bulletin, v. 77, no. 864, p. 57-68.

- Franklin, J.M., Lydon, J.W., and Sangster, D.F., 1981, Volcanic-associated massive sulfide deposits, *in* Skinner, B.J., ed., *Economic Geology Seventy-Fifth Anniversary Volume, 1905–1980*: Lancaster, Pennsylvania, Economic Geology Publishing Company, p. 485-627.
- Gair, J.E., and Slack, J.F., 1980, Stratabound massive sulfide deposits of the U.S. Appalachians, *in* Vokes, F.M., and Zachrisson, Ebbe, eds., *Review of Caledonian-Appalachian stratabound sulphides*: Geological Survey of Ireland, Special Paper No. 5, p. 68-81.
- Howard, P.F., 1969, The geology of the Elizabeth mine, Vermont: Vermont Geological Survey, *Economic Geology*, v. 64, 73 p.
- McKinstry, H.E., and Mikkola, A.K., 1954, The Elizabeth copper mine, Vermont: *Economic Geology*, v. 49, no. 1, p. 1-30.
- Singer, D.A., 1986, Grade and tonnage model of Besshi massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 136-138.
- Slack, J.F., 1990, Preliminary assessment of metallic mineral resources in the Glens Falls 1° x 2° quadrangle, New York, Vermont, and New Hampshire, *in* Slack, J.F., ed., *Summary results of the Glens Falls CUSMAP project*, New York, Vermont, and New Hampshire: U.S. Geological Survey Bulletin 1887-R, 26 p.
- Slack, J.F., 1993, Descriptive and grade-tonnage models for Besshi-type massive sulphide deposits, *in* Kirkham, R.V., Sinclair, W.D., Thorpe, R.I., and Duke, J.M., eds., *Mineral deposit modeling*: Geological Association of Canada, Special Paper 40, p. 343–371.
- Slack, J.F., Atelsek, P.J., and Whitlow, J.W., 1990, Geochemistry of stream sediments and heavy-mineral concentrates from the Orange County copper district, east-central Vermont, *in* Slack, J.F., ed., *Summary results of the Glens Falls CUSMAP project*, New York, Vermont, and New Hampshire: U.S. Geological Survey Bulletin 1887-Q, 21 p.
- Slack, J.F., Offield, T.W., Shanks, W.C. III, and Woodruff, L.G., 1993, Besshi-type massive sulfide deposits of the Vermont copper belt: Society of Economic Geologists, *Field Trip Guidebook Series*, v. 17, p. 32-73.
- Watts, K.C., Jr., 1990, Regional exploration geochemistry of the Glens Falls 1° x 2° quadrangle, New York, Vermont, and New Hampshire, *in* Slack, J.F., ed., *Summary results of the Glens Falls CUSMAP project*, New York, Vermont, and New Hampshire: U.S. Geological Survey Bulletin 1887-F, 70 p.
- White, W.S., and Eric, J.H., 1944, Preliminary report on the geology of the Orange County copper district, Vermont: U.S. Geological Survey Open-File Report, 36 p. [includes 8 separate plates].

NA08**Massive Sulfide Deposits, Besshi Type****Vermont****Descriptive Model 24b • Mark3 Index 98****Area = 491 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by J.F. Slack

Rationale for Model Choice

The only well-documented Besshi massive sulfide deposits in the northern United States Appalachians occur in the Vermont copper belt of east-central Vermont (White and Eric, 1944; Slack and others, 1993). These deposits are part of a group of stratabound, and generally stratiform, sulfide deposits that form mainly by submarine hydrothermal processes within clastic metasedimentary rocks and variable amounts of metabasalt, (Franklin and others, 1981; Fox, 1984; Slack, 1993). The largest such deposit in the New England Appalachians is at the Elizabeth mine, Vermont (McKinstry and Mikkola, 1954; Howard, 1969; Annis and others, 1983; Slack and others, 1993). Production from the Elizabeth mine was approximately 2.9 million metric tons of massive sulfide ore containing an estimated 1.8 percent copper and 0.5 percent zinc, with recoverable silver and gold; pyrrhotite was mined locally for the production of sulfuric acid (Howard, 1969; Gair and Slack, 1980). On the Besshi grade-tonnage curves of Slack (1993), production from the Elizabeth mine falls slightly above the median tonnage (1.3 million metric tons) and copper grade (1.4 percent Cu).

The Besshi grade-tonnage model of Slack (1993) was used in the calculation of undiscovered metal resources. In contrast with the model 24b of Singer (1986), which only included data for Besshi deposits in Japan, this model incorporates grade and tonnage data for Besshi deposits throughout the world, including those in the United States Appalachians, and is therefore more comprehensive.

Rationale for Tract Delineation

The permissive tract outlines the Vermont copper belt deposits of probable Silurian and Early Devonian age that occur within the Waits River Formation, the Standing Pond Volcanics, and the Gile Mountain Formation (Slack and others, 1993).

Rationale for Numerical Estimate

For the 90th, 50th, and 10th percentiles, the team estimated 1, 2, and 3 or more Besshi massive sulfide deposits consistent with the grade and tonnage model of Slack, (1994) (Mark3 index 98). The relatively high number of undiscovered deposits assigned to this tract in Vermont reflects: (1) the presence of many prospects and sulfide occurrences in the copper belt (White and Eric, 1944; J.F. Slack, unpub. data); (2) known geochemical anomalies in stream sediments and panned concentrates of the district (Watts, 1990; Slack and others, 1990); and (3) airborne geophysical anomalies identified in the region by industry exploration during the 1980s.

References

- Annis, M.P., Slack, J.F., and Rolph, A.L., 1983, Stratabound massive sulphide deposits of the Elizabeth mine, Orange County, Vermont, *in* Sangster, D.F., ed., Field trip guidebook to stratabound sulphide deposits, Bathurst area, N.B., Canada and west-central New England, U.S.A.: Geological Survey of Canada, Miscellaneous Report 36, p. 41-51.
- Fox, J.S., 1984, Besshi-type volcanogenic sulphide deposits—A review: Canadian Institute of Mining and Metallurgy Bulletin, v. 77, no. 864, p. 57-68.

- Franklin, J.M., Lydon, J.W., and Sangster, D.F., 1981, Volcanic-associated massive sulfide deposits, *in* Skinner, B.J., ed., *Economic Geology Seventy-Fifth Anniversary Volume, 1905–1980*: Lancaster, Pennsylvania, Economic Geology Publishing Company, p. 485-627.
- Gair, J.E., and Slack, J.F., 1980, Stratabound massive sulfide deposits of the U.S. Appalachians, *in* Vokes, F.M., and Zachrisson, Ebbe, eds., *Review of Caledonian-Appalachian stratabound sulphides*: Geological Survey of Ireland, Special Paper No. 5, p. 68-81.
- Howard, P.F., 1969, The geology of the Elizabeth mine, Vermont: Vermont Geological Survey, *Economic Geology*, v. 64, 73 p.
- McKinstry, H.E., and Mikkola, A.K., 1954, The Elizabeth copper mine, Vermont: *Economic Geology*, v. 49, no. 1, p. 1-30.
- Singer, D.A., 1986, Grade and tonnage model of Besshi massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 136-138.
- Slack, J.F., 1990, Preliminary assessment of metallic mineral resources in the Glens Falls 1° x 2° quadrangle, New York, Vermont, and New Hampshire, *in* Slack, J.F., ed., *Summary results of the Glens Falls CUSMAP project*, New York, Vermont, and New Hampshire: U.S. Geological Survey Bulletin 1887-R, 26 p.
- Slack, J.F., 1993, Descriptive and grade-tonnage models for Besshi-type massive sulphide deposits, *in* Kirkham, R.V., Sinclair, W.D., Thorpe, R.I., and Duke, J.M., eds., *Mineral deposit modeling*: Geological Association of Canada, Special Paper 40, p. 343–371.
- Slack, J.F., Atelsek, P.J., and Whitlow, J.W., 1990, Geochemistry of stream sediments and heavy-mineral concentrates from the Orange County copper district, east-central Vermont, *in* Slack, J.F., ed., *Summary results of the Glens Falls CUSMAP project*, New York, Vermont, and New Hampshire: U.S. Geological Survey Bulletin 1887-Q, 21p.
- Slack, J.F., Offield, T.W., Shanks, W.C. III, and Woodruff, L.G., 1993, Besshi-type massive sulfide deposits of the Vermont copper belt: Society of Economic Geologists, *Field Trip Guidebook Series*, v. 17, p. 32-73.
- Watts, K.C., Jr., 1990, Regional exploration geochemistry of the Glens Falls 1° x 2° quadrangle, New York, Vermont, and New Hampshire, *in* Slack, J.F., ed., *Summary results of the Glens Falls CUSMAP project*, New York, Vermont, and New Hampshire: U.S. Geological Survey Bulletin 1887-F, 70 p.
- White, W.S., and Eric, J.H., 1944, Preliminary report on the geology of the Orange County copper district, Vermont: U.S. Geological Survey Open-File Report, 36 p. [includes 8 separate plates].

NA09**Massive Sulfide Deposits, Besshi Type**

Vermont

Descriptive Model 24b • Mark3 Index 98

Massachusetts

Area = 475 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by J.F. Slack

Rationale for Model Choice

Besshi massive sulfide deposits occur in terrigenous clastic sedimentary rocks interbedded with tholeiitic to andesitic flows, tuffs, and breccias (Fox, 1984). Similar rocks are present in this tract.

The Besshi grade-tonnage model of Slack (1993) was used in the calculation of undiscovered metal resources. In contrast with the model 24b of Singer (1986), which only included data for Besshi deposits in Japan, this model incorporates grade and tonnage data for Besshi deposits throughout the world, including those in the United States Appalachians, and is therefore more comprehensive.

Rationale for Tract Delineation

The permissive tract, to the southwest of the Vermont copper belt in southern Vermont and western Massachusetts, consists of a sequence of Cambrian and (or) Ordovician clastic metasedimentary rocks and minor metabasalts judged to be permissive for the occurrence of Besshi deposits.

Rationale for Numerical Estimate

For the 90th, 50th, and 10th percentiles, the team estimated 0, 1, and 2 or more Besshi massive sulfide deposits consistent with the grade and tonnage model of Slack (1993).

References

- Fox, J.S., 1984, Besshi-type volcanogenic sulphide deposits—A review: Canadian Institute of Mining and Metallurgy Bulletin, v. 77, no. 864, p. 57-68.
- Singer, D.A., 1986, Grade and tonnage model of Besshi massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 136-138.
- Slack, J.F., 1993, Descriptive and grade-tonnage models for Besshi-type massive sulphide deposits, *in* Kirkham, R.V., Sinclair, W.D., Thorpe, R.I., and Duke, J.M., eds., Mineral deposit modeling: Geological Association of Canada, Special Paper 40, p. 343-371.

NA10**Massive Sulfide Deposits, Besshi Type****Massachusetts
Connecticut****Descriptive Model 24b • Mark3 Index 98****Area = 954 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* J.F. Slack**Rationale for Model Choice**

Besshi massive sulfide deposits occur in terrigenous clastic sedimentary rocks interbedded with tholeiitic to andesitic flows, tuffs, and breccias (Fox, 1984). Similar rocks are present in this tract.

The Besshi grade-tonnage model of Slack (1993) was used in the calculation of undiscovered metal resources. In contrast with the model 24b of Singer (1986), which only included data for Besshi deposits in Japan, this model (Mark3 index 98) incorporates grade and tonnage data for Besshi deposits throughout the world, including those in the United States Appalachians, and is therefore more comprehensive.

Rationale for Tract Delineation

The tract is permissive for the occurrence of Besshi deposits in Late Proterozoic to possibly Ordovician units, including the Nashoba Formation, the Fish Brook Gneiss, the Shawsheen Gneiss, and the Quinebaug Formation in eastern Massachusetts and eastern Connecticut.

Rationale for Numerical Estimate

For the 90th, 50th, and 10th percentiles, the team estimated 0, 0, and 1 or more Besshi massive sulfide deposits, consistent with the grade and tonnage model of Slack (1993).

References

- Fox, J.S., 1984, Besshi-type volcanogenic sulphide deposits—A review: Canadian Institute of Mining and Metallurgy Bulletin, v. 77, no. 864, p. 57-68.
- Singer, D.A., 1986, Grade and tonnage model of Besshi massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 136-138.
- Slack, J.F., 1993, Descriptive and grade-tonnage models for Besshi-type massive sulphide deposits, *in* Kirkham, R.V., Sinclair, W.D., Thorpe, R.I., and Duke, J.M., eds., Mineral deposit modeling: Geological Association of Canada, Special Paper 40, p. 343-371.

NA11**Massive Sulfide Deposits, Kuroko Type****Maine****Descriptive Model 28a • Mark3 Index 104****Area = 1,520 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by J.F. Slack***Rationale for Model Choice**

Kuroko massive sulfide deposits within early Paleozoic volcanic belts of New England are part of a group of such deposits that occur throughout the Appalachian-Caledonian orogen (Stephens and others, 1984; Stephens, 1986). In the northern United States Appalachians, seven major kuroko deposits are known that contain significant amounts of base and precious metals. The deposits are within Cambrian, Ordovician, or Silurian volcanic rocks that are believed to have formed in or near ancient island arcs (Gair and Slack, 1980; Slack, 1981). Some of the deposits (e.g., Davis, Massachusetts), contain mainly copper and zinc, whereas others (e.g., Mount Chase, Maine) are polymetallic with abundant lead plus copper, zinc, silver, and gold. Production has come from only a few of the deposits: Davis, Massachusetts; Milan, New Hampshire; and Harborside (Penobscot), Maine. The largest kuroko deposit in New England, at Bald Mountain, Maine (Scully, 1993a), contains substantial amounts of copper and zinc, as well as minor gold. All of the deposits consist of semi-massive to massive pyrite with variable amounts of sphalerite, chalcopyrite, pyrrhotite, and galena; silver-bearing tetrahedrite, gold, and arsenopyrite occur locally (Gair and Slack, 1979, 1980; Slack, 1981).

The assignment of these New England deposits to a kuroko model is somewhat problematic based on geologic comparisons with the classic kuroko deposits of Japan (e.g., Franklin and others, 1981; Ohmoto and Skinner, 1983). First, several of the New England deposits such as Davis, Massachusetts and Ledge Ridge, Maine, are within sequences dominated by mafic metavolcanic rocks, in contrast to the Japanese deposits that are mainly contained in felsic metavolcanic and clastic metasedimentary rocks. Second, only the Milan deposit in northern New Hampshire (Emmons, 1910; Eric, 1943; Moench, 1990), the Harborside (Penobscot) deposit along the coast of Maine (Bouley and Hodder, 1984), and the Mount Chase deposit in northern Maine (Scully, 1993b) are known to be closely associated with rhyolite domes, which is characteristic of many of the Japanese kuroko deposits. A kuroko model nevertheless is considered reasonable for the purposes of this resource assessment because all of the New England deposits are related, at least to some extent, to felsic volcanic rocks.

A modified version of the kuroko model was used for the resource calculations. This model (Mark3 index 104) is based on a Phanerozoic subset of the database of Singer (1986) that includes both Precambrian and Phanerozoic deposits. Use of the Phanerozoic subset that more nearly matches the ages of rocks in the permissive tracts yields resource estimates with higher tonnages and higher lead and silver grades, relative to the results obtained with the original model.

Rationale for Tract Delineation

This tract outlines Ordovician volcanic rocks of the Winterville Formation and correlative units that contain the Bald Mountain and Mount Chase deposits.

Rationale for Numerical Estimate

Estimates of the number of undiscovered deposits were made by comparisons with the number of known deposits in other areas such as the Horokuru district of Japan. The choices were influenced by the presence of mines, prospects, and mineral occurrences; and by the degree of exploration interest. At 90th, 50th, and 10th percentiles, the estimated numbers of undiscovered deposits, respectively, are 1, 3, and 5 or more, consistent with the Phanerozoic subset of the grade and tonnage model of Singer (1986).

References

- Bouley, B.A., and Hodder, R.W., 1984, Strata-bound massive sulfide deposits in Silurian-Devonian volcanic rocks at Harborside, Maine: *Economic Geology*, v. 79, no. 7, p. 1693-1702.
- Emmons, W.H., 1910, Some ore deposits in Maine and the Milan mine, New Hampshire: U.S. Geological Survey Bulletin 432, 62 p.
- Eric, J.H., 1943, Preliminary geologic report on the Milan mine, Milan, Coos County, New Hampshire: U.S. Geological Survey Open-File Report 79-353, 11 p.
- Franklin, J.M., Lydon, J.W., and Sangster, D.F., 1981, Volcanic-associated massive sulfide deposits, in Skinner, B.J., ed., *Economic Geology Seventy-Fifth Anniversary Volume, 1905–1980*: Lancaster, Pennsylvania, Economic Geology Publishing Company, p. 485-627.
- Gair, J.E., and Slack, J.F., 1979, Map showing lithostratigraphic and structural setting of stratabound (massive) sulfide deposits in the U.S. Appalachians: U.S. Geological Survey Open-File Report 79-1517, scale 1:1,000,000 [4 sheets].
- Gair, J.E., and Slack, J.F., 1980, Stratabound massive sulfide deposits of the U.S. Appalachians, in Vokes, F.M., and Zachrisson, Ebbe, eds., *Review of Caledonian-Appalachian stratabound sulphides*: Geological Survey of Ireland, Special Paper No. 5, p. 67-81.
- Moench, R.H., 1990, The Piermont allochthon, northern Connecticut Valley area, New England—Preliminary description and resource implications, in Slack, J.F., ed., *Summary results of the Glens Falls CUSMAP project, New York, Vermont, and New Hampshire*: U.S. Geological Survey Bulletin 1887-J, 23 p.
- Ohmoto, Hiroshi, and Skinner, B.J., eds., 1983, The kuroko and related volcanogenic massive sulfide deposits: *Economic Geology Monograph* 5, 604 p.
- Scully, M.V., 1993a, The Bald Mountain massive-sulfide deposit, Aroostook County, Maine, in McCutcheon, S.R., ed., *Lower Paleozoic VMS deposits of Maine: Canadian Institute of Mining, Metallurgy and Petroleum, Bathurst '93, Application of Recent Geological Concepts to Exploration in the Northern Appalachians*, Bathurst, New Brunswick, September 9-11, 1993, p. 35-44.
- Scully, M.V., 1993b, The Mount Chase massive-sulfide deposit, Penobscot County, Maine, in McCutcheon, S.R., ed., *Lower Paleozoic VMS deposits of Maine: Canadian Institute of Mining, Metallurgy and Petroleum, Bathurst '93, Application of Recent Geological Concepts to Exploration in the Northern Appalachians*, Bathurst, New Brunswick, September 9-11, 1993, p. 45-54.
- Singer, D.A., 1986, Descriptive model of kuroko massive sulfide, in Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 189-197.
- Slack, J.F., 1981, Stratabound sulfide deposits of the New England region—An overview [abs.]: *Geological Society of America, Abstracts with Programs*, v. 13, no. 3, p. 177.
- Stephens, M.B. [compiler] 1986, Stratabound sulphide deposits of the Caledonian-Appalachian orogen: Geological Survey of Canada Map 1694-A, scale 1:5,000,000.
- Stephens, M.B., Swinden, H.S., and Slack, J.F., 1984, Correlation of massive sulfide deposits in the Appalachian-Caledonian orogen on the basis of paleotectonic setting: *Economic Geology*, v. 79, no. 7, p. 1442-1478.

NA12**Massive Sulfide Deposits, Kuroko Type****Maine****Descriptive Model 28a • Mark3 Index 104****Area = 2,350 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by J.F. Slack***Rationale for Model Choice**

Kuroko massive sulfide deposits within early Paleozoic volcanic belts of New England are part of a group of such deposits that occur throughout the Appalachian-Caledonian orogen (Stephens and others, 1984; Stephens, 1986). In the northern United States Appalachians, seven major kuroko deposits are known that contain significant amounts of base and precious metals. The deposits are within Cambrian, Ordovician, or Silurian volcanic rocks that are believed to have formed in or near ancient island arcs (Gair and Slack, 1980; Slack, 1981). Some of the deposits (e.g., Davis, Massachusetts), contain mainly copper and zinc, whereas others (e.g., Mount Chase, Maine) are polymetallic with abundant lead plus copper, zinc, silver, and gold. Production has come from only a few of the deposits: Davis, Massachusetts; Milan, New Hampshire; and Harborside (Penobscot), Maine. The largest kuroko deposit in New England, at Bald Mountain, Maine (Scully, 1993a), contains substantial amounts of copper and zinc, as well as minor gold. All of the deposits consist of semi-massive to massive pyrite with variable amounts of sphalerite, chalcopyrite, pyrrhotite, and galena; silver-bearing tetrahedrite, gold, and arsenopyrite occur locally (Gair and Slack, 1979, 1980; Slack, 1981).

The assignment of these New England deposits to a kuroko model is somewhat problematic based on geologic comparisons with the classic kuroko deposits of Japan (e.g., Franklin and others, 1981; Ohmoto and Skinner, 1983). First, several of the New England deposits such as Davis, Massachusetts and Ledge Ridge, Maine, are within sequences dominated by mafic metavolcanic rocks, in contrast to the Japanese deposits that are mainly contained in felsic metavolcanic and clastic metasedimentary rocks. Second, only the Milan deposit in northern New Hampshire (Emmons, 1910; Eric, 1943; Moench, 1990), the Harborside (Penobscot) deposit along the coast of Maine (Bouley and Hodder, 1984), and the Mount Chase deposit in northern Maine (Scully, 1993b) are known to be closely associated with rhyolite domes, which is characteristic of many of the Japanese kuroko deposits. A kuroko model nevertheless is considered reasonable for the purposes of this resource assessment because all of the New England deposits are related, at least to some extent, to felsic volcanic rocks.

A modified version of the kuroko model was used for the resource calculations. This model (Mark3 index 104) is based on a Phanerozoic subset of the database of Singer (1986) that includes both Precambrian and Phanerozoic deposits. Use of the Phanerozoic subset that more nearly matches the ages of rocks in the permissive tracts yields resource estimates with higher tonnages and higher lead and silver grades, relative to the results obtained with the original model.

Rationale for Tract Delineation

The permissive tract consists of Ordovician volcanic rocks of the Mirimichi belt that to the northeast in New Brunswick are associated with the large deposits of the Bathurst district; it also contains favorable volcanic rocks and chemical sedimentary rocks such as iron formation.

Rationale for Numerical Estimate

Estimates of the number of undiscovered deposits were made by comparisons with the number of known deposits in other areas such as the Horokuru district of Japan. The choices were influenced by the presence of mines, prospects, and mineral occurrences; and by the degree of exploration interest. At 90th, 50th, and 10th percentiles, the estimated numbers of undiscovered deposits, respectively, are 1, 2, and 2 or more, consistent with the Phanerozoic subset of the grade and tonnage model of Singer (1986).

References

- Bouley, B.A., and Hodder, R.W., 1984, Strata-bound massive sulfide deposits in Silurian-Devonian Volcanic Rocks at Harborside, Maine: *Economic Geology*, v. 79, no. 7, p. 1693-1702.
- Emmons, W.H., 1910, Some ore deposits in Maine and the Milan mine, New Hampshire: U.S. Geological Survey Bulletin 432, 62 p.
- Eric, J.H., 1943, Preliminary geologic report on the Milan mine, Milan, Coos County, New Hampshire: U.S. Geological Survey Open-File Report 79-353, 11 p.
- Franklin, J.M., Lydon, J.W., and Sangster, D.F., 1981, Volcanic-associated massive sulfide deposits, *in* Skinner, B.J., ed., *Economic Geology Seventy-Fifth Anniversary Volume, 1905–1980*: Lancaster, Pennsylvania, Economic Geology Publishing Company, p. 485-627.
- Gair, J.E., and Slack, J.F., 1979, Map showing lithostratigraphic and structural setting of stratabound (massive) sulfide deposits in the U.S. Appalachians: U.S. Geological Survey Open-File Report 79-1517, scale 1:1,000,000 [4 sheets].
- Gair, J.E., and Slack, J.F., 1980, Stratabound massive sulfide deposits of the U.S. Appalachians, *in* Vokes, F.M., and Zachrisson, Ebbe, eds., *Review of Caledonian-Appalachian stratabound sulphides*: Geological Survey of Ireland, Special Paper No. 5, p. 67-81.
- Moench, R.H., 1990, The Piermont allochthon, northern Connecticut Valley area, New England—Preliminary description and resource implications, *in* Slack, J.F., ed., *Summary results of the Glens Falls CUSMAP project, New York, Vermont, and New Hampshire*: U.S. Geological Survey Bulletin 1887-J, 23 p.
- Ohmoto, Hiroshi, and Skinner, B.J., eds., 1983, The kuroko and related volcanogenic massive sulfide deposits: *Economic Geology Monograph* 5, 604 p.
- Scully, M.V., 1993a, The Bald Mountain massive-sulfide deposit, Aroostook County, Maine, *in* McCutcheon, S.R., ed., *Lower Paleozoic VMS deposits of Maine: Canadian Institute of Mining, Metallurgy and Petroleum, Bathurst '93, Application of Recent Geological Concepts to Exploration in the Northern Appalachians*, Bathurst, New Brunswick, September 9-11, 1993, p. 35-44.
- Scully, M.V., 1993b, The Mount Chase massive-sulfide deposit, Penobscot County, Maine, *in* McCutcheon, S.R., ed., *Lower Paleozoic VMS deposits of Maine: Canadian Institute of Mining, Metallurgy and Petroleum, Bathurst '93, Application of Recent Geological Concepts to Exploration in the Northern Appalachians*, Bathurst, New Brunswick, September 9-11, 1993, p. 45-54.
- Singer, D.A., 1986, Descriptive model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 189-197.
- Slack, J.F., 1981, Stratabound sulfide deposits of the New England region—An overview [abs.]: *Geological Society of America, Abstracts with Programs*, v. 13, no. 3, p. 177.
- Stephens, M.B. [compiler] 1986, Stratabound sulphide deposits of the Caledonian-Appalachian orogen: *Geological Survey of Canada Map* 1694A, scale 1:5,000,000.
- Stephens, M.B., Swinden, H.S., and Slack, J.F., 1984, Correlation of massive sulfide deposits in the Appalachian-Caledonian orogen on the basis of paleotectonic setting: *Economic Geology*, v. 79, no. 7, p. 1442-1478.

NA13**Massive Sulfide Deposits, Kuroko Type****Maine****Descriptive Model 28a • Mark3 Index 104****Area = 76 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* J.F. Slack**Rationale for Model Choice**

Kuroko massive sulfide deposits within early Paleozoic volcanic belts of New England are part of a group of such deposits that occur throughout the Appalachian-Caledonian orogen (Stephens and others, 1984; Stephens, 1986). In the northern United States Appalachians, seven major kuroko deposits are known that contain significant amounts of base and precious metals. The deposits are within Cambrian, Ordovician, or Silurian volcanic rocks that are believed to have formed in or near ancient island arcs (Gair and Slack, 1980; Slack, 1981). Some of the deposits (e.g., Davis, Massachusetts), contain mainly copper and zinc, whereas others (e.g., Mount Chase, Maine) are polymetallic with abundant lead plus copper, zinc, silver, and gold. Production has come from only a few of the deposits: Davis, Massachusetts; Milan, New Hampshire; and Harborside (Penobscot), Maine. The largest kuroko deposit in New England, at Bald Mountain (Scully, 1993a), Maine, contains substantial amounts of copper and zinc, as well as minor gold. All of the deposits consist of semi-massive to massive pyrite with variable amounts of sphalerite, chalcopyrite, pyrrhotite, and galena; silver-bearing tetrahedrite, gold, and arsenopyrite occur locally (Gair and Slack, 1979, 1980; Slack, 1981).

The assignment of these New England deposits to a kuroko model is somewhat problematic based on geologic comparisons with the classic kuroko deposits of Japan (e.g., Franklin and others, 1981; Ohmoto and Skinner, 1983). First, several of the New England deposits such as Davis, Massachusetts and Ledge Ridge, Maine, are within sequences dominated by mafic metavolcanic rocks, in contrast to the Japanese deposits that are mainly contained in felsic metavolcanic and clastic metasedimentary rocks. Second, only the Milan deposit in northern New Hampshire (Emmons, 1910; Eric, 1943; Moench, 1990), the Harborside (Penobscot) deposit along the coast of Maine (Bouley and Hodder, 1984; Beck, 1993), and the Mount Chase deposit in northern Maine (Scully, 1993b) are known to be closely associated with rhyolite domes, which is characteristic of many of the Japanese kuroko deposits. A kuroko model nevertheless is considered reasonable for the purposes of this resource assessment because all of the New England deposits are related, at least to some extent, to felsic volcanic rocks.

A modified version of the kuroko model was used for the resource calculations. This model (Mark3 index 104) is based on a Phanerozoic subset of the database of Singer (1986) that includes both Precambrian and Phanerozoic deposits. Use of the Phanerozoic subset that more nearly matches the ages of rocks in the permissive tracts yields resource estimates with higher tonnages and higher lead and silver grades, relative to the results obtained with the original model.

Rationale for Tract Delineation

Along the coast of Maine, the permissive tract outlines the Castine Volcanics of Early Ordovician age that contains the Harborside (Penobscot) deposit.

Rationale for Numerical Estimate

Estimates of the number of undiscovered deposits were made by comparisons with the number of known deposits in other areas such as the Horokuru district of Japan. The choices were influenced by the presence of many mines, prospects, and mineral occurrences (Young, 1962); and by the degree of exploration interest. At the 90th, 50th, and 10th percentiles, the estimated numbers of undiscovered deposits, respectively, are 1, 3, and 5 or more, consistent with the Phanerozoic subset of the grade and tonnage model of Singer (1986).

References

- Beck, F.M., 1993, The Harborside base-metal mine, Cape Rosier, Maine, *in* McCutcheon, S.R., ed., Lower Paleozoic VMS deposits of Maine: Canadian Institute of Mining, Metallurgy and Petroleum, Bathurst '93, Application of Recent Geological Concepts to Exploration in the Northern Appalachians, Bathurst, New Brunswick, September 9-11, 1993, p. 64.
- Bouley, B.A., and Hodder, R.W., 1984, Strata-bound massive sulfide deposits in Silurian-Devonian Volcanic Rocks at Harborside, Maine: *Economic Geology*, v. 79, no. 7, p. 1693-1702.
- Emmons, W.H., 1910, Some ore deposits in Maine and the Milan mine, New Hampshire: U.S. Geological Survey Bulletin 432, 62 p.
- Eric, J.H., 1943, Preliminary geologic report on the Milan mine, Milan, Coos County, New Hampshire: U.S. Geological Survey Open-File Report 79-353, 11 p.
- Franklin, J.M., Lydon, J.W., and Sangster, D.F., 1981, Volcanic-associated massive sulfide deposits, *in* Skinner, B.J., ed., *Economic Geology Seventy-Fifth Anniversary Volume, 1905-1980*: Lancaster, Pennsylvania, Economic Geology Publishing Company, p. 485-627.
- Gair, J.E., and Slack, J.F., 1979, Map showing lithostratigraphic and structural setting of stratabound (massive) sulfide deposits in the U.S. Appalachians: U.S. Geological Survey Open-File Report 79-1517, scale 1:1,000,000 [4 sheets].
- Gair, J.E., and Slack, J.F., 1980, Stratabound massive sulfide deposits of the U.S. Appalachians, *in* Vokes, F.M., and Zachrisson, Ebbe, eds., *Review of Caledonian-Appalachian stratabound sulphides*: Geological Survey of Ireland, Special Paper No. 5, p. 67-81.
- Moench, R.H., 1990, The Piermont allochthon, northern Connecticut Valley area, New England—Preliminary description and resource implications, *in* Slack, J.F., ed., *Summary results of the Glens Falls CUSMAP project, New York, Vermont, and New Hampshire*: U.S. Geological Survey Bulletin 1887-J, 23 p.
- Ohmoto, Hiroshi, and Skinner, B.J., eds., 1983, The kuroko and related volcanogenic massive sulfide deposits: *Economic Geology Monograph* 5, 604 p.
- Scully, M.V., 1993a, The Bald Mountain massive-sulfide deposit, Aroostook County, Maine, *in* McCutcheon, S.R., ed., Lower Paleozoic VMS deposits of Maine: Canadian Institute of Mining, Metallurgy and Petroleum, Bathurst '93, Application of Recent Geological Concepts to Exploration in the Northern Appalachians, Bathurst, New Brunswick, September 9-11, 1993, p. 35-44.
- Scully, M.V., 1993b, The Mount Chase massive-sulfide deposit, Penobscot County, Maine, *in* McCutcheon, S.R., ed., Lower Paleozoic VMS deposits of Maine: Canadian Institute of Mining, Metallurgy and Petroleum, Bathurst '93, Application of Recent Geological Concepts to Exploration in the Northern Appalachians, Bathurst, New Brunswick, September 9-11, 1993, p. 45-54.
- Singer, D.A., 1986, Descriptive model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 189-197.
- Slack, J.F., 1981, Stratabound sulfide deposits of the New England region—An overview [abs.]: Geological Society of America, Abstracts with Programs, v. 13, no. 3, p. 177.
- Stephens, M.B. [compiler] 1986, Stratabound sulphide deposits of the Caledonian-Appalachian orogen: Geological Survey of Canada Map 1694A, scale 1:5,000,000.

- Stephens, M.B., Swinden, H.S., and Slack, J.F., 1984, Correlation of massive sulfide deposits in the Appalachian-Caledonian orogen on the basis of paleotectonic setting: *Economic Geology*, v. 79, no. 7, p. 1442-1478.
- Young, R. S., 1962, Prospect evaluations, Hancock County, Maine: Maine Geological Survey Special Economic Studies Series, no. 2, 113 p.

NA14**Massive Sulfide Deposits, Kuroko Type**

Descriptive Model 28a • Mark3 Index 104

Area = 9,860 km²

Maine
New Hampshire
Vermont
Massachusetts

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* J.F. Slack**Rationale for Model Choice**

Kuroko massive sulfide deposits within early Paleozoic volcanic belts of New England are part of a group of such deposits that occur throughout the Appalachian-Caledonian orogen (Stephens and others, 1984; Stephens, 1986). In the northern United States Appalachians, seven major kuroko deposits are known that contain significant amounts of base and precious metals. The deposits are within Cambrian, Ordovician, or Silurian volcanic rocks that are believed to have formed in or near ancient island arcs (Gair and Slack, 1980; Slack, 1981). Some of the deposits (e.g., Davis, Massachusetts), contain mainly copper and zinc, whereas others (e.g., Mount Chase, Maine) are polymetallic with abundant lead plus copper, zinc, silver, and gold. Production has come from only a few of the deposits: Davis, Massachusetts; Milan, New Hampshire; and Harborside (Penobscot), Maine. The largest kuroko deposit in New England, at Bald Mountain, Maine (Scully 1993a), contains substantial amounts of copper and zinc, as well as minor gold. All of the deposits consist of semi-massive to massive pyrite with variable amounts of sphalerite, chalcopyrite, pyrrhotite, and galena; silver-bearing tetrahedrite, gold, and arsenopyrite occur locally in some of the deposits (Gair and Slack, 1979, 1980; Slack, 1981).

The assignment of these New England deposits to a kuroko model is somewhat problematic based on geologic comparisons with the classic kuroko deposits of Japan (e.g., Franklin and others, 1981; Ohmoto and Skinner, 1983). First, several of the New England deposits such as Davis, Massachusetts and Ledge Ridge, Maine, are within sequences dominated by mafic metavolcanic rocks, in contrast to the Japanese deposits that are mainly contained in felsic metavolcanic and clastic metasedimentary rocks. Second, only the Milan deposit in northern New Hampshire (Emmons, 1910; Eric, 1943; Moench, 1990), the Harborside (Penobscot) deposit along the coast of Maine (Bouley and Hodder, 1984; Beck, 1993), and the Mount Chase deposit in northern Maine (Scully, 1993b) are known to be closely associated with rhyolite domes, which is characteristic of many of the Japanese kuroko deposits. A kuroko model nevertheless is considered reasonable for the purposes of this resource assessment because all of the New England deposits are related, at least to some extent, to felsic volcanic rocks.

A modified version of the kuroko model was used for the resource calculations. This model (Mark3 index 104) is based on a Phanerozoic subset of the database of Singer (1986) that includes both Precambrian and Phanerozoic deposits. Use of the Phanerozoic subset that more nearly matches the ages of rocks in the permissive tracts yields resource estimates with higher tonnages and higher lead and silver grades, relative to the results obtained with the original model.

Rationale for Tract Delineation

The permissive tract is considered favorable because of the nature of its volcanic geology, and because of contained mines, prospects, and (or) mineral occurrences that are analogous to those of the kuroko deposits of Japan and elsewhere. The tract outlines rocks of the Ordovician

Ammonoosuc Volcanics and related rocks within the Bronson Hill anticlinorium and Cambrian to Silurian volcanic rocks of the Boundary Mountains anticlinorium, that together contain several kuroko deposits such as Ledge Ridge, Alder Pond, and Milan.

Rationale for Numerical Estimate

Estimates of the number of undiscovered deposits were made by comparisons with the number of known deposits in other areas such as the Horokuru district of Japan. The choices were influenced by the presence of mines, prospects, and mineral occurrences; and by the degree of exploration interest. At 90th, 50th, and 10th percentiles, the estimated numbers of undiscovered deposits, respectively, are 4, 8, and 15 or more consistent with the Phanerozoic subset of the grade and tonnage model of Singer (1986).

References

- Beck, F.M., 1993, The Harborside base-metal mine, Cape Rosier, Maine, *in* McCutcheon, S.R., ed., Lower Paleozoic VMS deposits of Maine: Canadian Institute of Mining, Metallurgy and Petroleum, Bathurst '93, Application of Recent Geological Concepts to Exploration in the Northern Appalachians, Bathurst, New Brunswick, September 9-11, 1993, p. 64.
- Bouley, B.A., and Hodder, R.W., 1984, Strata-bound massive sulfide deposits in Silurian-Devonian Volcanic Rocks at Harborside, Maine: *Economic Geology*, v. 79, no. 7, p. 1693-1702.
- Emmons, W.H., 1910, Some ore deposits in Maine and the Milan mine, New Hampshire: U.S. Geological Survey Bulletin 432, 62 p.
- Eric, J.H., 1943, Preliminary geologic report on the Milan mine, Milan, Coos County, New Hampshire: U.S. Geological Survey Open-File Report 79-353, 11 p.
- Franklin, J.M., Lydon, J.W., and Sangster, D.F., 1981, Volcanic-associated massive sulfide deposits, *in* Skinner, B.J., ed., *Economic Geology Seventy-Fifth Anniversary Volume, 1905-1980*: Lancaster, Pennsylvania, Economic Geology Publishing Company, p. 485-627.
- Gair, J.E., and Slack, J.F., 1979, Map showing lithostratigraphic and structural setting of stratabound (massive) sulfide deposits in the U.S. Appalachians: U.S. Geological Survey Open-File Report 79-1517, scale 1:1,000,000 [4 sheets].
- Gair, J.E., and Slack, J.F., 1980, Stratabound massive sulfide deposits of the U.S. Appalachians, *in* Vokes, F.M., and Zachrisson, Ebbe, eds., *Review of Caledonian-Appalachian stratabound sulphides*: Geological Survey of Ireland, Special Paper No. 5, p. 67-81.
- Moench, R.H., 1990, The Piermont allochthon, northern Connecticut Valley area, New England—Preliminary description and resource implications, *in* Slack, J.F., ed., *Summary results of the Glens Falls CUSMAP project*, New York, Vermont, and New Hampshire: U.S. Geological Survey Bulletin 1887-J, 23 p.
- Ohmoto, Hiroshi, and Skinner, B.J., eds., 1983, The kuroko and related volcanogenic massive sulfide deposits: *Economic Geology Monograph* 5, 604 p.
- Scully, M.V., 1993a, The Bald Mountain massive-sulfide deposit, Aroostook County, Maine, *in* McCutcheon, S.R., ed., Lower Paleozoic VMS deposits of Maine: Canadian Institute of Mining, Metallurgy and Petroleum, Bathurst '93, Application of Recent Geological Concepts to Exploration in the Northern Appalachians, Bathurst, New Brunswick, September 9-11, 1993, p. 35-44.
- Scully, M.V., 1993b, The Mount Chase massive-sulfide deposit, Penobscot County, Maine, *in* McCutcheon, S.R., ed., Lower Paleozoic VMS deposits of Maine: Canadian Institute of Mining, Metallurgy and Petroleum, Bathurst '93, Application of Recent Geological Concepts to Exploration in the Northern Appalachians, Bathurst, New Brunswick, September 9-11, 1993, p. 45-54.
- Singer, D.A., 1986, Descriptive model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 189-197.

- Slack, J.F., 1981, Stratabound sulfide deposits of the New England region—An overview [abs.]: Geological Society of America, Abstracts with Programs, v. 13, no. 3, p. 177.
- Stephens, M.B. [compiler] 1986, Stratabound sulphide deposits of the Caledonian-Appalachian orogen: Geological Survey of Canada Map 1694A, scale 1:5,000,000.
- Stephens, M.B., Swinden, H.S., and Slack, J.F., 1984, Correlation of massive sulfide deposits in the Appalachian-Caledonian orogen on the basis of paleotectonic setting: Economic Geology, v. 79, no. 7, p. 1442-1478.

NA15**Massive Sulfide Deposits, Kuroko Type****Maine
Vermont****Descriptive Model 28a****Area = 29 km²**[Model](#)*by J.F. Slack***Rationale for Model Choice**

Kuroko massive sulfide deposits within early Paleozoic volcanic belts of New England are part of a group of such deposits that occur throughout the Appalachian-Caledonian orogen (Stephens and others, 1984; Stephens, 1986). In the northern United States Appalachians, seven major kuroko deposits are known that contain significant amounts of base and precious metals. The deposits are within Cambrian, Ordovician, or Silurian volcanic rocks that are believed to have formed in or near ancient island arcs (Gair and Slack, 1980; Slack, 1981). Some of the deposits (e.g., Davis, Massachusetts), contain mainly copper and zinc, whereas others (e.g., Mount Chase, Maine) are polymetallic with abundant lead plus copper, zinc, silver, and gold. Production has come from only a few of the deposits: Davis, Massachusetts; Milan, New Hampshire; and Harborside (Penobscot), Maine. The largest kuroko deposit in New England, at Bald Mountain, Maine (Scully 1993a), contains substantial amounts of copper and zinc, as well as minor gold. All of the deposits consist of semi-massive to massive pyrite with variable amounts of sphalerite, chalcopyrite, pyrrhotite, and galena; silver-bearing tetrahedrite, gold, and arsenopyrite occur locally (Gair and Slack, 1979, 1980; Slack, 1981).

The assignment of these New England deposits to a kuroko model is somewhat problematic based on geologic comparisons with the classic kuroko deposits of Japan (e.g., Franklin and others, 1981; Ohmoto and Skinner, 1983). First, several of the New England deposits such as Davis, Massachusetts and Ledge Ridge, Maine, are within sequences dominated by mafic metavolcanic rocks, in contrast to the Japanese deposits that are mainly contained in felsic metavolcanic and clastic metasedimentary rocks. Second, only the Milan deposit in northern New Hampshire (Emmons, 1910; Eric, 1943; Moench, 1990), the Harborside (Penobscot) deposit along the coast of Maine (Bouley and Hodder, 1984), and the Mount Chase deposit in northern Maine (Scully, 1993b) are known to be closely associated with rhyolite domes, which is characteristic of many of the Japanese kuroko deposits. A kuroko model nevertheless is considered reasonable for the purposes of this resource assessment because all of the New England deposits are related, at least to some extent, to felsic volcanic rocks.

Rationale for Tract Delineation

The permissive tract consists of the southern extension of a thin volcanic unit that contains a small kuroko deposit just across the international border in southeastern Quebec.

Rationale for Numerical Estimate

Because of its small size, no estimates of the number of undiscovered deposits were made for this tract.

References

- Bouley, B.A., and Hodder, R.W., 1984, Strata-bound massive sulfide deposits in Silurian-Devonian Volcanic Rocks at Harborside, Maine: *Economic Geology*, v. 79, no. 7, p. 1693-1702.
- Emmons, W.H., 1910, Some ore deposits in Maine and the Milan mine, New Hampshire: U.S. Geological Survey Bulletin 432, 62 p.

- Eric, J.H., 1943, Preliminary geologic report on the Milan mine, Milan, Coos County, New Hampshire: U.S. Geological Survey Open-File Report 79-353, 11 p.
- Franklin, J.M., Lydon, J.W., and Sangster, D.F., 1981, Volcanic-associated massive sulfide deposits, *in* Skinner, B.J., ed., *Economic Geology Seventy-Fifth Anniversary Volume, 1905–1980*: Lancaster, Pennsylvania, Economic Geology Publishing Company, p. 485-627.
- Gair, J.E., and Slack, J.F., 1979, Map showing lithostratigraphic and structural setting of stratabound (massive) sulfide deposits in the U.S. Appalachians: U.S. Geological Survey Open-File Report 79-1517, scale 1:1,000,000 [4 sheets].
- Gair, J.E., and Slack, J.F., 1980, Stratabound massive sulfide deposits of the U.S. Appalachians, *in* Vokes, F.M., and Zachrisson, Ebbe, eds., *Review of Caledonian-Appalachian stratabound sulphides*: Geological Survey of Ireland, Special Paper No. 5, p. 67-81.
- Moench, R.H., 1990, The Piermont allochthon, northern Connecticut Valley area, New England—Preliminary description and resource implications, *in* Slack, J.F., ed., *Summary results of the Glens Falls CUSMAP project, New York, Vermont, and New Hampshire*: U.S. Geological Survey Bulletin 1887-J, 23 p.
- Ohmoto, Hiroshi, and Skinner, B.J., eds., 1983, The kuroko and related volcanogenic massive sulfide deposits: *Economic Geology Monograph* 5, 604 p.
- Scully, M.V., 1993a, The Bald Mountain massive-sulfide deposit, Aroostook County, Maine, *in* McCutcheon, S.R., ed., *Lower Paleozoic VMS deposits of Maine: Canadian Institute of Mining, Metallurgy and Petroleum, Bathurst '93, Application of Recent Geological Concepts to Exploration in the Northern Appalachians*, Bathurst, New Brunswick, September 9-11, 1993, p. 35-44.
- Scully, M.V., 1993b, The Mount Chase massive-sulfide deposit, Penobscot County, Maine, *in* McCutcheon, S.R., ed., *Lower Paleozoic VMS deposits of Maine: Canadian Institute of Mining, Metallurgy and Petroleum, Bathurst '93, Application of Recent Geological Concepts to Exploration in the Northern Appalachians*, Bathurst, New Brunswick, September 9-11, 1993, p. 45-54.
- Singer, D.A., 1986, Descriptive model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 189-197.
- Slack, J.F., 1981, Stratabound sulfide deposits of the New England region—An overview [abs.]: Geological Society of America, *Abstracts with Programs*, v. 13, no. 3, p. 177.
- Stephens, M.B. [compiler] 1986, Stratabound sulphide deposits of the Caledonian-Appalachian orogen: Geological Survey of Canada Map 1694A, scale 1:5,000,000.
- Stephens, M.B., Swinden, H.S., and Slack, J.F., 1984, Correlation of massive sulfide deposits in the Appalachian-Caledonian orogen on the basis of paleotectonic setting: *Economic Geology*, v. 79, no. 7, p. 1442-1478.

NA16**Massive Sulfide Deposits, Kuroko Type**

Vermont

Descriptive Model 28a • Mark3 Index 104

Massachusetts

Area = 601 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by J.F. Slack

Rationale for Model Choice

Kuroko massive sulfide deposits within early Paleozoic volcanic belts of New England are part of a group of such deposits that occur throughout the Appalachian-Caledonian orogen (Stephens and others, 1984; Stephens, 1986). In the northern United States Appalachians, seven major kuroko deposits are known that contain significant amounts of base and precious metals. The deposits are within Cambrian, Ordovician, or Silurian volcanic rocks that are believed to have formed in or near ancient island arcs (Gair and Slack, 1980; Slack, 1981). Some of the deposits (e.g., Davis, Massachusetts), contain mainly copper and zinc, whereas others (e.g., Mount Chase, Maine) are polymetallic with abundant lead plus copper, zinc, silver, and gold. Production has come from only a few of the deposits: Davis, Massachusetts; Milan, New Hampshire; and Harborside (Penobscot), Maine. The largest kuroko deposit in New England, at Bald Mountain, Maine (Scully, 1993a), contains substantial amounts of copper and zinc, as well as minor gold. All of the deposits consist of semi-massive to massive pyrite with variable amounts of sphalerite, chalcopyrite, pyrrhotite, and galena; silver-bearing tetrahedrite, gold, and arsenopyrite occur locally (Gair and Slack, 1979, 1980; Slack, 1981).

The assignment of these New England deposits to a kuroko model is somewhat problematic based on geologic comparisons with the classic kuroko deposits of Japan (e.g., Franklin and others, 1981; Ohmoto and Skinner, 1983). First, several of the New England deposits such as Davis, Massachusetts and Ledge Ridge, Maine, are within sequences dominated by mafic metavolcanic rocks, in contrast to the Japanese deposits that are mainly contained in felsic metavolcanic and clastic metasedimentary rocks. Second, only the Milan deposit in northern New Hampshire (Emmons, 1910; Eric, 1943; Moench, 1990), the Harborside (Penobscot) deposit along the coast of Maine (Bouley and Hodder, 1984), and the Mount Chase deposit in northern Maine (Scully, 1993b) are known to be closely associated with rhyolite domes, which is characteristic of many of the Japanese kuroko deposits. A kuroko model nevertheless is considered reasonable for the purposes of this resource assessment because all of the New England deposits are related, at least to some extent, to felsic volcanic rocks.

A modified version of the kuroko model was used for the resource calculations. This model (Mark3 index 104) is based on a Phanerozoic subset of the database of Singer (1986) that includes both Phanerozoic and Precambrian deposits. Use of the Phanerozoic subset that more nearly matches the ages of rocks in the permissive tracts yields resource estimates with higher tonnages and higher lead and silver grades, relative to the results obtained with the original model.

Rationale for Tract Delineation

The permissive tract consists of Ordovician to possibly Silurian rocks of the Barnard Volcanic Member of the Missisquoi Formation in Vermont, and the partly correlative Hawley Formation, the latter containing the Davis deposit in northwestern Massachusetts (Slack and others, 1983).

Rationale for Numerical Estimate

Estimates of the number of undiscovered deposits were made by comparisons with the number of known deposits in other areas such as the Horokuru district of Japan. The choices were influenced by the presence of mines, prospects, and mineral occurrences; and by the degree of exploration interest. At 90th, 50th, and 10th percentiles, the estimated numbers of undiscovered deposits, respectively, are 1, 2, and 3 or more, consistent with the Phanerozoic subset of the grade and tonnage model of Singer (1986).

References

- Bouley, B.A., and Hodder, R.W., 1984, Strata-bound massive sulfide deposits in Silurian-Devonian Volcanic Rocks at Harborside, Maine: *Economic Geology*, v. 79, no. 7, p. 1693-1702.
- Emmons, W.H., 1910, Some ore deposits in Maine and the Milan mine, New Hampshire: U.S. Geological Survey Bulletin 432, 62 p.
- Eric, J.H., 1943, Preliminary geologic report on the Milan mine, Milan, Coos County, New Hampshire: U.S. Geological Survey Open-File Report 79-353, 11 p.
- Franklin, J.M., Lydon, J.W., and Sangster, D.F., 1981, Volcanic-associated massive sulfide deposits, *in* Skinner, B.J., ed., *Economic Geology Seventy-Fifth Anniversary Volume, 1905–1980*: Lancaster, Pennsylvania, Economic Geology Publishing Company, p. 485-627.
- Gair, J.E., and Slack, J.F., 1979, Map showing lithostratigraphic and structural setting of stratabound (massive) sulfide deposits in the U.S. Appalachians: U.S. Geological Survey Open-File Report 79-1517, scale 1:1,000,000 [4 sheets].
- Gair, J.E., and Slack, J.F., 1980, Stratabound massive sulfide deposits of the U.S. Appalachians, *in* Vokes, F.M., and Zachrisson, Ebbe, eds., *Review of Caledonian-Appalachian stratabound sulphides*: Geological Survey of Ireland, Special Paper No. 5, p. 67-81.
- Moench, R.H., 1990, The Piermont allochthon, northern Connecticut Valley area, New England—Preliminary description and resource implications, *in* Slack, J.F., ed., *Summary results of the Glens Falls CUSMAP project*, New York, Vermont, and New Hampshire: U.S. Geological Survey Bulletin 1887-J, 23 p.
- Ohmoto, Hiroshi, and Skinner, B.J., eds., 1983, The kuroko and related volcanogenic massive sulfide deposits: *Economic Geology Monograph* 5, 604 p.
- Scully, M.V., 1993a, The Bald Mountain massive-sulfide deposit, Aroostook County, Maine, *in* McCutcheon, S.R., ed., *Lower Paleozoic VMS deposits of Maine: Canadian Institute of Mining, Metallurgy and Petroleum, Bathurst '93, Application of Recent Geological Concepts to Exploration in the Northern Appalachians*, Bathurst, New Brunswick, September 9-11, 1993, p. 35-44.
- Scully, M.V., 1993b, The Mount Chase massive-sulfide deposit, Penobscot County, Maine, *in* McCutcheon, S.R., ed., *Lower Paleozoic VMS deposits of Maine: Canadian Institute of Mining, Metallurgy and Petroleum, Bathurst '93, Application of Recent Geological Concepts to Exploration in the Northern Appalachians*, Bathurst, New Brunswick, September 9-11, 1993, p. 45-54.
- Singer, D.A., 1986, Descriptive model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 189-197.
- Slack, J.F., 1981, Stratabound sulfide deposits of the New England region—An overview [abs.]: Geological Society of America, *Abstracts with Programs*, v. 13, no. 3, p. 177.
- Slack, J.F., Godchaux, M.M., and Graves, R.L., 1983, Volcanogenic massive sulphide deposits of the Davis mine, Hampshire County, Massachusetts, *in* Sangster, D.F., ed., *Field trip guidebook to stratabound sulphide deposits, Bathurst area, N.B., Canada and west-central New England, U.S.A.*: Geological Survey of Canada, *Miscellaneous Report* 36, p. 53-63.
- Stephens, M.B. [compiler] 1986, Stratabound sulphide deposits of the Caledonian-Appalachian orogen: Geological Survey of Canada Map 1694-A, scale 1:5,000,000.

Stephens, M.B., Swinden, H.S., and Slack, J.F., 1984, Correlation of massive sulfide deposits in the Appalachian-Caledonian orogen on the basis of paleotectonic setting: *Economic Geology*, v. 79, no. 7, p. 1442-1478.

NA17**Descriptive Model 26a****Area = 3,600 km²****Sediment-hosted Au Deposits****Vermont****New York**[Model](#)*by* J.F. Slack**Rationale for Model Choice**

No sediment-hosted gold deposits are known in the northern United States Appalachians. However, one part of the Taconic allochthons of southwestern Vermont and eastern New York has potential for this deposit type. Such deposits, which may form by uncertain processes, typically consist of disseminations of very fine-grained gold and minor silver-bearing minerals within (or associated with) altered carbonate rocks, siliceous shale, and silicified limestone (Bagby and Berger, 1985; Ruggieri and others, 1993).

Rationale for Tract Delineation

Geologic and geochemical studies under the auspices of the Glens Falls CUSMAP project identified significant gold and silver anomalies in heavy-mineral concentrates of stream sediments in parts of the Taconic allochthon (Watts, 1990). One anomaly is considered particularly significant, because it occurs on the northeastern side of the allochthon in the area of a known Mesozoic extensional fault. Slack (1990) interpreted this setting as having potential for gold and (or) silver mineralization in or near this fault, especially within carbonate-rich rocks of the allochthon or within those of the underlying lower Paleozoic shelf sequence. No undiscovered deposits are assigned to this tract, however.

References

- Bagby, W.C., and Berger, B.R., 1985, Geologic characteristics of sediment-hosted, disseminated precious-metal deposits in the western United States, *in* Berger, B.R., and Bethke, P.M., eds., *Geology and geochemistry of epithermal systems: Reviews in Economic Geology*, v. 2, p. 169-202.
- Ruggieri, G., Lattanzai, P., and Tanelli, G., 1993, Carbonate-hosted epithermal gold mineralization in southern Tuscany (Italy): The examples of Frassine and La Campigliola, *in* Fenoll Hach-Ali, P., Torres-Ruiz, J., and Gervilla, F., eds., *Current research in geology applied to ore deposits: Granada, Spain, University of Granada, Proceedings of the Second Annual Biennial SGA Meeting, Granada, Spain, September 9-11, 1993*, p. 551-554.
- Slack, J.F., 1990, Preliminary assessment of metallic mineral resources in the Glens Falls 1° x 2° quadrangle, New York, Vermont, and New Hampshire, *in* Slack, J.F., ed., *Summary results of the Glens Falls CUSMAP project, New York, Vermont, and New Hampshire: U.S. Geological Survey Bulletin 1887-R*, 26 p.
- Watts, K.C., Jr., 1990, Regional exploration geochemistry of the Glens Falls 1° x 2° quadrangle, New York, Vermont, and New Hampshire, *in* Slack, J.F., ed., *Summary results of the Glens Falls CUSMAP project, New York, Vermont, and New Hampshire: U.S. Geological Survey Bulletin 1887-F*, 70 p.

NA18**Descriptive Model 30a****Area = 8,510 km²****Sandstone-hosted Pb-Zn Deposits****Vermont
New York
Massachusetts
Connecticut**[Model](#)*by* John F. Slack, Sandra H.B. Clark, and John D. Peper**Rationale for Model Choice**

No major sandstone-hosted lead-zinc deposits are known in the United States, and deposits of this type are of relatively minor economic importance by world standards. The only significant deposit in the United States was developed at the Goose Creek mine in the Indian Creek district of southeast Missouri (Kyle and Gutierrez, 1988). However, the importance of some deposits, such as the large (80-million-metric-ton) Laisvall lead-zinc deposit in northern Sweden, demonstrates the importance of considering the occurrence of similar deposits in geologically analogous settings. Sandstone-hosted lead-zinc deposits are stratabound concentrations of galena and generally minor sphalerite that occur within quartz-rich sandstone and quartzite overlying feldspathic basement rocks (Rickard and others, 1979; Bjørlykke and Sangster, 1981). The origin of sandstone-hosted lead-zinc deposits by transport of metals through permeable channels to an environment with sufficiently high H₂S content to precipitate sulfides from groundwater or basinal brines resembles that proposed for sediment-hosted copper and Mississippi Valley deposits.

Clastic sedimentary sequences that occur near crystalline basement rocks are potential hosts for lead-zinc deposits. Although no deposits are known in the United States Appalachians, several occurrences have been described from Quebec (Schrijver and Beaudoin, 1987), suggesting potential for mineralization of the Cheshire Quartzite and correlative units of Early Cambrian age that overlie feldspathic basement rocks. Galena samples from the Rossie veins of western N.Y. have lead isotopic compositions and fluid inclusions (Ayuso and others, 1987) that are compatible with an origin from a Paleozoic basinal brine, which migrated into fractures during tectonism. The proposed migration of base-metals in brines suggests the possibility of the formation of sandstone-hosted lead-zinc deposits in favorable host rocks such as the Upper Cambrian Potsdam Sandstone that forms a basal unit overlying the Grenvillian basement of the Adirondacks.

Rationale for Tract Delineation

The permissive tract includes the Cambrian Cheshire Quartzite in Vermont, Potsdam Sandstone in New York, and stratigraphically equivalent Cambrian basal clastic sequences which are potential host rocks for sandstone lead-zinc deposits.

Rationale for Numerical Estimate

No estimates of undiscovered deposits were made for the permissive tract because, while occurrences of galena are known in the region, large sandstone-hosted lead-zinc deposits are uncommon on a worldwide basis. The lack of any known large deposits in the eastern United States or other indications beyond appropriate geologic settings over broad areas argues against estimating undiscovered resources of this deposit type.

References

- Ayuso, R.A., Foley, N.K., and Brown, C.E., 1987, Source of lead and mineralizing brines for Rossie-type Pb-Zn veins in the Frontenac axis area, New York: *Economic Geology*, v. 82, no. 2, p. 489-496.
- Bjørlykke, A., and Sangster, D.F., 1981, An overview of sandstone lead deposits and their relation to red-bed copper and carbonate-hosted lead-zinc deposits, *in* Skinner, B.J., ed., *Economic Geology Seventy-Fifth Anniversary Volume, 1905–1980*: Lancaster, Pennsylvania, Economic Geology Publishing Company, p. 179-213.
- Kyle, J.R., and Gutierrez, G.N., 1988, Origin of the Indian Creek sandstone-hosted lead deposits, southeast Missouri, USA, *in* Zachrisson, Ebbe, ed., *Proceedings of the Seventh Quadrennial IAGOD Symposium*, Luleå, Sweden, 1986: Stuttgart, E. Schweizerbart'sche Verlagsbuchhandlung, p. 669–684.
- Rickard, D.T., Willdén, M.Y., Marinder, N.-E., and Donnelly, T.H., 1979, Studies on the genesis of the Laisvall sandstone lead-zinc deposit, Sweden: *Economic Geology*, v. 74, no. 5, p. 1255-1285.
- Schrijver, K., and Beaudoin, G., 1987, Diverse occurrences of galena-cemented sandstones in the Paleozoic, northern Appalachians, Quebec: Canadian Smith, R.C., II, 1977, Zinc and lead occurrences in Pennsylvania: Pennsylvania Geological Survey, Mineral Resources Report 72, 318 p.

NA19**Sediment-hosted Cu Deposits****Massachusetts
Connecticut****Descriptive Model 30b • Mark3 Index 63****Area = 3,600 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Gilpin R. Robinson, Jr.**Rationale for Model Choice**

Numerous copper occurrences are known in the early Mesozoic basins of the eastern United States (Robinson and Sears, 1988; Woodward, 1944). Many of these occurrences resemble sediment-hosted copper deposits that occur in red-bed strata (Smoot and Robinson, 1988; Table 1A). However, the estimated sizes of most of these occurrences are smaller than those in the sediment-hosted copper model (Mosier and others, 1986).

The assessment was made using the sediment-hosted copper model of Cox (1986), which includes deposits from both red-bed and reduced-facies hosts. The model may not be completely appropriate for assessment of the early Mesozoic basin region because some of the deposits in the model have metal grades and tonnages that reflect enrichment by supergene processes not likely to be significant in the northeastern United States

Rationale for Tract Delineation

Because of the wide distribution of thick red-bed sequences and numerous small copper occurrences, the Hartford basin in Massachusetts and Connecticut is considered to be permissive for sediment-hosted copper deposits. Recent work has identified occurrences of copper concentrated in reduced lacustrine mudstone units. These lie in sequences of red sandstone and siltstones in the Hartford basin that resemble significant occurrences in the Culpeper basin, Virginia (Smoot and Robinson, 1988; Gray, 1988).

Rationale for Numerical Estimate

The permissive tract is large, poorly exposed, and inadequately explored for sediment-hosted copper deposits. For the 90th, 50th, and 10th percentiles, the team estimated 0, 0, and 1 or more sediment-hosted copper deposits consistent with the grade and tonnage model of Mosier and others (1986).

References

- Cox, D.P., 1986, Descriptive model for sediment-hosted copper, *in* Cox, D.P. and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 205.
- Gray, N.H., 1988, The origin of copper occurrences in the Hartford basin, *in* Froelich A.J., and Robinson, G.R., Jr., Studies of the early Mesozoic basins of the eastern United States: U.S. Geological Survey Bulletin 1776, p. 341-349.
- Mosier, D.L., Singer, D.A., and Cox, D.P., 1986, Grade and tonnage model for sediment-hosted copper, *in* Cox, D.P. and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 205-208.
- Robinson, G.R., Jr., and Sears, C.M., 1988, Inventory of metal mines and occurrences associated with the early Mesozoic basins of the eastern United States—Summary tables, *in* Froelich A.J., and Robinson, G.R., Jr., Studies of the early Mesozoic basins of the eastern United States: U.S. Geological Survey Bulletin 1776, p. 265-303.

- Smoot, J.P., and Robinson, G.R. Jr., 1988, Sedimentology of stratabound base-metal occurrences in the Newark Supergroup, *in* Froelich, A.J., and Robinson, G.R., Jr., Studies of the early Mesozoic basins of the eastern United States: U.S. Geological Survey Bulletin 1776, p. 356-376.
- Woodward, H.P., 1944, Copper mines and mining in New Jersey: Geologic Series, Bulletin 57, New Jersey Department of Conservation Development, Trenton, N.J., 1560.

NA20**Sedimentary Exhalative Zn-Pb Deposits**

Descriptive Model 31a • Mark3 Index 13

Area = 8,240 km²Vermont
New York
Massachusetts
Connecticut[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Sandra H.B. Clark and John F. Slack**Rationale for Model Choice**

Sedimentary-exhalative or sedex zinc-lead deposits, a class of stratiform sulfide deposits, have served as major metal sources in many countries (Gustafson and Williams, 1981). This deposit type is believed to form by subaqueous hydrothermal processes related to exhalation of a metalliferous brine, precipitating lead and (or) zinc sulfides either as chemical sediments and (or) as shallow subsurface replacements (Carne and Cathro, 1982; Goodfellow and others, 1993).

In the northern United States Appalachians, studies by Clark (1990) and Foley (1990) have documented sedex features in a small (about 9,000 tonnes Pb+Zn) deposit in the Cambrian to Ordovician carbonate-siliciclastic shelf sequence at Lion Hill near Brandon, Vermont. The choice of a sedimentary-exhalative model (Briskey, 1986) is based on recognition of associated layered magnetite iron formation and on textural features that suggest a partly syngenetic to diagenetic origin for the mineralization at Lion Hill. This interpretation is supported by studies of the paleoenvironmental setting, the geochemical distribution of elements relative to lithologic units, and the lead and sulfur isotopic composition of the sulfide minerals (N.K. Foley, personal commun., 1994). In addition to Lion Hill, the rocks of the shelf sequence contain numerous other base-metal sulfide occurrences from eastern New York to northwestern Massachusetts and southern Quebec, suggesting potential for Irish-type sedimentary-exhalative mineralization in much of the shelf sequence. The estimated size of the known mineralized zones at the Lion Hill prospect is far below the smallest deposits included in the tonnage curve for sedimentary-exhalative Zn-Pb of Menzie and Mosier (1986).

Rationale for Tract Delineation

The entire Cambrian to Ordovician carbonate siliciclastic shelf sequence of Vermont, New York, Massachusetts, and Connecticut is considered to be permissive for the occurrence of undiscovered sedimentary-exhalative deposits. The most favorable zones are the Cambrian Dunham Dolomite and Monkton Quartzite, which host known deposits. Tract borders were not extended beyond areas of surface outcrop because, even though the early Paleozoic platform deposits are believed to extend beneath the Taconic thrust slices, the platform deposits are thought to be at depths of more than one kilometer beneath the surface in most parts of the Taconics (J.D. Peper, oral commun.). Two areas within the tract are considered favorable, one near Brandon, Vt., and another near Franklin, Vt. A limited amount of exploration, including core drilling, was done on base-metal sulfide prospects in both areas about 1980. The tract is also considered permissive for the occurrence of Appalachian Zn and sandstone-hosted Pb-Zn deposits because of the presence of shelf carbonate rocks and a basal sandstone unit, known occurrences of zinc and lead sulfides, and the tectonic position of the tract beneath the Taconic allochthons. However, if Appalachian Zn or sandstone-hosted Pb-Zn mineralization is present in the tract, it is related to a mineralizing event that occurred much later than the inferred syngenetic to diagenetic mineralization at Lion Hill.

Rationale for Numerical Estimate

The consensus method was used to estimate the numbers of undiscovered deposits. Factors considered were the presence of known occurrences, the generally low level of modern exploration activity, the recent recognition of potential for sedimentary-exhalative deposits, and the sizes of the tracts relative to each other. For the 90th, 50th, and 10th percentiles, the team estimated 0, 1, and 5 or more sedimentary-exhalative deposits consistent with the grade and tonnage model of Menzie and Mosier (1986).

References

- Carne, R.C., and Cathro, R.J., 1982, Sedimentary exhalative (sedex) zinc-lead-silver deposits, northern Canadian Cordillera: Canadian Institute of Mining and Metallurgy Bulletin, v. 75, no. 875, p. 95-106.
- Clark, S.H.B., 1990, Stratabound zinc-lead-copper deposits in the Cambrian carbonate-siliciclastic shelf sequence at Lion Hill, west-central Vermont, *in* Slack, J.F., ed., Summary results of the Glens Falls CUSMAP project, New York, Vermont, and New Hampshire: U.S. Geological Survey Bulletin 1887-K, 9 p.
- Goodfellow, W.D., Lydon, J.W., and Turner, R.J.W., in press, Geology and genesis of stratiform sediment-hosted (SEDEX) Zn-Pb-Ag sulphide deposits, *in* Kirkham, R.V., Sinclair, W.D., Thorpe, R.I., and Duke, J.M., eds., Mineral deposit modeling: Geological Association of Canada, Special Paper 40, p. 201–251.
- Foley, N.K., 1990, The Lion Hill zinc-lead-copper deposit, Brandon, Vermont—Source of lead and fluid systematics, *in* Slack, J.F., ed., Summary results of the Glens Falls CUSMAP project, New York, Vermont, and New Hampshire: U.S. Geological Survey Bulletin 1887-L, 9 p.
- Gustafson, L.B., and Williams, Neil, 1981, Sediment-hosted stratiform deposits of copper, lead, and zinc, *in* Skinner, B.J., ed., Economic Geology Seventy-Fifth Anniversary Volume, 1905–1980: Lancaster, Pennsylvania, Economic Geology Publishing Company, p. 139-178.
- Menzie, W.D., and Mosier, D.L., 1986, Grade and tonnage model of sedimentary exhalative Zn-Pb, *in* Cox, D.P., and Singer, D.A., eds. 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 212-215.

NA21**Sedimentary Exhalative Zn-Pb Deposits**Vermont
New York

Descriptive Model 31a • Mark3 Index 13

Area = 5,380 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Sandra H.B. Clark and John F. Slack

Rationale for Model Choice

Sedimentary-exhalative or sedex zinc-lead deposits are a class of stratiform sulfide deposits that have served as major metal sources in many countries (Gustafson and Williams, 1981). This deposit type is believed to form by subaqueous hydrothermal processes related to exhalation of a metalliferous brine, precipitating lead and (or) zinc sulfides either as chemical sediments and (or) as shallow subsurface replacements (Carne and Cathro, 1982; Goodfellow and others, 1993).

One possible sedex lead-zinc occurrence is known within the Taconic allochthon at White Creek, New York, in the Cambrian Mudd Pond Quartzite member of the Browns Pond Formation (Slack, 1990). Regional geochemical surveys by Watts (1990) also identified major geochemical anomalies of lead, zinc, and barium in heavy-mineral concentrates of stream sediments in the Taconics, consistent with the occurrence of sedex mineralization. On the basis of these features, the area of the Taconic allochthons is considered permissive for the occurrence of sedex zinc-lead deposits. The choice of the sedimentary-exhalative model for this area is based on the tectonically active, deep-water marine sedimentary nature of the basin and the occurrence of associated lead, zinc, and barium anomalies.

Rationale for Tract Delineation

The area of the Taconic allochthon is designated as the permissive tract; it consists dominantly of shale and graywacke, in contrast to the shelf sequence that is made up largely of carbonate rocks. The Taconic allochthon is considered by most workers to represent a deeper water slope and basin facies, relative to the shelf sequence rocks, and to have been tectonically emplaced on top of the shelf sequence during the Middle Ordovician Taconic orogeny.

Rationale for Numerical Estimate

The consensus method was used to estimate the numbers of undiscovered deposits. Factors considered were the presence of known occurrences, the generally low level of modern exploration activity, the recent recognition of potential for sedimentary-exhalative deposits, and the sizes of the tracts relative to each other. For the Taconic allochthon, the team also considered the presence of geochemical anomalies, and of deep-water-facies sediments that were deposited in a tectonically active basin. At 90th, 50th, and 10th percentiles, the estimated numbers of undiscovered deposits, respectively, are 0, 1, and 3, consistent with the grade and tonnage model of Mosier and Menzie (1986).

References

- Gustafson, L.B., and Williams, Neil, 1981, Sediment-hosted stratiform deposits of copper, lead, and zinc, in Skinner, B.J., ed., *Economic Geology Seventy-Fifth Anniversary Volume, 1905–1980*: Lancaster, Pennsylvania, Economic Geology Publishing Company, p. 139-178.
- Carne, R.C., and Cathro, R.J., 1982, Sedimentary exhalative (sedex) zinc-lead-silver deposits, northern Canadian Cordillera: *Canadian Institute of Mining and Metallurgy Bulletin*, v. 75, no. 875, p. 95-106.

- Goodfellow, W.D., Lydon, J.W., and Turner, R.J.W., in press, Geology and genesis of stratiform sediment-hosted (SEDEX) Zn-Pb-Ag sulphide deposits, *in* Kirkham, R.V., Sinclair, W.D., Thorpe, R.I., and Duke, J.M., eds., Mineral deposit modeling: Geological Association of Canada, Special Paper 40, p. 201–251.
- Menzie, W.D., and Mosier, D.L., 1986, Grade and tonnage model of sedimentary exhalative Zn-Pb, *in* Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 212-215.
- Slack, J.F., 1990, Preliminary assessment of metallic mineral resources in the Glens Falls 1° x 2° quadrangle, New York, Vermont, and New Hampshire, *in* Slack, J.F., ed., Summary results of the Glens Falls CUSMAP project, New York, Vermont, and New Hampshire: U.S. Geological Survey Bulletin 1887-R, 26 p.
- Watts, K.C., Jr., 1990, Regional exploration geochemistry of the Glens Falls 1° x 2° quadrangle, New York, Vermont, and New Hampshire, *in* Slack, J.F., ed., Summary results of the Glens Falls CUSMAP project, New York, Vermont, and New Hampshire: U.S. Geological Survey Bulletin 1887-F, 70 p.

NA22**Mississippi Valley Deposits, Appalachian Zn****Descriptive Model 32b****Area = 10,800 km²**

Vermont
New York
Connecticut
Massachusetts

[Model](#)

by Sandra H.B. Clark, Joseph A. Briskey, Jr. and Dennis P. Cox

Rationale for Model Choice

Large resources of zinc occur in major stratabound Mississippi Valley (MVT) districts that extend from Pennsylvania to Tennessee. Because of the importance and distinctive geological features of the eastern United States deposits, they are the basis for definition of the world-wide Appalachian Zn model (32b of Briskey, 1986). Known Appalachian Zn districts in the east-central United States are stratabound within Lower Cambrian to Lower Ordovician dolostones and limestones that formed as platform carbonate deposits in the Appalachian basin sedimentary sequence. No examples are known in this tract, but carbonate rocks of the Lower and Middle Ordovician Beekmantown and stratigraphically equivalent units are host rocks for deposits in Pennsylvania

Rationale for Tract Delineation

The permissive tract includes Lower and Middle Ordovician carbonate rocks of the Beekmantown Group and stratigraphically equivalent units and their extensions under less than 1 km of cover. No estimate of undiscovered districts was made.

Reference

Briskey, J.A., 1986a, Descriptive model of Appalachian Zn, *in* Cox, D.P., and Singer, D.A., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 222.

NA23**Low-sulfide Au-quartz Vein Deposits****Vermont****Descriptive Model 36a • Mark3 Index 27****Area = 1,710 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* J.F. Slack**Rationale for Model Choice**

Many gold-bearing low-sulfide quartz veins (Berger, 1986) are known in the northern Appalachian region. These veins commonly occur in regionally metamorphosed sedimentary and volcanic rocks, and locally are associated with altered ultramafic rocks. The area in and near the ultramafic belt of Vermont contains rocks and structures permissive for this deposit type, and examples are known at the Taggart and Rooks mines in Vermont (Hager, 1861; Perry, 1929[?]).

Rationale for Tract Delineation

The permissive tract is in and near the Vermont ultramafic belt and outlines areas of known veins within metasedimentary and minor mafic and ultramafic metaigneous rocks, mainly of the Late Proterozoic and Cambrian Pinney Hollow and Cambrian Ottauquechee Formations. The tract contains significant gold and arsenic anomalies in panned concentrates of stream sediments (Watts, 1990).

Rationale for Numerical Estimate

Estimates of the number of undiscovered deposits were made on the basis of the number of occurrences and their distribution in the tract, and on the presence of geochemical anomalies in panned concentrates of stream sediments. At 90th, 50th, and 10th percentiles, the estimated numbers of undiscovered deposits, respectively, are 2, 3, and 5 or more consistent with the grade and tonnage model of Bliss (1986).

References

- Bliss, J.D., 1986, Grade and tonnage model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239-243.
- Hager, A.C., 1861, Economical geology of Vermont, *in* Hitchcock, E., Hitchcock, E., Jr., Hager, A.D., and Hitchcock, C.H., Report on the geology of Vermont: Descriptive, theoretical, economical, and scenographical: Claremont, New Hampshire, Claremont Manufacturing Company, v. II, pt. IX, p. 733-870.
- Perry, E.L., 1929[?], The geology of Bridgewater and Plymouth Townships, Vermont: Vermont Geological Survey, Report of the State Geologist for 1927-1928 (16th), p. 1-64.
- Watts, K.C., Jr., 1990, Regional exploration geochemistry of the Glens Falls 1° x 2° quadrangle, New York, Vermont, and New Hampshire, *in* Slack, J.F., ed., Summary results of the Glens Falls CUSMAP project, New York, Vermont, and New Hampshire: U.S. Geological Survey Bulletin 1887-F, 70 p.

NA24**Low-sulfide Au-quartz Vein Deposits**

Vermont

Descriptive Model 36a • Mark3 Index 27

New Hampshire

Area = 2,130 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by J.F. Slack

Rationale for Model Choice

Many gold-bearing low-sulfide quartz veins (Berger, 1986) are known in the northern Appalachian region. These veins commonly occur in regionally metamorphosed sedimentary and volcanic rocks, and locally are associated with altered ultramafic rocks. The greatest concentrations of such veins in New England are in the Bronson Hill anticlinorium of western New Hampshire. Only a few of the veins have been mined to any extent, however, including those at the Dodge mine in the so-called Ammonoosuc gold field of New Hampshire (Hitchcock, 1878; Moench, 1990). Production from the Dodge mine, perhaps the largest of these vein deposits in central New England, was reported to be \$50,000 in gold prior to 1878 (Hitchcock, 1878).

Rationale for Tract Delineation

A permissive tract outlines part of the Bronson Hill anticlinorium that contains known gold-bearing quartz veins within the Middle and Late Ordovician Ammonoosuc Volcanics and associated units. The tract contains significant gold and arsenic anomalies in panned concentrates of stream sediments (Watts, 1990).

Rationale for Numerical Estimate

Estimates of the number of undiscovered deposits were made on the basis of the number of occurrences and their distribution in the tract, and on the presence of geochemical anomalies in panned concentrates of stream sediments. At 90th, 50th, and 10th percentiles, the estimated numbers of undiscovered deposits, respectively, are 1, 1, and 2 or more, consistent with the grade and tonnage model of Bliss (1986).

References

- Berger, B.R., 1986, Descriptive model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239.
- Bliss, J.D., 1986, Grade and tonnage model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239-243.
- Hitchcock, C.H., 1878, The geology of New Hampshire, pt. V [Economic geology]: Concord, New Hampshire, State of New Hampshire, 103 p.
- Moench, R.H., 1990, The Piermont allochthon, northern Connecticut Valley area, New England—Preliminary description and resource implications, *in* Slack, J.F., ed., Summary results of the Glens Falls CUSMAP project, New York, Vermont, and New Hampshire: U.S. Geological Survey Bulletin 1887-J, 23 p.
- Slack, J.F., 1990, Preliminary assessment of metallic mineral resources in the Glens Falls 1° x 2° quadrangle, New York, Vermont, and New Hampshire, *in* Slack, J.F., ed., Summary results of the Glens Falls CUSMAP project, New York, Vermont, and New Hampshire: U.S. Geological Survey Bulletin 1887-R, 26 p.

Watts, K.C., Jr., 1990, Regional exploration geochemistry of the Glens Falls 1° x 2° quadrangle, New York, Vermont, and New Hampshire, *in* Slack, J.F., ed., Summary results of the Glens Falls CUSMAP project, New York, Vermont, and New Hampshire: U.S. Geological Survey Bulletin 1887-F, 70 p.

NR01**Skarn Cu Deposits**

Washington

Descriptive Model 18b • Mark3 Index 8

Area = 1,740 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Stephen E. Box and Arthur A. Bookstrom

Rationale for Model Choice

Copper skarns are an end-member of a spectrum of skarn deposit types that are variously copper-, zinc-lead-, or iron-rich. Skarns are metallic sulfide and oxide replacement deposits that occur in carbonate host lithologies adjacent to plutonic bodies with metal-bearing hydrothermal systems. The deposits are associated with shallow intermediate plutons, commonly those that are host to porphyry-style mineralization. The carbonate bodies that host the mineralization need not be regionally extensive, but can be small local bodies that are widely scattered essentially throughout the map area.

Rationale for Tract Delineation

The permissive tract is drawn to encompass the sedimentary rocks of the Quesnellia terrane in northeastern Washington (Stoffel and others, 1991). This terrane includes a belt of Triassic and Jurassic plutons that have generated a string of porphyry copper deposits in British Columbia and northern Washington, along with associated Au and Cu skarn deposits. Carbonate units are irregularly scattered through the Quesnellia terrane, such that the entire terrane is permissive.

Important Examples of Deposit Type

Two large skarn Cu (+Au) deposits are known just north of the Canadian border in southern British Columbia: Phoenix and Greenwood-Motherlode. No significant deposits are known within the tract, although several small occurrences of copper-bearing skarn mineralization are known around Mesozoic plutons within the tract.

Rationale for Numerical Estimate

The lack of significant skarn Cu deposits within the tract, even around the known porphyry copper deposit at Kelsey, led the team to be conservative in their estimate. The occurrence of significant Au in both the British Columbia deposits, enough to consider them gold skarns, led the team to judge that, whereas some undiscovered skarn Au deposits may have significant copper resources, the chance of a gold-poor copper skarn is low. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 1, 3, 5, and 7 or more copper skarn deposits consistent with the grade and tonnage model of Jones and Menzie (1986).

References

- Jones, G.M., and Menzie, W.D., 1986, Grade and tonnage model of Cu skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 86-89.
- Stoffel, K.L., Joseph, N.L., Waggoner, S.Z., Gulick, S.W., Korosec, M.A., and Bunning, B.B., 1991, Geologic map of Washington-Northeast quadrant: Washington Division of Geology and Earth Resources, Geologic Map GM-39, scale 1:250,000.

NR02**Skarn Cu Deposits**

Idaho

Descriptive Model 18b • Mark3 Index 8

Washington

Area = 21,300 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Stephen E. Box and Arthur A. Bookstrom**Rationale for Model Choice**

Copper skarns are an end-member of a spectrum of skarn deposit types that are variously copper-, zinc-lead-, or iron-rich. Skarns are metallic sulfide and oxide replacement deposits that occur in carbonate host lithologies adjacent to plutonic bodies with metal-bearing hydrothermal systems. The deposits are associated with shallow intermediate plutons, commonly those that are host to porphyry-style mineralization. The carbonate bodies that host the mineralization need not be regionally extensive, but can be small local bodies that are widely scattered essentially throughout the map area.

Rationale for Tract Delineation

The tract was delineated by excluding areas without significant carbonate rocks from the corresponding porphyry Cu tract. Permissive sedimentary packages include the Paleozoic sequence of northeastern Washington, the middle Belt carbonate units of the Belt Supergroup in northern Idaho, and the Paleozoic sequence of south-central Idaho (Bond, 1978; Stoffel and others, 1991).

Important Examples of Deposit Type

The Empire mine near Mackay, Idaho is the only copper skarn deposit known in the tract. This deposit is large and rich, compared with the grade and tonnage distributions of Jones and Menzie (1986). Significant gold grades (1.6 g/metric ton) occur in the Empire deposit. The deposit is localized in a Pennsylvanian limestone around an Eocene granodiorite stock on the east side of the Idaho batholith. A small skarn Zn-Pb deposit and a small skarn Fe deposit occur on the opposite side of the stock from the Empire deposit.

Rationale for Numerical Estimate

The occurrence of only one known deposit of this type and the lack of known porphyry copper deposits in this tract lead the team to give a very low estimate. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, and 1 or more copper skarn deposits consistent with the grade and tonnage model of Jones and Menzie (1986).

References

- Bond, J.G., 1978, Geologic map of Idaho: Idaho Bureau of Mines and Geology, scale 1:500,000.
- Jones, G.M., and Menzie, W.D., 1986, Grade and tonnage model of Cu skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 86-89.
- Stoffel, K.L., Joseph, N.L., Waggoner, S.Z., Gulick, S.W., Korosec, M.A., and Bunning, B.B., 1991, Geologic map of Washington-Northeast quadrant: Washington Division of Geology and Earth Resources, Geologic Map GM-39, scale 1:250,000.

NR03**Skarn Zn-Pb Deposits**

Idaho

Descriptive Model 18c • Mark3 Index 22

Washington

Area = 21,300 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Stephen E. Box and Arthur A. Bookstrom

Rationale for Model Choice

Skarn Zn-Pb deposits are an end-member of a spectrum of skarn deposit types that are variously copper-, zinc-lead-, or iron-rich. Skarns are metallic sulfide and oxide replacement deposits that occur in carbonate host lithologies adjacent to plutonic bodies with metal-bearing hydrothermal systems. The deposits are associated with shallow intermediate plutons, commonly those that are host to porphyry-style mineralization. The carbonate bodies that host the mineralization need not be regionally extensive, but can be small local bodies that are widely scattered essentially throughout the map area.

Rationale for Tract Delineation

The tract was delineated by excluding areas without significant carbonate rocks from the corresponding porphyry Cu tract. Permissive sedimentary packages include the Paleozoic sequence of northeastern Washington, the middle Belt carbonate units of the Belt Supergroup in northern Idaho, and the Paleozoic sequence of south-central Idaho (Bond, 1978; Stoffel and others, 1991).

Important Examples of Deposit Type

No significant deposits of this type are known from the tract. A small skarn Zn-Pb deposit mined at the Horseshoe mine near Mackay, Idaho is very small compared to the grade and tonnage distributions of Mosier (1986).

Rationale for Numerical Estimate

The lack of significant known deposits of this type and the lack of known porphyry copper deposits in this tract lead the team to give a very low estimate. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, and 1 or more skarn Zn-Pb deposits consistent with the grade and tonnage model of Jones and Menzie (1986).

References

- Bond, J.G., 1978, Geologic map of Idaho: Idaho Bureau of Mines and Geology, scale 1:500,000.
- Mosier, D.L., 1986, Grade and tonnage model of Zn-Pb skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 90-93.
- Stoffel, K.L., Joseph, N.L., Waggoner, S.Z., Gulick, S.W., Korosec, M.A., and Bunning, B.B., 1991, Geologic map of Washington-Northeast quadrant: Washington Division of Geology and Earth Resources, Geologic Map GM-39, scale 1:250,000.

NR04**Skarn Zn-Pb Deposits****Montana
Wyoming****Descriptive Model 18c • Mark3 Index 22****Area = 16,000 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* David Frishman**Rationale for Model Choice**

Zinc-lead skarns occur in Montana, though none are known to exist in Wyoming. Favorable environments for their occurrence exist in both States because sedimentary carbonate rocks are present adjacent to granitic intrusions. Zinc-lead skarns are responsible for an insignificant proportion of the zinc and lead produced in Montana. Polymetallic vein and replacement deposits containing Zn and Pb also occur in close association with Cretaceous or Tertiary intrusive rocks in many mining districts such as the Barker, Elkhorn, Hecla, and Castle Mountain districts, and skarns could occur in these environments.

Rationale for Tract Delineation

We used the maps of Ross and others (1955) and Love and Christiansen (1985) to delineate areas where Cretaceous or Tertiary intrusive rocks were emplaced into or were in close proximity to carbonate rocks. Precambrian (Belt Supergroup) and Phanerozoic carbonate rocks were considered separately. The permissive tract for skarn Zn-Pb deposits is identical to the corresponding polymetallic replacement tract, i.e., within the porphyry copper permissive tract where carbonate rocks are present, either at the surface or at a shallow depth. Areas that make up the tract are located in northwestern, southwestern, and south-central Montana and another area extends southeastward from south of Livingston into northwestern Wyoming.

Important Examples of Deposit Type

We know of no important skarn Zn-Pb deposits in either Montana or Wyoming. Very small skarn Pb deposits (the Mary and Edna mine and the McKinley mine) occur between the Hughsville stock and limestones of the Madison Group in the Barker (Hughsville) mining district in Cascade and Judith Basin Counties, Montana (Witkind, 1973). These deposits, probably between about 45 and 51 Ma in age, contained an insignificant proportion of the 20,000 metric tons of lead, 8,000 metric tons of zinc, and 80 metric tons of silver produced from the district; almost all the production from the district was from polymetallic vein deposits.

Rationale for Numerical Estimate

Probably the best prospective area for skarn Zn-Pb deposits is in carbonate terranes near the Pioneer batholith, which is similar to the Boulder Batholith, and is the host for, or genetically related to, many varied base-metal deposits. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 2, 4, and 6 or more districts consistent with the grade and tonnage model for skarn Zn-Pb deposits (Mosier, 1986).

References

- Cox, D.P., 1986, Descriptive model of Zn-Pb skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 90.
- Love, J.D., and Christiansen, A.C., 1985, Geologic map of Wyoming: U.S. Geological Survey, scale 1:500,000.
- Mosier, D.L., 1986, Grade and tonnage model of Zn-Pb skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 90-93.

- Ross, C.P., Andrews, D.A., and Witkind, I.J., 1955, Geologic map of Montana: U.S. Geological Survey . scale 1:500,000.
- Witkind, I.J., 1973, Igneous rocks and related mineral deposits of the Barker quadrangle, Little Belt Mountains, Montana: U.S. Geological Survey Professional Paper 752, 58 p.

NR05**Skarn Au Deposits**

Washington

Descriptive Model Bull. 1930 • Mark3 Index 105

Area = 1,740 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Stephen E. Box and Arthur A. Bookstrom

Rationale for Model Choice

Skarn Au deposits are a subset of a spectrum of skarn types that are variously copper-, zinc-lead, or iron-rich. Skarns are metallic sulfide and oxide replacement deposits that occur in carbonate host lithologies adjacent to plutonic bodies with metal-bearing hydrothermal systems. The deposits are associated with shallow intermediate plutons, commonly those that are host to porphyry-style mineralization. The carbonate bodies that host the mineralization need not be regionally extensive, but can be small local bodies that are widely scattered throughout the map area. Since a significant porphyry copper deposit and a significant skarn Au deposit both occur within the tract, the gold skarn model is clearly appropriate.

Rationale for Tract Delineation

The permissive tract is drawn to encompass the sedimentary rocks of the Quesnellia terrane in northeastern Washington (Stoffel and others, 1991). This terrane includes a belt of Triassic and Jurassic plutons that have generated a string of porphyry copper deposits in British Columbia and northern Washington, along with associated Au and Cu skarn deposits. Carbonate units are irregularly scattered through the Quesnellia terrane, such that the entire terrane is permissive.

Important Examples of Deposit Type

Only one gold-bearing skarn, Buckhorn Mountain (Hickey, 1992), is known in northeastern Washington. This skarn is localized within rocks of the Quesnellia terrane around a pluton of uncertain but probable Mesozoic age, and lies to the south of a cluster of gold skarn deposits in southern British Columbia (Theodore and others, 1991), which also occur around Mesozoic plutons in the Quesnellia terrane. The known deposit has very large tonnage greater than 90 percent of the deposits in the tonnage distribution of Theodore and others (1991), with a contained Au content more than 10 times larger than the median Au content from the grade and tonnage distributions.

Rationale for Numerical Estimate

Seven deposits of this type are known in the Quesnellia terrane, all but one in British Columbia. The Buckhorn deposit in Washington, a prospect for nearly one hundred years, was only recently proved to be a significant deposit, and at least five more similar prospects are known in Okanogan County, Washington (Derkey and others, 1990). The association of this deposit type with magnetite mineralization makes buried targets easy to delineate. Since the discovery of the Buckhorn deposit, exploration for this deposit type has been brisk. For these reasons the team expressed cautious optimism about the potential for undiscovered deposits in this tract. Because the grade and tonnage model of Theodore and others (1991) includes some very small deposits, we felt we could estimate more accurately using a model that is truncated to include only those deposits with more than 15,000 metric tons of mineralized rock. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 1, 3, 5, and 7 or more deposits that are comparable in grade and tonnage to the gold skarn grade and tonnage model (truncated) of Theodore and others (1991).

References

- Derkey, R.E., Joseph, N.L., and Lasmanis, Raymond, 1990, Metal mines of Washington—Preliminary report: Washington Division of Geology and Earth Resources Open-File Report 90-18, 577 p.
- Hickey, R.J., 1992, The Buckhorn Mountain (Crown Jewel) gold skarn deposit, Okanogan County, Washington: *Economic Geology*, v. 87, no. 1, p. 125-141.
- Stoffel, K.L., Joseph, N.L., Waggoner, S.Z., Gulick, S.W., Korosec, M.A., and Bunning, B.B., 1991, Geologic map of Washington-Northeast quadrant: Washington Division of Geology and Earth Resources, Geologic Map GM-39, scale 1:250,000.
- Theodore, T.G., Orris, G.J., Hammarstrom, J.M., and Bliss, J.D., 1991, Gold-bearing skarns: U.S. Geological Survey Bulletin 1930, 61 p.

NR06**Skarn Au Deposits**

Idaho

Descriptive Model Bull. 1930 • Mark3 Index 105

Washington

Area = 21,300 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Stephen E. Box and Arthur A. Bookstrom**Rationale for Model Choice**

Skarn Au deposits are a subset of a spectrum of skarn types that are variously copper-, zinc-lead, or iron-rich. Skarns are metallic sulfide and oxide replacement deposits that occur in carbonate host lithologies adjacent to plutonic bodies with metal-bearing hydrothermal systems. The deposits are associated with shallow intermediate plutons, commonly those that are host to porphyry-style mineralization. The carbonate bodies that host the mineralization need not be regionally extensive, but can be small local bodies that are widely scattered throughout the map area.

Rationale for Tract Delineation

The tract was delineated by excluding areas without significant carbonate rocks from the corresponding porphyry Cu tract. Permissive sedimentary packages include the Paleozoic sequence of northeastern Washington, the middle Belt carbonate units of the Belt Supergroup in northern Idaho, and the Paleozoic sequence of south-central Idaho (Bond, 1978; Stoffel and others, 1991).

Important Examples of Deposit Type

No significant deposits of this type are known from the tract.

Rationale for Numerical Estimate

The lack of known deposits of this type and the lack of known porphyry copper deposits in this tract lead the team to give a very low estimate. Because the grade and tonnage model of Theodore and others (1991) includes some very small deposits, we felt we could estimate more accurately using a model that is truncated to include only those deposits with more than 15,000 metric tons of mineralized rock. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, and 1 or more gold skarn deposits consistent with the grade and tonnage model (truncated) of Theodore and others (1991).

References

- Bond, J.G., 1978, Geologic map of Idaho: Idaho Bureau of Mines and Geology, scale 1:500,000.
- Stoffel, K.L., Joseph, N.L., Waggoner, S.Z., Gulick, S.W., Korosec, M.A., and Bunning, B.B., 1991, Geologic map of Washington-Northeast quadrant: Washington Division of Geology and Earth Resources, Geologic Map GM-39, scale 1:250,000.
- Theodore, T.G., Orris, G.J., Hammarstrom, J.M., and Bliss, J.D., 1991, Gold-bearing skarns: U.S. Geological Survey Bulletin 1930, 61 p.

NR07**Skarn Au Deposits****Montana
Wyoming****Descriptive Model Bull. 1930 • Mark3 Index 82****Area = 16,200 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* James E. Elliott**Rationale for Model Choice**

The model used for the assessment of gold-bearing skarns is based on the descriptive model by Theodore and others (1991). The main criteria used for this model are: (1) The deposits must have an average gold grade of at least 1 g/t, and (2) the mineral assemblage of the deposit must be representative of a skarn environment. Pyroxene and garnet are the most important diagnostic minerals. Gold-bearing skarns are commonly the result of large-scale metasomatic transfer of components between hydrothermal fluids and predominately carbonate rocks. They are generally calcic exoskarns associated with intense retrograde hydrosilicate alteration. The igneous rocks act as the heat source and, in most cases, the source of components for the hydrothermal fluids. Gold-bearing skarns can be associated with porphyry copper or copper-molybdenum, polymetallic replacement, and polymetallic vein deposits.

Rationale for Tract Delineation

The permissive tract for gold-bearing skarns is the same as that for polymetallic replacement deposits (C07); these areas are located in northwestern, southwestern, and south-central parts of Montana. The tract is made up of those parts of the porphyry copper permissive tracts that have sedimentary carbonate rocks at the surface or at shallow depths (less than 1 km) below the surface, based on geologic maps of Montana (Ross and others, 1955) and Wyoming (Love and Christiansen, 1985). The more favorable parts of these areas are where sedimentary carbonate rocks are near igneous contacts, especially near margins of Late Cretaceous or Eocene granite, granodiorite, or dacite porphyry. The most favorable environment for the occurrence of gold-bearing skarns is at or near an intrusive-sedimentary carbonate contact whereas polymetallic replacement deposits can form at some distance from an intrusive contact.

The most favorable sedimentary carbonate rocks are Paleozoic, and include the Meagher and Pilgrim Limestones of Cambrian age, the Jefferson Formation of Devonian age, and the Madison Group of Mississippian age. Less favorable carbonate rocks are Mesozoic (Lower Cretaceous Kootenai Formation and Jurassic Ellis Group) and Middle Proterozoic in age (Belt Supergroup: Newland, Empire, Helena, and Wallace Formations).

Important Examples of Deposit Type

There are several important gold-bearing skarn deposits and districts in southwestern and south-central Montana. The most important ones are the Bannack district (Loen and Pearson, 1989; Theodore and others, 1991); the Butte Highlands district (Sahinen, 1950); the Silver Star district (Loen and Pearson, 1989); the Cable mine in the Georgetown district (Emmons and Calkins, 1913); the New World district (Elliott and others, 1992); and the Diamond Hill mine. All of the gold-bearing skarns are located at contacts of intrusive rocks. Two (Butte Highlands and Silver Star) are located at contacts of the Late Cretaceous Boulder batholith with Cambrian sedimentary carbonate rocks, three (Bannack, Cable, and Diamond Hill) are located along margins of small Late Cretaceous stocks, and several deposits in the New World district are located at contacts with Eocene dacitic porphyritic intrusive complexes. Host rocks for these deposits are mostly Paleozoic sedimentary carbonate rocks. The most favorable host rocks are the Cambrian Meagher Limestone(or Silver Hill Formation) and Pilgrim Limestone(or Hasmark

Formation). The Diamond Hill mine is unusual in that no carbonate rocks are present; the ore bodies occur in garnet-diopside-epidote skarn that replaced Cretaceous volcanic rocks.

Rationale for Numerical Estimate

Within the permissive tract for gold-bearing skarns, six subtracts or areas are favorable for the occurrence of undiscovered gold-bearing skarn deposits. Separate estimates were made for undiscovered gold-bearing skarns in each of these areas. A seventh estimate was made for undiscovered deposits in the remaining less-favorable permissive area. The estimates considered the presence of known deposits, prospects, and favorability of geologic setting. The favorable areas are: (1) the Absaroka-Gallatin volcanic province (Chadwick, 1970) in south-central Montana and northwestern Wyoming; (2) the Dillon area including the eastern margin of the Pioneer batholith and southern margin of the Boulder batholith in southwestern Montana; (3) the Elkhorn area, along the eastern side of the Boulder batholith; (4) the Helena area, along the northern side of the Boulder batholith; (5) the southern Flint Creek Range in southwestern Montana, and (6) the Garnet area, east of Missoula. The individual estimates are:

percentile	90th	50th	10th	5th	1st
Absaroka-Gallatin	2	5	8	10	12
Dillon	0	2	3	4	5
Elkhorn	1	1	2	3	4
Helena	1	1	2	3	4
Flint Creek Range	1	2	3	4	5
Garnet	0	1	1	2	3
Other areas	0	0	1	2	3

Combining these estimates, for the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 5, 12, 20, 28, and 36 or more gold skarn deposits consistent with the grade and tonnage model of Theodore and others (1991).

References

- Chadwick, R.A., 1970, Belts of eruptive centers in the Absaroka-Gallatin volcanic province, Wyoming-Montana: Geological Society of America Bulletin, v. 81, p. 267-274.
- Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, 379 p.
- Elliott, J.E., Kirk, A.R., and Johnson, T.W., 1992, Field guide; gold-copper-silver deposits of the New World district, *in* Elliott, J.E., ed., 1992, Guidebook for the Red Lodge-Beartooth Mountains-Stillwater Area, Tobacco Root Geological Society Seventeenth Annual Field Conference: Northwest Geology, v. 20/21, p. 1-19.
- Emmons, W.H., and Calkins, F.C., 1913, Geology and ore deposits of the Philipsburg quadrangle, Montana: U.S. Geological Survey Professional Paper 78, 271 p.
- Hammarstrom, J.M., Zientek, M.L., and Elliott, J.E., eds., 1993, Mineral resource assessment of the Absaroka-Beartooth study area, Custer and Gallatin National Forests, Montana: U.S. Geological Survey Open-File Report 93-207, 296 p., 19 plates.
- Loen, J.S., and Pearson, R.C., 1989, Map showing locations of mines and prospects in the Dillon 1° x 2° quadrangle, Idaho and Montana: U.S. Geological Survey Map I-1803-C, scale 1:250,000.
- Sahinen, U.M., 1950, Geology and ore deposits of the Highland Mountains, southwestern Montana: Montana Bureau of Mines and Geology Memoir 32, 63 p.
- Theodore, T.G., Orris, G.J., Hammarstrom, J.M., and Bliss, J.D., 1991, Gold-bearing skarns: U.S. Geological Survey Bulletin 1930, 61 p.

NR08**Porphyry Cu Deposits**

Washington

Descriptive Model 17 • Mark3 Index 89

Area = 5,580 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Stephen E. Box and Arthur A. Bookstrom

Rationale for Model Choice

Porphyry copper deposits consist of copper-bearing minerals in disseminated grains and in stockwork quartz veinlets in hydrothermally altered, intermediate to felsic porphyritic intrusions and adjacent country rocks (Cox, 1986). Porphyry copper deposits are generally found in magmatic belts associated with convergent plate margins, and are associated with plutonic rocks of a wide variety of igneous compositions, ranging from diorite to granite. However, gabbros and high-silica granites are seldom associated with porphyry copper deposits. Associated mineral deposits include polymetallic vein, base metal skarn, and (or) base metal replacement deposits (Cox, 1986). Compositionally appropriate granitic plutons of Jurassic, Cretaceous, and Tertiary age intrude the Quesnellia terrane in northeastern Washington. Porphyry copper deposits in Mesozoic accreted terranes in British Columbia and Alaska are somewhat smaller than the well-known Arizona deposits, and have been characterized by a separate grade and tonnage model used here (Menzie and Singer, 1993). Choice of this model reflects the opinion of the team that deposits in this tract would be more like those of British Columbia than the deposits in southwestern U.S. that have higher copper grades.

Rationale for Tract Delineation

The tract encompasses Triassic, Jurassic, and (or) Cretaceous intermediate composition plutons that intrude the Quesnellia terrane (Stoffel and others, 1991). Since some of these plutons could be yet unexposed by erosion, the entire Quesnellia terrane is considered permissive.

Examples of Deposit Type

The Kelsey deposit (Derkey and others, 1990), along the Washington-British Columbia border, is the southernmost known (and the only U.S. representative) in the British Columbia porphyry copper belt, a 1,300-km-long belt of Late Triassic and Early Jurassic deposits associated with mildly alkaline intermediate plutons. The deposit has a tonnage greater than about 60 percent of those shown on the tonnage distribution of Menzie and Singer (1993), but has a copper grade (0.286 percent) lower than 90 percent of those shown on the grade distribution. The grade of the Kelsey deposit is about half of the median of these deposits, the tonnage is about twice the median, and the contained metal is about equal to the median size of these deposits.

Rationale for Numerical Estimate

Polymetallic veins occur in two clusters south of the Kelsey deposit, and a gold skarn associated with a separate Mesozoic pluton occurs to the east. The relatively small favorable area and the knowledge of extensive exploration for these deposits in the region in the 1960s and 1970s limits our estimate of the number of undiscovered deposits. For the 90th, 50th, 10th, and 5th percentiles, the team estimated 0, 0, 2, 3, and 4 or more deposits consistent with the grade and tonnage model of Menzie and Singer (1993).

References

Cox, D.P., 1986, Descriptive model of porphyry Cu, in Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 76.

- Derkey, R.E., Joseph, N.L., and Lasmanis, Raymond, 1990, Metal mines of Washington—Preliminary report: Washington Division of Geology and Mineral Resources Open-File Report 90-18, 577 p.
- Menzie, W.D., and Singer, D.A., 1993, Grade and tonnage model of porphyry Cu deposits in British Columbia, Canada, and Alaska, USA: U.S. Geological Survey Open-File Report 93-275, 8 p.
- Stoffel, K.L., Joseph, N.L., Waggoner, S.Z., Gulick, S.W., Korosec, M.A., and Bunning, B.B., 1991, Geologic map of Washington-Northeast quadrant: Washington Division of Geology and Earth Resources, Geologic Map GM-39, scale 1:250,000.

NR09**Porphyry Cu Deposits**

Idaho

Descriptive Model 17 • Mark3 Index 81

Washington

Area = 91,700 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Stephen E. Box and Arthur A. Bookstrom

Rationale for Model Choice

Porphyry copper deposits consist of copper-bearing minerals in disseminated grains and in stockwork quartz veinlets in hydrothermally altered, intermediate to felsic porphyritic intrusions and adjacent country rocks (Cox, 1986). Porphyry copper deposits are generally found in magmatic belts associated with convergent plate margins, and are associated with plutonic rocks of a wide variety of igneous compositions, ranging from diorite to granite. However, gabbros and high-silica granites are seldom associated with porphyry copper deposits. Associated mineral deposits include polymetallic vein, base metal skarn, and(or) base metal replacement deposits (Cox, 1986). Compositionally appropriate granitic plutons of Cretaceous and Tertiary age occur throughout this broad tract.

Rationale for Tract Delineation

The tract includes most of the Eocene and older rocks of northeastern Washington and Idaho north of the Snake River plain in which intermediate plutons of Cretaceous and Tertiary age are widespread (Stoffel and others, 1991; Bond, 1978). Since the deposit model requires shallow (<5 km) emplacement depths for the ore-related plutons, the deeply emplaced western part of the Cretaceous Idaho batholith and the Tertiary core complexes (i.e., Okanogan, Kettle, Priest River-Spokane, and Pioneer core complexes) are excluded, except where intruded by shallow Eocene plutons. Areas north of the Idaho batholith, where no plutonic rocks are known at the surface and geophysical evidence for plutons at depth is not known, were also excluded from the tract.

Important Examples of Deposit Type

No copper deposits of this type are known from this tract. Several molybdenum porphyry deposits, some with significant copper resources, do occur in the tract, but are characterized by a separate deposit model (Theodore, 1986; Menzie and Theodore, 1986).

Rationale for Numerical Estimate

For the assessment, a North American subset of the porphyry copper tonnage and grade model of Singer and others (1986) was used (Hammarstrom and others, 1993; Mark3 index 81). The lack of known deposits or prospects of this deposit type in the tract, combined with relatively thorough exploration in the 1960s and 1970s led the team to give a very low estimate for the number of undiscovered deposits. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, and 1 or more deposits consistent with the grade and tonnage model.

References

- Bond, J.G., 1978, Geologic map of Idaho: Idaho Bureau of Mines and Geology, scale 1:500,000.
- Cox, D.P., 1986, Descriptive model of porphyry Cu, in Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 76.
- Hammarstrom, J.M., Zientek, M.L., and Elliott, J.E., eds., 1993, Mineral resource assessment of the Absaroka-Beartooth study area, Custer and Gallatin National Forests, Montana: U.S. Geological Survey Open-File Report 93-207, 296 p., 19 plates.

- Menzie, W.D., and Theodore, T.G., 1986, Descriptive model of porphyry Mo, low-F, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 120.
- Singer, D.A., Mosier, D.L., and Cox, D.P., 1986, Grade and tonnage model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 77-81.
- Stoffel, K.L., Joseph, N.L., Waggoner, S.Z., Gulick, S.W., Korosec, M.A., and Bunning, B.B., 1991, Geologic map of Washington-Northeast quadrant: Washington Division of Geology and Earth Resources, Geologic Map GM-39, scale 1:250,000.
- Theodore, T.G., 1986, Grade and tonnage model of porphyry Mo, low-F, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 120-122.

NR10**Porphyry Cu Deposits****Montana****Descriptive Model 17 • Mark3 Index 81****Area = 42,100 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* James E. Elliott**Rationale for Model Choice**

The descriptive porphyry copper model of Cox (1986) was used in the assessment of undiscovered Cretaceous deposits in Montana. Porphyry copper deposits consist of copper-bearing minerals in disseminated grains and in stockwork veinlets in hydrothermally altered porphyry and adjacent country rocks (Cox, 1986). These deposits generally occur in high-level intrusive rocks contemporaneous with abundant dikes, breccia pipes, and faulting and contemporaneous with or slightly younger than volcanism. The intrusive rocks are typically porphyritic rocks, commonly including epizonal or hypabyssal dacite, latite, quartz latite, and rhyolite porphyries but also including their equigranular plutonic equivalents such as quartz diorite, monzonite, quartz monzonite, and granite (Guilbert and Park, 1986).

Porphyry copper deposits commonly show concentric zoning both in the types and concentration of metals and in alteration facies. Alteration includes pyritic, argillic, phyllic, and potassic types. Porphyry deposits commonly show a spatial relationship to vein, replacement, and skarn deposits of base and precious metals.

Rationale for Tract Delineation

The criteria used to define the permissive tract in Montana are: (1) mapped areas of Cretaceous and Eocene volcanic, hypabyssal, and plutonic rocks as shown on the geologic map of Montana (Ross and others, 1955); (2) the predicted extent or presence of subsurface intrusive rocks based on gravity and magnetic data; (3) the presence of known mines, prospects, and occurrences of this deposit type.

The tract is located in western Montana, coincident with Cretaceous and Eocene volcanic and plutonic belts. Most of the known deposits and prospects are situated along a northeasterly-trending Idaho-Montana porphyry belt (Rostad, 1978), in southwestern Montana.

Important Examples of Deposit Type

The only known deposit of Late Cretaceous age is the Continental deposit in the Butte district. This deposit and other prospects of this age are associated with plutonic and hypabyssal intrusive rocks of the Boulder, Pioneer, Idaho, and Tobacco Root batholiths and other intrusive bodies of southwestern Montana. Several prospects also exist, that have either low grade or are incompletely explored. They include Beaverton, Golconda, areas on the east flank of the Elkhorn Range, Rochester, Jackson Creek, West Fork of the Bitterroot, Cold Springs-Bannack, Argenta, Westside Tobacco Root, and Gold Hill.

The famous Butte district, in southwestern Montana, has been recognized as a porphyry copper district as well as one of the largest and most productive polymetallic vein districts in the world. The Continental porphyry copper-molybdenum deposit, presently being mined, is hosted by the Butte Quartz Monzonite (Boulder batholith) of Late Cretaceous age (Meyer and others, 1968; Ratcliff, 1973). Hypogene copper and molybdenum minerals occur as disseminations and in stockwork veinlets. Much of the ore-grade mineralized rock results from oxidation and supergene enrichment of hypogene minerals.

The Heddleston deposit, of Eocene age, is located in the west-central part of Montana near Lincoln. The deposit is associated with porphyritic intrusive rocks that invaded

metasedimentary rocks of the Middle Proterozoic Belt Supergroup. These intrusions may be related to the nearby Lincoln andesitic and rhyolitic volcanic rocks. The Heddleston deposit consists of disseminated chalcopyrite and molybdenite and quartz-molybdenite veinlets in Eocene quartz monzonite, quartz monzonite porphyry, and a breccia pipe. A blanket-like supergene deposit is superimposed on the hypogene mineralized zones. The host rocks for this deposit are metasedimentary and metaigneous rocks of Proterozoic age (Miller and others, 1973).

Rationale for Numerical Estimate

For the assessment, a North American subset of the porphyry copper tonnage and grade model of Singer and others (1986) was used (Hammarstrom and others, 1993; Mark3 index 81). This subset of 107 deposits, which range in age from Late Cretaceous through middle Tertiary, has a median size of 142 million metric tons and a median copper grade of 0.5 percent. Byproducts include silver, gold, and molybdenum. Montana deposits have relatively high contents of molybdenum and thus are distinctly different than most other porphyry copper deposits. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 1, 3, 6, and 7 or more deposits consistent with the grade and tonnage model of Hammarstrom and others (1993).

References

- Cox, D.P., 1986, Descriptive model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 76.
- Guilbert, J.M., and Park, C.F., Jr., 1986, The geology of ore deposits: New York, W.H. Freeman and Company, 985 p.
- Hammarstrom, J.M., Zientek, M.L., and Elliott, J.E., eds., 1993, Mineral resource assessment of the Absaroka-Beartooth study area, Custer and Gallatin National Forests, Montana: U.S. Geological Survey Open-File Report 93-207, 296 p., 19 plates.
- Meyer, Charles, Shea, E.P., Goddard, C.C., Jr., Zeihen, L.G., Guilbert, J.M., Miller, R.N., McAleer, J.F., Brox, G.B., Ingersoll, R.G., Jr., Burns G.J., and Wigal, Thomas, 1968, Ore deposits at Butte, Montana, *in* Ridge, J.D., ed., Ore deposits of the United States, 1933–1967, v. 2: New York, American Institute of Mining, Metallurgical, and Petroleum Engineers, p. 1373-1416.
- Ratcliff, M.W., 1973, Copper and molybdenum mineralization in the Continental deposit, East Butte district, Montana, p. I-1 - I-8, *in* Miller, R.N., ed., Guidebook for the Butte Field Meeting of Society of Economic Geologists: Society of Economic Geologists, Butte, Montana, 120 p.
- Ross, C.P., Andrews, D.A., and Witkind, I.J., 1955, Geologic map of Montana: U.S. Geological Survey, scale 1:500,000.
- Rostad, O., 1978, K-Ar dates of mineralization in the White Cloud-Cannivan porphyry molybdenum belt of Idaho and Montana—A discussion: *Economic Geology*, v. 73, no. 7, p. 1366-1368.
- Singer, D.A., Mosier, D.L., and Cox, D.P., 1986, Grade and tonnage model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 77-81.

NR11**Porphyry Cu Deposits****Montana
Wyoming****Descriptive Model 17 • Mark3 Index 81****Area = 14,800 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* James E. Elliott**Rationale for Model Choice**

The descriptive porphyry copper model of Cox (1986) was used in the assessment of undiscovered Eocene deposits in Montana and northwestern Wyoming. Porphyry copper deposits consist of copper-bearing minerals in disseminated grains and in stockwork veinlets in hydrothermally altered porphyry and adjacent country rocks (Cox, 1986). These deposits generally occur in high-level intrusive rocks contemporaneous with abundant dikes, breccia pipes, and faulting and contemporaneous or slightly younger than volcanism. The intrusive rocks are typically porphyritic rocks, commonly including epizonal or hypabyssal dacite, latite, quartz latite, and rhyolite porphyries but also including their plutonic equivalents such as quartz diorite, monzonite, quartz monzonite, and granite (Guilbert and Park, 1986).

Porphyry copper deposits commonly show concentric zoning both in the types and concentration of metals and in alteration facies. Alteration includes pyritic, argillic, phyllic, and potassic types. Porphyry deposits commonly show a spatial relationship to vein, replacement, and skarn deposits of base and precious metals.

Rationale for Tract Delineation

The criteria used to define the permissive tract in south-central Montana and northwestern Wyoming are: (1) Mapped areas of Eocene intrusive and extrusive rocks of the Absaroka Volcanic Supergroup in the Absaroka ranges of Montana and Wyoming, as shown on the geologic map of Montana (Ross and others, 1955) and Wyoming (Love and Christiansen, 1985); (2) Predicted presence of subsurface intrusive rocks based on gravity and magnetic data; (3) Presence of known mines, prospects, and occurrences of this deposit type.

Permissive areas for porphyry copper deposits are located in south-central Montana and northwestern Wyoming, coincident with an Eocene volcano-plutonic belt. Most of the known deposits and prospects are situated within the northwesterly trending Absaroka-Gallatin volcanic province (Chadwick, 1970). The Kirwin deposit and 11 porphyry copper prospects are located along this belt (Hausel, 1982).

Important Examples of Deposit Type

Eocene deposits include the Kirwin deposit in northwestern Wyoming near Meeteetse. The Kirwin deposit is located in the southern part of the Absaroka-Gallatin volcanic province (Chadwick, 1970) in northwestern Wyoming. It is associated with rhyolitic tuffs and breccias that intruded andesitic volcanic and volcanoclastic rocks. The deposit is contained within an area of intense hydrothermal alteration associated with a volcanic vent complex. The mineralized zone consists of stockworks with pyrite, chalcopyrite, and molybdenite in quartz-calcite veins and disseminated sulfides in altered rocks. A secondary enriched blanket containing chalcocite, digenite, and covellite overlies a part of the stockworks (Hausel, 1982).

Eleven other porphyry copper prospects are known and are located along two northwesterly-trending belts in the Absaroka-Gallatin province in northwestern Wyoming and south-central Montana. These prospects are New World, Independence, Emigrant, Silver Creek, Stinkingwater, Sunlight, Eagle Creek, Clouds Home Peak, Robinson Creek, Birthday, and Yellow Ridge.

Rationale for Numerical Estimate

A comprehensive analysis of part of the Absaroka-Gallatin volcanic province by Hammarstrom and others (1993) was used as a guide for the whole of that province. For the assessment, a North American subset of the porphyry copper tonnage and grade model of Singer and others (1986) was used (Hammarstrom and others, 1993; Mark3 index 81). This subset of 107 deposits, which range in age from Late Cretaceous through middle Tertiary, has a median size of 142 million metric tons and a median copper grade of 0.5 percent. Byproducts include silver, gold, and molybdenum. Montana deposits have relatively high contents of molybdenum and thus are distinctly different than most other porphyry copper deposits. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 1, 4, 6, 7, and 9 or more deposits consistent with the grade and tonnage model of Hammarstrom and others (1993).

References

- Chadwick, R.A., 1970, Belts of eruptive centers in the Absaroka-Gallatin volcanic province, Wyoming-Montana: Geological Society of America Bulletin, v. 81, p. 267-274.
- Cox, D.P., 1986, Descriptive model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 76.
- Guilbert, J.M., and Park, C.F., Jr., 1986, The geology of ore deposits: New York, W.H. Freeman and Company, 985 p.
- Hammarstrom, J.M., Zientek, M.L., and Elliott, J.E., eds., 1993, Mineral resource assessment of the Absaroka-Beartooth study area, Custer and Gallatin National Forests, Montana: U.S. Geological Survey Open-File Report 93-207, 296 p., 19 plates.
- Hausel, W.D., 1982, General geologic setting and mineralization of the porphyry copper deposits, Absaroka Volcanic Plateau, Wyoming: Wyoming Geological Association, Guidebook for Thirty-Third Annual Field Conference, p. 297-313.
- Love, J.D., and Christiansen, A.C., 1985, Geologic map of Wyoming: U.S. Geological Survey, scale 1:500,000.
- Ross, C.P., Andrews, D.A., and Witkind, I.J., 1955, Geologic map of Montana: U.S. Geological Survey, scale 1:500,000.
- Singer, D.A., Mosier, D.L., and Cox, D.P., 1986, Grade and tonnage model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 77-81.

NR12**Polymetallic Replacement Deposits**

Idaho

Descriptive Model 19a • Mark3 Index 47

Washington

Area = 21,300 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Stephen E. Box and Arthur A. Bookstrom

Rationale for Model Choice

These deposits are hydrothermal epigenetic deposits that consist of silver-, lead-, zinc-, and copper-bearing minerals in massive lenses, pipes, and veins in carbonate sedimentary rocks near igneous intrusions (Morris, 1986). Associated igneous rocks are commonly calc-alkaline and porphyritic. Types of alteration include dolomitization and silicification. On a district scale, the deposits are commonly zoned from a copper-rich central area, through a wide lead-silver zone, outward to a zinc- and manganese-rich fringe. A permissive tract for polymetallic replacement deposits in Idaho and northeastern Washington is delineated based on the widespread occurrence of Jurassic, Cretaceous, and Tertiary calc-alkaline plutonic rocks and carbonate-bearing sedimentary sequences.

Rationale for Tract Delineation

The tract was delineated by excluding areas without significant carbonate rocks from the corresponding porphyry Cu tract. Host sedimentary packages include Paleozoic rocks in northeastern Washington, the Wallace Formation of the Middle Proterozoic Belt Supergroup in northern Idaho, and Paleozoic rocks in south-central Idaho (Stoffel and others, 1991; Bond, 1978).

Important Examples of Deposit Type

The Clayton Silver deposit in south-central Idaho is considered to be a polymetallic replacement deposit (Ross, 1937). The deposit occurs as an elongate cigar-shaped stratabound replacement of a carbonate member of the Cambrian Kinnikinnik Quartzite. The mine produced significant silver, lead, and zinc.

Rationale for Numerical Estimate

The low estimate for undiscovered porphyry copper deposits for this tract, the rarity of significant prospects of this deposit type, and the long exploration history of the region led the team to make a very low estimate for undiscovered deposits of this type. For the 90th, 50th, 10th, and 5th percentiles, the team estimated 0, 0, 0, and 1 or more deposits consistent with the grade and tonnage model of Mosier and others (1986).

References

- Bond, J.G., 1978, Geologic map of Idaho: Idaho Bureau of Mines and Geology, scale 1:500,000.
- Morris, H.T., 1986, Descriptive model of polymetallic replacement deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 99-100.
- Mosier, Dan L., Morris, H.T., and Singer, D.A., 1986, Grade and tonnage model of polymetallic replacement deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 101-104.
- Ross, C.P., 1937, Geology and ore deposits of the Bayhorse region, Custer county, Idaho: U.S. Geological Survey Bulletin 877, 161 p.
- Stoffel, K.L., Joseph, N.L., Waggoner, S.Z., Gulick, S.W., Korosec, M.A., and Bunning, B.B., 1991, Geologic map of Washington-Northeast quadrant: Washington Division of Geology and Earth Resources, Geologic Map GM-39, scale 1:250,000.

NR13**Polymetallic Replacement Deposits****Montana
Wyoming****Descriptive Model 19a • Mark3 Index 47****Area = 16,000 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* James E. Elliott**Rationale for Model Choice**

The descriptive model for polymetallic replacement deposits by Morris (Cox and Singer, 1986) was used for undiscovered deposits in Montana and northwestern Wyoming. These deposits are hydrothermal epigenetic deposits consisting of silver-, lead-, zinc-, and copper-bearing minerals in massive lenses, pipes, and veins in carbonate sedimentary rocks near igneous intrusions. Associated igneous rocks are commonly calc-alkaline and porphyritic. Types of alteration include dolomitization and silicification. On a district scale, the deposits are commonly zoned from a copper-rich central area, through a wide lead-silver zone, and to a zinc- and manganese-rich fringe.

Rationale for Tract Delineation

The permissive tract for polymetallic replacement deposits is made up of areas in northwestern, southwestern, and south-central Montana. It consists of those parts of the porphyry copper permissive tract that have sedimentary carbonate rocks at the surface or at shallow depths (less than 1 km) below the surface, based on geologic maps of Montana (Ross and others, 1955) and Wyoming (Love and Christiansen, 1985). The more favorable parts of these areas are where sedimentary carbonate rocks are near igneous contacts, especially near margins of Late Cretaceous or Eocene granite, granodiorite, or dacite porphyry.

The most favorable sedimentary carbonate rocks are Paleozoic, and include the Meagher and Pilgrim Limestones of Cambrian age, the Jefferson Formation of Devonian age, and the Madison Group of Mississippian age. Less favorable carbonate rocks are Mesozoic (Lower Cretaceous Kootenai Formation and Jurassic Ellis Group) and Middle Proterozoic in age (Belt Supergroup: Newland, Empire, Helena, and Wallace Formations).

Important Examples of Deposit Type

There are many known polymetallic replacement deposits or districts in southwestern Montana and numerous prospects in southwestern and south-central Montana and northwestern Wyoming. These have been important producers of silver and lead and were less important for zinc, copper, and gold. The known deposits are the Elkhorn mine, Elkhorn district (Klepper and others, 1957); the Hecla district (Karlstrom, 1948); the Castle Mountain district (Winters, 1968); and the Hope mine, Philipsburg district (Emmons and Calkins, 1913). The prospects occur in many districts where plutons of granitic, granodioritic, or dacitic composition are in contact with sedimentary carbonate rocks, especially those of Paleozoic age.

Ore bodies at the Elkhorn mine consisted of saddle-reefs, pipe-like bodies, and irregular masses in Cambrian limestone (Pilgrim Limestone) below the contact with a shale-limestone sequence (Red Lion Formation). The Elkhorn district is located near the margin of the Boulder batholith (Late Cretaceous), and was a large producer of lead and silver and small amounts of gold.

In the Hecla district, stratiform, pipe-like, and irregular-shaped ore bodies in Cambrian limestone and dolomite (Meagher and Pilgrim Limestones) were mined mainly for lead and silver. Small amounts of gold and copper were also produced. Ore zones in the Hecla district were controlled by anticlines and structural domes. The district is located near the northern margin of the Pioneer batholith, a granitic composite pluton of Late Cretaceous age.

Pipe-, pod-, and irregular-shaped ore bodies that are generally conformable to bedding were exploited in the Castle Mountain mining district. Host rocks for these deposits are limestones of Mississippian (Madison Group), Cambrian (Pilgrim Limestone), and Devonian (Jefferson Limestone) age. The district is located along the margin of a granite pluton and ore bodies are commonly localized along Tertiary dacite porphyry intrusions that are younger than the granite. The district is a large producer of lead and silver.

The Philipsburg district is famous as a large producer of silver and manganese from vein and replacement deposits. One of the principal mines of the district, the Hope mine, is a polymetallic replacement deposit with ore bodies in saddle reefs and irregular stratiform masses that parallel bedding in Devonian limestone (Jefferson Limestone). The district is located near the margins of the Late Cretaceous Philipsburg batholith (granodiorite). The Hope mine was a large producer of silver with minor production of copper, manganese, and lead.

Rationale for Numerical Estimate

For the assessment of polymetallic replacement deposits, the grade-tonnage model of Mosier and others (Cox and Singer, 1986) was used. This set of 52 deposits has a median size of 1.8 million metric tons and median grades of: 5.2 percent lead; 3.9 percent zinc; 0.09 percent copper; 150 g/t silver; and 0.19 g/t gold. The known deposits in Montana are mainly lead-silver deposits and thus differ from the above median grades by having higher grades of lead and silver and lower grades of zinc, copper, and gold. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 1, 4, 6, 8, and 12 or more districts consistent with the grade and tonnage model of Mosier and others (1986).

References

- Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, 379 p.
- Emmons, W.H., and Calkins, F.C., 1913, Geology and ore deposits of the Philipsburg quadrangle, Montana: U.S. Geological Survey Professional Paper 78, 271 p.
- Karlstrom, T.N.V., 1948, Geology and ore deposits of the Hecla mining district, Beaverhead County, Montana: Montana Bureau of Mines and Geology, Memoir No. 25, 87 p.
- Klepper, M.R., Weeks, R.A., and Ruppel, E.T., 1957, Geology of the southern Elkhorn Mountains, Jefferson and Broadwater Counties, Montana: U.S. Geological Survey Professional Paper 292, 82 p.
- Love, J.D., and Christiansen, A.C., 1985, Geologic map of Wyoming: U.S. Geological Survey, scale 1:500,000.
- Ross, C.P., Andrews, D.A., and Witkind, I.J., 1955, Geologic map of Montana: U.S. Geological Survey, scale 1:500,000.
- Winters, A.S., 1968, Geology and ore deposits of the Castle Mountain mining district, Meagher County, Montana: Montana Bureau of Mines and Geology, Bulletin 64, 64 p.

NR14**Alkaline Au-Te Deposits****Washington****Descriptive Model 22b • Mark3 Index 80****Area = 6,420 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Stephen E. Box and Arthur A. Bookstrom**Rationale for Model Choice**

Au-Ag-Te vein deposits, characterized by gold telluride minerals and fluorite, occur as veins and breccia bodies related to hypabyssal or extrusive alkalic rocks (Cox and Bagby, 1986). This description fits a class of gold occurrences in northeastern Washington associated with Mesozoic alkalic igneous complexes. In British Columbia, some deposits are also associated with Eocene alkalic intrusive bodies.

Rationale for Tract Delineation

The permissive tract was defined primarily by the location of Paleozoic and Mesozoic rock units of the Quesnellia island arc terrane (Stoffel and others, 1991), which hosts the Late Triassic to Early Jurassic alkalic intrusive bodies in a late-stage shoshonitic volcanic-intrusive setting (Mortimer, 1986). Eocene alkalic rocks occur sporadically within the Quesnellia terrane near the Canadian border, and have some associated Au prospects. The tract includes several known alkalic intrusive centers (Fox, 1973), with several known telluride-bearing gold deposits.

Important Examples of Deposit Type

The Rossland camp near Rossland, British Columbia (40 km north of the Canada-U.S. border) is considered by some to be a deposit of this type (Fyles, 1984). This deposit is associated with Early Jurassic alkalic volcanic rocks and shallow intrusive bodies. Its tonnage is greater than over 90 percent of deposits of this type. The Comstock and Gold Dike deposits in the Shasket Creek district (a few km south of the Canada-U.S. border north of Republic, Washington) occur in syenitic dikes cutting older Quesnellia terrane rocks (Herdrick and Bunning, 1984; Tschauder, 1989). The grade and tonnage of these deposits are slightly less than the median for this deposit type.

Rationale for Numerical Estimate

As defined by Bliss and others (1992), alkaline Au-Te deposits are small, exhibiting a median of 1.78 million metric tons of ore with a median Au grade of nearly 10 g/t. The Rossland deposit is much larger than the median size and Shasket Creek is slightly smaller than the median. Favorable areas for undiscovered deposits are located south of Rossland in the U.S., near the Shasket Creek intrusive bodies, and near the Similkameen alkalic pluton to the west. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 1, 2, 4 or more deposits consistent with the grade and tonnage model for Au-Ag-Te deposits associated with alkaline rocks (Bliss and others, 1992).

References

- Bliss, J.D., Sutphin, D.M., Mosier, D.L., and Allen, M.S., 1992, Grade-tonnage and target-area models of Au-Ag-Te veins associated with alkaline rocks: U.S. Geological Survey Open-File Report 92-208, 15 p.
- Cox, D.P., and Bagby, W.C., 1986, Descriptive model of Au-Ag-Te veins *in* Cox, D. P., and Singer, D. A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 124.
- Fox, K.F., Jr., 1973, The geology of alkalic complexes in north-central Washington: U.S. Geological Survey Open-File Report 73-73, 192 p.

- Fyles, J.T., 1984, Geological setting of the Rossland mining camp: British Columbia Ministry of Energy, Mines and Petroleum Resources, Bulletin 74, 61 p.
- Herdrick, Melvin, and Bunning, B.B., 1984, Geology of the Gold Dike mine, Ferry County, Washington: Washington Geologic Newsletter, v. 12, no. 1, p. 20-22.
- Mortimer, N., 1986, Late Triassic, arc-related potassic igneous rocks in the North American Cordillera: Geology, v. 14, p. 1035-1038.
- Stoffel, K.L., Joseph, N.L., Waggoner, S.Z., Gulick, S.W., Korosec, M.A., and Bunning, B.B., 1991, Geologic map of Washington-Northeast quadrant: Washington Division of Geology and Earth Resources, Geologic Map GM-39, scale 1:250,000.
- Tschauder, R., 1986, Gold deposits in northern Ferry County, *in* Joseph, N.L., ed., Geologic guidebook for Washington and adjacent areas: Washington Division of Geology and Earth Resources Information Circular 86, p. 239-254.

NR15**Alkaline Au-Te Deposits****Montana****Descriptive Model 22b • Mark3 Index 80****Area = 5,990 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* David Frishman**Rationale for Model Choice**

The descriptive model of Cox and Bagby (1986) and the grade-tonnage and target area model of Bliss and others (1992) were deemed to be the most appropriate models available for this class of deposits. The model is roughly comparable to the deposits termed “alkaline rock-related, gold-only epithermal systems” by Mutschler and Mooney (1995), although we note that many of these deposits are not epithermal using classic definitions. Many of the large precious-metal mines currently in production in Montana are of the alkaline Au-Te type (broadly defined). In Montana, all of these deposits are spatially, and presumable genetically, associated with intrusive centers of Late Cretaceous to Tertiary age that are part of what has been called the Central Montana Alkalic Province (CMAP, Baker and Berg, 1991). This province is characterized by alkaline (dominantly potassic) rocks that occur with subalkaline rocks. Known hypogene deposits are commonly associated with fluorite and tellurides, but host rocks and ore controls can be quite varied. At deposits in the Kendall mining district, most ore is disseminated but stratabound in brecciated Mississippian Madison Limestone, whereas in the Little Rocky Mountains mining area, the vast majority of the tonnage has been produced from epithermal “crackle-breccias” developed in the intrusive rocks themselves. In the Judith Mountains, most production has come from the contact zone between the intrusive rocks and enclosing limestones, whereas at the Golden Sunlight mine in the Whitehall district, ore is associated with potassic alteration and molybdenum mineralization and is localized in a breccia pipe.

Rationale for Tract Delineation

Some of the well-studied examples (Cripple Creek and Boulder County, Colorado and Vatukoula, Fiji) are characterized by great abundance of precious-metal tellurides and the presence of vanadium-bearing mica (roscoelite) in the alteration assemblage. These features are sufficient to characterize deposits, but, because they are easily destroyed by oxidation, and often not noted or overlooked when mining is by bulk methods, they were not useful in tract delineation.

The permissive tract was defined primarily by the location of Cretaceous and Tertiary alkaline intrusive centers believed to be part of the CMAP. Tracts were identified based on lithologic information presented on the State map compiled by Ross and others (1955) supplemented by the personal knowledge of the assessors. Geophysical evidence was used to extend some tracts to covered areas where alkaline plutons may occur in the subsurface. In general, however, the country between known igneous centers, that lacks specific evidence for the existence of concealed intrusions, was excluded. If it were included, the area of this tract would be several times larger, and the apparent density of undiscovered deposits commensurately lower. The intrusive centers identified include those in productive districts (the Judith, North Moccasin, and Little Rocky Mountains, as well as the area around Whitehall), as well as other areas where alkaline rocks of Late Cretaceous to early Tertiary age are present. These areas include the South Moccasin Mountains, the Sweet Grass Hills-Gold Butte area near the Canadian border, the Bearpaw Mountains-Rocky Boy area, the Highwood Mountains, and the northern part of the Little Belt Mountains.

Important Examples of Deposit Type

The Golden Sunlight mine near Whitehall (45 km east-southeast of Butte), the Zortman and Landusky mining areas in the Little Rocky Mountains, and the Canyon Resources mine (formerly the Barnes-King, Muleshoe, Horseshoe, and other underground mines) in the Kendall mining district, North Moccasin Mountains are all large producing mines (Foster and Childs, 1993). The Gies mine (Cone Butte district) and the Spotted Horse mine (Gilt Edge district), both in the Judith Mountains, were minor producers in the late 1980s or early 1990s, and the Spotted Horse, Gilt Edge, and Maginnis mines (Gilt Edge district), the Barnes-King, Horseshoe, Muleshoe and other mines (Kendall district), and numerous mines in the Zortman and Landusky areas in the Little Rocky Mountains were important producers in first half of this century. Numerous gold and fluorite prospects occur in the Bearpaw Mountains and the Sweet Grass Hills; mining companies have explored both of these areas for gold in recent years.

Rationale for Numerical Estimate

As defined by Bliss and others (1992), alkaline Au-Te deposits are small, exhibiting a median of 1.78 million metric tons of ore with a median Au grade of nearly 10 g/t. Most of the producing mines in Montana are larger and lower in grade (Zortman-Landusky contains more than 100 million metric tons of ore at 0.6 g/t Au; Golden Sunlight contains 70 million metric tons of ore at 1.8 g/t Au), but the assessment was made using the low tonnage and high grade specified in the deposit model. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 1, 6, 11, 12, and 20 or more deposits consistent with the grade and tonnage model of Bliss and others (1992).

References

- Baker, D.W., and Berg, R.B., eds., 1991, Guidebook of the Central Montana Alkaline Province—Geology, ore deposits, and origin: Montana Bureau of Mines and Geology Special Publication 100, 201 p.
- Bliss, J.D., Sutphin, D.M., Mosier, D.L., and Allen, M.S., 1992, Grade-tonnage and target-area models of Au-Ag-Te veins associated with alkaline rocks: U.S. Geological Survey Open-File Report 92-208, 15 p.
- Cox, D.P., and Bagby, W.C., 1986, Descriptive model of Au-Ag-Te veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 124.
- Foster, Fess, and Childs, J.F., 1993, An overview of significant lode gold systems in Montana, and their regional geologic setting: *Exploration and Mining Geology*, v. 2, p. 217-244.
- Mutschler, F.E., and Mooney, T.C., 1995, Precious metal deposits related to alkaline igneous rocks—Provisional classification, grade-tonnage data, and exploration frontiers: IAGOD symposium (in press).
- Ross, C.P., Andrews, D.A., and Witkind, I.J., 1955, Geologic map of Montana: U.S. Geological Survey, scale 1:500,000.

NR16**Alkaline Au-Te Deposits**South Dakota
Wyoming

Descriptive Model 22b • Mark3 Index 80

Area = 1,250 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Alan R. Wallace and Steve Ludington

Rationale for Model Choice

A belt of early Tertiary alkaline intrusions cuts across the northern Black Hills. These intrusive systems have associated precious-metal (\pm Te) deposits in the porphyries and adjacent carbonate rocks. The descriptive model of Cox and Bagby (1986) and the grade-tonnage and target area model of Bliss and others (1992) were deemed to be the most appropriate models available for this class of deposit. The model is roughly comparable to the deposits termed “alkaline rock-related, gold-only epithermal systems” by Mutschler and Mooney (1995), although we note that many of these deposits are not epithermal using classic definitions.

Rationale for Tract Delineation

Some of the well-studied examples (Cripple Creek and Boulder County, Colorado and Vatukoula, Fiji) are characterized by great abundance of precious-metal tellurides and the presence of vanadium-bearing mica (roscoelite) in the alteration assemblage. These features are sufficient to characterize deposits, but, because they are easily destroyed by oxidation, and often not noted or overlooked when mining is by bulk methods, they were not useful in tract delineation.

Alkaline igneous rocks, ranging in age from about 62 to 38 Ma, form a more-or-less continuous east-trending belt across the northern Black Hills, in South Dakota and Wyoming. Rocks range in composition from quartz-normative rhyolite to nepheline-normative phonolite (DeWitt and others, 1986). They were emplaced into Phanerozoic sedimentary rocks and Precambrian metamorphic rocks, and many undoubtedly are present at a shallow depth in intervening areas between exposures. The permissive tract is the area encompassing: (1) the exposed igneous rocks, (2) the intervening areas, which likely have concealed igneous rocks within a kilometer of the surface, and (3) a somewhat arbitrary buffer around the outside margins of the area of exposed rocks to take into account peripheral bodies less than a kilometer deep.

Important Examples of Deposit Type

The northern Black Hills contain several producing mines and abundant prospects of various sizes. Porphyry-hosted deposits are present at the Gilt Edge, Golden Reward, and Richmond Hill mines; Ragged Top, Cutting, and Mineral Hill are important prospects. DeWitt and Wilson (1990) list at least nineteen other prospects of this deposit type. Many deposits formed as replacement deposits in Paleozoic carbonate rocks adjacent to alkaline intrusions. Known deposits in carbonate rocks, which also have significant amounts of ore in the adjacent porphyries, include Annie Creek and Foley Ridge; DeWitt and Wilson (1990) list several dozen more prospects hosted in carbonate rocks.

Rationale for Numerical Estimate

Although the permissive area has been explored for more than a century, only in the last 15 years have many previously mined areas, such as at Annie Creek, Gilt Edge, and Golden Reward, been explored for bulk-mineable deposits. The area contains numerous small prospects as well as a significant covered area that could contain more porphyry- and carbonate-hosted deposits. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 1, 2, 3, 4, and 5 or more deposits consistent with the grade and tonnage model of Bliss and others (1992).

References

- Bliss, J.D., Sutphin, D.M., Mosier, D.L., and Allen, M.S., 1992, Grade-tonnage and target-area models of Au-Ag-Te veins associated with alkaline rocks: U.S. Geological Survey Open-File Report 92-208, 15 p.
- Cox, D.P., and Bagby, W.C., 1986, Descriptive model of Au-Ag-Te veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 124.
- DeWitt, Ed, and Wilson, A.B., 1990, Metallic mineral districts and mines of the northern Black Hills, South Dakota and Wyoming: Society of Economic Geologists Guidebook Series, v. 7, p. 20-30.
- DeWitt, Ed, Redden, J.A., Wilson, A.B., and Buscher, David, 1986, Mineral resource potential and geology of the Black Hills National Forest, South Dakota and Wyoming, *with a section on* Salable commodities by J.S. Dersch: U.S. Geological Survey Bulletin 1580, 135 p.
- Mutschler, F.E., and Mooney, T.C., 1994, Precious metal deposits related to alkaline igneous rocks—Provisional classification, grade-tonnage data, and exploration frontiers: IAGOD symposium, in press.

NR17**Massive Sulfide Deposits, Besshi Type**

Washington

Descriptive Model 24b • Mark3 Index 30

Area = 1,660 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Stephen E. Box and Arthur A. Bookstrom

Rationale for Model Choice

Besshi massive sulfide deposits are thin, sheetlike bodies of massive to well-laminated pyrite, pyrrhotite, and chalcopyrite within marine clastic sedimentary deposits and mafic tuffs associated with submarine mafic volcanic rocks (Cox, 1986). Besshi-type volcanic-hosted massive sulfide ore deposits produce copper and zinc, with gold and silver as common byproducts. Paleozoic rocks of the Covada Group or Kootenay terrane in northern Washington and southern British Columbia are host to deposits and prospects that have characteristics similar to Besshi-type massive sulfide deposits.

Rationale for Tract Delineation

The genesis of this deposit type is uncertain due to the amount of regional deformation and metamorphism of the deposits in the type locality in Japan. However, the general exploration criteria for these deposits include: (1) clastic terrigenous sedimentary rocks and interbedded mafic volcanic tuffs and breccia host rocks; (2), local association with black shale, oxide-facies iron formation and red chert; (3) formation from submarine hot springs related to basaltic magmatism in rifted basins in island-arc or back-arc tectonic settings.

The Kootenay terrane or Covada Group consists of a Paleozoic continental slope and rise sequence west of the North American Paleozoic continental shelf sequence (Smith and Gehrels, 1992). Sporadic occurrences of ferruginous chert associated with volcanic rocks indicate synvolcanic hot-spring activity, which is believed to be conducive to the formation of Besshi-type massive sulfide deposits. The permissive tract was drawn to include all of the Covada Group in the U.S. (Stoffel and others, 1991).

Important Examples of Deposit Type

In British Columbia, two important deposits of this type are known from this belt of rocks. The Goldstream deposit has reserves of 3.2 million metric tons containing 4.5 percent copper, 3.1 percent zinc, and 20 grams per metric ton of silver (Hoy, 1991). The True Blue deposit further south is another deposit of this type in British Columbia. In Washington, prospects and small deposits of this type are known but none have been major producers.

Rationale for Numerical Estimate

The lack of known major deposits in Washington or immediately across the border in British Columbia, along with the long history of exploration in northern Washington, cause us to consider this tract to have low potential for undiscovered deposits of this type. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, 1 or more deposits consistent with the grade and tonnage model described by Singer (1986).

References

- Cox, D.P., 1986, Descriptive model of Besshi massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 136.
- Hoy, Trygve, 1991, Volcanogenic massive sulphide deposits in British Columbia, *in* McMillan, W.J., and others, eds., Ore deposits, tectonics and metallogeny in the Canadian Cordillera: Ministry of Energy, Mines, and Petroleum Resources, Paper 1991-4, p. 89-123.

- Smith, Moira, and Gehrels, G.E., 1992, Stratigraphic comparison of the Lardeau and Covada Groups: implications for revision of stratigraphic relations in the Kootenay Arc: *Canadian Journal of Earth Sciences*, v. 29, p. 1320-1329.
- Singer, D.A., 1986, Grade and tonnage model of Besshi massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 136-138.
- Stoffel, K.L., Joseph, N.L., Waggoner, S.Z., Gulick, S.W., Korosec, M.A., and Bunning, B.B., 1991, *Geologic map of Washington-Northeast quadrant*: Washington Division of Geology and Earth Resources, Geologic Map GM-39, scale 1:250,000.

NR18**Massive Sulfide Deposits, Kuroko Type**

Washington

Descriptive Model 28a • Mark3 Index 93

Area = 1,570 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Stephen E. Box and Arthur A. Bookstrom

Rationale for Model Choice

Kuroko massive sulfide deposits are stratabound accumulations of massive Fe-sulfides with subordinate (but economically significant) layers and lenses of Cu, Zn, and Pb sulfide minerals (Singer, 1986). These are deposited on the seafloor around hydrothermal vents associated with felsic and intermediate volcanic rocks in and around island-arc volcanic complexes. The Quesnellia terrane in northeastern Washington is considered to be an accreted island-arc terrane (Mortimer, 1986).

Rationale for Tract Delineation

All of the Permian through Jurassic rocks of the Quesnellia terrane are considered permissive for kuroko massive sulfide deposits (Stoffel and others, 1991). The Quesnellia terrane in northeastern Washington consists of Permian through Jurassic arc volcanic rocks and associated sedimentary rocks (Mortimer, 1986).

Important Examples of Deposit Type

Although no known Kuroko massive sulfide deposits are known from this terrane in Washington, there are known deposits in the Quesnellia terrane in British Columbia to the north.

Rationale for Numerical Estimate

The lack of known deposits or prospects of massive sulfide deposits in northeastern Washington led the team to give a very low estimate for the occurrence of an undiscovered deposit here. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, and 1 or more kuroko deposits consistent with the grade and tonnage model of Singer and Mosier (1986).

References

- Mortimer, N., 1986, Late Triassic, arc-related potassic igneous rocks in the North American Cordillera: *Geology*, v. 14, p. 1035-1038.
- Singer, D.A., 1986, Descriptive model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models: U.S. Geological Survey Bulletin 1693*, p. 189.
- Singer, D.A., and Mosier, D.L., 1986, Grade and tonnage model of kuroko deposits, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models: U.S. Geological Survey Bulletin 1693*, p. 190-197.

NR19**Massive Sulfide Deposits, Kuroko Type****Montana****Descriptive Model 28a • Mark3 Index 93****Area = 1,570 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* B.R. Berger and Alan R. Wallace**Rationale for Model Choice**

Archean metamorphic rocks in the southern Ruby Range and the Gravelly Range contain metabasalts with some associated sulfides. In the Ruby Range, the rocks contain silica- and alumina-rich minerals, including anthophyllite and corundum, that may represent a metamorphosed alteration assemblage. This association may indicate a kuroko massive sulfide environment.

Rationale for Tract Delineation

The tract consists of areas of Archean metamorphic rocks in the southern Ruby Range and the Gravelly Range that contain metabasalts with some associated sulfides. Apparently these are very local within the larger package of Archean metamorphic rocks.

Important Examples of Deposit Type

None are known.

Rationale for Numerical Estimate

Based upon the limited information available, the team judged that the presence of metabasalts could allow massive sulfide deposits to be present, although a bimodal volcanic assemblage is not known. The possible metamorphosed alteration assemblage could indicate siliceous alteration, which would suggest a kuroko-type setting. Lacking further positive information, the team made a small estimate. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, and 1 or more deposits consistent with the grade and tonnage model for kuroko massive sulfide deposits (Singer and Mosier, 1986).

Reference

Singer, D.A., and Mosier, D.L., 1986, Grade and tonnage model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 190-197.

NR20**Massive Sulfide Deposits, Kuroko Type****Wyoming****Descriptive Model 28a • Mark3 Index 93****Area = 2,540 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Warren Day**Rationale for Model Choice**

In Wyoming, the Proterozoic rocks exposed in Precambrian uplifts contain several small massive sulfide deposits and occurrences that have characteristics similar to kuroko massive sulfide deposits. These deposits generally form near the top of bimodal submarine volcanic sequences in island-arc-related extensional basins near centers of felsic volcanism and range from Archean to Cenozoic in age. The upper parts of the deposits are stratiform and contain sulfide minerals of copper, zinc, and iron; there is commonly an underlying zone of stockwork, stringers, and veins rich in copper and iron sulfides. The descriptive model of Singer (1986) was used for the assessment.

Rationale for Tract Delineation

Several Precambrian terranes in Wyoming, north of the Nash Fork-Mullen suture zone, have potential for kuroko-type volcanic-hosted massive sulfide deposits, which are important sources of copper and zinc and commonly have byproduct gold and silver. The criteria for delineation of the permissive tract include: (1) submarine volcanic host rocks of felsic composition; (2) island-arc tectonic setting with local extensional deformation at the time of mineralization; and, (3) exhalative horizons within the supracrustal sequence associated with the volcanic rocks (for example, iron-formations or cherty horizons) that indicate the evidence for submarine hydrothermal hot-spring activity during volcanism. The team outlined 14 areas that meet the criteria outlined above, and, together, they constitute the permissive tract. The criteria used for this assessment followed those outlined by Eckstrand (1984) and Singer (1986) for regional evaluations of Precambrian terranes similar to those of Wyoming.

Important Examples of Deposit Type

Although prospects of this type are known in several locations, few had reported production.

Rationale for Numerical Estimate

The assessment team wishes to acknowledge the helpful suggestions of W. D. Hausel of the Geological Survey of Wyoming. These estimates were tempered with the fact that there has been minimal development of massive sulfide deposits of this type in Wyoming. The area thought to have highest probability was the Hartville uplift region, with an estimated 8 percent chance of hosting such a deposit. The volcanic and sedimentary rocks of the South Pass-Atlantic City area was estimated to have a 5 percent chance to host a volcanic-hosted massive sulfide deposit, based on the presence of the large banded iron-formation deposit at South Pass, Wyoming. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 3, and 4 deposits consistent with the grade and tonnage model of Singer and Mosier (1986).

References

- Eckstrand, O.R., Canadian mineral deposit types—A geological synopsis: Geological Survey of Canada Economic Geology Report 36, 86 p.
- Singer, D.A., 1986, Descriptive model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 189-190.

Singer, D.A., and Mosier, D.L., 1986, Grade and tonnage model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 190-197.

NR21**Epithermal Vein Deposits, Comstock Type****Washington****Descriptive Model 25c • Mark3 Index 16****Area = 3,180 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* Stephen E. Box and Arthur A. Bookstrom**Rationale for Model Choice**

Epithermal Au-Ag quartz-adularia vein deposits are hosted in subaerial, intermediate to felsic volcanic rocks (Mosier and others, 1986a). The Republic mining district consists of several such deposits (Tschauder, 1986). Deposits in this district occur in Eocene dacitic volcanic and volcanoclastic rocks that are widespread in northeastern Washington (Pearson and Obradovich, 1977).

Rationale for Tract Delineation

The permissive tract was delineated to include the Eocene volcanic and volcanoclastic rocks of the Republic graben and adjacent areas of northeastern Washington (Stoffel and others, 1991). Most of the permissive tract in northeastern Washington was considered to be favorable, because of the similarity of volcanic stratigraphy and structural setting, and the occurrence of three known districts. Volcanism and mineralization were broadly contemporaneous with detachment faulting above the Okanogan, Kettle, and Priest River metamorphic core complexes. The 15 or so apparently separate volcanic fields may have originally been part of a more continuous volcanic province that was extended and dismembered by detachment faulting and erosion.

Important Examples of Deposit Type

The Republic and adjacent areas of northeastern Washington contains numerous volcanic-hosted deposits, prospects, and occurrences. The Golden Promise mine in Republic is an important example of this type (Tschauder, 1986). The vein system has been mined for over 300 m down dip. The prominent vein system becomes a stockwork system in the upper part, and grades into an overlying hot-spring Au-bearing sinter, which is being exploited as part of the underground mine.

Rationale for Numerical Estimate

The widely scattered favorable areas, the existence of numerous Au prospects in the region, the great productivity of the Republic district, and the poor exposure caused us to give a fairly optimistic estimate of the number of undiscovered districts. Although Comstock veins in the area grade up into more disseminated hot-spring systems, erosion has removed much of the favorable ground for hot springs, and we assessed only for Comstock deposits. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 1, 2, 4, 5, and 8 or more districts consistent with the grade and tonnage model of Mosier and others (1986b).

References

- Mosier, D.L., Singer, D.A., and Berger, B.R., 1986a, Descriptive model of Comstock epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 150.
- Mosier, D.L., Singer, D.A., and Berger, B.R., 1986b, Grade and tonnage model of Comstock epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 151-153.

- Pearson, R.C., and Obradovich, J.D., 1977, Eocene rocks in northeast Washington—Radiometric ages and correlation: U.S. Geological Survey Bulletin 1433, 41 p.
- Stoffel, K.L., Joseph, N.L., Waggoner, S.Z., Gulick, S.W., Korosec, M.A., and Bunning, B.B., 1991, Geologic map of Washington-Northeast quadrant: Washington Division of Geology and Earth Resources, Geologic Map GM-39, scale 1:250,000.
- Tschauder, R., 1986, Gold deposits in northern Ferry County, *in* Joseph, N.L., ed., Geologic guidebook for Washington and adjacent areas: Washington Division of Geology and Earth Resources Information Circular 86, p. 239-254.

NR22**Epithermal Vein Deposits, Comstock Type**

Idaho

Descriptive Model 25c

Area = 17,600 km²[Model](#)

by Stephen E. Box and Arthur A. Bookstrom

Rationale for Model Choice

Epithermal Au-Ag quartz-adularia vein deposits are hosted in subaerial, intermediate to felsic volcanic rocks (Mosier and others, 1986). Known deposits of Comstock type occur in the Eocene Challis volcanic field, and have been mined historically (i.e., Yankee Fork district) (Anderson, 1949). Typically these deposits consist of a vein system that becomes dispersed into stockwork veining upward, sometimes capped by hot-spring sinter deposits. Older mining concentrated on the vein system, whereas, recently active mines are focused in the upper, more disseminated stockwork and hot-spring parts of the mineralized systems, typically as open pit mines.

Rationale for Tract Delineation

The permissive tract was delineated to include the Eocene Challis volcanic field of south-central Idaho (Bond, 1978). Favorable areas for epithermal districts include broad areas of known mineralization associated with a major northeast-trending, subvertical Trans-Challis fault zone (Kiilsgaard and others, 1986).

Important Examples of Deposit Type

The Eocene Challis volcanic field in south-central Idaho is host to three major districts: the Thunder Mountain district in the Thunder Mountain caldera on the west, the Yankee Fork district in the northeast-trending Trans-Challis fault zone, and the Champagne deposit at the margin with the Snake River plain (a Pliocene feature). Active mines in each district exploit the stockwork, disseminated, upper parts of these hydrothermal deposits, which have the grade and tonnage characteristics of hot-spring Au-Ag deposits. However older mines, in the Yankee Fork district in particular, were concentrated on the deeper, vein portion of these hydrothermal deposits.

Rationale for Numerical Estimate

Contemporaneous faulting and volcanism in the Trans-Challis fault zone, along with two known prospect areas there, lead us to consider the area of the intersection of the fault zone and the volcanic field as favorable for undiscovered epithermal districts. Irregular cover of the favorable lower part of the volcanic field by younger lavas and ash-flows of the unmineralized upper part of the field suggests exploration has not fully evaluated this area. However, because recent mining has focused on the bulk mineable part of the mineralized systems, we expect that most undiscovered Comstock mineralization will be mined as part of an open pit operation that will result in a higher tonnage and lower grade production that better fits the hot-spring Au-Ag grade and tonnage model of Berger and Singer (1992). Therefore, since we estimate the number of undiscovered hot-spring Au-Ag deposits, we make no estimate for the number of undiscovered Comstock deposits.

References

- Anderson, A.L., 1949, Silver-gold deposits of the Yankee Fork district, Custer County, Idaho: Idaho Bureau of Mines and Geology Pamphlet 83, 37 p.
- Berger, B.R., and Singer, D.A., 1992, Grade and tonnage model for hot spring Au-Ag, in Bliss, J.D., ed., Developments in mineral deposit modeling, U.S. Geological Survey Bulletin 2004, p. 23-25.

- Bond, J.G., 1978, Geologic map of Idaho: Idaho Bureau of Mines and Geology, scale 1:500,000.
- Kiilsgaard, T.H., Fisher, F.S., and Bennett, E.H., 1986, The Trans-Challis fault system and associated precious metal deposits, Idaho: *Economic Geology*, v. 81, no. 3, p. 721-724.
- Mosier, D.L., Singer, D.A., and Berger, B.R., 1986, Descriptive model of Comstock epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 150.

NR23**Epithermal Vein Deposits, Comstock Type**

Idaho

Descriptive Model 25c

Area = 14,400 km²[Model](#)*by* Stephen E. Box and Arthur A. Bookstrom**Rationale for Model Choice**

Epithermal Au-Ag quartz-adularia vein deposits are hosted in subaerial, intermediate to felsic volcanic rocks (Mosier and others, 1986). The Pliocene to Holocene Yellowstone volcanic field to the east consists of Neogene felsic volcanic rocks with known Holocene and present-day hot springs. Some of these hot-spring systems are presumed to grade downward into structurally controlled vein systems of Comstock type.

Rationale for Tract Delineation

The permissive tract was delineated to include felsic volcanic rocks of the Pliocene to Holocene Yellowstone volcanic field. These volcanic rocks are buried on the west by basaltic lavas of the Snake River Plain. The permissive tract was drawn to include the felsic volcanic rocks where they are covered by less than a kilometer of overlying basalt (Bond, 1978).

Important Examples of Deposit Type

The modern hot springs of Yellowstone National Park are taken to be active discharges of deeper, developing Comstock vein systems. However, no Comstock vein systems are presently known.

Rationale for Numerical Estimate

Since the Yellowstone volcanic field has not been strongly eroded and is buried by younger basalts on the west, any undiscovered Comstock-type deposit will probably be found beneath a high-level stockwork and hot-spring deposit, and would probably be bulk mined along with the more disseminated high-level deposit that will result in a higher tonnage and lower grade production that better fits the hot-spring Au-Ag grade and tonnage model of Berger and Singer (1992). Therefore, since we estimate the number of undiscovered hot-spring Au-Ag deposits, we make no estimate for the number of undiscovered Comstock deposits.

References

- Berger, B.R., and Singer, D.A., 1992, Grade and tonnage model for hot-spring Au-Ag, *in* Bliss, J.D., ed., *Developments in mineral deposit modeling*, U.S. Geological Survey Bulletin 2004, p. 23-25.
- Bond, J.G., 1978, *Geologic map of Idaho*: Idaho Bureau of Mines and Geology, scale 1:500,000.
- Mosier, D.L., Singer, D.A., and Berger, B.R., 1986, Descriptive model of Comstock epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 150.

NR24 **Epithermal Vein Deposits, Quartz-adularia Type** **Montana**
Descriptive Model 25c + 25d • Mark3 Index 25
Area = 2,160 km²

[Cumulative Distribution](#)

[Histogram](#)

[Table](#)

[Model](#)

[Mineral Deposits](#)

by David Frishman

Rationale for Model Choice

We chose to evaluate Montana for epithermal quartz-adularia vein deposits because the geology of Montana seems to be permissive for the occurrence of this type of deposit. Several important examples are known. We did not feel that we could distinguish between the different styles of mineralization described by Mosier, Menzie, and Kleinhampl (1986), and so we evaluated the possible occurrence of epithermal vein districts using a combination of the Comstock and Sado grade and tonnage models (Mark3 index 25).

Rationale for Tract Delineation

For the purpose of delineating the permissive tract, the three subtypes of epithermal precious-metal vein deposits (quartz-adularia, quartz alunite, and hot-spring) were treated the same. It was judged that the criteria available to discriminate between the subtypes were too imprecise to use effectively. Probabilities of occurrence for the individual types were assigned separately, however.

Permissive areas that constitute the tract are generally small, and are scattered throughout western Montana. They were defined by the location of known active or fossil hot springs, the location of mines, prospects, and occurrences believed to represent epithermal deposits, and the location of Tertiary and Quaternary volcanic and hypabyssal rocks as shown on the Montana geologic map (Ross and others, 1955).

Areas identified include the Hog Heaven volcanic field, volcanic rocks near Lincoln (McDonald Meadows property), volcanic rocks near Helena and Avon, several areas of the Lowland Creek Volcanics southwest of Helena and north and west of Butte, the Virginia City-Alder Gulch area, an area of Challis Volcanics exposed in the Horse Prairie area southwest of Dillon, the Marysville district, and small parts of Montana adjacent to the Yellowstone caldera in Wyoming.

Important Examples of Deposit Type

Possible representatives include the Flathead and West Flathead mines and related Oligocene deposits in the Hog Heaven volcanic field west of Flathead Lake, some of the andesite-hosted veins (age unknown) in the Virginia City district, an epithermal vein in the Elkhorn Mountains, and chalcedony veins in the Clancy district south of Helena. It should be noted that some deposits, for example, the epithermal Pb-Ag deposits at the Flathead mine, do not possess exactly the same attributes as the published models. The deposits at the Flathead mine apparently occur at the very uppermost levels of the hydrothermal system, yet they are dominantly Pb-Ag deposits, not gold-rich deposits as might be expected according to some models.

Rationale for Numerical Estimate

For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 1, 3, 5, 6, and 9 or more deposits consistent with the grade and tonnage model.

References

Mosier, D.L., Menzie, W.D., and Kleinhampl, F.J., 1986, Geologic and grade-tonnage information on Tertiary epithermal precious- and base-metal vein districts associated with volcanic rocks: U.S. Geological Survey Bulletin 1666, 39 p.

Ross, C.P., Andrews, D.A., and Witkind, I.J., 1955, Geologic map of Montana: U.S. Geological Survey. scale 1:500,000.

NR25**Epithermal Vein Deposits, Comstock Type****Wyoming****Descriptive Model 25c • Mark3 Index 16****Area = 5,380 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Steve Ludington and David Frishman**Rationale for Model Choice**

The cluster of volcanic centers called the Yellowstone caldera system, northwestern Wyoming is an excellent example of a modern geothermal system. The deeper parts of systems like this are the environment where epithermal vein deposits form, and it seems quite likely that precious-metal-bearing veins lie below the surface in northwestern Wyoming.

Rationale for Tract Delineation

The permissive tract is delineated to include the central part of the Yellowstone volcanic field, including the three Yellowstone calderas (White and others, 1988); some areas were excluded from the permissive tract where the volcanic rocks are known to be only a thin mantle of distal outflow facies. Most tract boundaries were derived from the geologic map of Wyoming by Love and Christiansen (1985).

Important Examples of Deposit Type

There are no known vein deposits within or near the tract, however, the area has been withdrawn from mineral entry since 1872 and there has been no exploration. There are several areas of intense hydrothermal activity and alteration, which are indicative of mineralization below. Areas currently experiencing hydrothermal activity and alteration include Mammoth Hot Springs, the Norris-Elk Park-Gibbon Geyser Basin area, the Lower, Midway, and Upper Geyser Basins, Yellowstone Canyon, the West Thumb Geyser Basin, the Heart Lake Geyser Basin, Washburn Hot Springs and a large area to the east that hosts Whistler geyser, Rainbow Springs, and Coffee Hot Springs, among others.

Rationale for Numerical Estimate

The presence of many active hydrothermal systems is indicative of mineralization. In addition, anomalous gold values (0.5 to 10 g/t) have been detected in sinter from Gibbon geyser basin and in hydrothermal quartz from Norris geyser basin (White and others, 1992). However, some deposits may be buried by younger rocks, and our estimate is smaller than the one for hot-spring Au-Ag in the corresponding tract. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 1, 4, and 5 or more deposits consistent with the grade and tonnage model of Mosier and others (1986).

References

- Love, J.D., and Christiansen, A.C., 1985, Geologic map of Wyoming: U.S. Geological Survey, scale 1:500,000.
- Mosier, D.L., Singer, D.A., and Berger, B.R., 1986b, Grade and tonnage model of Comstock epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 151-153.
- White, D.E., Hutchinson, R.A., and Keith, T.E.C., 1988, The geology and remarkable thermal activity of Norris Geyser Basin, Yellowstone National Park, Wyoming: U.S. Geological Survey Professional Paper 1456, 84 p.

White, D.E., Heropoulos, Chris, and Fournier, R.O., 1992, Gold and other minor elements associated with hot springs and geysers of Yellowstone National Park, Wyoming, supplemented with data from Steamboat Springs, Nevada: U.S. Geological Survey Bulletin 2001, 19 p.

NR26**Epithermal Vein Deposits, Quartz-alunite Type****Montana****Descriptive Model 25e • Mark3 Index 38****Area = 2,160 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* David Frishman**Rationale for Model Choice**

We chose to evaluate Montana for epithermal quartz-alunite gold deposits of the type described by Berger (1986) because the geology of Montana seems to be permissive for the occurrence of this type of deposit. We used the grade and tonnage model of Mosier and Menzie (1986).

Rationale for Tract Delineation

For the purpose of delineating the permissive tract, the three subtypes of epithermal precious-metal vein deposits (quartz-adularia, quartz alunite, and hot-spring) were treated the same. It was judged that the criteria available to discriminate between the subtypes were too imprecise to use effectively. Probabilities of occurrence for the individual types were assigned separately, however.

Permissive areas that constitute the tract are generally small, and are scattered throughout western Montana. They were defined by the location of known active or fossil hot springs, the location of mines, prospects, and occurrences believed to represent epithermal deposits, and the location of Tertiary and Quaternary volcanic and hypabyssal rocks as shown on the Montana geologic map (Ross and others, 1955).

Areas identified include the Hog Heaven volcanic field, volcanic rocks near Lincoln (McDonald Meadows property), volcanic rocks near Helena and Avon, several areas of the Lowland Creek Volcanics southwest of Helena and north and west of Butte, the Virginia City-Alder Gulch area, an area of Challis Volcanics exposed in the Horse Prairie area southwest of Dillon, the Marysville district, and small parts of Montana adjacent to the Yellowstone caldera in Wyoming.

Important Examples of Deposit Type

We know of no deposits of this type in the State, nor any sizeable areas that have undergone quartz-alunite alteration, although alunite is present locally in some of the geyser basins in Yellowstone National Park (White and others, 1988) and quartz-kaolinite-alunite alteration occurs in the Hog Heaven volcanic field (Cossaboom, 1981).

Rationale for Numerical Estimate

Because there are no known prospects or areas of alteration and because the tectonic regime during volcanism was apparently never extensional, it was judged that the chance for the occurrence of quartz-alunite deposits in the permissive tract was very low. The team assigned a 1 percent chance for the occurrence of an undiscovered quartz-alunite gold deposit like those described by Mosier and Menzie (1986).

References

- Berger, B.R., 1986, Descriptive model of epithermal quartz-alunite Au, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 158.
- Cossaboom, C.C., 1981, Alteration, petrology, and mineralization of the Flathead mine, Hog Heaven mining district, Flathead County, Montana: Missoula, University of Montana, Masters thesis, 103 p.

- Mosier, D.L., and Menzie, W.D., 1986, Grade and tonnage model of epithermal quartz-alunite Au, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 159-161.
- Ross, C.P., Andrews, D.A., and Witkind, I.J., 1955, Geologic map of Montana: U.S. Geological Survey . scale 1:500,000.
- White, D.E., Hutchinson, R.A., and Keith, T.E.C., 1988, The geology and remarkable thermal activity of Norris Geyser Basin, Yellowstone National Park, Wyoming: U.S. Geological Survey Professional Paper 1456, 84 p.

NR27**Hot-spring Au-Ag Deposits**

Washington

Descriptive Model 25a**Area = 3,180 km²**[Model](#)*by* Stephen E. Box and Arthur A. Bookstrom**Rationale for Model Choice**

Hot-spring Au-Ag deposits consist of precious metal-bearing siliceous sinters and silicified rocks cut by breccias and stockworks of veins and veinlets, which were deposited at or near the surface in and around felsic volcanic fields, usually associated with normal faults (Berger, 1986). Hot-spring Au-Ag deposits are known in the Republic mining district (Tschauder, 1989), although they appear to be small deposits in the upper part of associated Comstock-type deposits.

Rationale for Tract Delineation

The permissive tract was delineated to include the Eocene volcanic and volcanoclastic rocks of the Republic graben and adjacent areas of northeastern Washington (Stoffel and others, 1991). Volcanism and mineralization were broadly contemporaneous with detachment faulting above the Okanogan, Kettle, and Priest River metamorphic core complexes. Eocene, gold-bearing hydrothermal systems are known from several of these volcanic sequences.

Important Examples of Deposit Type

The Republic and adjacent areas of northeastern Washington contains numerous volcanic-hosted Au-Ag deposits, prospects, and occurrences. Each of these appears to be primarily a Comstock vein system with a subordinate hot-spring deposit in its upper part. The Golden Promise mine in Republic is an important example of this type (Tschauder, 1986). The vein system has been mined for over 300 m down dip. The prominent vein system becomes a stockwork system in the upper part, and grades into an overlying hot-spring Au-bearing sinter, which has been mined as part of the underground mine .

Rationale for Numerical Estimate

Since Comstock veins in the area grade up into more disseminated hot-spring systems, our estimate for undiscovered Comstock deposits includes both deposit types as part of the same system (Mosier and others, 1986), and we do not make a separate estimate for hot-spring Au-Ag deposits.

References

- Berger, B. R., 1986, Descriptive model of hot-spring Au-Ag deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 143.
- Mosier, D.L., Singer, D.A., and Berger, B.R., 1986b, Grade and tonnage model of Comstock epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 151-153.
- Stoffel, K.L., Joseph, N.L., Waggoner, S.Z., Gulick, S.W., Korosec, M.A., and Bunning, B.B., 1991, Geologic map of Washington-Northeast quadrant: Washington Division of Geology and Earth Resources, Geologic Map GM-39, scale 1:250,000.
- Tschauder, R., 1986, Gold deposits in northern Ferry County, *in* Joseph, N.L., ed., Geologic guidebook for Washington and adjacent areas: Washington Division of Geology and Earth Resources Information Circular 86, p. 239-254.

NR28**Hot-spring Au-Ag Deposits**

Idaho

Descriptive Model 25a • Mark3 Index 45

Area = 17,600 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Stephen E. Box and Arthur A. Bookstrom

Rationale for Model Choice

Hot-spring Au-Ag deposits consist of precious metal-bearing siliceous sinters and silicified rocks cut by breccias and stockworks of veins and veinlets, which were deposited at or near the surface in and around felsic volcanic fields, usually associated with normal faults (Berger, 1986). Typically this disseminated mineralization focuses downward into a vein system of the Comstock type. In this tract, older mining concentrated on the vein system in underground mines. Associated hot-spring type mineralization is known to occur around the older mining districts and elsewhere in the Eocene Challis volcanic field.

Rationale for Tract Delineation

The permissive tract was delineated to include the Eocene Challis volcanic field of south-central Idaho (Bond, 1978), the host of the three known deposits.

Important Examples of Deposit Type

The Eocene Challis volcanic field in south-central Idaho is host to three major deposits or districts of this type, each of which has an open-pit mine operating in 1994: the Thunder Mountain district in the Thunder Mountain caldera, the Yankee Fork district in the northeast-trending Trans-Challis fault zone, and the Champagne deposit in the Lava Creek district at the margin of the Snake River plain (a Pliocene feature). The Yankee Fork and Lava Creek districts include a number of inactive mines which exploited associated Comstock-type mineralization.

Rationale for Numerical Estimate

Contemporaneous faulting and volcanism in the Trans-Challis fault zone, along with two known prospect areas there, lead us to consider the area of the intersection of the fault zone and the volcanic field as favorable for undiscovered hot-spring deposits. Irregular cover of the favorable lower part of the volcanic field by younger lavas and ash-flows of the unmineralized upper part of the field suggests that exploration has not fully evaluated this area. At the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 2, 5, 7, and 8 or more deposits consistent with the grade and tonnage model of Berger and Singer (1992).

References

- Berger, B.R., 1986, Descriptive model of hot-spring Au-Ag deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 143.
- Berger, B.R., and Singer, D.A., 1992, Grade and tonnage model for hot-spring Au-Ag, *in* Bliss, J.D., ed., Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, p. 23-25.
- Bond, J.G., 1978, Geologic map of Idaho: Idaho Bureau of Mines and Geology, scale 1:500,000.
- Mosier, D.L., Singer, D.A., and Berger, B.R., 1986a, Descriptive model of Comstock epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 150.
- Mosier, D.L., Singer, D.A., and Berger, B.R., 1986b, Grade and tonnage model of Comstock epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 151-153.

NR29**Hot-spring Au-Ag Deposits**

Idaho

Descriptive Model 25a • Mark3 Index 45

Area = 14,400 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Stephen E. Box and Arthur A. Bookstrom

Rationale for Model Choice

Hot-spring Au-Ag deposits consist of precious-metal-bearing siliceous sinters and silicified rocks cut by breccias and stockworks of veins and veinlets, which were deposited at or near the paleo-ground surface in and around felsic volcanic fields, usually associated with normal faults (Berger, 1986). The Yellowstone volcanic field consists of Neogene felsic volcanic rocks with known present-day hot springs. Gold is known to occur in subeconomic grades in modern hot springs in Yellowstone National Park to the east (White and others, 1992).

Rationale for Tract Delineation

The permissive tract was delineated to include felsic volcanic rocks of the Pliocene to Holocene Yellowstone volcanic field (Bond, 1978). This includes the Pliocene rhyolites of the Island Mountain caldera. These volcanics rocks are buried on the west by basaltic lavas of the Snake River Plain. The permissive tract was drawn to include the felsic volcanic rocks where they are covered by less than a kilometer of overlying basalt.

Important Examples of Deposit Type

The modern hot springs of Yellowstone National Park indicate that hydrothermal systems are associated with this rhyolitic volcanic province, some with anomalous gold concentrations (White and others, 1972). Although no economic deposits are known, some anomalous Au, Hg, and As concentrations in stream sediments in the area indicate potential for undiscovered deposits (Shannon, 1980).

Rationale for Numerical Estimate

Since the Pliocene precursor of the Yellowstone volcanic field has not been strongly eroded and is buried by younger basalts on the west, undiscovered hot-spring Au-Ag deposits could be buried beneath younger, unmineralized volcanic rocks with no surface indication of mineralization. Based on the few stream sediment anomalies and the lack of known prospects, the team estimated a low probability of undiscovered deposits. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 2, 3, and 4 or more deposits consistent with the grade and tonnage model of Berger and Singer (1992).

References

- Berger, B.R., 1986, Descriptive model of hot-spring Au-Ag deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 143.
- Berger, B.R., and Singer, D.A., 1992, Grade and tonnage model of hot-spring Au-Ag, *in* Bliss, J.D., ed., Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, p. 23-25.
- Bond, J.G., 1978, Geologic map of Idaho: Idaho Bureau of Mines and Geology, scale 1:500,000.
- White, D.E., Heropoulos, Chris, and Fournier, R.O., 1992, Gold and other minor elements associated with hot springs and geysers of Yellowstone National Park, Wyoming, supplemented with data from Steamboat Springs, Nevada: U.S. Geological Survey Bulletin 2001, 19 p.
- Shannon, S.S., Jr., 1980, Uranium hydrogeochemical and stream-sediment reconnaissance data release for the Ashton NTMS quadrangle, Idaho/Montana/Wyoming, including concentrations of 42 additional elements: U.S. Department of Energy, GJBX no. 189 (80).

NR30**Hot-spring Au-Ag Deposits****Montana****Descriptive Model 25a • Mark3 Index 45****Area = 2,170 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by David Frishman

Rationale for Model Choice

We chose to evaluate Montana for hot-spring Au-Ag deposits because the geology is permissive for the occurrence of this type of deposit and because deposits of this type occur in the State. We used the descriptive model of Berger (1986) and the grade and tonnage model of Berger and Singer (1992).

Rationale for Tract Delineation

For the purpose of delineating the permissive tract, the three subtypes of epithermal precious-metal vein deposits (quartz-adularia, quartz alunite, and hot-spring) were treated the same. It was judged that the criteria available to discriminate between the subtypes were too imprecise to use effectively. Probabilities of occurrence for the individual types were assigned separately, however.

Permissive areas that constitute the tract are generally small, and are scattered throughout western Montana. They were defined by the location of known active or fossil hot springs, the location of mines, prospects, and occurrences believed to represent epithermal deposits, and the location of Tertiary and Quaternary volcanic and hypabyssal rocks as shown on the Montana geologic map (Ross and others, 1955).

Areas identified include the Hog Heaven volcanic field, the Lincoln volcanics (McDonald Meadows property), the Helena-Avon volcanics, several areas of the Lowland Creek volcanics southwest of Helena and north and west of Butte, the Virginia City-Alder Gulch area, an area of Challis volcanics exposed in the Horse Prairie area southwest of Dillon, the Marysville district, and small portions of Montana adjacent to the Yellowstone caldera in Wyoming.

Important Examples of Deposit Type

Possible representatives of this class of deposit are all apparently Tertiary in age (<50 Ma) and include the volcanic-hosted McDonald Meadows deposit, south of Lincoln in Lewis and Clark County; the Pauper's Dream property (or Basin Creek mine), southwest of Helena; and the Tuxedo prospect, west-northwest of Butte.

Rationale for Numerical Estimate

For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 1, 3, 5, 6, and 9 or more deposits consistent with the grade and tonnage model of Berger and Singer (1992).

References

- Berger, B.R., 1986, Descriptive model of hot-spring Au-Ag deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 143.
- Berger, B.R., and Singer, D.A., 1992, Grade and tonnage model of hot-spring Au-Ag, *in* Bliss, J.D., ed., Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, p. 23-25.
- Ross, C.P., Andrews, D.A., and Witkind, I.J., 1955, Geologic map of Montana: U.S. Geological Survey, scale 1:500,000.

NR31**Hot-spring Au-Ag Deposits****Wyoming****Descriptive Model 25a • Mark3 Index 45****Area = 5,380 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* David Frishman**Rationale for Model Choice**

The area inside and near the Yellowstone calderas in northwestern Wyoming and adjacent parts of Montana contains numerous thermal pools, springs, fumaroles, and geysers. Obviously, the hot-spring model is appropriate for this terrane. We used the descriptive model of Berger (1986) and the grade and tonnage model of Berger and Singer (1992).

Rationale for Tract Delineation

The tract identified as permissive for hot-spring Au-Ag deposits is an area that encloses the three Yellowstone calderas (about 2.0, 1.3, and 0.6 Ma; White and others, 1988) and the surrounding area of thick rhyolitic ash flow tuffs and rhyolite flows as shown by Love and Christiansen (1985). Some areas were excluded from the permissive tract because the rhyolitic rocks exposed there are known to be only a thin mantle of distal outflow facies.

Important Examples of Deposit Type

There are no known hot-spring Au-Ag deposits within or near the Yellowstone calderas, but the area has been withdrawn from mineral entry since 1872 and there has been essentially no exploration. There are areas of intense hydrothermal activity and alteration, and hydrothermal activity has been taking place for the last 150,000 years or longer (White and others, 1988). Areas currently experiencing hydrothermal activity and alteration include Mammoth Hot Springs, the Norris-Elk Park-Gibbon Geyser Basin area, the Lower, Midway, and Upper Geyser Basins, Yellowstone Canyon, the West Thumb Geyser Basin, the Heart Lake Geyser Basin, Washburn Hot Springs and a large area to the east that hosts Whistler geyser, Rainbow Springs, and Coffee Hot Springs, among others.

Rationale for Numerical Estimate

The presence of many active hydrothermal systems was believed to be very favorable. In addition, anomalous gold values (0.5 to 10 g/t) have been detected in sinter from Gibbon geyser basin and in hydrothermal quartzite from Norris geyser basin (White and others, 1992). For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 2, 3, 4 and 5 or more deposits consistent with the grade and tonnage model of Berger and Singer (1992).

References

- Berger, B. R., 1986, Descriptive model of hot-spring Au-Ag deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 143.
- Berger, B. R., and Singer, D. A., 1992, Grade and tonnage model of hot-spring Au-Ag, *in* Bliss, J.D., ed., Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, p 23-25.
- Love, J.D., and Christiansen, A.C., 1985, Geologic map of Wyoming: U.S. Geological Survey, scale 1:500,000.
- White, D.E., Hutchinson, R.A., and Keith, T.E.C., 1988, The geology and remarkable thermal activity of Norris Geyser Basin, Yellowstone National Park, Wyoming: U.S. Geological Survey Professional Paper 1456, 84 p.

White, D.E., Heropoulos, Chris, and Fournier, R.O., 1992, Gold and other minor elements associated with hot springs and geysers of Yellowstone National Park, Wyoming, supplemented with data from Steamboat Springs, Nevada: U.S. Geological Survey Bulletin 2001, 19 p.

NR32**Sediment-hosted Au Deposits**

Washington

Descriptive Model 26a • Mark3 Index 17

Area = 2,420 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Stephen E. Box and Arthur A. Bookstrom

Rationale for model choice

These deposits consist of very fine-grained gold and sulfide minerals disseminated in carbonaceous calcareous sedimentary rocks and associated jasperoids (Berger, 1986). This model was considered to include disseminated gold deposits hosted in carbonaceous, silty, and shaley carbonate sequences along the continental margin. The host rock lithology of carbonaceous, silty, and shaley carbonate sequences was considered to be the primary criteria for inclusion in a permissive tract for this deposit type. Paleozoic miogeoclinal strata in northeastern Washington include this lithology.

Rationale for tract delineation

Strictly on the basis of host rock lithology, the Cambrian through Devonian miogeoclinal rocks of northeastern Washington (Stoffel and others, 1991) are considered permissive for Carlin-type, sediment-hosted gold deposits. However, there was disagreement within the team as to whether the host lithology is the most significant factor in the localization of these deposits, and whether the model is appropriate to northeastern Washington.

Significant examples of deposit type

No deposits or prospects of this deposit type are known from the permissive area or from the contiguous correlative area across the Canadian border in southern British Columbia.

Rationale for Numerical Estimate

Since a large number of gold exploration companies (including several with major producing sediment-hosted gold deposits in Nevada) have been actively exploring for gold deposits of several other types in the general vicinity, we presume that this area has been explored to some degree for deposits of this type. Given this presumed exploration history and the lack of known prospects, the assessment team judged the possibility of undiscovered deposits to be very low. However exposure in the area is poor, and forest cover is extensive, so that undiscovered deposits might still occur in the upper kilometer of the tract. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, and 1 or more for deposits consistent with the grade and tonnage model of Mosier and others (1992).

References

- Berger, B.R., 1986, Descriptive model of carbonate-hosted Au-Ag, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 175.
- Mosier, D.L., Singer, D.A., Bagby, W.C., and Menzie, W.D., 1992, Grade and tonnage model of sediment-hosted Au, *in* Bliss, J.D., ed. Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, p. 26–28.
- Stoffel, K.L., Joseph, N.L., Waggoner, S.Z., Gulick, S.W., Korosec, M.A., and Bunning, B.B., 1991, Geologic map of Washington-Northeast quadrant: Washington Division of Geology and Earth Resources, Geologic Map GM-39, scale 1:250,000.

NR34**Sediment-hosted Cu Deposits, Red-bed Type**

Montana

Descriptive Model 30b.2

Idaho

Area = 81,900 km²

Washington

[Model](#)*by* Michael L. Zientek**Rationale for Model Choice**

Syngenetic to diagenetic deposits are hosted in sedimentary rocks in epicratonic and intracratonic basins. The formation of sediment-hosted copper deposits depends on a redox reaction between an oxidized brine containing dissolved copper and a reductant. The brine, in equilibrium with hematite and free of sulfide maintains the copper in solution as a stable complex ion. The source of the brines may be trapped seawater or fluids derived from evaporite basins. The copper in the brines may be derived from volcanic rock clasts and labile clastic minerals in red beds, hydrous ferrous oxide cements in red beds, or subareal mafic volcanic rocks. Reductants include a wide variety of organic and inorganic material (see Kirkham, 1989).

Rationale for Tract Delineation

Permissive lithologic units in this area include the entire Middle Proterozoic Belt Supergroup above the Prichard Formation. (see Harrison, 1972) and the Yellowjacket Formation and Lemhi Group in Idaho. Small, laterally impersistent, sediment-hosted copper deposits and occurrences, known as green-bed-type deposits, occur in all formations in the Belt Supergroup above the lower Belt (Prichard and stratigraphic equivalents) (Lange and Sherry, 1986). This style of mineralization is similar to those deposits described in the red-bed model and consists of copper-sulfide minerals localized in gray or green beds of argillite, siltite, or sandstone in thinly bedded, alternating red bed-green bed stratigraphic sequences. They are particularly common in tidal flat and shallow shelf facies of the Ravalli and Missoula Groups (Harrison and others, 1986).

Important Examples of Deposit Type

There are no known deposits of this type in the permissive tract, although numerous prospects and occurrences are known. An example of this type of mineralization in the Ravalli Group at Blacktail Mountain in the Kalispell 1°x2° quadrangle is described by Harrison and Reynolds (1979) and Rye and others (1984). Prospects in the Missoula Group are described by Stanley and Sinclair (1989). Descriptions and locations of "green-bed" mineralization can also be found in Harrison and others (1986), Pearson and others (1990), Earhart and others (1981), and Elliott and others (1992). Sediment-hosted Cu-Ag occurrences are also reported in a diamictite in the Lemhi Group in the Lemhi Range, Idaho and at the Freeman Creek area in the Yellowjacket Formation in the Bitterroot Range, Idaho (C.R. Allen, personal commun., 1994). We do not have enough information on these deposits in Idaho to differentiate them into the Revett or red-bed models.

Rationale for Numerical Estimate

No estimate of the number of undiscovered deposits was made, because deposits of this type are small, and generally not economically significant.

References

Earhart, R.L., Mudge, M.R., Whipple, J.W., and Connor, J.J., 1981, Mineral resources of the Choteau 1°x2° quadrangle, Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF- 858-A.

- Elliott, J.E., Loen, J.S., Wise, K.K., and Blaskowski, M.J., 1992, Maps showing locations of mines and prospects in the Butte 1°x2° quadrangle, western Montana: U.S. Geological Survey Miscellaneous Field Investigations Series Map I-2050-C.
- Harrison, J.E. and Reynolds, M.W., 1979, Preliminary geology of the Blacktail Mountain drilling site, Flathead County, Montana: U.S. Geological Survey Open-File Report 79-938, 30 p.
- Harrison, J.E., 1972, Precambrian Belt basin of northwestern United States—Its geometry, sedimentation, and copper occurrences: Geological Society of America Bulletin, v. 83, p. 1215-1240.
- Harrison, J.E., Domenico, J.A., and Leach, D.L., 1986, Resource appraisal map for stratabound copper-silver deposits, in the Wallace 1°x2° quadrangle, Montana and Idaho: U.S. Geological Survey Miscellaneous Investigation Series Map I-1509-F.
- Kirkham, R.V., 1989, Distribution, settings, and genesis of sediment-hosted stratiform copper deposits, *in* Boyle, R.W., Brown, A.C., Jefferson, C.W., Jowett, E.C., and Kirkham, R.V., eds., Sediment-hosted stratiform copper deposits: Geological Association of Canada Special Paper 36, p. 3-38.
- Lange, I.M. and Sherry, R.A., 1986, Monmassive sulfide deposits in the Late Precambrian Belt Supergroup of western Montana, *in* Roberts, S.M., ed., Belt Supergroup—A guide to Proterozoic rocks of western Montana and adjacent areas: Montana Bureau of Mines and Geology Special Publication 94, p. 269-278.
- Pearson, R.C., Hanna, W.F., James, H.L., Loen, J.S., Moll, S.H., Ruppel, E.T., and Trautwein, C.M., 1990, Map showing mineral resource assessment for silver, cobalt, and base metals in Proterozoic sedimentary rocks and for iron, chromium, nickel, talc, chlorite, gold, and graphite in Archean crystalline rocks, Dillon 1°x2° quadrangle, Idaho and Montana: U.S. Geological Survey Miscellaneous Field Investigation Series Map I-1803-D.
- Rye, R.O., Whelan, J.F., Harrison, J.E., and Hayes, T.S., 1984, The origin of copper-silver mineralization in the Ravalli Group as indicated by preliminary studies of stable isotopes, *in* Hobbs, S.W., ed., The Belt, abstracts and summaries, Belt Symposium II, 1983: Montana Bureau of Mines and Geology Special Publication 90, p. 104-107.
- Stanley, C.R. and Sinclair, A.J., 1989, Depositional environment and stratigraphic setting of stratabound Cu-Ag occurrences in the Bonner Quartzite, Belt Supergroup, western Montana, *in* Boyle, R.W., Brown, A.C., Jefferson, C.W., Jowett, E.C., and Kirkham, R.V., eds., Sediment-hosted stratiform copper deposits: Geological Association of Canada Special Paper 36, p. 305-318.

NR35**Sediment-hosted Cu Deposits, Red-bed Type****Descriptive Model 30b.2****Area = 6,310 km²****Idaho
Wyoming
Utah**[Model](#)*by* David A. Lindsey and Dennis P. Cox**Rationale for Model Choice**

Deposits in the Triassic(?) and Jurassic Nugget Sandstone of western Wyoming and southeastern Idaho occur in bleached zones of otherwise oxidized (red) sandstone (Love and Antweiler, 1973). Most occurrences are near the top of the Nugget and below the basal breccia bed of the Gypsum Spring Member of the Jurassic Twin Creek Limestone. No plant matter is associated with copper, but in places the host sandstone is petroliferous. Concentrations of silver and zinc accompany the copper. These characteristics indicate that the Nugget occurrences belong to the red-bed model, with oil probably serving as the reductant.

Rationale for Tract Delineation

All deposits are within the Nugget Sandstone, and it constitutes the permissive tract, along with underlying Triassic rocks, which may be linked with the Nugget in geologic setting, including the history of diagenesis and oil migration.

Important Examples of Deposit Type

The Griggs mine in the Lake Alice district is the most important copper occurrence in the Nugget Sandstone. According to Love and Antweiler (1973), copper was mined in the Lake Alice district from about 1895 to 1920; they did not tabulate production.

Rationale for Numerical Estimate

Only two other occurrences, about 80 km north of the Lake Alice district, have been reported in the Nugget (Love and Antweiler, 1973). Not enough is known about the distribution of occurrences or other potentially mineralized areas in reduced zones of the Nugget to warrant numerical estimation.

Reference

Love, J.D., and Antweiler, J.C., 1973, Copper, silver, and zinc in the Nugget Sandstone, western Wyoming, *in* Geology and mineral resources of the greater Green River Basin, Wyoming Geological Association Guidebook, 25th Field Conference, p. 139-147.

NR36	Sediment-hosted Cu Deposits, Reduced-facies Type	Montana
Descriptive Model 30b.1 • Mark3 Index 96		Idaho
Area = 81,900 km²		Washington

[Cumulative Distribution](#)

[Histogram](#)

[Table](#)

[Model](#)

by Michael L. Zientek, Stephen E. Box, and Arthur A. Bookstrom

Rationale for Model Choice

These syngenetic to diagenetic deposits are hosted in sedimentary rocks in epicratonic and intracratonic basins. The formation of sediment-hosted copper deposits depends on a redox reaction between an oxidized brine containing dissolved copper and a reductant. The brine, in equilibrium with hematite and free of sulfide maintains the copper in solution as a stable complex ion. The source of the brines may be trapped seawater or fluids derived from evaporite basins. The copper in the brines may be derived from volcanic rock clasts and labile clastic minerals in red beds, hydrous ferrous oxide cements in red beds, or subareal mafic volcanic rocks. Reductants include a wide variety of organic and inorganic material (see Kirkham, 1989).

Three subtypes of sediment-hosted copper deposits are distinguished based on geologic setting, tonnage, and grade. Deposits of the red-bed model are found where oxidized continental clastic rocks (red beds) serve as a reductant, but no laterally extensive reduced-facies strata are found. They are relatively small. Deposits of the Revett model include deposits in the Revett Formation in the Belt Supergroup. Deposits of the reduced-facies model are found where oxidized continental clastic rocks (red beds) or basaltic to intermediate subaerial volcanic rocks are overlain by laterally extensive reduced marine or lacustrine shales or carbonate rocks. They can be quite large.

The reduced-facies model was chosen for assessment because of the widespread distribution of red-bed-type prospects and occurrences; this indicates that copper was mobile in oxidized parts of the section. Any reduced-facies beds, such as black shale or stromatolitic carbonate, in contact with the oxidized beds, would be a likely site for the occurrence of reduced-facies deposits.

Rationale for Tract Delineation

Permissive lithologic units in this area include the entire Middle Proterozoic Belt Supergroup above the Prichard Formation and the Yellowjacket Formation and Lemhi Group in Idaho. Areas favorable for deposits of the reduced facies model would include thick sequences of laterally extensive reduced shales or carbonate rocks. One such favorable interval is the base of the middle Belt carbonate rocks. The transition from the Ravalli Group to the middle Belt carbonate rocks represents a major marine transgression that places reduced lithologies over oxidized, red-bed sequences (J.W. Whipple, personal commun., 1994).

Important Examples of Deposit Type

Carbonate-type copper mineralization occurs throughout the middle Belt carbonate rocks (Empire, Helena, and Wallace Formations) where local accumulations of organic material (such as algal mats) appear to control metal deposition (see Harrison, 1972). No examples of identified deposits are known, but occurrences at Red Mountain and Wolf Creek, Montana have been described by Lange and Sherry (1986). Additional deposits that occur in this stratigraphic interval near these prospects are described by Elliott and others (1992). Laterally extensive, low-grade mineralization in this same stratigraphic interval has been described in Alberta and British Columbia (Binda and others, 1989). These prospects and occurrences indicate that the processes that generate reduced-facies deposits did operate in the Belt basin.

Rationale for Numerical Estimate

Although small examples of this mineralization type occur in the tract, no significant deposits of this type are known. A long exploration history for copper deposits in the region leads us to give a low estimate of the number of undiscovered deposits of this type. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 1, 3, and 5 or more reduced facies deposits consistent with the grade and tonnage model.

References

- Binda, P.L., Koopman, H.T., and Koopman, E.R., 1989, A stratiform copper occurrence in the Helikian Siyeh Formation of Alberta and British Columbia, *in* Boyle, R.W., Brown, A.C., Jefferson, C.W., Jowett, E.C., and Kirkham, R.V., eds., *Sediment-hosted stratiform copper deposits: Geological Association of Canada Special Paper 36*, p. 269-285.
- Elliott, J.E., Loen, J.S., Wise, K.K., and Blaskowski, M.J., 1992, Maps showing locations of mines and prospects in the Butte 1°x2° quadrangle, western Montana: U.S. Geological Survey Miscellaneous Field Investigations Series Map I-2050-C.
- Harrison, J.E., 1972, Precambrian Belt basin of northwestern United States—Its geometry, sedimentation, and copper occurrences: *Geological Society of America Bulletin*, v. 83, p. 1215-1240.
- Kirkham, R.V., 1989, Distribution, settings, and genesis of sediment-hosted stratiform copper deposits, *in* Boyle, R.W., Brown, A.C., Jefferson, C.W., Jowett, E.C., and Kirkham, R.V., eds., *Sediment-hosted stratiform copper deposits: Geological Association of Canada Special Paper 36*, p. 3-38.
- Lange, I.M. and Sherry, R.A., 1986, Monmassive sulfide deposits in the Late Precambrian Belt Supergroup of western Montana, *in* Roberts, S.M., ed., *Belt Supergroup—A guide to Proterozoic rocks of western Montana and adjacent areas: Montana Bureau of Mines and Geology Special Publication 94*, p. 269-278.

NR37**Sediment-hosted Cu Deposits, Revett Type**

Montana

Descriptive Model 30b.3 • Mark3 Index 64

Idaho

Area = 81,900 km²

Washington

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Michael L. Zientek, Stephen E. Box, and Arthur A. Bookstrom

Rationale for Model Choice

These syngenetic to diagenetic deposits are hosted in sedimentary rocks in epicratonic and intracratonic basins. The formation of sediment-hosted copper deposits depends on a redox reaction between an oxidized brine containing dissolved copper and a reductant. The brine, in equilibrium with hematite and free of sulfide, maintains the copper in solution as a stable complex ion. The source of the brines may be trapped seawater or fluids derived from evaporite basins. The copper in the brines may be derived from volcanic rock clasts and mafic clastic minerals in red beds, hydrous ferrous oxide cements in red beds, or subareal mafic volcanic rocks. Reductants include a wide variety of organic and inorganic material (see Kirkham, 1989).

Three subtypes of sediment-hosted copper deposits are distinguished based on geologic setting, tonnage, and grade. Deposits of the reduced-facies model are found where oxidized continental clastic rocks (red beds) or basaltic to intermediate subaerial volcanic rocks are overlain by laterally extensive reduced marine or lacustrine shales or carbonate rocks. Deposits of the red-bed model are similar those of the reduced-facies model but lack laterally extensive reduced facies strata. Deposits of the Revett model include deposits in the Revett Formation in the Belt Supergroup. Cu-bearing oxidized brines migrated into reduced, permeable quartzites to form roll-front-like, mineralogically-zoned deposits at the redox boundary.

The Revett grade and tonnage model (Spanski, 1992) is based on deposits from the Belt Supergroup, and is clearly the model of choice.

Rationale for Tract Delineation

Permissive lithologic units in this area include the entire Middle Proterozoic Belt Supergroup above the Prichard Formation and the Yellowjacket Formation and Lemhi Group in Idaho. The Uinta Mountains Supergroup may contain similar rocks, but that area was not included in the tract because we lacked information. Although sandstone bodies that host known ore deposits are limited to those areas underlain by the Revett Formation in Idaho and western Montana (Spanski, 1992), reduced sandstone bodies large enough to host deposits comparable in size to Revett orebodies are present throughout the permissive area. For example, arenite-hosted silver-bearing copper deposits occur in Spokane Formation in the eastern part of the Belt basin (Lange and others, 1989) and sediment-hosted Cu-Ag mineralization has been reported to occur in the Yellowjacket Formation and Lemhi Group in Idaho (C.R. Allen, personal commun., 1994).

Important Examples of Deposit Type

Numerous deposits and occurrences, including those that comprise the Revett grade and tonnage model are known from the Libby trough in western Montana and Idaho (Lange and Sherry, 1986; Harrison and others, 1986; Spanski, 1992). Examples include the Spar Lake deposit (Hayes and Einaudi, 1986) and the Montanore deposit (Adkins, 1993). Green-bed Cu-Ag deposits in the Spokane Formation in the Choteau 1°x2° quadrangle, Montana may have potential for Revett-type mineralization. Green bed-type mineralization is commonly found in the upper part of the Spokane Formation in a stratigraphic interval that represents an upwards transition from a predominately oxidized red-bed sequence to the reduced siliclastic-carbonate rocks of the Empire Formation. Earhart and others (1981) describe mineralized zones that range up to 3 m in thickness and may extend for 49 km on strike. Earhart and others (1981) estimate

that one zone in the upper part of the Spokane Formation may contain about 35 million metric tons of submarginal resources that average 0.1 percent Cu and 7.1 g/metric ton Ag. This interval of mineralized Spokane Formation is also described by Lange and others (1989). Although copper grades are lower than most Revett-type deposits, tonnages are comparable (Spanski, 1992). In Idaho, sediment-hosted Cu-Ag occurrences reported in a diamictite in the Lemhi Group in the Lemhi Range and at the Freeman Creek area in the Yellowjacket Formation in the Bitterroot Range are large enough to be considered as exploration targets (C.R. Allen, personal commun., 1994). We do not have enough information on these deposits in Idaho to differentiate them into the Revett or red-bed models.

Rationale for Numerical Estimate

The estimate for Revett-type deposits was based on earlier quantitative estimates for the most prospective area in western Montana (Spanski, 1992) and from consultation with industry geologists with extensive knowledge of the geology and exploration activity of this region. In the Kootenai National Forest, which covers most, but not all, of the area favorable for Revett deposits, Spanski (1992) describes 26 occurrences of Revett mineralization. Of these, 13 are sufficiently explored to assure their status as deposits. Four of the 13 have reported grades and tonnages, leaving 9 as only partially determined. The estimation team used this number of partially explored deposits for their estimate for the 90th percentile. Spanski (1992) estimated the following distribution for undiscovered Revett-type deposits for one tract in the Kootenai Forest: 25 deposits at the 90th percentile, 50 at the 50th percentile and 85 at the 10th percentile. The team consulted with members of the estimation team for the Kootenai Forest and with exploration geologists in private industry. Based on these discussion, the team made a lower estimate for undiscovered deposits in the Belt basin than was earlier reported for the Kootenai Forest. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 9, 10, 15, 20, and 30 or more Revett-type deposits consistent with the grade and tonnage model of Spanski (1992).

References

- Adkins, A.R., 1993, Geology of the Montanore stratabound Cu-Ag deposit, Lincoln and Sanders Counties, Montana: Belt Symposium III, Program and Abstracts, Belt Association, Inc., unpaginated.
- Harrison, J.E., 1972, Precambrian Belt basin of northwestern United States—Its geometry, sedimentation, and copper occurrences: *Geological Society of America Bulletin*, v. 83, p. 1215-1240.
- Harrison, J.E., Domenico, J.A., and Leach, D.L., 1986, Resource appraisal map for stratabound copper-silver deposits, in the Wallace 1°x2° quadrangle, Montana and Idaho: U.S. Geological Survey Miscellaneous Investigation Series Map I-1509-F.
- Hayes, T.S., and Einaudi, M.T., 1986, Genesis of the Spar Lake strata-bound copper-silver deposit, Montana—Part I. Controls inherited from sedimentation and preore diagenesis: *Economic Geology*, v. 81, no. 8, p. 1899-1931.
- Kirkham, R.V., 1989, Distribution, settings, and genesis of sediment-hosted stratiform copper deposits, *in* Boyle, R.W., Brown, A.C., Jefferson, C.W., Jowett, E.C., and Kirkham, R.V., eds., *Sediment-hosted stratiform copper deposits: Geological Association of Canada Special Paper 36*, p. 3-38.
- Kirkham, R.V., 1989, Distribution, settings, and genesis of sediment-hosted stratiform copper deposits, *in* Boyle, R.W., Brown, A.C., Jefferson, C.W., Jowett, E.C., and Kirkham, R.V., eds., *Sediment-hosted stratiform copper deposits: Geological Association of Canada Special Paper 36*, p. 3-38.
- Lange, I.M., Herberger, D., Whipple, J.W., and Krouse, H.R., 1989, Stratabound Cu-Ag and Pb-Zn mineralization in the Spokane and Helena Formations in the eastern part of the Belt Basin, Montana—A common origin?, *in* Boyle, R.W., Brown, A.C., Jefferson, C.W., Jowett, E.C., and Kirkham, R.V., eds., *Sediment-hosted stratiform copper deposits: Geological Association of Canada Special Paper 36*, p. 287-304.

- Lange, I.M. and Sherry, R.A., 1986, Monmassive sulfide deposits in the Late Precambrian Belt Supergroup of western Montana, *in* Roberts, S.M., ed., Belt Supergroup—A guide to Proterozoic rocks of western Montana and adjacent areas: Montana Bureau of Mines and Geology Special Publication 94, p. 269-278.
- Spanski, G.T., 1992, Quantitative assessment of future development of copper/silver resources in the Kootenai National Forest, Idaho/Montana: Part 1—Estimation of the copper and silver endowments: *Nonrenewable Resources*, v. 1, no. 2, p. 163-183.

NR38**Sedimentary Exhalative Zn-Pb Deposits****Washington****Descriptive Model 31a • Mark3 Index 13****Area = 4,680 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Stephen E. Box and Arthur A. Bookstrom**Rationale for Model Choice**

These stratabound, massive Zn-Pb sulfide deposits form by the precipitation of sulfide and sulfate minerals from metalliferous brines that were exhaled along active submarine faults during deposition of the enclosing sedimentary sequence. The mineral deposits are dominantly Fe sulfide accumulations, which enclose economic ore deposits as layers and lenses rich in Zn and Pb sulfides. These syngenetic deposits are hosted in euxinic marine sedimentary rocks in epicratonic and intracratonic basins, often associated with synsedimentary faults (Briskey, 1986). Paleozoic off-shelf black shale units in northeastern Washington were deposited in a rifted continental slope-and-rise setting, and are appropriate hosts for this deposit type.

Rationale for Tract Delineation

All sedimentary units with significant black shales in northeastern Washington (exclusive of the Belt Supergroup and stratigraphic equivalents) are regarded as permissive for this deposit type. The permissive tract is defined by lithologic units that include the Late Proterozoic Windermere Group, the lower Paleozoic Metaline Formation and the Paleozoic Covada Group (Stoffel and others, 1991).

Examples of Deposit Type

Three small prospects occur in Paleozoic deep-water strata in northeastern Washington, although they are too small to be considered significant deposits. Two of these occur in the Covada Group, an upper Paleozoic continental slope-and-rise sequence. One prospect is known east of the Covada Group in lower Paleozoic shales of the Metaline Formation (continental shelf-slope environment). Numerous barite occurrences and Pb and Zn prospects in the area could also be examples of this deposit type, although other Pb- and Zn-bearing deposit types are also present in the area.

Rationale for Numerical Estimate

This area is considered to be part of the rifted early Paleozoic continental margin. None of the prospects is large enough to be comparable to deposits in the grade and tonnage models. Cominco has had an exploration effort in northeastern Washington for many years, so the assessment team considered the area to have been thoroughly explored. However exposure in the area is poor, structure is complex, and forest cover is extensive, so that the team judged that some undiscovered deposits might remain. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 1, 2, and 4 or more for deposits consistent with the grade and tonnage model of Menzie and Mosier (1986).

References

- Briskey, J.A., 1986, Descriptive model of sedimentary exhalative Zn-Pb, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 211.
- Menzie, W.D., and Mosier, D.L., 1986, Grade and tonnage model of sedimentary exhalative Zn-Pb, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 212-215.

Stoffel, K.L., Joseph, N.L., Waggoner, S.Z., Gulick, S.W., Korosec, M.A., and Bunning, B.B., 1991, Geologic map of Washington-Northeast quadrant: Washington Division of Geology and Earth Resources, Geologic Map GM-39, scale 1:250,000.

NR39**Sedimentary Exhalative Zn-Pb Deposits**

Montana

Descriptive Model 31a • Mark3 Index 13

Idaho, Washington

Area = 100,100 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Michael L. Zientek, Stephen E. Box, and Arthur A. Bookstrom

Rationale for Model Choice

These stratabound, massive Zn-Pb sulfide deposits form by the precipitation of sulfide and sulfate minerals from metalliferous brines that were exhaled along active submarine faults during deposition of the enclosing sedimentary sequence. The mineral deposits are dominantly iron sulfide accumulations, which enclose economic ore deposits as layers and lenses rich in Zn and Pb sulfides. These syngenetic deposits are hosted in euxinic marine sedimentary rocks in epicratonic and intracratonic basins, often associated with synsedimentary faults related to rifting and subsidence of the sedimentary basin (Briskey, 1986). Proterozoic sedimentary strata deposited in intracratonic basins that formed along the rifted continental margin of North America (Belt Supergroup and Yellowjacket Formation) have Pb-Zn deposits and occurrences as well as evidence for sydepositional faulting and fluid movement. We examined the general applicability of the grade and tonnage model of Menzie and Mosier (1986) to this Proterozoic basin, in particular, the question of whether the grade and tonnages of Proterozoic and Phanerozoic deposits are different. No differences are apparent, and we decided that no modification of the grade and tonnage models are warranted.

Rationale for Tract Delineation

Traditionally, exploration for sedimentary exhalative Zn-Pb deposits in the Belt basin has focused on a particular horizon (the host horizon of the Sullivan deposit) in the Prichard Formation, the lowest unit of the Belt Supergroup. More recent exploration strategies have expanded the search to all black shale horizons throughout the Belt basin. Two other black shale horizons are now known from the lower Belt. In the central and western parts of the basin, one black shale horizon in the Ravalli Group, one in the middle Belt carbonate rocks, and up to four in the upper Belt are considered viable targets. Thus, the permissive area for undiscovered deposits was defined by the entire outcrop area of the Middle Proterozoic Belt Supergroup in northern Idaho and western Montana (including highly metamorphosed areas marginal to the Idaho batholith) as well as rocks mapped as Yellowjacket Formation and Lemhi Group in Idaho. The Uinta Mountains Supergroup may contain similar rocks, but that area was not included in the tract because we lacked information.

Examples of Deposit Type

Only one large sedimentary exhalative Zn-Pb deposit is known in the Belt basin: the Sullivan deposit in southeastern British Columbia (Hamilton and others, 1982). That deposit is much larger than the median or mean deposit size of the grade and tonnage distributions of Menzie and Mosier (1986).

Rationale for Numerical Estimate

Exhalative massive sulfide deposits are known only from the lower Belt, which includes the Prichard, Aldridge, and Newland Formations, and from the Yellowjacket Formation. Exhalative mineralization includes Pb-Zn deposits such as the Sullivan mine in Canada but also Cu-Co deposits at Sheep Creek, Montana and Blackbird, Idaho. In addition to these 3 deposits with reported grades and tonnages, exploration for sedimentary-exhalative deposits in the lower Belt basin has identified 11 prospects or districts that have been drilled or mined that have ore grades and 55 exploration targets that have unknown grade but meet 2 or more of the following

criteria: (1) appropriate depositional environment, (2) evidence of syndepositional extensional tectonics, (3) evidence for the circulation of hydrothermal fluids, and (4) evidence of synsedimentary sulfide mineralization (J.W. Whipple, oral commun., 1993). Seven of the exploration targets are in British Columbia, 12 are in Idaho, and 36 are in Montana. Information on the location of these targets was not available. These are exhalative targets and may contain either Pb-Zn or Cu-Co mineralization.

Although we lack specific information about the location of all the deposits, prospects, and exploration targets summarized above, some favorable areas can be identified. Zn-Pb mineralization has been reported at Sheep Creek, Montana and in the Highland Mountains (Soap Gulch prospect?), Montana (Thorson, 1984; Thorson, 1993; Zieg and Leitch, 1993). Areas favorable for Sullivan-type Pb-Zn mineralization were identified in both the Wallace (the Perma-Plains area) and Dillon (Highland Mountains) 1° x 2° sheet mineral resource assessments (Pearson and others, 1990; Harrison and others, 1986). Tourmalinization is the alteration type most closely related to mineralization at Sullivan (Turner and others, 1993); Slack (1993) identified at least 30 locations in Proterozoic sedimentary rocks in the United States that may have some relation to sedimentary-exhalative mineralization. At least two of these localities, Trestle Creek (Beaty and others, 1988) and Morning Glory (J.F. Slack, oral comm., 1994), have been drilled. Synsedimentary massive sulfide mineralization has also been described in the Whitehall area (Foster and others, 1993).

Although extensive exploration efforts have focused on the Prichard Formation (and stratigraphic equivalents), only one large Pb-Zn deposit, Sullivan, has been found. One industry source indicated that over \$15 million has been expended for exploration in the Prichard in the U.S. over a 15 year period. Mineralized Pb-Zn occurrences that have less than a million metric tons of rock have been identified but no mineable deposits have been found.

Despite this apparent lack of success, there is still optimism about the discovery of new deposits. Exploration efforts have focused on the lower Belt; reports of sedex-type mineralization in the middle Belt suggest that some of the other argillaceous units in the Belt Supergroup may be prospective and are underexplored. The Wallace breccias appear to be most favorable units. One industry source offered the following conservative estimates for the discovery of a mineable Pb-Zn deposit in various parts of the Proterozoic basin: 50 percent chance in the Prichard Formation, 50 percent chance in the Helena embayment, 25 percent chance in Wallace breccias within the middle Belt carbonate rocks, <10 percent chance in the Yellowjacket Formation, and <10 percent chance in the argillaceous units in the Ravalli and Missoula Group.

The team was cautiously optimistic that the large permissive area, the presence of one very large known deposit, and many prospective areas indicates a reasonable chance that undiscovered deposits exist in the upper kilometer of the crust in the permissive tract. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 2, 4, 6, and 8 or more deposits consistent with the grade and tonnage model of Menzie and Mosier (1986).

References

- Beaty, D.W., Hahn, G.A., and Threlkeld, W.E., 1988, Field, isotopic, and chemical studies of tourmaline-bearing rocks in the Belt-Purcell Supergroup—Genetic constraints and exploration significance for Sullivan-type ore deposits: *Canadian Journal of Earth Sciences*, v. 25, p. 392-402.
- Briskey, J.A., 1986, Descriptive model of sedimentary exhalative Zn-Pb, in Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 211.
- Foster, F., Chadwick, T., and Nilsen, T.H., 1993, Paleodepositional setting and synsedimentary mineralization in Belt Supergroup rocks of the Whitehall area: *Belt Symposium III, Program and Abstracts*, Belt Association, Inc., unpaginated.

- Hamilton, J.M., Bishop, D.T., Morris, H.C., and Owens, O.E., 1982, Geology of the Sullivan orebody, Canada, *in* Hutchinson, C.D.S. and Franklin, J.M, eds., Precambrian sulphide deposits: Geological Association of Canada Special Paper 25, p. 597-665.
- Harrison, J.E., Cressman, E.R., Long, C.L., Leach, D.L., and Domenico, J.A., 1986, Resource appraisal map for Sullivan-type stratabound lead-zinc-silver deposits in the Wallace 1° x 2° quadrangle, Montana and Idaho: U.S. Geological Survey Miscellaneous Investigation Series Map I-1509-G.
- Menzie, W.D., and Mosier, D.L., 1986, Grade and tonnage model of sedimentary exhalative Zn-Pb, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 212-215.
- Pearson, R.C., Hanna, W.F., James, H.L., Loen, J.S., Moll, S.H., Ruppel, E.T., and Trautwein, C.M., 1990, Map showing mineral resource assessment for silver, cobalt, and base metals in Proterozoic sedimentary rocks and for iron, chromium, nickel, talc, chlorite, gold, and graphite in Archean crystalline rocks, Dillon 1° x 2° quadrangle, Idaho and Montana: U.S. Geological Survey Miscellaneous Investigation Series Map I-1803-D.
- Slack, J.F., Models for tourmaline formation in the Middle Proterozoic Belt and Purcell supergroups (Rocky Mountains) and their exploration significance: Current Research, Part E, Geological Survey of Canada, Paper 93-1E, p. 33-40.
- Thorson, J.P., 1984, Suggested revisions of the lower Belt Supergroup stratigraphy of the Highland Mountains, southwestern Montana, *in* Hobbs, ed., The Belt, abstracts with summaries, Belt Symposium II, 1983: Montana Bureau of Mines and Geology Special Publication 90, p. 10-12.
- Thorson, J.P., 1993, Controls of massive sulfide mineralization in the Belt Supergroup: Belt Symposium III, Program and Abstracts, Belt Association, Inc., unpaginated.
- Turner, R.J.W., Hagen, Arthur, Hoy, Trygve, and Leitch, C.H.G., 1993, The Sullivan-North Star corridor—Regional-scale alteration, fragmental rocks and mineralization associated with the Sullivan stratiform lead-zinc deposit, southeastern British Columbia: Belt Symposium III, Program and Abstracts, Belt Association, Inc., unpaginated.
- Zieg, G.A. and Leitch, C.H.B., 1993, The geology of the Sheep Creek copper deposits, Meagher County, Montana: Belt Symposium III, Program and Abstracts, Belt Association, Inc., unpaginated.

NR40**Sedimentary Exhalative Zn-Pb Deposits**

Idaho, Montana

Descriptive Model 31a • Mark3 Index 13

Area = 4,470 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Stephen E. Box and Arthur A. Bookstrom

Rationale for Model Choice

Stratabound, massive Zn-Pb sulfide deposits form by the precipitation of sulfide and sulfate minerals from metalliferous brines that were exhaled along active submarine faults during deposition of the enclosing sedimentary sequence. The mineral deposits are dominantly iron sulfide accumulations, which enclose economic ore deposits as layers and lenses rich in Zn and Pb sulfides. These syngenetic deposits are hosted in euxinic marine sedimentary rocks in epicratonic and intracratonic basins, often associated with synsedimentary faults related to rifting and subsidence of the sedimentary basin (Briskey, 1986). The Paleozoic black shale belt in south-central Idaho (Hall, 1986; Wavra and others, 1986) is characterized by argillite, siltite, limy sandstone, shale, and siltstone, combined with the presence of synsedimentary faults, indicates that this deposit type may exist here.

Rationale for Tract Delineation

The tract was drawn to encompass the lower and upper Paleozoic, deep-marine sedimentary rocks of the black shale belt in the Wood River valley area of south-central Idaho (Hall, 1986; Bond, 1978). Abrupt facies changes and interstratified slump breccias suggest the presence of synsedimentary faults. Numerous lead and zinc occurrences within the tract, as well as one known deposit of this type, suggest the possibility of undiscovered deposits.

Examples of Deposit Type

The Triumph deposit (Kiilsgaard, 1950) near Ketchum, Idaho is considered to be a deposit of this type. The deposit is small relative to those of the grade and tonnage distributions of Menzie and Mosier (1986). Although the grade of lead and zinc are higher than 80 percent and 60 percent, respectively, of the model deposits, the tonnage is less than 10 percent of the median value. As a result the total metal content of the Triumph deposit (production and reserves) is only about 3 percent of that of typical deposits of this type.

Rationale for Numerical Estimate

The Triumph deposit is very small relative to other deposits in the grade and tonnage distributions for sedimentary exhalative Zn-Pb deposits (Menzie and Mosier, 1986). Other prospects in the region fall well outside of the grade and tonnage fields of known deposits. The region was extensively explored for this deposit type in the 1970s and 1980s by Exxon and Noranda, with no new discoveries reported. However the occurrence of a known deposit and several prospects, along with the complex structure of the region and the possibility of structurally or stratigraphically buried deposits that could elude exploration, the team judged that there was a low but still viable chance for undiscovered deposits in this tract. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 1, 2, and 3 or more deposits consistent with the grade and tonnage model of Menzie and Mosier (1986).

References

- Bond, J.G., 1978, Geologic map of Idaho: Idaho Bureau of Mines and Geology, scale 1:500,000.
- Briskey, J.A., 1986, Descriptive model of sedimentary exhalative Zn-Pb, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 211.

- Hall, W.E., 1986, Stratigraphy of and mineral deposits in Middle and Upper Paleozoic rocks of the black-shale mineral belt, central Idaho: U.S. Geological Survey Bulletin 1658-J, p. 117–131.
- Kiilsgaard, T.H., 1950, Geology and ore deposits of the Triumph-Parker mine mineral belt, *in* Anderson, A.L., Kiilsgaard, T.H., and Frykland, V.C., Jr., Detailed geology of certain areas in the Mineral Hill and Warm Springs mining districts, Blaine County, Idaho: Idaho Bureau of Mines and Geology Pamphlet 90, 73 p.
- Menzie, W.D., and Mosier, D.L., 1986, Grade and tonnage model of sedimentary exhalative Zn-Pb, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 212-215.
- Wavra, C.S., Isaacson, P.E., and Hall, W.E., 1986, Studies of the Idaho black shale belt—Stratigraphy, depositional environment, and economic geology of the Permian Dollarhide Formation: Geological Society of America Bulletin, v. 97, p. 1504–1511.

NR41**Sedimentary Exhalative Zn-Pb Deposits****South Dakota****Descriptive Model 31a****Area = 352 km²**[Model](#)*by* Alan R. Wallace**Rationale for Model Choice**

Proterozoic metamorphosed carbonaceous and pyritic black shale in the central Black Hills indicate an environment permissive for the formation of sedimentary exhalative Zn-Pb deposits, which typically form in euxinic basins, often associated with synsedimentary faults.

Rationale for Tract Delineation

The permissive tract is confined to a Proterozoic metamorphosed carbonaceous and pyritic black shale (units Xsh and Xbs; DeWitt and others, 1989), which is exposed in a large area generally centered on the town of Rochford in the central Black Hills.

Important Examples of Deposit Type

No deposits, prospects, or occurrences are known in this tract.

Rationale for Numerical Estimate

DeWitt and others (1986) gave this deposit type an "unknown" ranking of favorability, citing the lack of geochemical data and known prospects. For the present assessment, the only positive aspect is the presence of what seems to be a favorable host rock. The amount of modern exploration activity in this area is low to unknown. However, the total absence of any prospects or minor workings, considering how heavily this area has been prospected in the last 120 years, strongly indicates that ore-forming processes were not sufficiently concentrated to generate even a minor occurrence that was prospected. As a result, the team estimated that there was less than a one percent chance for the occurrence of a sedimentary exhalative Zn-Pb deposit consistent with the grade and tonnage curves for this deposit type (Menzie and Mosier, 1986). Consequently, there is no estimate.

References

- DeWitt, Ed, Redden, J.A., Wilson, A.B., and Buscher, David, 1986, Mineral resource potential and geology of the Black Hills National Forest, South Dakota and Wyoming, *with a section on Salable commodities* by J.S. Dersch: U.S. Geological Survey Bulletin 1580, 135 p.
- DeWitt, Ed, Redden, J.A., Buscher, David, and Wilson, A.B., 1989, Geologic map of the Black Hills area, South Dakota and Wyoming: U.S. Geological Survey Bulletin Miscellaneous Field Investigations Map I-1910, scale 1:250,000.
- Menzie, W.D., and Mosier, D.L., 1986, Grade and tonnage model of sedimentary exhalative Zn-Pb, in Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 212-215.

NR42**Sedimentary Exhalative Zn-Pb Deposits****Wyoming****Descriptive Model 31a • Mark3 Index 13****Area = 147 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by Warren Day***Rationale for Model Choice**

Metamorphosed Precambrian carbonaceous and pyritic black shale are exposed in the Hartville uplift region of eastern Wyoming, and the team judged that this area warranted consideration for sedimentary exhalative deposits.

Rationale for Tract Delineation

Precambrian metashales exposed in the Hartville uplift, north of Ft. Laramie, some of which reportedly contain stratabound sulfides, constitute the permissive tract.

Important Examples of Deposit Type

The McCann Pass prospect is reported to be a massive sulfide deposit hosted in metagraywacke. The Sunrise iron deposit has massive sulfide horizons associated with the iron ore. Neither of these deposits have reported reserves of base-metal ore.

Rationale for Numerical Estimate

Beyond the presence of favorable host rocks with some stratabound sulfides, the permissive tract has little evidence for the presence of an undiscovered deposit. However, the Hartville uplift region has been the scene of exploration directed at sedex deposits, indicating that industry has additional information indicative of deposits. We have little information and, for the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, and 1 or more sedimentary exhalative Zn-Pb deposits consistent with the grade and tonnage model of Menzie and Mosier (1986).

Reference

Menzie, W.D., and Mosier, D.L., 1986, Grade and tonnage model of sedimentary exhalative Zn-Pb, in Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 212-215.

NR43**Mississippi Valley Deposits****Washington****Descriptive Model 32a + 32b • Mark3 Index 94****Area = 2,410 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* Stephen E. Box and Arthur A. Bookstrom**Rationale for Model Choice**

Mississippi Valley deposits are low-temperature replacement deposits of galena, sphalerite, and chalcopryite, hosted in dolomitic carbonate rocks (Briskey, 1986). The host rocks are typically shallow-water marine carbonate rocks of the cratonic platform. Deposits within the tract near Metaline, Washington, are interpreted to be deposits of this type (Mills, 1976).

Rationale for Tract Delineation

The team used a simple approach, considering all carbonate shelf sedimentary sequences in the map area as permissive for Mississippi Valley-type (MVT) deposits. Rocks in the permissive tract are part of the Paleozoic craton-margin shelf in northeastern Washington. Permissive lithologic units include the Cambrian and Ordovician stratigraphic units in northeastern Washington (Stoffel and others, 1991).

Examples of Deposit Type

Two districts of significant production from this deposit type are known in northeastern Washington: Metaline and Van Stone (Mills, 1977). In Canada, along strike, other districts include Robb Lake and Monarch-Kicking Horse. An alternative interpretation is that they are sediment-hosted, syndepositional exhalative deposits similar to the Irish carbonate-hosted deposits (Morton, 1992). However, the ages of the deposits in the Washington and British Columbia indicates mineralization occurred well after deposition of the host rocks, which supports the MVT deposit model. Pb isotopic data from galena of the Metaline-area deposits indicate mineral deposition well after sedimentation (Devonian mineralization in Cambrian and Ordovician sedimentary rocks; S.E. Church, U.S. Geological Survey, personal communication, 1993). Deposits along strike to the north in Canada have yielded Devonian mineralization ages.

Rationale for Numerical Estimate

The grade and tonnage models for MVT deposits are for districts, as opposed to individual deposits. The grade and tonnage of the two known districts in Washington are on the low side of the median, as are the two Canadian deposits along strike, Robb Lake and Monarch-Kicking Horse. The team decided to use a revised tonnage model for Cordilleran MVT deposits that consists only of the smaller half of the deposits in the worldwide model. There seemed to be room for one or two more districts in the favorable area west of Metaline and north of Van Stone. Two clusters of Pb-Zn prospects in that area were deemed to indicate potential for undiscovered districts. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 1, 1, 2, and 2 or more Mississippi Valley Pb-Zn deposits consistent with the modified grade and tonnage model of Mosier and Briskey (1986).

References

- Briskey, J.A., 1986, Descriptive model of southeast Missouri Pb-Zn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 220-221.
- Mills, J.W., 1976, Metamorphism of the zinc-lead sulfide ores of the Yellowhead horizon, Metaline Limestone Formation, northeast Washington: *Economic Geology*, v. 71, no. 8, p. 1601-1609.

- Mills, J.W., 1977, Zinc and lead deposits in carbonate rocks, Stevens County, Washington: Washington Division of Geology and Earth Resources Bulletin 70, 171 p.
- Morton, J.A., 1992, Re-evaluation of the geology and Zn-Pb ore deposits of the Metaline mining district, northeastern Washington: Washington Geology, Washington Department of Natural Resources, Division of Geology and Earth Resources, v. 20, no. 3, p. 3-14.
- Mosier, D.L., and Briskey, J.A., 1986, Grade and tonnage model of southeast Missouri Pb-Zn and Appalachian Zn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 224-226.
- Stoffel, K.L., Joseph, N.L., Waggoner, S.Z., Gulick, S.W., Korosec, M.A., and Bunning, B.B., 1991, Geologic Map of Washington-Northeast quadrant: Washington Division of Geology and Earth Resources, Geologic Map GM-39, scale 1:250,000.

NR44**Low-sulfide Au-quartz Vein Deposits**

Washington

Descriptive Model 36a • Mark3 Index 27

Area = 3,480 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Stephen E. Box and Arthur A. Bookstrom

Rationale for Model Choice

This deposit type consists of massive quartz-gold veins that typically are low in sulfide minerals (<5 percent), are vertically and horizontally persistent, and are deformed into pinch-and-swell structures due to compressive deformation (Berger, 1986). These mesothermal veins occur in belts of regionally metamorphosed, low- to moderate-grade, marine sedimentary and volcanic rocks, penetratively deformed, and cut by high-angle regional-scale faults. Rocks of the Quesnellia terrane and the Covada Group of northeastern Washington (Stoffel and others, 1991) fit this description.

Rationale for Tract Delineation

The tract outlines the rocks of the Quesnellia terrane and the Covada Group in northeastern Washington (Stoffel and others, 1991). The tract boundaries were drawn to include areas that are covered by less than a km of younger rocks. Younger cross-cutting granitic plutons were excluded.

Important Examples of Deposit Type

No major low-sulfide Au-quartz deposits are recognized in this tract in northeastern Washington. Small deposits north of Republic, Washington near Danville are considered by some to be examples of this type of deposit (Tschauder, 1989). However several deposits are known in correlative rocks in British Columbia less than 100 km to the north.

Rationale for Numerical Estimate

The lack of known low-sulfide Au-quartz deposits or prospects led the team to give a very low estimate for the occurrence of an undiscovered deposit here. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, and 1 or more deposits consistent with the grade and tonnage model of Bliss (1986).

References

- Berger, B.R., 1986, Descriptive model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239.
- Bliss, J.D., 1986, Grade and tonnage model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239-243.
- Stoffel, K.L., Joseph, N.L., Waggoner, S.Z., Gulick, S.W., Korosec, M.A., and Bunning, B.B., 1991, Geologic map of Washington-Northeast quadrant: Washington Division of Geology and Earth Resources, Geologic Map GM-39, scale 1:250,000.
- Tschauder, R., 1986, Gold deposits in northern Ferry County, *in* Joseph, N.L., ed., Geologic guidebook for Washington and adjacent areas: Washington Division of Geology and Earth Resources Information Circular 86, p. 239-254.

NR45**Low-sulfide Au-quartz Vein Deposits**

South Dakota

Descriptive Model 36a • Mark3 Index 27

Wyoming

Area = 3,780 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Alan R. Wallace

Rationale for Model Choice

In the Black Hills, Proterozoic medium-grade metamorphic rocks contain known Au-bearing quartz veins and shear zones.

Rationale for Tract Delineation

The criteria for the delineation of the permissive tract are the presence of Proterozoic volcanic and sedimentary rocks that have undergone medium-grade regional metamorphism, evidence of large-scale faulting and shearing, and the presence of alteration and sulfide minerals in and around those structures. Although the age of many of the prospects is uncertain, some veins are cut by pegmatites related to the 1.7-Ga Harney Peak Granite, which, as a result, is excluded from the permissive tract, following DeWitt and others (1986). Faults are present throughout the crystalline basement (DeWitt and others, 1989), and prospects are common along many of those faults. Therefore, all of the Proterozoic rocks in the Black Hills except for the Harney Peak Granite are included in the permissive tract, with a small peripheral buffer to account for areas covered by less than a kilometer of Phanerozoic sedimentary rocks.

Important Examples of Deposit Type

The Clover Leaf mine near Roubaix and the Holy Terror mine near Keystone are the two largest vein deposits in the tract, and many other small- to medium-sized vein deposits and prospects occur throughout the Black Hills.

Rationale for Numerical Estimate

DeWitt and others (1986) identified 11 areas for which they identified known vein deposits and for which they assigned high, medium, or low potential for additional deposits. The team reviewed the 11 areas identified, and somewhat arbitrarily evaluated the areas as follows. Those areas identified to have a high potential (1 area) were assigned a 50 percent chance for the occurrence of an undiscovered deposit, or an expected value of 0.5 deposits. Those areas identified to have a medium potential (7 areas) were assigned a 10 percent chance for the occurrence of an undiscovered deposit, or an expected value of 0.1 deposits. Those areas identified to have a low potential (3 areas) were assigned a 1 percent chance for the occurrence of an undiscovered deposit, or an expected value of 0.01 deposits. The sum of expected values is 1.23, and since younger rocks cover only a very small proportion of this tract, and because the area has been well explored, we believe this figure is a good estimate of the expected number of undiscovered deposits for the entire tract. An estimate consistent with this expected value is, for the 90th, 50th, 10th, 5th, and 1st percentiles, 0, 1, 2, 3, and 8 or more deposits consistent with the grade and tonnage model of Bliss (1986) for low-sulfide Au-quartz vein deposits (Mark3 index 27). There are probably additional occurrences, but their relatively small size (DeWitt and others, 1986) means they would probably be smaller than deposits that make up the grade and tonnage model.

References

Bliss, J.D., 1986, Grade and tonnage model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239–243.

- DeWitt, Ed, Redden, J.A., Wilson, A.B., and Buscher, David, 1986, Mineral resource potential and geology of the Black Hills National Forest, South Dakota and Wyoming, *with a section on* Salable commodities by J.S. Dersch: U.S. Geological Survey Bulletin 1580, 135 p.
- DeWitt, Ed, Redden, J.A., Buscher, David, and Wilson, A.B., 1989, Geologic map of the Black Hills area, South Dakota and Wyoming: U.S. Geological Survey Bulletin Miscellaneous Field Investigations Map I-1910, scale 1:250,000.

NR46**Low-sulfide Au-quartz Vein Deposits****Wyoming****Descriptive Model 36a • Mark3 Index 27****Area = 244 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by Warren Day***Rationale for Model Choice**

Proterozoic medium-grade (upper greenschist to amphibolite grade) metamorphic rocks are cut by Proterozoic shear zones and faults. Scattered prospects and occurrences of Au-bearing quartz veins are present.

Rationale for Tract Delineation

To delineate the permissive tract, we used the following criteria: (1) the presence of supracrustal (volcanic or sedimentary) and granitoid host rocks of Proterozoic age; (2) medium-grade (greenschist to lower-amphibolite facies) regional metamorphism; (3) the presence of gold deposits, prospects, and occurrences; (4) evidence of large-scale shearing and faulting, and; (5) alteration mineral assemblages within and adjacent to faults and shear zones that contain quartz and carbonate veining, phyllosilicate minerals (sericite, chlorite, and/or biotite), and sulfide minerals (pyrite, arsenopyrite, and/or pyrrhotite). As in the Archean examples for Wyoming, there are no known low-sulfide Au-quartz vein deposits of significant size in Proterozoic granitoids or gneissic terranes, and areas underlain by these rock types were not considered permissive. Proterozoic rocks are found only in the southern part of the State.

Important Examples of Deposit Type

A small amount of high-grade (up to 67 g/t) ore was produced from the Gold Hill district on the western flank of the Snowy Range in the central Medicine Bow Mountains (Hausel, 1989).

Rationale for Numerical Estimate

The Gold Hill district on the western flank of the Snowy Range in the central Medicine Bow Mountains is estimated to have about an 8 percent chance of hosting an undiscovered low-sulfide gold deposit. The small bedrock mines of the district were developed on quartz veins associated with mafic dikes. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 1, and 2 or more deposits consistent with the grade and tonnage model for low-sulfide Au-quartz vein deposits of Bliss (1986).

References

- Bliss, J.D., 1986, Grade and tonnage model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239–243.
- Hausel, W.D., 1989, The geology of Wyoming's precious metal lode and placer deposits: Geological Survey of Wyoming Bulletin 68, 248 p.

NR47 **Low-sulfide Au-quartz Vein Deposits, Archean Type** **Wyoming**
Descriptive Model 36b • Mark3 Index 101
Area = 2,390 km²

[Cumulative Distribution](#)

[Histogram](#)

[Table](#)

[Model](#)

[Mineral Deposits](#)

by Warren Day

Rationale for Model Choice

The criteria used to evaluate the potential for undiscovered Archean lode gold deposits in Wyoming include: (1) the presence of supracrustal (volcanic or sedimentary) and granitoid host rocks of Archean age; (2) medium-grade (greenschist to lower-amphibolite facies) regional metamorphism; (3) the presence of gold deposits, prospects, and occurrences; (4) evidence of large-scale shearing and faulting, and; (5) alteration mineral assemblages within and adjacent to faults and shear zones that contain quartz and carbonate veining, phyllosilicate minerals (sericite, chlorite, and/or biotite), and sulfide minerals (pyrite, arsenopyrite, and/or pyrrhotite). On a worldwide basis, Archean low-sulfide Au-quartz deposits are larger in tonnage than younger low-sulfide Au-quartz vein deposits, but are lower grade; worldwide, they account for the third largest amount of gold production of any major deposit type after the Witwatersrand-type paleoplacer deposits of South Africa and porphyry Cu deposits. Therefore, deposits of this type are potentially a significant mineral resource for Wyoming. The model used in this assessment reflects the revisions made by Klein and Day (1994), who present new grade and tonnage data for Archean deposits from Precambrian shield terranes worldwide. The reader is referred to Eckstrand (1984), Colvine (1989), and Groves and Foster (1991) for excellent reviews of this deposit type.

Rationale for Tract Delineation

In Wyoming, areas that meet the basic criteria are exposed in the cores of several crustal blocks uplifted in Laramide and Tertiary time. To delineate the permissive tract, we used the distribution of Archean supracrustal rocks of appropriate metamorphic grade, and known occurrences of gold that exhibit appropriate alteration mineral assemblages. In Wyoming, no significant gold deposits is known in Archean granitoid intrusions, and these intrusions were excluded from the permissive tract.

Important Examples of Deposit Type

Archean supracrustal sequences of Wyoming contain deposits, occurrences, and prospects typical of worldwide Archean lode gold deposits. The deposits of the South Pass-Atlantic City mining district have produced the most gold. Although total gold production from the district is unknown because accurate records were not kept prior to 1933, Hausel (1991) estimated that production may have been as much as 10 metric tons of gold. The South Pass-Atlantic City area contains several known deposits, such as the Carissa, Duncan, Mary Ellen, Atlantic City, and Miners Delight mines in the western part of the permissive tract and the Burr, Goldhope, Bullion, Lone Pine in the eastern part, as well as several gold placer deposits developed from nearby bedrock sources.

Rationale for Numerical Estimate

We identified fourteen areas in Wyoming that could host an undiscovered Archean lode gold deposit, which together, make up the permissive tract. The South Pass-Atlantic City area, which includes the Lewiston mining district is viewed as the most favorable area, and we estimated that there is a 30 percent chance that it hosts an undiscovered deposit. For the entire tract, for the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 1, 4, and 5 or more deposits consistent with the grade and tonnage curve of Klein and Day (1994).

References

- Berger, B.R., 1986, Descriptive model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239.
- Colvine, A.C., 1989, Empirical model for Archean gold deposits, *in* Keays, R.R., Ramsay, W.R.H., and Groves, D.I., eds., The geology of gold deposits—The perspective of 1988: Economic Geology Monograph 6, Economic Geology Publishing Company, p. 37-53.
- Eckstrand, O.R., 1984, Canadian mineral deposit types—A geological synopsis: Geological Survey of Canada Economic Geology Report 36, 86 p.
- Groves, D.I., and Foster, R.P., 1991, Archean lode gold deposits, *in* Foster, R.P., ed., Gold metallogeny and exploration: London, Blackie and Sons, p. 63-103.
- Hausel, W.D., 1991, Economic geology of the South Pass granite-greenstone belt, southern Wind River Range, western Wyoming: Geological Survey of Wyoming Report of Investigations No. 44, 129 p.
- Klein, T.L., and Day, W.C., 1994, Descriptive and grade-tonnage models of Archean low-sulfide Au-quartz and a revised grade-tonnage model of Homestake Au: U.S. Geological Survey Open-File Report 94-250.

NR48**Homestake Stratiform Au Deposits**

Montana

Descriptive Model OFR 94-250 • Mark3 Index 100

Wyoming, Idaho

Area = 6,180 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by James E. Elliott

Rationale for Model Choice

These deposits are stratiform, and are found within predominantly carbonate and silicate facies of iron formation that is the product of submarine hot-spring activity related to volcanism. Metamorphism and deformation may have caused minor to significant remobilization of metals, sulfides, and gangue. Iron formations of this composition are exposed in several parts of Montana, and two deposits of this type are known.

Rationale for Tract Delineation

Iron formations and related sedimentary exhalative deposits are exposed in several areas in Montana and nearby parts of Wyoming and Idaho, including the Gravelly and Ruby Ranges and the Tobacco Root and Beartooth Mountains (Bayley and James, 1973). These areas were deemed permissive for Homestake stratiform gold deposits due to the association of this deposit type with iron formations. It should be noted that, at the scale of this assessment, the permissive areas do not take into account how thin (10–70 m) the host iron formations actually are. The tracts define general areas where iron formations are exposed, not the much smaller area that they actually occupy.

Important Examples of Deposit Type

The Jardine (Mineral Hill) deposit in the western Beartooth Mountains, east of Gardiner, is a known Homestake deposit. In addition, a new deposit named Crevice Mountain has been recently discovered nearby. Jardine is somewhat different from the typical Homestake deposit in that both arsenic and tungsten were produced in the earlier part of this century (Seager, 1944).

Rationale for Numerical Estimate

The permissive tract is relatively large, these deposits may have a minor surface expression, and there are two known deposits in the Beartooth Mountains. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 2, 4, 5, and 6 or more deposits consistent with the grade and tonnage model for Homestake stratiform gold deposits of Klein and Day (1994).

References

- Bayley, R.W., and James, H.L., 1973, Precambrian iron-formations of the United States: Economic Geology, v. 68, no. 7, p. 934-959.
- Klein, T.L., and Day, W.C., 1994, Descriptive and grade-tonnage models of Archean low-sulfide Au-quartz and a revised grade-tonnage model of Homestake Au: U.S. Geological Survey Open-File Report 94-250.
- Seager, G.F., 1944, Gold, arsenic, and tungsten deposits of the Jardine-Crevasse Mountain district, Park County, Montana: Montana Bureau of Mines and Geology Memoir 23, 111 p.

NR49**Homestake Stratiform Au Deposits****South Dakota****Descriptive Model OFR 94-250 • Mark3 Index 100****Area = 246 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* Alan R. Wallace**Rationale for Model Choice**

These deposits are stratiform, and are found within predominantly carbonate and silicate facies of iron formation that is the product of submarine hot-spring activity related to volcanism. Metamorphism and deformation may have caused minor to significant remobilization of metals, sulfides, and gangue. The Black Hills of South Dakota contains deposits and prospects of this type, including the Homestake mine itself, that were subsequently modified by Proterozoic metamorphism and deformation and by Tertiary hydrothermal and tectonic activity.

Rationale for Tract Delineation

In the Black Hills, carbonate and silicate facies of iron formations are Early Proterozoic in age (DeWitt and others, 1986). They are exposed in four areas, where they are relatively thin, dip moderately to steeply, and are strongly folded and deformed (DeWitt and others, 1989). They extend beneath the Phanerozoic cover, which exceeds a kilometer in thickness. The permissive tract includes four areas near Lead, Rochford, Keystone, and Nemo, as well as a buffer to include areas covered by Phanerozoic sedimentary rocks that are less than a kilometer thick. It should be noted that, at the scale of this assessment, the permissive tract does not take into account how thin (20–70 m) the host iron formations actually are. The tract is composed of general areas where iron formations are exposed, not the much smaller area that they actually occupy. The northern two areas include the Homestake Formation, which is the extremely productive iron formation that hosts the Homestake deposit and should be considered a more favorable unit. The two southern areas contain other iron formations that, while containing Homestake-type gold prospects, are less prospective and may contain deposits that are relatively smaller (DeWitt and others, 1986).

Important Examples of Deposit Type

The world-class Homestake deposit in the northern Black Hills has produced more than a thousand metric tons of gold, and has reserves of nearly 200 metric tons. Other smaller deposits and prospects are exposed in the Lead, Rochford, Keystone, and Nemo areas (DeWitt and others, 1986).

Rationale for Numerical Estimate

Although the genesis of the Homestake gold deposit is controversial, this assessment assumes that the deposit is syngenetic (not a low-sulfide gold deposit related to a shear zone) as proposed by Bachman and Caddey (1990). This is important in assessing the potential for other undiscovered deposits because the sizes of the other known syngenetic deposits in the Black Hills are trivial compared to that at the Homestake mine. With Homestake included in the deposit model, the chances of another deposit consistent with the grade and tonnage distributions is significantly less than if it were not part of the data set.

At the Homestake mine, ore is present irregularly along the steeply dipping iron formation horizon, which is 20–70 m thick, and is not continuously mineralized in surface exposures. Therefore, fortuitous erosion plays an important part in surface exploration. Parts of some major orebodies at the Homestake mine, such as the Main Ledge, are blind orebodies that are about a kilometer or less beneath the surface (Bachman and Caddey, 1990). This pattern of

irregular distribution of orebodies in a thin, steeply dipping host unit, is apparently prevalent throughout the exposures of iron formation in the Black Hills. Therefore, although the level of surface exploration has been great, blind orebodies could be present. However, the thinness of the host units and their relatively small surface area considerably reduces the actual area that is permissive for this type of deposit. Considering all these factors, for the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 1, 2, 3, and 4 or more deposits consistent with the grade and tonnage model for Homestake stratiform gold deposits of Klein and Day (1994).

References

- Bachman, R.L., and Caddey, S.W., 1990, The Homestake mine, Lead, South Dakota—An overview: Society of Economic Geologists Guidebook Series, v. 7, p. 89-94.
- DeWitt, Ed, Redden, J.A., Wilson, A.B., and Buscher, David, 1986, Mineral resource potential and geology of the Black Hills National Forest, South Dakota and Wyoming, *with a section on Salable commodities* by J.S. Dersch: U.S. Geological Survey Bulletin 1580, 135 p.
- DeWitt, Ed, Redden, J.A., Buscher, David, and Wilson, A.B., 1989, Geologic map of the Black Hills area, South Dakota and Wyoming: U.S. Geological Survey Bulletin Miscellaneous Field Investigations Map I-1910, scale 1:250,000.
- Klein, T.L., and Day, W.C., 1994, Descriptive and grade-tonnage models of Archean low-sulfide Au-quartz and a revised grade-tonnage model of Homestake Au: U.S. Geological Survey Open-File Report 94-250.

NR50**Homestake Stratiform Au Deposits****Wyoming****Descriptive Model OFR 94-250 • Mark3 Index 100****Area = 152 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Warren Day**Rationale for Model Choice**

These deposits are stratiform and are found within predominantly carbonate- and silicate-facies iron formation that is the product of submarine hot-spring activity related to volcanism. Metamorphism and deformation may have caused minor to significant remobilization of metals, sulfides, and gangue. Precambrian rocks of this composition are present locally in several mountain ranges in Wyoming.

Rationale for Tract Delineation

Carbonate- and silicate-facies iron formations are exposed in two small areas in southern Wyoming. These areas are the Hartville uplift, north of Ft. Laramie, and in the Medicine Bow Mountains, west of Laramie. The delineated tracts are larger than the area of the iron formations, which are only tens of meters thick.

Important Examples of Deposit Type

No deposits of this type are known in the permissive tracts.

Rationale for Numerical Estimate

The primary (and perhaps only) rationale for considering this model type for this area is the presence of favorable lithologies. The areas are small and no deposits or prospects are known. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, and 1 or more deposits consistent with the grade and tonnage model for Homestake stratiform gold deposits of Klein and Day (1994).

Reference

Klein, T.L., and Day, W.C., 1994, Descriptive and grade-tonnage models of Archean low-sulfide Au-quartz and a revised grade-tonnage model of Homestake Au: U.S. Geological Survey Open-File Report 94-250.

PC01**Skarn Cu Deposits**

Descriptive Model 18b • Mark3 Index 8

Area = 15,900 km²

Idaho

Oregon

Washington

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Stephen E. Box and Arthur A. Bookstrom

Rationale for Model Choice

Copper skarns are an end-member of a spectrum of skarn deposit types that are variously copper-, zinc-lead-, or iron-rich. Skarns are metallic sulfide and oxide replacement deposits that occur in carbonate host lithologies adjacent to plutonic bodies with metal-bearing hydrothermal systems. The deposits are associated with shallow intermediate plutons, commonly those that are host to porphyry-style mineralization. The carbonate bodies that host the mineralization need not be regionally extensive, but can be small local bodies that are widely scattered essentially throughout the map area.

Rationale for tract delineation

The tract was delineated by excluding areas without significant carbonate rocks from the corresponding porphyry Cu tract, and consists of the Wallowa, Baker, and Huntington terranes of northeastern Oregon, west-central Idaho, and southeasternmost Washington (Brooks and Vallier, 1978; Walker and MacLeod, 1991). Plutonic rocks of Jurassic and Cretaceous(?) age are widely scattered through these terranes, and where large enough, these were excluded from the permissive tract. Small, irregular carbonate horizons occur throughout all three structurally complex terranes such that carbonate rocks could be present in the subsurface of any part of these terranes. The Izee terrane of north-central Oregon lacks carbonate rocks and was excluded from the tract.

Important Examples of Deposit Type

The Peacock deposit is a copper skarn deposit located near Cuprum, east of the Snake River. Grade and tonnage information on the deposit (Terry Close, U.S. Bureau of Mines, personal commun., 1994) indicate it is larger than the median of the grade and tonnage distributions of Jones and Menzie (1986). This deposit and about a dozen other prospects occur in small carbonate bodies within a roof pendant to an Early Jurassic quartz diorite pluton in the Wallowa terrane. Numerous small prospects are also known around the Wallowa batholith in northeastern Oregon.

Rationale for Numerical Estimate

The presence of a number of copper skarn prospects, most of which have not been adequately explored, indicates reasonable potential for undiscovered deposits (including prospects that prove to be deposits with further exploration). The Payette National Forest, which makes up much of the Idaho part of the tract, has most of the known prospects. A recent U.S. Geological Survey assessment of mineral potential in the Payette National Forest (Bruce Johnson, U.S. Geological Survey, personal commun., 1994) estimated (at the 90th, 50th, 10th, 5th, and 1st percentiles) 0, 2, 3, 7, and 10 or more undiscovered copper skarn deposits consistent with the grade and tonnage model of Jones and Menzie (1986). Adding in the less prospective Oregon part of the tract, the National Assessment team estimated 0, 3, 5, 9, 12 (at the 90th, 50th, 10th, 5th, and 1st percentiles) or more undiscovered copper skarn deposits consistent with the grade and tonnage model of Jones and Menzie (1986).

References

- Bond, J.G., 1978, Geologic map of Idaho: Idaho Bureau of Mines and Geology, scale 1:500,000.
- Brooks, H.C., and Vallier, T.L., 1978, Mesozoic rocks and tectonic evolution of eastern Oregon and western Idaho, *in* Howell, D.G., and McDougall, K.A., eds., Mesozoic paleogeography of the western United States: Pacific section, Society of Economic Paleontologists and Mineralogists, Pacific Coast Paleogeography Symposium 2, p. 133-146
- Jones, G.M., and Menzie, W.D., 1986, Grade and tonnage model of Cu skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 86-89.
- Walker, G.W., and MacLeod, N.S., 1991, Geologic map of Oregon: U.S. Geological Survey, 2 sheets, scale 1:500,000.

PC02**Skarn Au Deposits**

Descriptive Model Bull. 1930 • Mark3 Index 105

Area = 15,900 km²Idaho
Oregon
Washington[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Stephen E. Box and Arthur A. Bookstrom

Rationale for Model Choice

Skarn Au deposits are a subset of a spectrum of skarn types that are variously copper-, zinc-lead, or iron-rich. Skarns are metallic sulfide and oxide replacement deposits that occur in carbonate host lithologies adjacent to plutonic bodies with metal-bearing hydrothermal systems. The deposits are associated with shallow intermediate plutons, commonly those that are host to porphyry-style mineralization. The carbonate bodies that host the mineralization need not be regionally extensive, but can be small local bodies that are widely scattered throughout the map area. Favorable areas are considered to be those which have known deposits or prospects of this type of deposit.

Rationale for tract delineation

The tract was delineated by excluding areas without significant carbonate rocks from the corresponding porphyry Cu tract, and consists of the Wallowa, Baker, and Huntington terranes of northeastern Oregon, west-central Idaho, and southeasternmost Washington (Brooks and Vallier, 1978; Walker and MacLeod, 1991). Plutonic rocks of Jurassic and Cretaceous(?) age are widely scattered through these terranes, and where large enough, these were excluded from the permissive tract. Small, irregular carbonate horizons occur throughout all three structurally complex terranes such that carbonate rocks could be present in the subsurface of any part of these terranes. The Izee terrane of north-central Oregon lacks carbonate rocks and was excluded from the tract.

Important Examples of Deposit Type

No significant deposits are known from this tract.

Rationale for Numerical Estimate

The lack of known deposits of this type and the lack of known porphyry copper deposits in this tract lead the team to give a very low estimate. Because the grade and tonnage model of Theodore and others (1991) includes some very small deposits, we felt we could estimate more accurately using a model that is truncated to include only those deposits with more than 15,000 metric tons of mineralized rock. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, and 1 or more deposits that are comparable in grade and tonnage to the gold skarn grade and tonnage model (truncated) of Theodore and others (1991).

References

- Brooks, H.C., and Vallier, T.L., 1978, Mesozoic rocks and tectonic evolution of eastern Oregon and western Idaho, *in* Howell, D.G., and McDougall, K.A., eds., *Mesozoic paleogeography of the western United States: Pacific section*, Society of Economic Paleontologists and Mineralogists, Pacific Coast Paleogeography Symposium 2, p. 133-146.
- Theodore, T.G., Orris, G.J., Hammarstrom, J.M., and Bliss, J.D., 1991, Gold-bearing skarns: U.S. Geological Survey Bulletin 1930, 61 p.
- Walker, G.W., and MacLeod, N.S., 1991, Geologic map of Oregon: U.S. Geological Survey, 2 sheets, scale 1:500,000.

PC03**Skarn Cu Deposits**California
Oregon

Descriptive Model 18b • Mark3 Index 8

Area = 68,900 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Dennis P. Cox, Steve Ludington, and Michael F. Diggles

Rationale for Model Choice

Skarn deposits form where intermediate to felsic intrusive rocks, which are the principal sources of the metals, are emplaced into carbonate rocks. On the Pacific margin of North America, the deposits are mainly Mesozoic in age.

Rationale for Tract Delineation

The plutons of the Klamath Mountains, the Sierra Nevada, the Salinian block, and the Southern California batholith include felsic rocks that, in places, intrude minor Triassic and older carbonate-bearing rocks.

Important Examples of Deposit Type

The only important skarn deposit in the Klamath Mountains is the King Solomon mine in the Cecilville district, which produced nearly a metric ton of gold (Hotz, 1971). There are no significant copper skarn deposits in the tract.

Rationale for Numerical Estimate

Although no significant deposits of this type are known in the tract, the region is permissive in terms of the overall geologic environment. Since no clear examples are known and since carbonate rocks make up a small proportion of the terrane intruded by plutons, it seemed most appropriate to make a small estimate. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, and 1 or more deposits consistent with the copper skarn model of Jones and Menzie (1986).

References

- Cox, D.P., and Theodore, T.G., 1986, Descriptive model of Cu skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 86.
- Hotz, P.E., 1971, Geology of lode gold districts in the Klamath Mountains, California and Oregon: U.S. Geological Survey Bulletin 1290, 91 p.
- Jones, G.M., and Menzie, W.D., 1986, Grade and tonnage model of Cu skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 86-89.

PC04**Porphyry Cu Deposits**

Washington

Descriptive Model 17 • Mark3 Index 89

Area = 30,000 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Roger P. Ashley

Rationale for Model Choice

Granitic stocks and batholiths intrude the Tertiary volcanic rocks of the western Cascades in southern Washington, and batholiths of both Mesozoic and Tertiary age intrude the pre-Tertiary rocks of the northern Cascades. Seven known porphyry copper deposits are spatially associated with these subvolcanic intrusions, and there are about two dozen porphyry-type prospects (Peterson, 1991), indicating that magmatism in the Cascade arc produced a favorable environment for these deposits. Mesozoic magmatism produced many porphyry copper deposits in the Canadian Cordillera and accounts for one of the seven known deposits in Washington. The model for porphyry copper deposits in British Columbia and Alaska (Menzie and Singer, 1993) is used here, rather than the worldwide model (Singer and others, 1986), because the lower copper grades of the known Washington deposits fit this model better. Although some porphyry copper deposits of the Cascade Range have significant gold and molybdenum resources, not enough information is available to determine whether the Cu-Au or Cu-Mo porphyry models would be more appropriate than the British Columbia-Alaska model.

Rationale for Tract Delineation

The southern boundary of the tract is the northwest-trending Olympic-Wallowa lineament, which approximately marks the northern limit of extensive Tertiary volcanic rocks in the Cascade Range. The tract includes all significant exposures of intrusive rocks in the Cascades from the Olympic-Wallowa lineament northward to the Canadian border (Smith, 1993). It also includes concealed magnetic plutons shown on an interpretive geophysical map prepared from aeromagnetic and gravity data (Blakely and Plouff, 1991). Parts of the western boundary represent an approximate projection of plutonic or metamorphic rocks under 1 km of Quaternary cover. Locally, the west boundary is defined by exposed plutons; a buffer zone about 3 km wide has been drawn around these exposures. The southeast boundary represents the projection of plutonic, metamorphic, and Tertiary volcanic rocks under flows of the Miocene Columbia River Basalt Group (Drost and Whiteman, 1986), where they are <1 km thick.

Important Examples of Deposit Type

The Glacier Peak deposit is the largest known porphyry copper deposit in this tract, having a reserve of 1.7 billion metric tons of ore containing 0.334 percent copper (Derkey and others, 1990). Other known deposits in the tract include Mazama, Gold Mountain, Sunrise, North Fork, Clipper-Three Brothers, and Condor-Hemlock (Peterson, 1991; Derkey and others, 1990). The tract also contains three copper-bearing breccia pipes that contain substantial known ore reserves. These are not included here as known porphyry copper deposits because their grades are too high and tonnages too low to fit the published porphyry copper models. However, because several of the known porphyry deposits include breccia pipes in addition to stockwork mineralization, the breccia pipes are regarded as porphyry prospects.

Rationale for Numerical Estimate

For the 90th, 50th, and 10th percentiles, the team estimated respectively, 3, 6, and 15 deposits consistent with the grade and tonnage model of Menzie and Singer (1993); (Mark3 index 89). This estimate expresses the belief that additional exploration of known prospects would

disclose porphyry deposits. Note that at the 10th percentile, more than half of the known prospects are expected to yield deposits. The lack of additional deposits at lower percentiles reflects the perception that exploration of this tract for this deposit type has been relatively thorough, and there is a very low probability that completely undiscovered prospects remain.

References

- Blakely, R.J., and Plouff, Donald, 1991, Geophysical interpretations, *in* Diggles, M.F., ed., Assessment of undiscovered porphyry copper deposits within the range of the Northern Spotted Owl, northwestern California, western Oregon, and western Washington: U.S. Geological Survey Open-File Report 91-377, p. 21-30.
- Derkey, R.E., Joseph, N.L., and Lasmanis, Raymond, 1990, Metal mines of Washington—Preliminary report: Washington Division of Geology and Earth Resources Open-File Report 90-18, 577 p.
- Drost, B.W., and Whiteman, K.J., 1986, Surficial geology, structure, and thickness of selected geohydrologic units in the Columbia Plateau, Washington: U.S. Geological Survey Water Resources Investigations Report 84-4326, 1 text sheet, 10 map sheets, scale 1:500,000.
- Menzie, W.D., and Singer, D.A., 1993, Grade and tonnage model of porphyry Cu deposits in British Columbia, Canada, and Alaska, USA: U.S. Geological Survey Open-File Report 93-275, 8 p.
- Peterson, J.A., 1991, Known copper deposits, *in* Diggles, M.F., ed., Assessment of undiscovered porphyry copper deposits within the range of the Northern Spotted Owl, northwestern California, western Oregon, and western Washington: U.S. Geological Survey Open-File Report 91-377, p. 17-21.
- Singer, D.A., Mosier, D.L., and Cox, D.P., 1986, Grade and tonnage model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 77-81.
- Smith, J.G., 1993, Geologic map of upper Eocene to Holocene volcanic and related rocks in the Cascade Range, Washington: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-2005, scale 1:500,000, 19 p.

PC05**Porphyry Cu Deposits**

Oregon, Washington

Descriptive Model 17 • Mark3 Index 89

Area = 45,100 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Roger P. Ashley

Rationale for Model Choice

Granitic stocks and batholiths intrude the Tertiary volcanic rocks of the western Cascades in Oregon and southern Washington. One known porphyry copper deposit is associated with these subvolcanic intrusions, and there are about a dozen porphyry-type prospects (Peterson, 1991), indicating that magmatism in the Cascade arc produced a favorable environment for these deposits. The porphyry copper grade and tonnage model for British Columbia and Alaska (Menzie and Singer, 1993) is used here because known deposits in the north Cascades of Washington fit this model, and deposits in the southern Cascades are expected to be similar.

Rationale for Tract Delineation

The tract includes all significant exposures of intrusive rocks in the Cascades south of the Olympic-Wallawa lineament. In the eastern part of the Cascades in southern Washington and throughout the Cascades of Oregon, exposures of intrusive rocks are scattered throughout the extensive Tertiary volcanic rocks, and regional maps for Oregon (Sherrod and Smith, 1989; Walker and MacLeod, 1991) do not distinguish phaneritic intrusions from finer-grained bodies. Therefore, in Oregon and in much of the area in Washington, the tract includes both volcanic and intrusive rocks of Tertiary age. The tract also includes concealed magnetic plutons shown on an interpretive geophysical map prepared from aeromagnetic and gravity data (Blakely and Plouff, 1991).

In detail, the western boundary of the tract in Washington is drawn to include all exposed intrusions, both coarse-grained and fine-grained, shown on the regional geologic maps of Smith (1993) and Walsh and others (1987). A buffer zone about 3 km wide has been drawn around individual exposed intrusions. Tertiary rocks without intrusions that are likely older than the Cascades arc have been excluded. Outlines of inferred concealed plutons lie east of this boundary. The western boundary in Oregon is drawn to include all Cascades volcanic, volcanoclastic, and intrusive rocks, but in most places is located at the approximate projection of these rocks under either the Columbia River Basalt Group or Quaternary deposits, where they are <1 km thick. North of Eugene, the tract has been expanded to include an inferred concealed intrusion.

The southern boundary of the tract is the southern edge of an area where concealed intrusions can be inferred. Although intrusions exist in the Tertiary Cascades farther south in Oregon and northern California, they are dikes, sills, and small plugs, mostly fine-grained, and thus are unlikely sources for porphyry copper deposits. Also, there are no known base-metal vein occurrences or other signs of porphyry systems in Tertiary rocks south of the tract, so we conclude that porphyry mineralization, if it exists, is deeper than 1 km.

The eastern boundary in Washington and northern Oregon represents the approximate projection of Tertiary volcanic rocks under flows of the Miocene Columbia River Basalt Group (Drost and Whiteman, 1986) and Quaternary volcanic rocks, where they are <1 km thick. Inliers of pre-Cascades rocks are included in the tract east of Mt. Rainier because many Tertiary intrusions are exposed there. In Oregon, the eastern boundary represents the approximate projection of Tertiary volcanic rocks under Quaternary High Cascades volcanic rocks, where they are <1 km thick.

Important Examples of Deposit Type

The Margaret deposit of southwestern Washington is the only known porphyry copper deposit in this tract. It contains an estimated ore reserve of at least 523 million metric tons grading 0.36 percent copper, and has significant amounts of molybdenum, gold, and silver (Derkey and others, 1990). The tract also contains two copper-bearing breccia pipes that contain substantial known reserves of copper, molybdenum, gold, and silver. These are not included here as known porphyry copper deposits because their grades are too high and tonnages too low to fit the published porphyry copper models. However, because several of the known porphyry deposits in the northern Cascades include breccia pipes in addition to stockwork mineralization, the breccia pipes are regarded as porphyry prospects.

Rationale for Numerical Estimate

Our estimate reflects the belief that additional exploration of known prospects would disclose deposits. Note that at the 10th percentile, almost all known prospects are expected to yield deposits. The lack of additional deposits below the 10th percentile reflects the perception that, although exploration of this tract for this deposit type has not been as thorough as it has in the northern Cascades, the potential for new deposits lies almost entirely within known polymetallic vein districts, which constitute or contain the known porphyry prospects in this tract. Thus, there is a very low probability that completely undiscovered prospects remain. For the 90th, 50th, and 10th percentiles, the team estimated 1, 3, and 10 or more porphyry-copper deposits consistent with the grade and tonnage model of Menzie and Singer (1986).

References

- Blakely, R.J., and Plouff, Donald, 1991, Geophysical interpretations, *in* Diggles, M.F., ed., Assessment of undiscovered porphyry copper deposits within the range of the Northern Spotted Owl, northwestern California, western Oregon, and western Washington: U.S. Geological Survey Open-File Report 91-377, p. 21-30.
- Derkey, R.E., Joseph, N.L., and Lasmanis, Raymond, 1990, Metal mines of Washington—preliminary report: Washington Division of Geology and Earth Resources Open-File Report 90-18, 577 p.
- Drost, B.W., and Whiteman, K.J., 1986, Surficial geology, structure, and thickness of selected geohydrologic units in the Columbia Plateau, Washington: U.S. Geological Survey Water Resources Investigations Report 84-4326, 1 text sheet, 10 map sheets, scale 1:500,000.
- Menzie, W.D., and Singer, D.A., 1993, Grade and tonnage model of porphyry Cu deposits in British Columbia, Canada, and Alaska, USA: U.S. Geological Survey Open-File Report 93-275, 8 p.
- Peterson, J.A., 1991, Known copper deposits, *in* Diggles, M.F., ed., Assessment of undiscovered porphyry copper deposits within the range of the Northern Spotted Owl, northwestern California, western Oregon, and western Washington: U.S. Geological Survey Open-File Report 91-377, p. 17-21.
- Sherrod, D.R., and Smith, J.G., 1989, Preliminary map of upper Eocene to Holocene volcanic and related rocks of the Cascade Range, Oregon: U.S. Geological Survey Open-File Report 89-14, 1:500,000 scale, text 20 p.
- Smith, J.G., 1993, Geologic map of upper Eocene to Holocene volcanic and related rocks in the Cascade Range, Washington: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-2005, scale 1:500,000, 19 p.
- Walker, G.W., and MacLeod, N.S., 1991, Geologic map of Oregon: U.S. Geological Survey, 2 sheets, scale 1:500,000.
- Walsh, T.J., Korosec, M.A., Phillips, W.M., Logan, R.L., and Schasse, H.W., 1987, Geologic map of Washington—southwest quadrant: 1:250,000 scale, 28 p.

PC06**Porphyry Cu Deposits****Oregon****Descriptive Model 17 • Mark3 Index 89****Idaho, Washington****Area = 28,500 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Stephen E. Box and Arthur A. Bookstrom**Rationale for Model Choice**

Porphyry copper deposits consist of copper-bearing minerals in disseminated grains and in stockwork quartz veinlets in hydrothermally altered, intermediate to felsic porphyritic intrusions and adjacent country rocks (Cox, 1986). Porphyry copper deposits are generally found in magmatic belts associated with convergent plate margins, and are associated with plutonic rocks of a wide variety of igneous compositions, ranging from diorite to granite. However, gabbros and high-silica granites are seldom associated with porphyry copper deposits. Associated mineral deposits include polymetallic vein, base metal skarn, and (or) base metal replacement deposits (Cox, 1986). Compositionally appropriate granitic plutons of Jurassic, Cretaceous, and Tertiary age intrude accreted Mesozoic terranes in northeast Oregon and adjacent parts of west-central Idaho and southeasternmost Washington. Porphyry copper deposits in Mesozoic accreted terranes in British Columbia and Alaska are somewhat smaller than the well-known Arizona deposits, and have been characterized by a separate grade and tonnage model used here (Menzie and Singer, 1993). Choice of this model reflects the opinion of the team that deposits in this tract would be more like those of British Columbia than the deposits in southwestern U.S. that have higher copper grades.

Rationale for Tract Delineation

All areas with shallowly emplaced (<5 km) convergent-margin plutonic rocks of any age are considered permissive for porphyry copper deposits. Factors that exclude areas from such permissive terranes would include location outside of known plutonic belts, the presence of gabbroic or high-silica granites only, or the presence of only deeply emplaced plutonic rocks. Both large and small bodies of Jurassic and Cretaceous granitic rocks occur throughout the Wallowa, Baker, and Olds Ferry terranes of eastern Oregon and adjacent parts of west-central Idaho and southeasternmost Washington (Walker and MacLeod, 1991). Areas of Eocene and Oligocene(?) volcanic and volcanoclastic rocks (Clarno Formation) are included since they are typically intruded by coeval hypabyssal dikes, sills, and plugs of intermediate to felsic composition. The boundaries of the tract are generally delimited where the cover of younger rocks is greater than 1 km. A favorable area within the tract consists of a belt of associated copper skarns in the Wallowa-Seven Devils Mountains region that straddles the Oregon-Idaho border.

Important Examples of Deposit Type

No porphyry Cu deposits are known within the tract, but the area contains several small skarn Cu deposits in a belt from the Seven Devils Mountains to the Wallowa batholith. Five or more areas with acid sulfate alteration are known in the Mineral district of western Idaho. These areas might be related to porphyry Cu systems at depth.

Rationale for Numerical Estimate

Although no porphyry Cu deposits are known, the estimate was influenced by the presence of the small Cu skarns around the Wallowa batholith, and in the Mineral district. Some major copper companies have had exploration programs in the area, so the lack of even a single known deposit is an indication for relatively low likelihood for undiscovered deposits. For the

90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 1, 2, and 5 or more deposits consistent with the grade and tonnage model of Menzie and Singer (1993).

References

- Cox, D.P., 1986, Descriptive model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 76.
- Menzie, W.D., and Singer, D.A., 1993, Grade and tonnage model of porphyry Cu deposits in British Columbia, Canada, and Alaska, USA: U.S. Geological Survey Open-File Report 93-275, 8 p.
- Walker, G.W., and MacLeod, N.S., 1991, Geologic map of Oregon: U.S. Geological Survey, 2 sheets, scale 1:500,000.

PC07**Porphyry Cu Deposits**

Idaho

Descriptive Model 17

Area = 2,810 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Stephen E. Box and Arthur A. Bookstrom

Rationale for Model Choice

Porphyry copper deposits consist of copper-bearing minerals in disseminated grains and in stockwork quartz veinlets in hydrothermally altered, intermediate to felsic porphyritic intrusions and adjacent country rocks (Cox, 1986). Porphyry copper deposits are generally found in magmatic belts associated with convergent plate margins, and are associated with plutonic rocks of a wide variety of igneous compositions, ranging from diorite to granite. However, gabbros and high-silica granites are seldom associated with porphyry copper deposits. Associated mineral deposits include polymetallic vein, base metal skarn, and (or) base metal replacement deposits (Cox, 1986). Compositionally appropriate granitic plutons of Cretaceous and Tertiary age occur throughout this broad tract.

Rationale for Tract Delineation

The tract delineates an area of Eocene and older rocks surrounded by Tertiary volcanic and sedimentary rocks. The geology is a southwest continuation of the Idaho batholith and its country rock across the Neogene Snake River plain to the northeast.

Important Examples of Deposit Type

No porphyry Cu deposits or prospects are known from this tract.

Rationale for Numerical Estimate

The lack of known deposits or prospects of this deposit type in the tract, combined with its small size and the apparent relatively thorough exploration led the team to give a very low estimate for undiscovered porphyry copper deposits. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, and 1 or more porphyry-copper deposits consistent with the grade and tonnage model of Singer and others (1986).

References

- Bond, J.G., 1978, Geologic map of Idaho: Idaho Bureau of Mines and Geology, scale 1:500,000.
- Cox, D.P., 1986, Descriptive model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 76.
- Singer, D.A., Mosier, D.L., and Cox, D.P., 1986, Grade and tonnage model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 77-81.

PC08**Porphyry Cu Deposits**California
Oregon

Descriptive Model 17 • Mark3 Index 4

Area = 143,100 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Dennis P. Cox and Roger P. Ashley

Rationale for Model Choice

The Lights Creek porphyry copper deposit (Storey, 1978) is located in the northernmost part of the Sierra Nevada, in the Plumas County copper belt of Knopf (1935). Lights Creek consists of two mineralized zones 3 km apart. It differs from typical porphyry copper systems in that magnetite is more abundant than pyrite and chlorite is the main alteration mineral. Zoned potassic and phyllic alteration typical of porphyry copper deposits is indistinct. The copper belt includes the Engels and Superior copper vein deposits near Lights Creek (Anderson, 1931) and the Walker vein deposit 20 km to the southeast. The vein deposits are large compared to polymetallic vein median tonnage, and contain magnetite, tourmaline and actinolite in addition to chalcopyrite, bornite and other sulfides. Deposits in the Plumas County copper belt are all related to stocks of gabbroic to granodioritic composition that are older than the major batholiths in the northern Sierra Nevada.

The abundance of magnetite in these deposits suggests an affinity with porphyry copper-gold systems, but no gold grades for the deposits are available. The general porphyry copper grade and tonnage model (Singer and others, 1986) was used in the assessment.

Rationale for Tract Delineation

The permissive tract includes all the major plutons of the Sierra Nevada, Salinian block, and Klamath Mountains. Plutons permissive for porphyry copper deposits are believed to be emplaced at shallow levels in the crust, but because we have no way to distinguish this environment on a regional scale, the entire tract is considered permissive. Despite the apparent scarcity of pluton-related deposits in the Klamath Mountains, this part of the tract is considered permissive for several types of pluton-related deposits. Of these, polymetallic veins might be indicators of concealed porphyry copper systems. The only vein deposits that clearly fit the polymetallic vein model are quartz veins rich in silver and base metal sulfides in the South Fork district, located in the Shasta Bally pluton at the southern edge of the Klamath Mountains (Silberman and Danielson, 1993). Some occurrences in the Gold Hill, Ashland, and Applegate districts of Oregon may also be polymetallic veins.

Important Examples of Deposit Type

The Lights Creek bodies contain 315 million metric tons of mineralized rock that average 0.34 percent copper. The Engels and Superior veins together produced about four million metric tons of ore averaging 1.79 percent copper (Storey, 1978). In the Klamath Mountains, the most important polymetallic vein deposit is the Silver Falls-Chicago Consolidated mine in the South Fork district, which produced \$1,000,000 worth of metal, mainly silver (Hotz, 1971).

Rationale for Numerical Estimate

Because of the scarcity and restricted extent of porphyry copper environments in the Sierra Nevada and Klamath Mountains, a low estimate of undiscovered deposits was made. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 1, and 1 or more porphyry copper deposits consistent with the grade and tonnage model of Singer and others (1986) (Mark3 index 4). Most of the undiscovered resource is believed to be in the northern Sierra Nevada.

References

- Anderson, C.A., 1931, Geology of the Engels and Superior mines, Plumas County, California (with a note on the ore deposits of the Superior mine): California University Geological Sciences Bulletin, v. 20, no. 8, p. 293-330.
- Hotz, P.E., 1971, Geology of lode gold districts in the Klamath Mountains, California and Oregon: U.S. Geological Survey Bulletin 1290, 91 p.
- Knopf, Adolph, 1935, The Plumas County copper belt, California, *in* Copper resources of the world: 16th International Geologic Congress, Washington D.C., v. 1, p. 241-245.
- Silberman, M.L., and Danielson, Joanne, 1993, Gold-bearing quartz veins in the Klamath Mountains in the Redding 1° x 2° degree quadrangle, northern California: California Geology, v. 46, p. 35-44.
- Singer, D.A., Mosier, D.L., and Cox, D.P., 1986, Grade-tonnage model of porphyry copper, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 77-81.
- Storey, L.O., 1978, Geology and mineralization of the Lights Creek stock, Plumas County, California in Proceedings of the porphyry copper symposium: Arizona Geological Society Digest, v. XI, p. 49-58.

PC09**Massive Sulfide Deposits, Cyprus Type**Oregon
Idaho

Descriptive Model 24a • Mark3 Index 11

Area = 5,210 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Stephen E. Box and Arthur A. Bookstrom

Rationale for Model Choice

Cyprus massive-sulfide deposits are massive, stratabound Cu-, Zn-, and Fe- sulfide deposits deposited with submarine basalts in ophiolite sequences (Singer, 1986). Recent work in modern ocean basins has identified active modern analogues in hydrothermal vents associated with modern mid-ocean ridge spreading centers (Koski and others, 1994). Widespread ophiolite fragments in the Baker terrane of northeastern Oregon are thought to be remnants of Phanerozoic oceanic plate crust accreted to the edge of the Proterozoic continent (Brooks and Vallier, 1978).

Rationale for Tract Delineation

The Baker terrane is composed of a melange of crustal fragments of ocean basin and island arc origin in a highly deformed argillaceous matrix (Brooks and Vallier, 1978). Large and small fragments of ophiolite sequences occur widely throughout the terrane. The entire terrane as shown by Walker and MacLeod (1991) was considered permissive for Cyprus deposits.

Important Examples of Deposit Type

No known examples of this type of deposit are known from the Baker terrane, but some prospects are considered to have characteristics that could be indicative of this deposit type.

Rationale for Numerical Estimate

Although there are no deposits known, the estimators judged there was still some potential for undiscovered deposits. The exploration for them has not been thorough, and the potential exploration area is quite large. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, 1 or more undiscovered deposits consistent with the grade and tonnage model of Singer and Mosier (1986) .

References

- Brooks, H.C., and Vallier, T.L., 1978, Mesozoic rocks and tectonic evolution of eastern Oregon and western Idaho, *in* David G. Howell and Kristin A. McDougall, eds., Mesozoic paleogeography of the western United States: Pacific section, Society of Economic Paleontologists and Mineralogists, Pacific Coast Paleogeography Symposium 2, p. 133-146.
- Koski, R.A., Jonasson, I.R., Kadko, D.C., Smith, V.K., and Wong, F.L., Compositions, growth mechanisms, and temporal relations of hydrothermal sulfide-sulfate-silica chimneys at the northern Cleft segment, Juan de Fuca Ridge: *Journal of Geophysical Research*, v. 99, p. 4813-4832.
- Singer, D.A., 1986, Descriptive model of Cyprus massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 131.
- Singer, D.A., and Mosier, D.L., 1986, Grade-tonnage model of Cyprus massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 131-135.
- Walker, G.W., and MacLeod, N.S., 1991, Geologic map of Oregon: U.S. Geological Survey, 2 sheets, scale 1:500,000.

PC10**Massive Sulfide Deposits, Cyprus Type**California
Oregon

Descriptive Model 24a • Mark3 Index 11

Area = 16,000 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Dennis P. Cox, Steve Ludington, and Michael F. Diggles

Rationale for Model Choice

Cyprus massive-sulfide deposits are associated with basaltic submarine volcanic rocks in ophiolite sequences. Ophiolites are widespread in the Klamath Mountains and one Cyprus-type deposit, and several prospects are known (Koski and Derkey, 1981).

Rationale for Tract Delineation

Submarine basalts and associated ultramafic rocks ranging in age from Permian through Jurassic are widespread in the Klamath terrane. All sedimentary and volcanic rocks of these ages as well as the eastern part of the Josephine Peridotite were delineated as permissive for Cyprus-type deposits.

Important Examples of Deposit Type

The Turner Albright deposit contains three million metric tons of massive sulfide ore averaging 1.46 percent copper, 3.33 percent zinc, 15 grams per metric ton silver, and 3.7 grams per metric ton gold (Kuhns and Baitis, 1987).

Rationale for Numerical Estimate

Because of the presence of one known deposit, and 2 significant prospects, the estimators decided that there is an even chance of an equal number of undiscovered deposits (3), and that belief guided our estimate. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 3, 4, 5, and 6 or more undiscovered deposits consistent with the grade and tonnage model of Singer and Mosier (1986).

References

- Koski, R.A., and Derkey, R.E., 1981, Massive sulfide deposits in ocean-crust and island-arc terranes in southwestern Oregon: Oregon Geology, v. 43, no. 9, p. 119-125.
- Kuhns, R.J., and Baitis, H.W., 1987, Preliminary study of the Turner Albright Zn-Cu-Ag-Au-Co massive sulfide deposit, Josephine County, Oregon: Economic Geology, v. 82, no. 5, p. 1362-1376.
- Singer, D.A., and Mosier, D.L., 1986, Grade-tonnage model of Cyprus massive sulfide, in Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 131-135.

PC11**Massive Sulfide Deposits, Besshi Type**California
Oregon, Washington

Descriptive Model 24b • Mark3 Index 30

Area = 38,700 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Dennis P. Cox and Steve Ludington

Rationale for Model Choice

Volcanogenic massive sulfide deposits in western United States and have been an historically important source of Cu, Zn, Ag, and Au. Relatively high grades of polymetallic ores, simple metallurgy, and potential for large deposits make these deposits an attractive exploration target. Besshi massive sulfide deposits form in marine sedimentary rocks associated with subordinate marine basalt flows and breccias (Fox, 1984).

Rationale for Tract Delineation

One massive sulfide deposit, Island Mountain, occurs in Cretaceous rocks of the Franciscan Complex in California. Island Mountain is difficult to classify as to massive sulfide subtype but, as it is in a sedimentary rather than volcanic environment, it most resembles a Besshi-type deposit. We have, therefore, included all of the Franciscan Complex in a permissive tract for Besshi deposits even though only one example is known and only a small amount of this map unit is probably favorable for the occurrence of volcanogenic massive sulfide deposits. The Franciscan Complex is composed chiefly of graywacke, siltstone, chert, and greenstone (Dickinson and others, 1982).

In western Oregon and Washington, the submarine basalt and minor intercalated sedimentary rocks of the Tertiary Crescent Formation and lithologically equivalent units are considered permissive for Besshi deposits although no occurrences are known.

Important Examples of Deposit Type

The Island Mountain massive-sulfide deposit, which has produced 120,000 metric tons of pyrrhotite-rich ore averaging 3.3 percent Cu, 33 g/t Ag, and 2 g/t Au, was classified as a Besshi-type deposit by Koski and others (1993). Host rocks are a mélange of sandstone, siltstone, and minor chert and greenstone.

Rationale for Numerical Estimate

The team made a low estimate because only one Besshi type deposit is known. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, and 1 or more undiscovered deposits consistent with the Besshi grade and tonnage model of Singer (1986).

References

- Dickinson, W.R., Ingersoll, R.W., Cowan, D.S., Helmhold, K.P., and Cuczek, C.A., 1982, Provenance of Franciscan sandstones in coastal California: Geological Society of America Bulletin, v. 93, p. 95–107.
- Fox, J.S., 1984, Besshi-type volcanogenic sulfide deposits—A review: Canadian Institute Mining and Metallurgy Bulletin, v. 77, no. 864, p. 57–68.
- Koski, R.A., Lamons, R.C., Dumoulin, J.A., and Bouse, R.M., 1993, Massive sulfide metallogenesis at a late Mesozoic sediment-covered spreading axis—Evidence from the Franciscan complex and contemporary analogues: Geology, v. 21, p. 137–140.
- Singer, D.A., 1986, Grade and tonnage model of Besshi massive sulfide deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 136–138.

PC12**Massive Sulfide Deposits, Sierran Kuroko Type**

Washington

Descriptive Model 28a.1 • Mark3 Index 44

Area = 5,720 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Dennis P. Cox, Steve Ludington, and Michael F. Diggles

Rationale for Model Choice

Volcanogenic massive sulfide deposits in western Washington have been an historically important source of Cu, Zn, Ag, and Au. Relatively high grades of polymetallic ores, simple metallurgy, and potential for large deposits make these deposits attractive exploration targets. Kuroko massive sulfide deposits form in marine volcanic rocks of intermediate to felsic composition that include rhyolite, dacite, and subordinate basalt and associated sedimentary rocks. These rock types are present in tectonostratigraphic terranes derived from island-arc volcanism. The Sierran kuroko model, which is defined to be restricted to deposits of Triassic and Jurassic age, is used for this tract because the only known deposit is hosted in a belt of gneiss and hornblende schist of Late Triassic age.

Rationale for Tract Delineation

All map units containing sequences of submarine volcanic rocks in the Northern Cascades have been included and define the permissive area for kuroko massive sulfide deposits. Although some of these areas may be permissive for Cyprus and Besshi deposits, the team assessed only for kuroko, because of lack of detailed stratigraphic information in the area.

Important Examples of Deposit Type

The Holden deposit, in western Washington, produced 9 million metric tons of ore averaging 1.06 percent Cu, 0.2 percent Zn, 6.8 grams per metric ton Ag, and 2 grams per metric ton Au between 1938 and 1957 (McWilliams, 1958). This deposit is larger than all other deposits in the Sierran kuroko grade and tonnage model, but this difference is not deemed sufficient to rule out the use of that model.

Rationale for Numerical Estimate

The Holden deposit is in a part of the permissive tract that may continue under rocks of the Columbia River Basalt Group. The area that is covered may be the site of undiscovered deposits. For the 90th, 50th, 10th, and 5th percentiles, the team estimated 0, 0, 1, and 2 or more Sierran kuroko deposits consistent with the grade and tonnage model of Singer (1992).

References

- Dragovitch, J.D., and Derkey, R.E., 1994, A Late Triassic island-arc setting for the Holden volcanogenic massive sulfide deposit, North Cascades, Washington: *Washington Geology*, v. 22, no. 1, p. 22-39.
- McWilliams, J.R., 1958, Mining methods and costs at the Holden mine, Chelan Division, Howe Sound Company, Chelan County, Washington: U.S. Bureau of Mines Information Circular 7870, 44 p.
- Singer, D.A., 1986, Descriptive model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 189.
- Singer, D.A., 1992, Grade and tonnage model of Sierran kuroko deposits, *in* Bliss, J.D., ed., *Developments in mineral deposit modeling*: U.S. Geological Survey Bulletin 2004, p. 29-32.

PC13**Massive Sulfide Deposits, Kuroko Type**Oregon
Idaho, Washington

Descriptive Model 28a • Mark3 Index 93

Area = 15,900 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Stephen E. Box and Arthur A. Bookstrom

Rationale for Model Choice

Kuroko massive sulfide deposits are stratabound accumulations of massive Fe-sulfides with subordinate (but economically significant) layers and lenses of Cu-, Zn-, and Pb-sulfides (Singer, 1986). These are deposited on the seafloor around hydrothermal vents associated with felsic and intermediate volcanic rocks in and around island arc volcanic complexes. Two kuroko deposits are known in Permian volcanic rocks of the Blue Mountains of Oregon.

Rationale for Tract Delineation

Island arc volcanic terranes in the Blue Mountains of northeastern Oregon are considered permissive environments for kuroko massive sulfide deposits. These include the Wallowa and Huntington terranes in Oregon, Idaho and southeasternmost Washington (Brooks and Vallier, 1978; Walker and MacLeod, 1991). The Baker melange terrane is also included because it incorporates some fragments of arc volcanic and plutonic rocks. Plutonic bodies that intrude these terranes were excluded from the permissive tracts.

Important Examples of Deposit Type

In the Hells Canyon area of Oregon and Idaho, the Red Ledge (Fifarek and others, 1994) and Iron Dyke (Bussey and Anderson, 1994) deposits of Permian age have grade and tonnage characteristics that fit the kuroko grade and tonnage model of Singer and Mosier (1986). In addition, several more prospects of this type are known in the Hells Canyon area in Idaho and south of the Wallowa Mountains in Oregon.

Rationale for Numerical Estimate

Within the tract, only the Hells Canyon and south Wallowa Mountains areas are considered favorable for the presence of undiscovered deposits. Despite the presence of two deposits and several more prospects in the Hells Canyon area, the poor economics for any but the largest of these has led to an incomplete exploration effort. The tendency for these deposits to occur in clusters leads us to further optimism. The uncertainty, given the presence of only two known deposits in the area, is rather high. For the 90th, 50th, and 10th percentiles, the team estimated 1, 3, and 6 or more kuroko deposits consistent with the grade and tonnage model of Singer and Mosier (1986).

References

- Brooks, H.C., and Vallier, T.L., 1978, Mesozoic rocks and tectonic evolution of eastern Oregon and western Idaho, *in* David G. Howell and Kristin A. McDougall, editors, Mesozoic paleogeography of the western United States: Pacific section, Society of Economic Paleontologists and Mineralogists, Pacific Coast Paleogeography Symposium 2, p. 133-146.
- Bussey, S.D., and Anderson, P.J., 1994, Geology of the Iron Dyke mine and surrounding Permian Hunsaker Creek Formation *in* Vallier, T.L., and Brooks, H.C., eds., Geology of the Blue Mountains region of Oregon, Idaho, and Washington: U.S. Geological Survey Professional Paper 1439, p. 151-182.
- Fifarek, R.H., Juhas, A.P., and Field, C.W., 1994, Geology, mineralization, and alteration of the Red Ledge volcanogenic massive sulfide deposit, western Idaho, *in* Vallier, T.L., and Brooks, H.C., eds.,

- Geology of the Blue Mountains region of Oregon, Idaho, and Washington: U.S. Geological Survey Professional Paper 1439, p. 113-150.
- Singer, D.A., 1986, Descriptive model of Cyprus massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 131.
- Singer, D.A., 1986, Descriptive model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 189.
- Singer, D.A. and Mosier, D.L., 1986, Grade and tonnage model of kuroko deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 190-197.
- Walker, G.W., and MacLeod, N.S., 1991, Geologic map of Oregon: U.S. Geological Survey, 2 sheets, scale 1:500,000.

PC14**Massive Sulfide Deposits, Sierran Kuroko Type**

California

Descriptive Model 28a.1 • Mark3 Index 44

Oregon

Area = 15,500 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Dennis P. Cox, Steve Ludington, and Michael F. Diggles

Rationale for Model Choice

Volcanogenic massive sulfide deposits in the Klamath Mountains have been a moderately important source of Cu, Zn, Ag, and Au. Relatively high grades of polymetallic ores, simple metallurgy, and potential for large deposits make these deposits a attractive exploration targets. Kuroko massive sulfide deposits form in marine volcanic rocks of intermediate to felsic composition that include marine rhyolite, dacite, and subordinate basalt derived from island-arc volcanism. The Sierran kuroko model, which is defined to be restricted to deposits of Triassic and Jurassic age (Singer, 1992), was selected because the known deposits are in Jurassic rocks.

Rationale for Tract Delineation

All map units containing sequences of submarine volcanic rocks have been included and define the permissive tract for volcanogenic massive sulfide deposits. Paleozoic, Triassic, and Jurassic rocks are present in the tract. Although some of this tract may also be permissive for Besshi deposits, the team assessed only for Cyprus and kuroko types, because of lack of detailed stratigraphic information in the area.

Important Examples of Deposit Type

The Gray Eagle mine in the Happy Camp district, California, produced over 50,000 metric tons of copper. Two smaller deposits are known in Oregon.

Rationale for Numerical Estimate

In addition to the Gray Eagle deposit, there are two kuroko-type occurrences. The estimators decided that there was an even chance of an equal number of undiscovered deposits, and that belief guided our estimate. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 3, 7, 15, and 20 or more Sierran kuroko deposits consistent with the grade and tonnage model of Singer (1992).

References

- Koski, R.A., and Derkey, R.E., 1981, Massive sulfide deposits in ocean-crust and island-arc terranes in southwestern Oregon: Oregon Geology, v. 43, no. 9, p. 119-125.
- Singer, D.A., 1992, Grade and tonnage model of Sierran kuroko deposits, in Bliss, J.D., ed., Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, p. 29-32.

PC15**Massive Sulfide Deposits, Kuroko Type**

California

Descriptive Model 28a • Mark3 Index 93

Area = 1,020 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Dennis P. Cox, Steve Ludington, and Michael F. Diggles

Rationale for Model Choice

Volcanogenic massive sulfide deposits have been an historically important source of Cu, Zn, Ag, and Au. Their relatively high grades, simple metallurgy, and potential for large deposits make these deposits attractive exploration targets. Kuroko massive sulfide deposits form in marine volcanic rocks of intermediate to felsic composition that include marine rhyolite, dacite, and subordinate basalt and associated sedimentary rocks (Singer, 1986). In the West Shasta district, known deposits and host rocks are Devonian in age.

Rationale for Tract Delineation

The permissive tract is based on the extent of the Devonian Copley Greenstone and Balaklala Rhyolite, host rocks for deposits in the West Shasta district (Kinkel and others, 1956; Albers and Bain, 1985).

Important Examples of Deposit Type

The West Shasta District, in the Klamath Mountains, has been an important mineral producer in the past. The Iron Mountain mine is one of the larger examples of volcanogenic massive sulfide deposits in the United States, and has produced nearly 11 metric tons of gold.

Rationale for Numerical Estimate

In light of the small size of the district, the relative ease of observing altered areas, and the thoroughness with which the area has been explored, low numbers were estimated. For the 90th, 50th, and 10th percentiles, the team estimated 0, 1, and 2 or more kuroko deposits consistent with the grade and tonnage model of Singer and Mosier (1986).

References

- Albers, J.P., and Bain, J.H.C., 1985, Regional setting and new information on some critical geologic features of the West Shasta copper-zinc district, Shasta County, California: *Economic Geology*, v. 80, no. 8, p. 2072–2091.
- Kinkel, A.R., Jr., Hall, W.E., and Albers, J.P., 1956, Geology and base-metal deposits of West Shasta copper-zinc district, Shasta County, California: U.S. Geological Survey Professional Paper 285, 156 p.
- Singer, D.A., 1986, Descriptive model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 189.
- Singer, D.A., and Mosier, D.L., 1986, Grade and tonnage model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 190–197.

PC16**Massive Sulfide Deposits, Kuroko Type**

California

Descriptive Model 28a.1 • Mark3 Index 93

Area = 197 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Dennis P. Cox, Steve Ludington, and Michael F. Diggles

Rationale for Model Choice

Volcanogenic massive sulfide deposits in the East Shasta district have been a moderately important source of Cu, Zn, Ag, and Au. Relatively high grades of polymetallic ores, simple metallurgy, and potential for large deposits make these deposits attractive exploration targets. Kuroko massive sulfide deposits form in marine volcanic rocks of intermediate to felsic composition that include marine rhyolite, dacite, and subordinate basalt and associated sedimentary rocks (Singer, 1986). These rock types are present in the East Shasta district, and are of Middle Permian age.

Rationale for Tract Delineation

The permissive tract is based on the extent of the Middle Permian Dekkas Andesite and Bully Hill Rhyolite, host rocks for the deposits in the East Shasta district (Albers and Bain, 1985).

Important Examples of Deposit Type

Deposits in this district are small. The district produced less than 700,000 metric tons of ore, mainly from two massive sulfide deposits, the Afterthought and Bully Hill-Rising Star.

Rationale for Numerical Estimate

In light of the small size of the district, the relative ease of observing altered areas, and the thoroughness with which the area has been explored, very low numbers were estimated. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, and 1 or more undiscovered deposits consistent with the kuroko grade and tonnage model of Singer and Mosier (1986).

References

- Albers, J.P., and Bain, J.H.C., 1985, Regional setting and new information on some critical geologic features of the West Shasta copper-zinc district, Shasta County, California: *Economic Geology*, v. 80, no. 8, p. 2072–2091.
- Singer, D.A., 1986, Descriptive model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models: U.S. Geological Survey Bulletin 1693*, p. 189.
- Singer, D.A., and Mosier, D.L., 1986, Grade and tonnage model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models: U.S. Geological Survey Bulletin 1693*, p. 190–197.

PC17 **Massive Sulfide Deposits, Sierran Kuroko Type** **California**
Descriptive Model 28a.1 • Mark3 Index 44
Area = 6,210 km²

[Cumulative Distribution](#) [Histogram](#) [Table](#) [Model](#) [Mineral Deposits](#)

by Dennis P. Cox, Steve Ludington, and Michael F. Diggles

Rationale for Model Choice

Volcanogenic massive sulfide deposits are located in the foothills of the Sierra Nevada, in belts of marine felsic to intermediate volcanic rocks. Volcanogenic massive sulfide deposits have been an historically important source of Cu, Zn, Ag, and Au in this region. Relatively high grades of polymetallic ores, simple metallurgy, and potential for large deposits make these deposits attractive exploration targets, and exploration for, and development of, these deposits continues. Although both kuroko and Cyprus types of massive sulfide deposits are possible in this tract, the team only assessed the kuroko type. The Sierran kuroko model, which is defined to be restricted to deposits of Triassic and Jurassic age (Singer, 1992), was selected because the known deposits, many of which are included in the Sierran kuroko model, are in Jurassic rocks.

Rationale for Tract Delineation

All map units in the foothills of the Sierra Nevada that contain sequences of submarine volcanic rocks have been included and define the permissive tract for volcanogenic massive sulfide deposits. The tract extends westward under the Great Valley where the depth to Jurassic basement is no more than one kilometer, based on drillhole data (Wentworth and others, in press).

Important Examples of Deposit Type

The Penn mine is one of the larger examples of volcanogenic massive sulfide deposits from the Sierra Foothills metavolcanic terranes. It produced 38,000 metric tons of copper, 10,000 metric tons of zinc, 66 metric tons of silver, and 2 metric tons of gold. The Blue Moon and Western World deposits have been actively explored in recent years.

Rationale for Numerical Estimate

This region has been explored extensively in the past, focusing on easily-observed surface gossans. There are seven known deposits and 19 smaller occurrences in the area, and we judged that about a quarter of those occurrences could be developed into deposits with further exploration and development. This, coupled with consideration of substantial amounts of concealed potential host rocks, guided our estimate for the 50th percentile. The substantial concealed area also guided our estimate for the 10th percentile. For the 90th, 50th, and 10th percentiles, the team estimated 2, 13, and 25 or more deposits consistent with the Sierran kuroko grade and tonnage model of Singer (1992).

References

- Singer, D.A., 1986, Descriptive model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 189.
- Singer, D.A., 1992, Grade and tonnage model of Sierran kuroko deposits, *in* Bliss, J.D., ed., Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, p. 29-32.
- Wentworth, C.M., Fisher, G.R., and Jachens, R.C., in press, Contour map of the Great Valley basement, California: U.S. Geological Survey Miscellaneous Field Studies Map, scale 1:750,000.

PC18**Massive Sulfide Deposits, Sierran Kuroko Type**

California

Descriptive Model 28a.1 • Mark3 Index 44

Area = 1,030 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Dennis P. Cox, Steve Ludington, and Michael F. Diggles

Rationale for Model Choice

Volcanogenic massive sulfide deposits form in belts of marine felsic to intermediate volcanic rocks, and have been an historically important source of Cu, Zn, Ag, and Au, due to their relatively high grades and simple metallurgy. The Sierran kuroko model, which is defined to be restricted to deposits of Triassic and Jurassic age (Singer, 1992), was selected because the host rocks in this tract are primarily Jurassic in age.

Rationale for Tract Delineation

On the west side of the Southern California batholith, there are Jurassic metavolcanic rocks that host gold and base-metal deposits. Rocks of this type also underlie a small area in the south. These rocks are permissive for both low-sulfide Au-quartz vein deposits and for kuroko deposits (Weber, 1963).

Important Examples of Deposit Type

There are no known kuroko deposits in the tract. Known mineralized areas in the Julian district are low-sulfide Au-quartz vein deposits.

Rationale for Numerical Estimate

The fact that there are no known deposits of this type in the tract convinced us that a small estimate was appropriate. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, and 1 or more Sierran kuroko deposits consistent with the grade and tonnage model of Singer (1992).

References

- Singer, D.A., 1992, Grade and tonnage model of Sierran kuroko deposits, *in* Bliss, J.D., ed., *Developments in deposit modeling: U.S. Geological Survey Bulletin 2004*, p. 29-32.
- Weber, F.H., Jr., 1963, *Geology and mineral resources of San Diego County, California*: California Division of Mines and Geology County Report 3, 309 p.

PC19**Epithermal Vein Deposits, Comstock Type**

Washington

Descriptive Model 25c • Mark3 Index 16

Area = 4,600 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Roger P. Ashley

Rationale for Model Choice

Comstock-type deposits, mostly in the Wenatchee district, occur in Eocene sandstones on the east side of the Cascade Range in central Washington. Mineralization is localized near Eocene and Oligocene domes, which are related to a magmatic episode older than the Cascade arc. The sandstones overlie a basement dominated by metasedimentary and plutonic rocks mostly of Cretaceous age. Such basement rocks are favorable for Comstock deposits (Mosier and others, 1986a, b).

Rationale for Tract Delineation

The tract includes upper Eocene and Oligocene sandstones of the Chiwaukum graben, because mineralization in and near the Wenatchee district is localized where Eocene and Oligocene domes cut these rocks (Tabor and others, 1982; Gresens, 1983; Margolis, 1989). It also includes early Eocene sandstones that host epithermal veins of the Swauk district, west of Wenatchee. Some pre-Tertiary rocks are included in a 3-km-wide buffer zone around small Tertiary intrusions immediately east of the Chiwaukum graben (Tabor and others, 1987). Where flows of the Columbia River Basalt Group cover the lower Tertiary sandstones on the southeast, the boundary is drawn where the younger basalt covers the sandstone to a depth of approximately 1 km (Drost and Whiteman, 1986).

Important Examples of Deposit Type

The most prominent example is the Wenatchee district (Cannon and Lovitt mines), Chelan County, Washington, with total resources (production and reserves) of nearly 50 metric tons of gold and more than 100 metric tons of silver (Margolis, 1989). The Swauk district, in Kittitas County, has produced more than 0.25 metric tons of gold from lode mines, and considerably more from placers (Hunting, 1956).

Rationale for Numerical Estimate

For the 90th, 50th, and 10th percentiles, the team estimated 1, 3, and 4 or more Comstock epithermal-vein districts consistent with the grade and tonnage model of Mosier and others (1986b) (Mark3 index 16). The single district estimated at the 90th percentile reflects reports that exploration continues at several mineralized sites near Wenatchee (Derkey, 1993). The estimate of three districts at the 50th percentile and an additional district at the 10th percentile expresses a relatively high perceived probability that additional districts may exist elsewhere in the tract, particularly in the Chiwaukum graben in a geologic setting similar to Wenatchee.

References

- Derkey, R.E., 1993, Washington's mineral industry—1992, metallic mineral deposits: Washington Geology, v. 21, p. 4-25.
- Drost, B.W., and Whiteman, K.J., 1986, Surficial geology, structure, and thickness of selected geohydrologic units in the Columbia Plateau, Washington: U.S. Geological Survey Water Resources Investigations Report 84-4326, 1 text sheet, 10 map sheets, scale 1:500,000.
- Gresens, R.L., 1983, Geology of the Wenatchee and Monitor quadrangles, Chelan and Douglas Counties, Washington: Washington Division of Geology and Earth Resources Bulletin 75, 75 p.

- Huntting, M.T., 1956, Inventory of Washington minerals—Part II, Metallic minerals: Washington Division of Mines and Geology Bulletin 37, v. 1, 428 p./ v. 2, 67 p.
- Margolis, Jacob, 1989, Arkose-hosted, aquifer-controlled, epithermal Au-Ag mineralization, Wenatchee, Washington: Economic Geology, v. 84, no. 7, p. 1891-1902.
- Mosier, D.W., Singer, D.A., Sato, T., and Page, N.J, 1986a, Relationship of grade, tonnage, and basement lithology in volcanic-hosted epithermal precious- and base-metal quartz-adularia-type districts: Mining Geology, v. 36, p. 245-264.
- Mosier, D.W., Singer, D.A., and Berger, B.R., 1986b, Descriptive model of Comstock epithermal veins, in Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 150.
- Tabor, R.W., Frizzell, V.A., Jr., Whetten, J.T., Waitt, R.B., Swanson, D.A., Byerly, G.R., Booth, D.B., Hetherington, M.J., and Zartman, R.E., 1987, Geologic map of the Chelan 30-minute by 60-minute quadrangle, Washington: U.S. Geological Survey Miscellaneous Investigations Map I-166 1, scale 1:100,000, text 33 p.
- Tabor, R.W., Waitt, R.B., Jr., Frizzell, V.A., Jr., Swanson, D.A., Byerly, G.R., and Bentley, R.D., 1982, Geologic map of the Wenatchee 1:100,000 quadrangle, central Washington: U.S. Geological Survey Miscellaneous Investigations Map I-1311, scale 1:100,000, text 26 p.

PC20**Epithermal Vein Deposits, Comstock Type****Oregon****Descriptive Model 25c • Mark3 Index 16****Area = 82,800 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Roger P. Ashley**Rationale for Model Choice**

Central Oregon and northeastern California, including the east side of the Cascade Range and the northwestern part of the Basin and Range province, are dominated by volcanic rocks of Tertiary and Quaternary age. The magmatism that produced these extensive volcanic sequences could generate ore-depositing hydrothermal systems, and the region contains many structures that could be sites for resulting epithermal ores, including through-going fracture systems, major normal faults, and fractures related to local doming (Rytuba, 1988; 1989). Several small districts with Comstock-type epithermal gold-silver deposits are present in the tract in Oregon.

Geophysical and isotopic data indicate that pre-Tertiary basement rocks exist beneath the area, with the possible exception of the northwest corner (Couch and Riddihough, 1989; Church and others, 1986) suggesting that this volcanic terrane is favorable for Comstock-type deposits rather than Sado-type deposits (Mosier and others, 1986a, b).

Rationale for Tract Delineation

Calc-alkaline volcanic rocks of the Cascade volcanic arc, mainly late Miocene to Quaternary in age, occupy the western part of the tract (Sherrod and Smith, 1989; Walker and MacLeod, 1991; Jennings, 1977). The tract includes calc-alkaline rocks of the Eocene and Oligocene(?) Clarno Formation in north-central Oregon (Walker and MacLeod, 1991). South-central Oregon and northeastern California have back-arc Cascades andesites, and basalts and rhyolites of the bimodal suite of the Basin and Range Province (Walker and MacLeod, 1991; Jennings, 1977). High-level intrusions are locally associated with all volcanic sequences. All volcanic rocks in the tract are considered permissive for Comstock-type deposits.

In Oregon and northernmost California the west side of the tract is the boundary between Oligocene and Miocene rocks of the western Cascades and predominantly Quaternary volcanic rocks of the high Cascades. Ridge-capping flows of late Miocene and Pliocene age are included in the tract. In most of northern California, the tract includes both Tertiary and Quaternary rocks of the Cascades; here the west side of the tract is the boundary between Tertiary rocks and pre-Tertiary rocks of the Klamath Mountains province.

East of this tract is an area recognized in a mineral resource assessment of the Malheur-Jordan BLM Resource Area (work in progress) as favorable for epithermal precious metal deposits (Tract PC21). The location of the boundary with the latter tract, in which hot-spring Au-Ag occurrences are relatively common, is somewhat arbitrary. The southeast edge of the tract, which closely follows the Oregon-Nevada and California-Nevada borders, is the boundary of the Great Basin region, which has abundant epithermal precious metal occurrences. The eastern and southeastern boundaries do not represent a geologic discontinuity or a distinct change in geologic features.

In north-central Oregon, the boundary is drawn where flows of the Columbia River Basalt Group cover the Cascade rocks to a depth of approximately 1 km. An isolated area of rocks of the Columbia River Basalt Group near the northeast corner of the tract is also excluded because it is underlain by pre-Tertiary rocks; favorable volcanic rocks of the Basin and Range bimodal suite and the Clarno Formation are missing. Areas covered with more than 1 km of Quaternary alluvium in the Goose Lake, Summer Lake, and Klamath grabens are also excluded.

Important Examples of Deposit Type

The largest deposit of Comstock type in the tract is the Oregon King mine, Jefferson County, Oregon, which produced 0.075 metric tons of gold, 0.72 metric tons of silver, and small amounts of copper and lead (Libby and Corcoran, 1962). It is not large enough to fit the Comstock grade-tonnage model. Parts of the tract in northeastern California have been prospected for epithermal occurrences but there are no known Comstock-type deposits with production (Diggles and others, 1988; Munts and Peters, 1987).

Rationale for Numerical Estimate

For the 90th, 50th, and 10th and 5th percentiles, the team estimated 0, 1, 3 and 5 or more Comstock epithermal-vein districts consistent with the grade and tonnage model of Mosier and others (1986b) (Mark3 index 16). The estimates of one deposit at the 50th percentile and three deposits at the 10th percentile together express a the perceived probability that exploration of known districts and prospects could yield deposits. Two additional districts are included at the 5th percentile because there is extensive favorable ground in the tract, but the density of known deposits is low, so there is a low probability that other districts large enough to fit the grade-tonnage model may exist.

References

- Church, S.E., LeHuray, A.P., Grant, A.R., Delevaux, M.H., and Gray, J.E., 1986, Lead-isotopic data from sulfide minerals from the Cascade Range, Oregon and Washington: *Geochimica et Cosmochimica Acta*, v. 50, p. 317-328.
- Couch, R.W., and Riddihough, R.P., 1989, The crustal structure of the western continental margin of North America, *in* Pakiser, L.C., and Mooney, W.D., eds., *Geophysical framework of the continental United States: Geological Society of America Memoir 172*, p. 103-128.
- Diggles, M.F., Frisken, J.G., Plouff, Donald, Munts, S.R., and Peters, T.J., 1988, Mineral resources of the Skedaddle Mountain Wilderness Study Area, Lassen County, California, and Washoe County, Nevada: U.S. Geological Survey Bulletin 1706-C, 27 p.
- Jennings, C.W., 1977, Geologic map of California: California Division of Mines and Geology, scale 750,000.
- Libby, F.W., and Corcoran, R.E., 1962, The Oregon King mine, Jefferson County, Oregon: Oregon Department of Geology and Mineral Industries Short Paper 23, 49 p.
- Mosier, D.W., Singer, D.A., Sato, T., and Page, N.J., 1986a, Relationship of grade, tonnage, and basement lithology in volcanic-hosted epithermal precious- and base-metal quartz-adularia-type districts: *Mining Geology*, v. 36, p. 245-264.
- Mosier, D.W., Singer, D.A., and Berger, B.R., 1986b, Descriptive model of Comstock epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models: U.S. Geological Survey Bulletin 1693*, p. 150.
- Munts, S.R., and Peters, T.J., 1987, Mineral resources of the Skedaddle study area, Lassen County, California and Washoe County, Nevada: U.S. Bureau of Mines Open-File Report MLA 022-87, 52 p.
- Rytuba, J.J., 1988, Volcanism, extensional tectonics, and epithermal systems in the northern Basin and Range, CA, NV, OR, and ID [abs.]: *Geological Society of Nevada Newsletter*, May, 1988.
- Rytuba, J.J., 1989, Volcanism, extensional tectonics, and epithermal mineralization in the northern Basin and Range Province, California, Nevada, Oregon, and Idaho, *in* Schindler, K.S., ed., *U.S. Geological Survey Eesearch on Mineral Resources—1989 Program and Abstracts, Fifth Annual V.E. McKelvey Forum on Mineral and Energy Resources [abs.]*: U.S. Geological Survey Circular 1035, p. 59-61.
- Sherrod, D.R., and Smith, J.G., 1989, Preliminary map of upper Eocene to Holocene volcanic and related rocks of the Cascade Range, Oregon: U.S. Geological Survey Open-File Report 89-14, 1:500,000 scale, text 20 p.

Walker, G.W., and MacLeod, N.S., 1991, Geologic map of Oregon: U.S. Geological Survey, 2 sheets, scale 1:500,000.

PC21**Epithermal Vein Deposits, Comstock Type****Oregon****Descriptive Model 25c • Mark3 Index 16****Area = 31,300 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Stephen E. Box and Arthur A. Bookstrom**Rationale for Model Choice**

Epithermal Au-Ag quartz-adularia vein deposits are hosted in subaerial, intermediate to felsic volcanic rocks (Mosier and others, 1986a). In southeastern Oregon, widespread Neogene felsic, intermediate, and mafic volcanic rocks, along with considerable Neogene normal faulting, provide a compositionally and structurally appropriate environment for epithermal vein occurrences. Known Au-Ag epithermal occurrences are of the quartz-adularia type.

Rationale for Tract Delineation

The tract encircles essentially all Neogene volcanic and associated sedimentary rocks in southeastern Oregon (Peters and others, 1994), outside of the Ore-Ida graben. The eastern and southern tract boundaries are arbitrarily drawn at the State boundaries. The western boundary is drawn to separate much less favorable ground in central Oregon. Some basaltic volcanic rocks are included which may not be appropriate for the occurrence of Comstock veins. However insufficient data are available to outline only the compositionally appropriate volcanic rocks.

Important Examples of Deposit Type

No significant Comstock-type Au-Ag deposits are known from this tract. However a number of hot-spring geothermal systems are known, and deeper, unexposed parts of these systems are likely to include tabular vein deposits of Comstock type.

Rationale for Numerical Estimate

An important factor considered in the development of estimates of the number of these deposits is that grade and tonnage values used in constructing the model include data from mining districts, as opposed to individual mines or deposits. District data is used where individual mines or deposits are spaced less than one mile apart, in which case the production and reserve data for the mines or deposits are aggregated. In this case several widely spaced hot-spring deposits at or near the surface may at depth be related to a system of epithermal veins, whose spacing is such that it would be treated as a district. This accounts for the lower estimated number of these deposits in comparison to the estimate for the number of hot-spring deposits for the same tract. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 2, 4, 7, 11, and 16 or more districts (Spanski, 1994) consistent with the grade and tonnage model of Mosier and others (1986b).

References

- Mosier, D.L., Singer, D.A., and Berger, B.R., 1986a, Descriptive model of Comstock epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 150.
- Mosier, D.L., Singer, D.A., and Berger, B.R., 1986b, Grade and tonnage model of Comstock epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 151-153.

- Peters, S.G., Albino, George, Brooks, H.C., Evans, J.G., Carlson, R.R., Lee, G.K., Griscom, Andrew, and Halvorson, P.F., 1994, Deposit models and tracts for undiscovered metallic resources in the Malheur-Jordan-Andrews Resource area, southeastern Oregon, *in* Smith, C.L., ed., Mineral and energy resources of the BLM Malheur-Jordan Resource Areas, southeastern Oregon: U.S. Geological Survey Administrative Report, p. B1-B21.
- Spanski, G.T., 1994, Quantitative resource assessment for locatable minerals, *in* Smith, C.L., ed., Mineral and energy resources of the BLM Malheur-Jordan Resource Area, southeastern Oregon, U.S. Geological Survey Administrative Report, p. C1-C12.

PC22**Epithermal Vein Deposits, Comstock Type****Oregon****Descriptive Model 25c • Mark3 Index 16****Area = 10,000 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Stephen E. Box and Arthur A. Bookstrom**Rationale for Model Choice**

Epithermal Au-Ag quartz-adularia vein deposits are hosted in subaerial, intermediate to felsic volcanic rocks (Mosier and others, 1986a). Within this tract, widespread occurrences of hydrothermal alteration, silica sinter, and anomalous concentrations of gold, silver, arsenic, antimony, and mercury in rocks, soil, and stream sediments indicates the presence of numerous extinct geothermal systems with precious metal contents (Peters and others, 1994). Commonly Comstock-type vein mineralization occurs in the deeper parts (below 100 m) of the geothermal systems.

Rationale for Tract Delineation

The permissive tract was delineated to include all the area of Neogene rocks within the Ore-Ida graben, a north-south structural feature controlling the distribution of Miocene volcanic and sedimentary rocks (Peters and others, 1994). Since much of the Neogene section is buried under younger Neogene rocks, essentially all of the prospective Comstock vein horizons are buried.

Important Examples of Deposit Type

The Grassy Mountain deposit is a large hot-spring Au-Ag deposit within the tract (Wheeler, 1988). Some parts of the deposit contain deeper vein-style epithermal mineralization that could be classified as Comstock-type. However all of the grade and tonnage of the Grassy Mountain deposit are included in the hot-spring model, since the deposit would be bulk-mined as one deposit.

Rationale for Numerical Estimate

An important factor considered in the development of estimates of the number of these deposits is that grade and tonnage values used in constructing the model include data from mining districts, as opposed to individual mines or deposits. District data is used where individual mines or deposits are spaced less than one mile apart, in which case the production and reserve data for the mines or deposits are aggregated. In this case several widely spaced hot-spring deposits at or near the surface may at depth be related to a system of epithermal veins, whose spacing is such that it would be treated as a district. This accounts for the lower estimated number of these deposits in comparison to the estimate for the number of hot-spring deposits for the same tract. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 2,3,4,6, and 8 or more districts (Spanski, 1994) consistent with the Au-Ag grade and tonnage model of Mosier and others (1986b).

References

Mosier, D.L., Singer, D.A., and Berger, B.R., 1986a, Descriptive model of Comstock epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 150.

- Mosier, D.L., Singer, D.A., and Berger, B.R., 1986b, Grade and tonnage model of Comstock epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 151-153.
- Peters, S.G., Albino, George, Brooks, H.C., Evans, J.G., Carlson, R.R., Lee, G.K., Griscom, Andrew, and Halvorson, P.F., 1994, Deposit models and tracts for undiscovered metallic resources in the Malheur-Jordan-Andrews Resource Area, southeastern Oregon, *in* Smith, C.L., ed., Mineral and energy resources of the BLM Malheur-Jordan Resource Area, southeastern Oregon: U.S. Geological Survey Administrative Report, p. B1-B21.
- Spanski, G.T., 1994, Quantitative resource assessment for locatable minerals, *in* Smith, C.L., ed., Mineral and energy resources of the BLM Malheur-Jordan Resource Area, southeastern Oregon, U.S. Geological Survey Administrative Report, p. C1-C12.
- Wheeler, G.R., 1988, Epithermal gold deposits in eastern Oregon: Mining Engineering, v. 40, no. 11, p. 1033-1035.

PC23**Epithermal Vein Deposits, Comstock Type**

Idaho

Descriptive Model 25c

Area = 3,040 km²[Model](#)*by* Stephen E. Box and Arthur A. Bookstrom**Rationale for Model Choice**

Epithermal Au-Ag quartz-adularia vein deposits are hosted in subaerial, intermediate to felsic volcanic rocks (Mosier and others, 1986). Hot-spring mercury mineralization at the Idaho Almaden mine near Weiser (Anderson, 1941) indicates the existence of extinct geothermal systems in this tract. Deeper parts of these systems may include veins of the Comstock type (Mosier and others, 1986).

Rationale for Tract Delineation

The tract was drawn around the Miocene Payette Formation, host rock of the Idaho Almaden mine, northwest of the western Snake River plain (Bond, 1978). The Miocene Payette Formation consists of fluvial arkosic sedimentary materials derived from the Idaho batholith and is capped by lavas of the Columbia River Basalt Group. The surrounding area where the Payette Formation may occur within a kilometer of the surface beneath rocks of the overlying Columbia River Basalt Group was also included.

Important Examples of Deposit Type

No examples of this deposit type are known in the tract. However, the existence of an extinct Au-bearing hot-spring hydrothermal system at the Idaho Almaden mine near Weiser suggests the possibility that Comstock-type vein systems may occur at depth. Gold occurs in subeconomic grades in the Idaho Almaden deposit.

Rationale for Numerical Estimate

The lack of known deposits within the tract and the dearth of information available on any exploration activity prevented the team from estimating the number of undiscovered deposits of this type.

References

- Anderson, Alfred L., 1941, Geology of the Idaho Almaden quicksilver mine: Idaho Bureau of Mines and Geology Pamphlet 55, 9 p.
- Bond, J.G., 1978, Geologic map of Idaho: Idaho Bureau of Mines and Geology, scale 1:500,000.
- Mosier, D.L., Singer, D.A., and Berger, B.R., 1986a, Descriptive model of Comstock epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 150.

PC24**Epithermal Vein Deposits, Comstock Type**

Idaho

Descriptive Model 25c

Area = 1,730 km²[Model](#)[Mineral Deposits](#)*by* Stephen E. Box and Arthur A. Bookstrom**Rationale for Model Choice**

Epithermal Au-Ag quartz-adularia vein deposits are hosted in subaerial, intermediate to felsic volcanic rocks (Mosier and others, 1986). Three known Comstock deposits occur within Miocene felsic volcanic rocks within the tract. The abundance of Neogene basaltic to felsic volcanic and volcanoclastic rocks and the presence of known deposits of this type within the Idaho part of the Ore-Ida graben indicate the tract is permissive for undiscovered deposits of this type.

Rationale for Tract Delineation

This permissive tract for undiscovered Comstock epithermal-vein districts was drawn to include the Idaho part of the Ore-Ida graben, as interpreted from the State geologic map (Bond, 1978). This area is underlain by a voluminous pile of Miocene basaltic and felsic volcanic rocks and associated volcanoclastic rocks and encompasses Miocene and younger zone of pervasive north-south faulting. As some vein mineralization extends into Cretaceous granitic rocks occur within the tract, these rocks were also included in the tract. The tract is buried on the northeast by younger basaltic lavas of the northwest Snake River plain. The southern boundary of the tract was drawn just south of the southernmost prospects known in southwestern Idaho.

Important Examples of Deposit Type

Three Comstock deposits (De Lamar, Stone Cabin, and War Eagle) are known within the permissive tract. These vein deposits variously cut Miocene rhyolites and Cretaceous granitic rocks (Asher, 1968). The contained metal contents of these three deposits overlap the mean metal content of Comstock deposits in the grade and tonnage model.

Rationale for Numerical Estimate

It is thought that all Comstock-type deposits exposed at the surface in the tract area are known, and any undiscovered deposits must be covered. Since the area has been mostly subsiding since the Miocene, the team inferred that any undiscovered Comstock vein deposit will probably still be overlain by a more disseminated hot-spring Au-Ag deposit, for which exploration is fairly incomplete. These undiscovered Comstock vein systems will probably be mined along with their overlying hot-spring deposit, and will be incorporated into the grade and tonnage of any undiscovered hot-spring deposit. For this reason, we only make an estimate for undiscovered hot-spring deposits for this area, and make no estimate for undiscovered Comstock deposits.

References

- Asher, R.R., 1968, Geology and mineral resources of a portion of the Silver City region, Owyhee County, Idaho: Idaho Bureau of Mines and Geology Pamphlet 138, 106 p.
- Bond, J.G., 1978, Geologic map of Idaho: Idaho Bureau of Mines and Geology, scale 1:500,000.
- Mosier, D.L., Singer, D.A., and Berger, B.R., 1986a, Descriptive model of Comstock epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 150.

PC25**Epithermal Vein Deposits, Comstock Type**

Idaho

Descriptive Model 25c

Area = 17,200 km²[Model](#)*by* Stephen E. Box and Arthur A. Bookstrom**Rationale for Model Choice**

Epithermal Au-Ag quartz-adularia vein deposits are hosted in subaerial, intermediate to felsic volcanic rocks (Mosier and others, 1986). Comstock-type vein mineralization occurs in tracts to the north and west that have generally similar geology.

Rationale for Tract Delineation

The tract was drawn to include the entire area of Miocene rhyolitic volcanism southwest of the Pleistocene Snake River plain, and south of the Idaho part of the Ore-Ida graben (Bond, 1978). The tract is underlain by two large Miocene caldera complexes, Juniper Mountain and Bruneau-Jarbidge (Ekren and others, 1982; Bonnicksen, 1982). Extensive rhyolitic ashflow tuffs erupted from the calderas, and these are overlain by Miocene basaltic lavas. A minor amount of older metamorphic and granitic rock is also included within the tract, since veins may extend into these lithologies, as they do in the Silver City area in the tract to the north.

Important Examples of Deposit Type

No examples of this deposit type are known within the tract.

Rationale for Numerical Estimate

The lack of known deposits within the tract and the dearth of information available on any exploration activity prevented the team from estimating the number of undiscovered deposits of this type.

References

- Bond, J.G., 1978, Geologic map of Idaho: Idaho Bureau of Mines and Geology, scale 1:500,000.
- Bonnicksen, Bill, 1982, The Bruneau-Jarbidge eruptive center, southwestern Idaho, *in* Bonnicksen, Bill and Breckenridge, Roy M., eds., Cenozoic geology of Idaho: Idaho Bureau of Mines and Geology Bulletin 26, p. 237-254.
- Eckren, E.B., McIntyre, D.H., Bennett, E.H., and Marvin, R.F., 1982, Cenozoic stratigraphy of western Owyhee County, Idaho, *in* Bonnicksen, Bill and Breckenridge, Roy M., eds., Cenozoic geology of Idaho: Idaho Bureau of Mines and Geology Bulletin 26, p. 215-236.
- Mosier, D.L., Singer, D.A., and Berger, B.R., 1986, Descriptive model of Comstock epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 150.

PC26**Epithermal Vein Deposits, Quartz-adularia Type**

California

Descriptive Model 25c + 25d • Mark3 Index 25

Nevada

Area = 41,900 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Michael F. Diggles

Rationale for Model Choice

Northeastern California contains intermediate to felsic Tertiary and bimodal volcanic rocks and associated high-level intrusions. The region contains appropriate through-going fracture systems, major normal faults, and fractures related to doming (Rytuba, 1988; 1989). Classification of deposits as Comstock or Sado type requires information on basement geology that is not available (Klein and Bankey, 1992). Therefore, a combined Comstock-Sado model was used

Rationale for Tract Delineation

The tract encompasses all Tertiary volcanic rocks in northeastern California, and was delineated using the geologic map of California (Jennings, 1977). Volcanic sequences include andesite and rhyolite domes of Tertiary age and other manifestations of volcanic centers where magmatic events might generate ore-depositing hydrothermal systems.

Important Examples of Deposit Type

There are no known quartz-adularia deposits in the area. The Skedaddle Mountain Wilderness Study Area on U.S. Bureau of Land Management land east of Susanville had over 280 lode claims for epithermal deposits (Diggles and others, 1987; Munts and Peters, 1987).

Rationale for Numerical Estimate

The estimators thought that there was an even chance of one or more undiscovered districts. For the 90th, 50th, and 10th percentiles, the team estimated 0, 1, and 2 or more quartz-adularia epithermal-vein districts consistent with the grade and tonnage model.

References

- Diggles, M.F., Frisken, J.G., Plouff, Donald, Munts, S.R., and Peters, T.J., 1988, Mineral resources of the Skedaddle Mountain Wilderness Study Area, Lassen County, California, and Washoe County, Nevada: U.S. Geological Survey Bulletin 1706-C, 27 p.
- Jennings, C.W., 1977, Geologic map of California: California Division of Mines and Geology, scale 750,000.
- Klein, D., and Banky, V., 1992, Geophysical model of Creede, Comstock, Sado, Goldfield and related epithermal precious metal deposits, Cox and Singer models 25b Creede, 25c Comstock, 25d Sado, and 25e quartz-alunite Au, *in* Hoover, D.B., Heran, W.D., and Hill, P.L., eds., The geophysical expression of selected mineral deposit models: U.S. Geological Survey Open-File Report 92-0557, p. 98-106.
- Munts, S.R., and Peters, T.J., 1987, Mineral resources of the Skedaddle study area, Lassen County, California and Washoe County, Nevada: U.S. Bureau of Mines Open-File Report MLA 022-87, 52 p.
- Rytuba, J.J., 1988, Volcanism, extensional tectonics, and epithermal systems in the northern Basin and Range, CA, NV, OR, and ID [abs.]: Geological Society of Nevada Newsletter, May, 1988.
- Rytuba, J.J., 1989, Volcanism, extensional tectonics, and epithermal mineralization in the northern Basin and Range Province, California, Nevada, Oregon, and Idaho, *in* Schindler, K.S., ed., U.S. Geological Survey Research on Mineral Resources —1989 Program and Abstracts, Fifth Annual V.E.

McKelvey Forum on Mineral and Energy Resources [abs.]: U.S. Geological Survey Circular 1035, p. 59-61.

PC27**Epithermal vein, Sado Type Deposits****Oregon
Washington****Descriptive Model 25d • Mark3 Index 28****Area = 56,200 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Roger P. Ashley**Rationale for Model Choice**

Calc-alkaline volcanic rocks of Tertiary and Quaternary age related to the Cascade arc are widespread in western Oregon and Washington. Arc volcanic sequences include volcanic centers in which magmatic events can generate ore-depositing hydrothermal systems. Several Sado-type deposits are present in the western Cascade Range, where the Tertiary arc rocks are mainly exposed. Geophysical and isotopic data indicate that pre-Tertiary basement rocks are thin or missing beneath the western Cascade Range of west-central Oregon and southwestern Washington (Couch and Riddihough, 1989; Church and others, 1986). Oceanic crust of Eocene age is inferred to lie beneath the Cascades rocks and extends to depths greater than 10 km. This basement geology is favorable for Sado type deposits rather than Comstock type deposits (Mosier and others, 1986).

Rationale for Tract Delineation

All areas of calc-alkaline volcanic rocks in the western Cascades are considered permissive for Sado-type deposits. Because these deposits usually have limited vertical extent (a few hundred meters), they could be present within the 1 km depth limit while having little surface manifestation.

The tract includes mainly volcanic and volcanoclastic rocks and associated plutonic bodies (dikes, sills, stocks, and small batholiths) of the Cascades arc (Oligocene and Miocene in age), as shown on maps of Smith (1993), Walker and MacLeod (1991), and Sherrod and Smith (1989). On the west side of the tract in both Oregon and Washington, Eocene marine sandstone units and pre-Cascades volcanic rocks, predominantly of basaltic composition, are excluded. Where the Cascades-related rocks are covered by non-volcanic Quaternary deposits, the boundary is drawn where the younger deposits are approximately 1 km thick. Batholiths of Tertiary age in the northern Cascades of Washington are excluded because they indicate an environment too deep for the presence of epithermal deposits.

In Oregon and northern California, the east side of the tract is the boundary between Oligocene and Miocene rocks of the western Cascades and predominantly Quaternary volcanic rocks of the high Cascades. Ridge-capping flows of late Miocene and Pliocene age are excluded from the tract. In Washington, on the east, the boundary is drawn where flows of the Columbia River Basalt Group cover the Oligocene and Miocene Cascade rocks to a depth of approximately 1 km (Drost and Whiteman, 1986). Quaternary volcanic rocks of Mt. Rainier, Mount St. Helens, Mt. Adams, and the Indian Heaven volcanic fields, which locally cover the Tertiary Cascades rocks in Washington, are included. A pre-Tertiary inlier east of Mt. Rainier is also included. Along the northeast edge of the tract, a small area of Eocene sandstone is included. North of Mt. Rainier, volcanic rocks of Eocene and Oligocene age are included, some of which predate Cascade arc volcanism.

Important Examples of Deposit Type

Sado-type deposits with recorded precious metal production, all relatively small, include the Quartzville district, the Blue River district, and the Al Sarena mine in Oregon, and the Wind River mine in Washington. The Quartzville district has the largest production that can definitely be attributed to Sado-type veins, with 0.27 metric tons gold and 0.09 metric tons silver

recorded (Brooks and Ramp, 1968), and possibly considerably more that is unrecorded (Munts, 1978).

Rationale for Numerical Estimate

For the 90th, 50th, 10th, and 5th percentiles, the team estimated 0, 2, 5, and 8 or more Sado deposits consistent with the grade and tonnage model of Mosier and Sato (1986) (Mark3 index 28). Known Sado-type prospects and occurrences, although mostly small and not numerous, are widely distributed throughout the tract. Hydrothermally-altered areas, many of which are favorable for epithermal deposits as well as porphyry deposits, are common in the Tertiary volcanic rocks of the western Cascades (Peck and others, 1964; Power, 1984). The estimates of two deposits at the 50th percentile and five deposits at the 10th percentile together express a relatively high perceived probability that exploration of known districts and prospects could yield additional deposits. Recent exploration drilling in several districts has produced ore-grade intercepts. The three additional deposits estimated at the 5th percentile reflects the perception that extensive favorable ground exists, but the density of known deposits is low, thus some, but probably not many, new Sado-type districts could be discovered in the tract.

References

- Brooks, H.C. , and Ramp, Len, 1968, Gold and silver in Oregon: Oregon Department of Geology and Mineral Industries Bulletin 61, 337 p.
- Church, S.E., LeHuray, A.P., Grant, A.R., Delevaux, M.H., and Gray, J.E., 1986, Lead-isotopic data from sulfide minerals from the Cascade Range, Oregon and Washington: *Geochimica et Cosmochimica Acta*, v. 50, p. 317-328.
- Couch, R.W., and Riddihough, R.P., 1989, The crustal structure of the western continental margin of North America, *in* Pakiser, L.C., and Mooney, W.D., eds., *Geophysical framework of the continental United States: Geological Society of America Memoir 172*, p. 103-128.
- Drost, B.W., and Whiteman, K.J., 1986, Surficial geology, structure, and thickness of selected geohydrologic units in the Columbia Plateau, Washington: U.S. Geological Survey Water Resources Investigations Report 84-4326, 1 text sheet, 10 map sheets, scale 1:500,000.
- Mosier, D.L., and Sato, Takeo, 1986, Grade and tonnage model of Sado epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models: U.S. Geological Survey Bulletin 1693*, p. 155-157.
- Mosier, D.W., Singer, D.A., Sato, T., and Page, N.J, 1986, Relationship of grade, tonnage, and basement lithology in volcanic-hosted epithermal precious- and base-metal quartz-adularia-type districts: *Mining Geology*, v. 36, p. 245-264.
- Munts, S.R., 1978, Geology and mineral deposits of the Quartzville mining district, Linn County, Oregon: University of Oregon, unpub. M.S. thesis, 212 p.
- Peck, D.L., Griggs, A.B., Schlicker, H.G., Wells, F.G., and Dole, H.M., 1964, Geology of the central and northern parts of the western Cascade Range in Oregon: U.S. Geological Survey Professional Paper 449, 56 p.
- Power, S.G., 1984, The “tops” of porphyry copper deposits—Mineralization and plutonism in the western Cascades, Oregon: Corvallis, Oregon State University, Ph.D. thesis, 234 p.
- Sherrod, D.R., and Smith, J.G., 1989, Preliminary map of upper Eocene to Holocene volcanic and related rocks of the Cascade Range, Oregon: U.S. Geological Survey Open-File Report 89-14, 1:500,000 scale, text 20 p.
- Smith, J.G., 1993, Geologic map of upper Eocene to Holocene volcanic and related rocks in the Cascade Range, Washington: U.S. Geological Survey Miscellaneous Investigations Series Map I-2005, scale 1:500,000, text, 19 p.
- Walker, G.W., and MacLeod, N.S., 1991, Geologic map of Oregon: U.S. Geological Survey, 2 sheets, scale 1:500,000.

PC28**Hot-spring Au-Ag Deposits**

Washington
Oregon
California

Descriptive Model 25a • Mark3 Index 45

Area = 185,500 km²

[Cumulative Distribution](#)

[Histogram](#)

[Table](#)

[Model](#)

[Mineral Deposits](#)

by Roger P. Ashley

Rationale for Model Choice

Hot-spring precious metal deposits are found in volcanic-dominated sequences containing subaerial, intermediate to felsic volcanic and volcanoclastic rocks (Berger, 1986). The volcanic sequences of the Basin and Range Province and the Clarno Formation are entirely continental, and those of the Cascades arc are mostly subaerial, so these volcanic-dominated terranes of western Washington, western and central Oregon, and northeastern California are permissive for hot-spring Au-Ag deposits. They are also permissive for Sado- or Comstock-type deposits. A few widely-scattered hot-spring-type deposits and prospects are recognized in the tract. Some deposits in the tract known only through brief examinations and descriptions by early investigators, and assumed to be veins, could be hot-spring deposits.

Rationale for Tract Delineation

Criteria for tract delineation are similar to those for Sado- and Comstock-type vein deposits, and this tract is coextensive with the combined Sado and Comstock tracts that cover the Cascade Range and central Oregon. All areas containing intermediate to silicic volcanic rocks are considered permissive for hot-spring Au-Ag deposits. Because these deposits usually have a very limited vertical extent, they could be present within 1 km of the surface and have little surface manifestation.

The tract includes all volcanic and volcanoclastic rocks and associated small plutonic bodies of the Cascades arc (Oligocene to Holocene in age), as shown on maps of Smith (1993), Walker and MacLeod (1991), Sherrod and Smith (1989), and Jennings (1977). On the west side of the tract in both Oregon and Washington, Eocene marine sandstone units and pre-Cascades volcanic rocks, predominantly of basaltic composition, are excluded. Where the Cascades-related rocks are covered by non-volcanic Quaternary deposits, the boundary is drawn where the younger rocks are approximately 1 km thick. Batholiths of Tertiary age in the northern Cascades of Washington are excluded because they indicate an environment too deep for the presence of epithermal deposits. Volcanic rocks of Eocene and Oligocene age in the northern Cascades are included, however, although some may predate Cascade arc volcanism.

In central Washington, Eocene and Oligocene sandstones in and west of the Chiwaukum graben are included because they host significant Comstock-type deposits. A pre-Tertiary inlier east of Mt. Rainier is also included.

The basaltic lavas of the Columbia Plateau are excluded. In north-central Oregon and east-central Washington, the boundary is drawn where flows of the Columbia River Basalt Group cover the Cascade rocks to a depth of approximately 1 km (Drost and Whiteman, 1986).

The tract includes calc-alkaline rocks of the Eocene and Oligocene(?) Clarno Formation in north-central Oregon. In south-central Oregon and northeastern California it includes Tertiary basalts and rhyolites of the bimodal suite of the Basin and Range Province and Tertiary back-arc Cascade rocks of intermediate composition (Walker and MacLeod, 1991; Sherrod and Smith, 1989; Jennings, 1977). The eastern boundary in eastern Oregon and northeastern California separates this tract from tracts in southeastern Oregon and the Great Basin that have numerous epithermal occurrences and are more favorable for undiscovered deposits.

An isolated area of rocks of the Columbia River Basalt Group in east-central Oregon is excluded because it is underlain by pre-Tertiary rocks; favorable volcanic rocks of the Basin and Range bimodal suite and Clarno Formation are missing. Areas covered with more than 1 km of Quaternary alluvium in the Goose Lake, Summer Lake, and Klamath grabens are also excluded.

Important Examples of Deposit Type

The largest hot-spring Au-Ag deposit in the tract is Quartz Mountain, in Lake County, south-central Oregon (Sawlan and Russell, 1991). It is associated with rhyolite domes related to bimodal volcanism. Although subeconomic at this time, it is credited with more than 60 metric tons of gold reserves (Wiley, 1991).

Several isolated precious-metal occurrences in the southern Oregon Cascades may be hot-spring deposits, and other poorly-known precious-metal occurrences in the western Cascades districts of Oregon could be hot-spring deposits as well. The recently-explored Mashel River prospect, in the western Cascades of Washington (Pierce County), may be a hot-spring deposit.

Hayden Hill, in California, is another prominent example, in northern California.

Rationale for Numerical Estimate

For the 90th, 50th, and 10th percentiles, the team estimated 0, 1, and 3 or more hot-spring Au-Ag deposits consistent with the grade and tonnage model of Berger and Singer (1992) (Mark3 index 45). This estimate reflects the perception that additional exploration in the vicinity of Quartz Mountain and in several western Cascades districts could yield deposits. The additional deposits included at the 5th and 1st percentiles reflect the probability that other districts large enough to fit the grade-tonnage model may exist, particularly in the southern Cascade Range of Oregon and Ochoco Mountains of north-central Oregon, where there are many hot-springs mercury deposits, or where through-going fracture systems cut late Tertiary rocks of the bimodal suite in south-central Oregon and northeastern California (Rytuba, 1988, 1989).

References

- Berger, B.R., 1986, Descriptive model of hot-spring Au-Ag, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 143-144.
- Berger, B.R., and Singer, D.A., 1992, Grade and tonnage model of hot-spring Au-Ag, *in* Bliss, J.D., ed., Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, p. 23-25.
- Drost, B.W., and Whiteman, K.J., 1986, Surficial geology, structure, and thickness of selected geohydrologic units in the Columbia Plateau, Washington: U.S. Geological Survey Water Resources Investigations Report 84-4326, 1 text sheet, 10 map sheets, scale 1:500,000.
- Jennings, C.W., 1977, Geologic map of California: California Division of Mines and Geology, scale 750,000.
- Sawlan, M.G., and Russell, K.D., 1991, Rhyolite domes, NW-trending faults, gold deposits, and high-alumina basalt in the Devils Garden-NW Basin and Range—Rapid volcanic and structural evolution from 8-6 Ma at Quartz Mountain, south-central Oregon [abs.]: Geological Society of America Abstracts with Programs, v. 23, p. 94.
- Rytuba, J.J., 1988, Volcanism, extensional tectonics, and epithermal systems in the northern Basin and Range, CA, NV, OR, and ID [abs.]: Geological Society of Nevada Newsletter, May, 1988.
- Rytuba, J.J., 1989, Volcanism, extensional tectonics, and epithermal mineralization in the northern Basin and Range Province, California, Nevada, Oregon, and Idaho, *in* Schindler, K.S., ed., U.S. Geological Survey Research on Mineral Resources - 1989 Program and Abstracts, Fifth Annual V.E. McKelvey Forum on Mineral and Energy Resources [abs.]: U.S. Geological Survey Circular 1035, p. 59-61.

- Sherrod, D.R., and Smith, J.G., 1989, Preliminary map of upper Eocene to Holocene volcanic and related rocks of the Cascade Range, Oregon: U.S. Geological Survey Open-File Report 89-14, 1:500,000 scale, text 20 p.
- Smith, J.G., 1993, Geologic map of upper Eocene to Holocene volcanic and related rocks in the Cascade Range, Washington: U.S. Geological Survey Miscellaneous Investigations Series Map I-2005, scale 1:500,000, text, 19 p.
- Walker, G.W., and MacLeod, N.S., 1991, Geologic map of Oregon: U.S. Geological Survey, 2 sheets, scale 1:500,000.
- Wiley, T.J., 1991, Mining and exploration in Oregon during 1990: Oregon Geology, v. 53, p. 63-69.

PC29**Hot-spring Au-Ag Deposits****Oregon****Descriptive Model 25a • Mark3 Index 45****Area = 31,200 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Stephen E. Box and Arthur A. Bookstrom**Rationale for Model Choice**

Hot-spring Au-Ag deposits consist of precious metal-bearing siliceous sinters and silicified rocks cut by breccias and stockworks of veins and veinlets, which were deposited at or near the paleo-ground surface in and around felsic volcanic fields, usually associated with normal faults (Berger, 1986). In Southeastern Oregon, widespread Neogene felsic volcanic rocks, along with considerable Neogene normal faulting, provide a compositionally and structurally appropriate environment for hot-spring Au-Ag deposits (Berger, 1986).

Rationale for Tract Delineation

The tract encircles essentially all Neogene volcanic and associated sedimentary rocks in southeastern Oregon (Peters and others, 1994), exclusive of the Ore-Ida graben. The most prospective area in southeastern Oregon is the Ore-Ida graben, which is not included in this tract but is included in a separate tract. Some basaltic volcanic rocks and/or thick Quaternary alluvial cover are included in this tract which may not be appropriate for the occurrence of hot-spring deposits. However insufficient data are available to exclude these unfavorable parts of the tract.

Important Examples of Deposit Type

No significant hot-spring Au-Ag deposits are known from this tract, although the Grassy Mountain deposit occurs in contemporary rocks in the adjacent tract to the east (Wheeler, 1988). Evidence for a number of hot-spring type geothermal systems are known within this tract, but none have had significant production or have known reserves.

Rationale for Numerical Estimate

The area has lesser potential for undiscovered hot-spring deposits than the Ore-Ida graben to the east. In this tract, there is less support for the existence of widespread geothermal activity. Surface erosion has been minimal, so most deposits were probably buried rather than eroded away. However the accumulated Neogene section is thinner and the opportunity for stacking deposits is more limited than in the adjacent Ore-Ida graben. For this reason the team expressed less confidence in its estimate for this tract. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 2, 6, 10, 16, and 30 or more deposits (Spanski, 1994) consistent with the Au-Ag grade and tonnage model for hot-spring deposits of Berger and Singer (1992).

References

- Berger, B.R., 1986, Descriptive model of hot-spring Au-Ag deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 143.
- Berger, B.R., and Singer, D.A., 1992, Grade and tonnage model of hot-spring Au-Ag, *in* Bliss, J.D., ed., Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, p 23-25.
- Peters, S.G., Albino, George, Brooks, H.C., Evans, J.G., Carlson, R.R., Lee, G.K., Griscom, Andrew, and Halvorson, P.F., 1994, Deposit models and tracts for undiscovered metallic resources in the Malheur-Jordan-Andrews Resource Area, southeastern Oregon, *in* Smith, C.L., ed., Mineral and energy resources

of the BLM Malheur-Jordan Resource Area, southeastern Oregon: U.S. Geological Survey Administrative Report, p. B1-B21.

Spanski, G.T., 1994, Quantitative resource assessment for locatable minerals, *in* Smith, C.L., ed., Mineral and energy resources of the BLM Malheur-Jordan Resource Area, southeastern Oregon: U.S. Geological Survey Administrative Report, p. C1-C12.

Wheeler, G.R., 1988, Epithermal gold deposits in eastern Oregon: *Mining Engineering*, v. 40, no. 11, p. 1033-1035.

PC30**Hot-spring Au-Ag Deposits****Oregon****Descriptive Model 25a • Mark3 Index 45****Area = 10,000 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* Stephen E. Box and Arthur A. Bookstrom**Rationale for Model Choice**

Hot-spring Au-Ag deposits consist of precious metal-bearing siliceous sinters and silicified rocks cut by breccias and stockworks of veins and veinlets, which were deposited at or near the surface in and around felsic volcanic fields, usually associated with normal faults (Berger, 1986). This tract encompasses the Ore-Ida graben, a north-south structural feature controlling the distribution of Miocene bimodal volcanic and sedimentary rocks. Within this tract, widespread occurrences of hydrothermal alteration, silica sinter, and anomalous concentrations of gold, silver, arsenic, antimony, and mercury in rocks, soil, and stream sediments indicates the presence of numerous extinct geothermal systems with precious metal contents.

Rationale for Tract Delineation

The permissive tract was delineated to include all the area of Neogene rocks within the Ore-Ida graben (Peters and others, 1994). Since much of the Neogene section is buried under younger Neogene rocks, much of the prospective ground is buried. Pervasive north-south Neogene faulting, recurring volcanism, evidence of numerous extinct hot springs, and overall subsidence within the Ore-Ida graben suggest the entire upper km of the tract is favorable for this deposit type.

Important Examples of Deposit Type

The Grassy Mountain deposit is a large Au-Ag hot-spring deposit (31 metric tons Au, 77 metric tons Ag) within the tract (Wheeler, 1988). The deposit is capped by an extensive zone of silica sinter.

Rationale for Numerical Estimate

The widespread occurrence of silica sinter confirms the existence of recent geothermal activity throughout the graben area. Based on his investigations in the area, J. Rytuba (U.S. Geological Survey, personal commun., 1993) infers that geothermal activity has persisted during subsidence and filling of the graben from the Miocene to the present day, suggesting that deposits of this type may be found associated with deeper stratigraphic horizons, representing earlier ground surfaces in the graben. This suggests there is a uniform likelihood for deposit occurrence throughout the km below the present surface. Combined with an exploration history dating back only to the early 1980s for this type of deposit in this area, and the shallow depth targets for this exploration for bulk mineable deposits (Spanski, 1994), the team estimated 6, 12, 18, 24, and 30 or more deposits at the 90th, 50th, 10th, 5th, and 1st percentiles. These deposits would be consistent with the Au-Ag grade and tonnage model for hot-spring deposits of Berger and Singer (1992).

References

- Berger, B.R., 1986, Descriptive model of hot-spring Au-Ag deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 143.
- Berger, B.R., and Singer, D.A., 1992, Grade and tonnage model of hot-spring Au-Ag, *in* Bliss, J.D., ed., Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, p. 23-25.

- Peters, S.G., Albino, George, Brooks, H.C., Evans, J.G., Carlson, R.R., Lee, G.K., Griscom, Andrew, and Halvorson, P.F., 1994, Deposit models and tracts for undiscovered metallic resources in the Malheur-Jordan-Andrews Resource Area, southeastern Oregon, *in* Smith, C.L., ed., Mineral and energy resources of the BLM Malheur-Jordan Resource Area, southeastern Oregon: U.S. Geological Survey Administrative Report, p. B1-B21.
- Spanski, G.T., 1994, Quantitative resource assessment for locatable minerals, *in* Smith, C.L., ed., Mineral and energy resources of the BLM Malheur-Jordan Resource Area, southeastern Oregon: U.S. Geological Survey Administrative Report, p. C1-C12.
- Wheeler, G.R., 1988, Epithermal gold deposits in eastern Oregon: *Mining Engineering*, v. 40, no. 11, p. 1033-1035.

PC31**Hot-spring Au-Ag Deposits**

Idaho

Descriptive Model 25a

Area = 3,040 km²[Model](#)[Mineral Deposits](#)

by Stephen E. Box and Arthur A. Bookstrom

Rationale for Model Choice

Hot-spring Au-Ag deposits consist of precious-metal-bearing siliceous sinters and silicified rocks cut by breccias and stockworks of veins and veinlets, which were deposited at or near the paleo-ground surface in and around felsic volcanic fields, usually associated with normal faults (Berger, 1986). The tract is underlain by Miocene arkosic sedimentary rocks derived from the Idaho batholith and capped by lavas of the Columbia River Basalt Group. Hot-spring mercury mineralization, with subeconomic gold grade, at the Idaho Almaden mine near Weiser (Anderson, 1941) indicates the existence of extinct geothermal systems. Although rhyolitic magmatism typically associated with the hot-spring deposits (Berger, 1986) is not known, the occurrence of extinct hot spring systems indicates the tract is permissive for this deposit type.

Rationale for Tract Delineation

The tract was drawn around the Miocene Payette Formation, host rock of the Idaho Almaden mine, northwest of the younger basalts of the western Snake River plain (Bond, 1978). The surrounding area, where the Payette Formation may occur within a km of the surface beneath overlying rocks of the Columbia River Basalt Group, is also included.

Important Examples of Deposit Type

No examples of this deposit type are known in the tract. However, hot-spring mercury system at the Idaho Almaden mine near Weiser has similar structural characteristics and abundant silica deposits characteristic of this deposit type. Gold occurs in subeconomic grades in the Idaho Almaden deposit.

Rationale for Numerical Estimate

The lack of known deposits within the tract and the dearth of information available on any exploration activity precluded estimation of the number of undiscovered deposits of this type.

References

- Anderson, Alfred L., 1941, Geology of the Idaho Almaden quicksilver mine: Idaho Bureau of Mines and Geology Pamphlet 55, 9 p.
- Berger, B. R., 1986, Descriptive model of hot-spring Au-Ag deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 143.
- Bond, J.G., 1978, Geologic map of Idaho: Idaho Bureau of Mines and Geology, scale 1:500,000.

PC32**Hot-spring Au-Ag Deposits**

Idaho

Descriptive Model 25a • Mark3 Index 45

Area = 1,730 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Stephen E. Box and Arthur A. Bookstrom

Rationale for Model Choice

Hot-spring Au-Ag deposits consist of precious metal-bearing siliceous sinters and silicified rocks cut by breccias and stockworks of veins and veinlets, which were deposited at or near the paleo-ground surface in and around felsic volcanic fields, usually associated with normal faults (Berger, 1986). Three epithermal Au-Ag vein deposits, each with associated hot-spring-type mineralization, occur within or beneath Miocene felsic volcanic rocks within the tract. The abundance of Neogene basaltic to felsic volcanic and volcanoclastic rocks and the presence of known deposits of this type within the Idaho part of the Ore-Ida graben indicate the tract is permissive for undiscovered deposits of this type.

Rationale for Tract Delineation

This permissive tract for undiscovered hot-spring Au-Ag deposits was drawn to include the Idaho part of the Ore-Ida graben, as interpreted from the State geologic map (Bond, 1978). This tract is underlain by a voluminous pile of Miocene basaltic and felsic volcanic rocks and associated volcanoclastic rocks and encompasses a Miocene and younger zone of pervasive north-south faulting. Minor amounts of Cretaceous granitic rocks are exposed beneath the Miocene rocks and locally contain epithermal mineralization; they are also included in the tract. The tract is buried on the northeast by younger basaltic lavas of the northwest Snake River plain.

Important Examples of Deposit Type

Three epithermal Au-Ag deposits (De Lamar, Stone Cabin, and War Eagle) are known within the permissive tract. Two of the deposits (Delamar, Stone Cabin) grade from disseminated hot-spring type mineralization to more focused vein-type mineralization in different parts of the deposits (Asher, 1968). These two deposits have gold contents at and just below the mean Au content of hot-spring Au-Ag deposits. Silver contents are well above the mean for this deposit type.

Rationale for Numerical Estimate

It is thought that all Comstock-type deposits exposed at the surface in the tract area are known, and any undiscovered deposits must be covered. Since the area has been mostly subsiding since the Miocene, we concluded that any undiscovered Comstock vein deposit will probably still be overlain by a more disseminated Au-Ag hot-spring deposit, for which exploration is fairly incomplete. These undiscovered Comstock vein systems will probably be mined along with their overlying hot-spring deposit, and will be incorporated into the grade and tonnage of any undiscovered hot-spring deposit. For this reason, we only make an estimate for undiscovered hot-spring deposit for the area of this tract, and make no estimate for undiscovered Comstock-type deposits. Since a lot of the tract is covered by rock younger than the favorable Miocene rhyolite horizon, much of the ground is open for the occurrence of undiscovered deposits. Exploration for this deposit type has been incomplete, having begun only in the 1980s. For the 90th, 50th, 10th, 5th and 1st percentiles, the team estimated 0, 1, 3, 5, and 5 or more undiscovered hot-spring Au-Ag deposits, consistent with the grade and tonnage model of Berger and Singer (1992).

References

- Asher, R.R., 1968, Geology and mineral resources of a portion of the Silver City region, Owyhee County, Idaho: Idaho Bureau of Mines and Geology Pamphlet 138, 106 p.
- Berger, B.R., 1986, Descriptive model of hot-spring Au-Ag deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 143.
- Berger, B.R., and Singer, D.A., 1992, Grade and tonnage model of hot-spring Au-Ag, *in* Bliss, J.D., ed., Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, p. 23-25.
- Bond, J.G., 1978, Geologic map of Idaho: Idaho Bureau of Mines and Geology, scale 1:500,000.

PC33**Hot-spring Au-Ag Deposits**

Idaho

Descriptive Model 25aArea = 17,200 km²[Model](#)*by* Stephen E. Box and Arthur A. Bookstrom**Rationale for Model Choice**

Hot-spring Au-Ag deposits consist of precious metal-bearing siliceous sinters and silicified rocks cut by breccias and stockworks of veins and veinlets, which were deposited at or near the surface in and around felsic volcanic fields, usually associated with normal faults (Berger, 1986). Hot-spring Au-Ag mineralization occurs in tracts to the north and west that have generally similar geology.

Rationale for Tract Delineation

The tract was drawn to include the entire area of Miocene rhyolitic volcanism southwest of the Pleistocene Snake River plain and south of the Idaho part of the Ore-Ida graben (Bond, 1978). The tract is underlain by two large Miocene caldera complexes, Juniper Mountain and Bruneau-Jarbridge (Ekren and others, 1982; Bonnicksen, 1982). Extensive rhyolitic ashflow tuffs erupted from the calderas, and these are overlain by Miocene basaltic lavas. A minor amount of older metamorphic and granitic rock is also included within the tract, since veins may extend into these lithologies, as they do in the Silver City area in the tract to the north.

Important Examples of Deposit Type

No examples of this deposit type are known within the tract, and little is known about the exploration history.

Rationale for Numerical Estimate

The lack of known deposits within the tract and the dearth of information available on any exploration activity precluded estimation of the number of undiscovered deposits of this type.

References

- Berger, B.R., 1986, Descriptive model of hot-spring Au-Ag deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 143.
- Bond, J.G., 1978, Geologic map of Idaho: Idaho Bureau of Mines and Geology, scale 1:500,000.
- Bonnicksen, Bill, 1982, The Bruneau-Jarbridge eruptive center, southwestern Idaho, *in* Bonnicksen, Bill and Breckenridge, Roy M., eds., Cenozoic geology of Idaho: Idaho Bureau of Mines and Geology Bulletin 26, p. 237-254.
- Eckren, E.B., McIntyre, D.H., Bennett, E.H., and Marvin, R.F., 1982, Cenozoic stratigraphy of western Owyhee County, Idaho, *in* Bonnicksen, Bill and Breckenridge, Roy M., eds., Cenozoic geology of Idaho: Idaho Bureau of Mines and Geology Bulletin 26, p. 215-236.

PC34**Hot-spring Au-Ag Deposits****California****Descriptive Model 25a • Mark3 Index 45****Area = 37,000 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* James J. Rytuba**Rationale for Model Choice**

Hot-spring Au-Ag deposits are closely associated with intermediate to felsic volcanic fields emplaced in zones of extensional tectonics or in dilational jogs within transpressional tectonic zones (Berger, 1986). Host rocks include volcanic and subvolcanic intrusive rocks as well as adjacent country rocks with high permeability or hydrothermally altered rocks with fracture permeability. Hot-spring sinter is typically present at the paleo-surface and the disseminated or vein type gold ore bodies occur below the sinter and are localized along a through going structure. Associated mineral deposits include hot-spring mercury deposits and antimony deposits.

Rationale for Tract Delineation

Permissive terranes include intermediate to felsic volcanic fields and areas of emplacement of subvolcanic intrusive rocks within zones of extensional tectonism. Factors that would exclude areas from such permissive terranes would include location outside of known volcanic belts and the presence of deeply emplaced plutonic rocks, with no subsequent igneous activity. Favorable areas are delineated by the presence of known economic and subeconomic hot-spring gold deposits or deposits commonly associated with these deposits.

Hot-spring Au-Ag deposits in the Coast Ranges of California are closely associated with Miocene to Holocene volcanic fields. The intermediate to felsic volcanism resulted from passage of the Mendocino triple junction as it migrated northward along the coast of California. Magmatic activity above the slab window, the area of thin crust underlain by hot asthenosphere that replaces the subducting slab, is characterized by andesitic to rhyolitic dome and ash-flow fields and associated plutons and batholiths. The volcanic fields and associated intrusive rocks extend eastward from the Coast Ranges into the Great Valley of California and the youngest volcanic field, the Clear Lake volcanic field is, in part, time equivalent to the Sutter Buttes dome field in the Central Valley. Permissive tracts for undiscovered hot-spring Au-Ag deposits were delineated to include those areas with known Miocene to Holocene volcanic and intrusive rocks and areas above the slab window where intrusive rocks can be expected to occur.

Favorable areas for undiscovered hot-spring Au-Ag deposits are those where prospects and deposits of hot-spring gold and related deposits are present in and adjacent to Miocene to Holocene volcanic and intrusive rocks. The Clearlake and Sonoma volcanic fields and areas adjacent to them are included as favorable because of the presence of volcanic and associated intrusive rocks and the occurrence of three known gold-mercury districts. Other areas in the Coast Ranges with known occurrences of volcanic rocks and occurrence of mercury, gold, and or antimony are also favorable for hot-spring gold deposits (Peters, 1991).

Important Examples of Deposit Type

There are two examples of these types of deposits within this permissive terrane. One is the McLaughlin gold deposit (Lehrman, 1986), the largest and only active gold deposit in the Coast Ranges of California, and the second is the Cherry Hill deposit, which is presently uneconomic.

Rationale for Numerical Estimate

Factors that contributed to the numerical estimate for undiscovered resources included the presence of one mine and one undeveloped deposit of this type, the presence of other prospects and deposits related to hot-spring gold, and a large area of the permissive terrane having small volcanic centers and subvolcanic intrusions or high heat flow. Based upon these factors, the team estimated, for the 90th, 50th, and 10th percentiles, 1, 1, and 2 or more hot-spring Au-Ag deposits consistent with the grade and tonnage model of Berger and Singer(1992).

References

- Berger, B.R., 1986, Descriptive model of hot-spring Au-Ag, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 143-144.
- Berger, B.R., and Singer, D.A., 1992, Grade and tonnage model of hot-spring Au-Ag, *in* Bliss, J.D., ed., Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, p. 23-25.
- Lehrman, N.J., 1986, The McLaughlin mine, Napa and Yolo Counties, California, *in* Tingley, J.V., and Bonham, H.F., Jr., eds., Precious-metal mineralization in hot-spring systems, Nevada-California: Nevada Bureau of Mines and Geology Report 41, p. 90-92.
- Peters, E.K., 1991, Gold-bearing hot spring systems of the northern Coast Ranges, California: *Economic Geology*, v. 86, no. 7, p. 1519-1528.

PC35**Hot-spring Au-Ag Deposits**

California

Descriptive Model 25a • Mark3 Index 45

Area = 7,820 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Richard M. Tosdal

Rationale for Model Choice

The Salton Sea basin is the site of recent volcanism, hot-spring activity, and geothermal activity principally in the southern and eastern parts of the basin. Fossil hot-spring systems are known along the western margin of the basin.

Rationale for Tract Delineation

Hot-spring deposits form near shallow heat sources and represent fossil geothermal systems. In the Salton Sea basin, recent rhyolitic volcanism and active geothermal systems are localized in the southern and eastern parts of the basin, and a gold-bearing hot-spring prospect, the Modoc prospect, is known along the western shore of the Salton Sea (Hillemeier and others, 1991). These two observations justify the delineation of this permissive tract. In addition, the extensive young alluvial sedimentation, particularly along the western margin of the basin may conceal hot-spring deposits.

Important Examples of Deposit Type

The nearby Mesquite and Picacho deposits in the Chocolate Mountains are the closest examples of hot-spring Au-Ag deposits to this permissive tract.

Rationale for Numerical Estimate

Several lines of evidence lead to the numerical estimate. One is the presence of one known hot-spring prospect, which suggests the potential for additional fossil geothermal systems. Second is the presence of volcanism and high heat flow centered on the Salton Sea basin, indicative of magmatism and the potential to drive hydrothermal circulation. Third is the presence of active geothermal systems, some of which are known to be depositing precious and base metals from brine at depth. Finally, the large expanse of area covered by unconsolidated alluvial deposits may conceal hot-spring Au-Ag deposits. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 1, 1, 3, 5, and 5 or more deposits consistent with the worldwide grade and tonnage model (Berger and Singer, 1992).

References

- Berger, B.R., and Singer, D.A., 1992, Grade and tonnage model of hot-spring Au-Ag, in Bliss, J.D., ed., *Developments in mineral deposit modeling*: U.S. Geological Survey Bulletin 2004, p. 23-25.
- Hillemeier, F.L., Johnson, M.D., and Kern, R.R., 1991, Geology, alteration and mineralization of the Modoc hot springs gold prospect, Imperial County, California, in McKibben, M.A., ed., *The diversity of mineral & energy resources of southern California: Society of Economic Geologists Guidebook Series*, v. 12, p. 139-156.

PC36**Low-sulfide Au-quartz Vein Deposits**

Washington

Descriptive Model 36a

Area = 21,800 km²[Model](#)*by* William J. Pickthorn and Michael F. Diggles**Rationale for Model Choice**

The Northern Cascades contains belts of low- to moderate-grade regionally metamorphosed marine sedimentary and volcanic rocks which are penetratively deformed and cut by high-angle regional-scale faults and crosscutting serpentine bodies. Consideration of this tract as permissive for low-sulfide Au-quartz vein deposits (Berger, 1986) is supported by numerous small gold mines and occurrences in this area that are considered to belong to this model type.

Rationale for Tract Delineation

This tract was defined principally on the presence of belts of low- to moderate-grade regionally metamorphosed marine sedimentary and volcanic rocks depicted on the Washington State geologic map (Hunting and others, 1961) and the personal knowledge of the assessors. Although this tract contains no major low-sulfide Au-quartz vein deposits, several major mesothermal gold districts in similar or possibly equivalent rocks are found to the north in Canada.

Important Examples of Deposit Type

No major low-sulfide Au-quartz deposits are recognized in this tract.

Rationale for Numerical Estimate

The team was unable to make an estimate because of lack of information on the nature of the gold occurrences in the tract.

Reference

Berger, B.R., 1986, Descriptive model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239.

PC37**Low-sulfide Au-quartz Vein Deposits**

Idaho

Descriptive Model 36a • Mark3 Index 27

Oregon, Washington

Area = 8,810 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by Stephen E. Box and Arthur A. Bookstrom

Rationale for Model Choice

This deposit type consists of massive quartz-gold veins that typically are low in sulfide minerals (<5 percent), are vertically and horizontally persistent, and are deformed into pinch-and-swell structures due to compressive deformation (Berger, 1986). These mesothermal veins occur in belts of regionally metamorphosed, low- to moderate-grade, marine sedimentary and volcanic rocks, penetratively deformed, and cut by high-angle regional-scale faults. Pre-Cenozoic rocks of northeastern Oregon and adjacent west-central Idaho and southeasternmost Washington are the appropriate lithologies and metamorphic grade for this deposit type.

Rationale for Tract Delineation

Pre-Cenozoic rocks of northeastern Oregon and adjacent west-central Idaho and southeasternmost Washington consist of andesitic and basaltic volcanic rocks, marine clastic and pelagic sedimentary rocks, dismembered ophiolitic sequences, and cross-cutting granitic rocks (Walker and MacLeod, 1991; Bond, 1978). Except for the granitic rocks, these rocks were moderately to strongly deformed and metamorphosed to greenschist during Triassic and Jurassic time. Amphibolite-facies metamorphism of Early Cretaceous age is localized along Salmon River suture, which constitutes the northeast margin of the tract (Lund and Snee, 1988). The area of these rocks in west-central Idaho is currently under study for its mineral resource potential (Bruce Johnson, U.S. Geological Survey, personal commun., 1994), and this tract includes all the pre-Cenozoic rocks of the Wallowa, Baker, and Olds Ferry terranes east of the western rim of the Snake River canyon (Brooks and Vallier, 1978). Where large enough, cross-cutting, post-metamorphic Jurassic and Cretaceous plutons are excluded from the tract.

Important Examples of Deposit Type

Although several prospects of this deposit type occur within the tract, no significant deposits are known. The Black Lake deposit in the Seven Devils mining district produced about 11,000 metric tons of ore averaging 15 g/metric ton of Au (Livingston and Laney, 1920). This is smaller than 85 percent of the deposits used to construct the grade-tonnage model for low-sulfide Au-quartz veins by Bliss (1986), but the grade is near the median for such deposits. In addition four deposits are known in the generally similar rocks in the tract immediately to the west.

Rationale for Numerical Estimate

Thorough exploration for placer and lode gold in this region in the late 1800s and early 1900s probably led to the discovery of almost all deposits that are exposed at the surface. However some of the target rock units are covered by younger rocks along the margin of the tract and locally within it. Possibly some of the known prospects, upon more thorough testing, might be found to be deposits. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 2, 4, and 7 or more undiscovered deposits consistent with the grade and tonnage model of Bliss (1986).

References

Berger, B.R., 1986, Descriptive model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239.

- Bliss, J.D., 1986, Grade and tonnage model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239-243.
- Bond, J.G., 1978, Geologic map of Idaho: Idaho Bureau of Mines and Geology, scale 1:500,000.
- Brooks, H.C., and Vallier, T.L., 1978, Mesozoic rocks and tectonic evolution of eastern Oregon and western Idaho, *in* Howell, D.G., and McDougall, K.A., eds., Mesozoic paleogeography of the western United States: Pacific section, Society of Economic Paleontologists and Mineralogists, Pacific Coast Paleogeography Symposium 2, p. 133-146
- Livingston, D.C., and Laney, F.B., 1920, The copper deposits of the Seven Devils and adjacent districts: Idaho Bureau of Mines and Geology Bulletin No. 1, 105 p.
- Lund, Karen, and Snee, L.W., 1988, Metamorphism, structural development, and age of the continent-island arc juncture in west-central Idaho, *in* Ernst, W.G., ed., Metamorphism and crustal evolution of the western United States, Rubey volume VII: New Jersey, Prentice-Hall, p. 296-331.

PC38**Low-sulfide Au-quartz Vein Deposits****Oregon****Descriptive Model 36a • Mark3 Index 27****Area = 7,100 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* Stephen E. Box and Arthur A. Bookstrom**Rationale for Model Choice**

This deposit type consists of massive quartz-gold veins that typically are low in sulfide minerals (<5 percent), are vertically and horizontally persistent, and are deformed into pinch-and-swell structures due to compressive deformation (Berger, 1986). These mesothermal veins occur in belts of regionally metamorphosed, low- to moderate-grade, marine sedimentary and volcanic rocks, penetratively deformed, and cut by high-angle regional-scale faults. Pre-Cenozoic rocks of northeastern Oregon and adjacent west-central Idaho and southeasternmost Washington fit this description. Four deposits considered to be examples of this type occur in northeastern Oregon.

Rationale for Tract Delineation

Pre-Cenozoic rocks of northeastern Oregon and adjacent west-central Idaho and southeasternmost Washington consist of andesitic and basaltic volcanic rocks, marine clastic and pelagic sedimentary rocks, dismembered ophiolitic sequences, and cross-cutting granitic rocks (Walker and MacLeod, 1991). Except for the granitic rocks, these rocks are moderately to strongly deformed and metamorphosed to greenschist facies. Because the area of these rocks in west-central Idaho is currently under study for its mineral resource potential (Bruce Johnson, U.S. Geological Survey, personal commun., 1994), we have separated that part of the area as a separate tract. In northeast Oregon all rocks of the Wallowa, Baker, and Olds Ferry terranes are included as part of the permissive tract (Brooks and Vallier, 1978). Major cross-cutting, post-metamorphic Jurassic and Cretaceous plutons are excluded from the tract.

Important Examples of Deposit Type

Four mining districts in northeastern Oregon are considered here to be examples of this type (Mormon Basin, Connor Creek, Sanger and Virtue districts), all in the Baker terrane. The tonnage, Au grade and Ag grade of these deposits overlap the median on the grade and tonnage model for low-sulfide Au-quartz vein deposits of Bliss (1986). Other, apparently related, Au-bearing quartz veins in northeastern Oregon differ from the above districts in their higher sulfide content and higher silver grade. Recently Bliss (1994) suggested that all of the mesothermal vein deposits in northeastern Oregon represent a distinct deposit-type, although he noted the similarity of some of the above deposits to the low-sulfide Au-quartz vein deposit type. For this assessment, we consider only the above-named districts as representative of the low-sulfide Au-quartz vein deposit type.

Rationale for Numerical Estimate

Extensive exploration for this deposit type occurred in the late 1800s, and most of the known deposits and prospects were developed at that time. We presume that any exposed deposits have been discovered and thoroughly explored. However areas covered by younger rocks have received little exploration. Because of the relatively small unexplored area and the small size of the known deposits within the tract, the team made a relatively low estimate with a high uncertainty. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 1, 3, and 8 or more undiscovered deposits consistent with the grade and tonnage model of Bliss (1986).

References

- Berger, B.R., 1986, Descriptive model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239.
- Bliss, J.D., 1986, Grade and tonnage model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239-243.
- Bliss, J. D., 1994, Grade, tonnage, and other models of Blue Mountain-type Au-Ag polymetallic veins, Blue Mountains, Oregon, for use in resource and environmental assessment: U.S. Geological Survey Open-File Report 94-677, 33 p.
- Brooks, H.C., and Vallier, T.L., 1978, Mesozoic rocks and tectonic evolution of eastern Oregon and western Idaho, *in* Howell, D.G., and McDougall, K.A., eds., Mesozoic paleogeography of the western United States: Pacific section, Society of Economic Paleontologists and Mineralogists, Pacific Coast Paleogeography Symposium 2, p. 133-146
- Walker, G.W., and MacLeod, N.S., 1991, Geologic map of Oregon: U.S. Geological Survey, 2 sheets, scale 1:500,000.

PC39**Low-sulfide Au-quartz Vein Deposits**California
Oregon

Descriptive Model 36a • Mark3 Index 27

Area = 54,300 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by William J. Pickthorn and Michael F. Diggles

Rationale for Model Choice

Low-sulfide gold-quartz veins (Berger, 1986) are localized in accretionary terranes consisting of belts of low- to moderate-grade regionally metamorphosed marine sedimentary and volcanic rocks, penetratively deformed, and cut by high-angle regional-scale faults.

Rationale for Tract Delineation

This tract was defined principally by the presence of belts of low- to moderate-grade regionally metamorphosed marine sedimentary and volcanic rocks in the Franciscan Complex in the California Coast Ranges. One small district containing low-sulfide Au-quartz vein mines and prospects is reported from the Coast Ranges. Based on the rock type, geologic setting, and the presence of mesothermal gold-bearing vein systems, this tract is considered permissive for undiscovered resources of this deposit type.

Important Examples of Deposit Type

Although there are no recognized major low-sulfide Au-quartz vein deposits in the Coast Ranges, small amounts of placer gold are found in almost all streams draining rocks of the Franciscan Complex. In southern Monterey County the Los Burros mining district, which produced approximately 0.16 metric tons of gold from low-sulfide Au-quartz veins, is localized in greenschist facies rocks of the Franciscan Complex that are intruded by serpentinite (Hart, 1966). Similar higher-grade metamorphic rocks may be present elsewhere in the Coast Ranges.

Rationale for Numerical Estimate

Inasmuch as the largest known deposit is well below the mean size of the model, it seemed appropriate to make a low estimate. For the 90th, 50th, 10th, 5th, and 1st percentiles the team estimated 0, 0, 0, 0, and 1 or more undiscovered deposits consistent with the grade and tonnage model of Bliss (1986).

References

- Berger, B.R., 1986, Descriptive model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239.
- Bliss, J.D., 1986, Grade and tonnage model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239-243
- Bliss, J.D., and Jones, G.M., 1988, Mineralogic and grade-tonnage information on low-sulfide Au-quartz veins: U.S. Geological Survey Open-File Report 88-0229, 99 p.
- Hart, E.W., 1966, Mines and mineral resources of Monterey County, California: California Division of Mines and Geology County Report 5, 142 p.
- Jennings, C.W., 1977, Geologic map of California: California Division of Mines and Geology, scale 750,000.

PC40**Low-sulfide Au-quartz Vein Deposits**California
Oregon

Descriptive Model 36a • Mark3 Index 27

Area = 103,300 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by William J. Pickthorn and Michael F. Diggles

Rationale for Model Choice

Gold-bearing mesothermal quartz veins are localized along major deep-seated through-going structural features in low- to moderate-grade marine metasedimentary and metavolcanic rocks. Many of the type examples used by Berger (1986) in the low-sulfide Au-quartz descriptive model are in the Pacific Coast region.

Rationale for Tract Delineation

The permissive tract was defined principally by the location of low- to moderate-grade regionally metamorphosed marine sedimentary and volcanic rocks of Jurassic and older age, based on the State geologic maps for California and Oregon (Jennings, 1977; Walker and MacLeod, 1991) and the personal knowledge of the assessors. Geophysical evidence was used to extend the tracts into areas of valley fill or thin Quaternary, Tertiary, or Cretaceous cover. In California and Oregon most of the tract contains known gold deposits and includes those deposits in the famed California Mother Lode and the Ashland district in southern Oregon. In southern California, metavolcanic and metasedimentary rocks that enclose, or occur as roof pendants in the major batholiths were also considered permissive. These rocks host small low-sulfide Au-quartz veins in the Julian-Banner district.

Important Examples of Deposit Type

The low-sulfide Au-quartz grade and tonnage model is based on deposits containing 100 metric tons or more of gold (Bliss, 1986). Over 50 percent of the deposits in the worldwide model (Bliss and Jones, 1988) are located within this tract and include those of the California Mother Lode and the Grass Valley district in the Sierra Nevada foothills, and deposits in the Klamath, Siskiyou, and Trinity Mountains in northern California and southern Oregon. Several major mines in the tract are currently or have been recently active. Most notable are the Harvard mine near Jamestown and the Royal Mountain King mine near Copperopolis, both in the California Mother Lode. Reserves at the Harvard mine are estimated to be in excess of 100 metric tons of gold (Bliss and Jones, 1988).

Rationale for Numerical Estimate

The team concluded that nearly all of the deposits that are exposed at the surface have been discovered. The part of the tract most favorable for undiscovered deposits is that part that is covered by less than 1 km of Cretaceous sedimentary and Tertiary volcanic rocks between the Klamath Mountains and the Sierra Nevada. Estimates for this area were made using deposit density data. The shallow-covered area extending southeast from the Klamath Mountains has an area of 490 km². The shallow-covered area extending northwest from the Sierra is 1,700 km². The density of distribution of low-sulfide Au-quartz vein deposits in the Klamath Mountains is 4.0 deposits per 1,000 km²; for the Sierra Nevada, the density is 4.6 according to Bliss and others (1987). Inasmuch as the concentration of deposits tends to drop off with distance from the zones of greatest mineralization, we expect that the density of deposits in the areas beyond the known deposits is half that given by Bliss. These densities (2 and 2.3 per 1,000 km²) multiplied by the areas of covered tract results in an expected value of about one deposit for the Klamath Mountains and about four for the Sierra Nevada.

In the exposed part of the tract, the team estimated only about one undiscovered deposit could exist giving a total expected value of about six deposits. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 2, 6, 9, 12, and 15 or more deposits consistent with the grade and tonnage model of Bliss (1986).

References

- Berger, B.R., 1986, Descriptive model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239.
- Bliss, J.D., 1986, Grade and tonnage model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239-243.
- Bliss, J.D., Menzie, W.D., Orris, G.J., and Page, N.J., 1987, Mineral deposit density—A useful tool for mineral-resource assessment, *in* Sachs, J.S., ed., U.S. Geological Survey Research on Mineral Resources—1987 program and abstracts: U.S. Geological Survey Circular 995, p. 6.
- Bliss, J.D., and Jones, G.M., 1988, Mineralogic and grade-tonnage information on low-sulfide Au-quartz veins: U.S. Geological Survey Open-File Report 88-0229, 99 p.
- Clark, W.B., 1976, Gold districts of California: California Division of Mines and Geology Bulletin 193, 186 p.
- Jennings, C.W., 1977, Geologic map of California: California Division of Mines and Geology, scale 1:750,000.
- Walker, G.W., and MacLeod, N.S., 1991, Geologic map of Oregon: U.S. Geological Survey, 2 sheets, scale 1:500,000.

SA01**Massive Sulfide Deposits, Besshi Type**

Descriptive Model 24b • Mark3 Index 98

Area = 12,100 km²Virginia
North Carolina
Georgia[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by J.F. Slack

Rationale for Model Choice

The southern Appalachians region contains several large Besshi massive sulfide deposits (Gair and Slack, 1980). These deposits are similar to other stratabound and commonly stratiform sulfide deposits that form mainly by submarine hydrothermal processes within intercalated clastic metasedimentary rocks and metabasalt (Franklin and others, 1981; Fox, 1984; Slack, 1993). The largest deposits of this type in the southern Appalachians were mined in the Ducktown district of southeastern Tennessee (Emmons and Laney, 1926; Magee, 1968; Slater, 1982), and produced major amounts of copper, as well as minor zinc and pyrrhotite, the latter for manufacture of sulfuric acid. In southwestern Virginia, the Gossan Lead district contains several separate Besshi massive sulfide deposits that together accounted for significant production of copper, zinc, and sulfur (Stose and Stose, 1957; Gair and Slack, 1984). Smaller deposits of this type occur at Fontana and Ore Knob, North Carolina (Ross, 1935; Espenshade, 1963; Kinkel, 1967).

The Besshi grade-tonnage model of Slack (1993) was used in the calculation of undiscovered metal resources. In contrast with the model 24b of Singer (1986), which only included data for Besshi deposits in Japan, this model incorporates grade and tonnage data for Besshi deposits throughout the world, including those in the United States Appalachians, and is therefore more comprehensive.

Rationale for Tract Delineation

The permissive tract outlines the Late Proterozoic Ashe Formation (Rankin and others, 1973) in southwestern Virginia and northwestern North Carolina, which consists of metamorphosed clastic metasedimentary rocks and variable amounts of associated metabasalt that host the Besshi deposits of the Gossan Lead district and the Ore Knob mine. This tract also includes rocks of similar age and lithology along strike to the southwest, in western and southwestern North Carolina, and in northeastern Georgia.

Rationale for Numerical Estimate

Estimates of the number of undiscovered deposits were made by comparisons with the number of known deposits in other areas such as the Besshi district of Japan. The choices were influenced by the presence of mines, prospects, and mineral occurrences; by geochemical anomalies; and by the level of exploration interest. At 90th, 50th, and 10th percentiles, the estimated numbers of undiscovered deposits are 1, 3, and 5, respectively, consistent with the grade and tonnage model of Slack (1993).

References

- Emmons, W.H., and Laney, F.B., 1926, Geology and ore deposits of the Ducktown mining district, Tennessee: U.S. Geological Survey Professional Paper 139, 114 p.
- Espenshade, G.H., 1963, Geology of some copper deposits in North Carolina, Virginia, and Alabama: U.S. Geological Survey Bulletin 1142-I, 50 p.

- Fox, J.S., 1984, Besshi-type volcanogenic sulphide deposits—A review: *Canadian Institute of Mining Bulletin*, v. 77, no. 864, p. 57–68.
- Franklin, J.M., Lydon, J.W., and Sangster, D.F., 1981, Volcanic-associated massive sulfide deposits, *in* Skinner, B.J., ed., *Economic Geology Seventy-Fifth Anniversary Volume, 1905–1980*: Lancaster, Pennsylvania, Economic Geology Publishing Company, p. 485–627.
- Gair, J.E., and Slack, J.F., 1979, Map showing lithostratigraphic and structural setting of stratabound (massive) sulfide deposits of the U.S. Appalachians: U.S. Geological Survey Open-File Report 79–1517, scale 1:1,000,000 [four oversize sheets].
- Gair, J.E., and Slack, J.F., 1980, Stratabound massive sulfide deposits of the U.S. Appalachians, *in* Vokes, F.M., and Zachrisson, Ebbe, eds., *Review of Caledonian-Appalachian stratabound sulphides: Geological Survey of Ireland Special Paper No. 5*, p. 68–81.
- Gair, J.E., and Slack, J.F., 1984, Deformation, geochemistry, and origin of massive sulfide deposits, Gossan Lead district, Virginia: *Economic Geology*, v. 79, no. 7, p. 1483–1520.
- Kinkel, A.R., Jr., 1967, The Ore Knob copper deposit, North Carolina, and other massive sulfide deposits of the Appalachians: U.S. Geological Survey Professional Paper 558, 58 p.
- Magee, Maurice, 1968, Geology and ore deposits of the Ducktown district, Tennessee, *in* Ridge, J.D., ed., *Ore deposits of the United States, 1933–1967 (Graton-Sales Volume)*: New York, American Institute of Mining, Metallurgical, and Petroleum Engineers, v. I, p. 207–241.
- Rankin, E.W., Espenshade, G.H., and Shaw, K.W., 1973, Stratigraphy and structure of the metamorphic belt in northwestern North Carolina and southwestern Virginia—A study from the Blue Ridge across the Brevard fault zone to the Sauratown Mountains anticlinorium: *American Journal of Science*, v. 273A, p. 1–40.
- Ross, C.S., 1935, Origin of the copper deposits of the Ducktown type in the southern Appalachian region: U.S. Geological Survey Professional Paper 179, 165 p.
- Shearer, H.K., and Hull, J.P.D., 1918, A preliminary report on a part of the pyrite deposits of Georgia: *Georgia Geological Survey Bulletin* 33, 229 p.
- Slack, J.F., 1993, Descriptive and grade-tonnage models for Besshi-type massive sulphide deposits, *in* Kirkham, R.V., Sinclair, W.D., Thorpe, R.I., and Duke, J.M., eds., *Mineral deposit modeling: Geological Association of Canada, Special Paper No. 40*, p. 343–371.
- Slater, Randy, 1982, Massive sulfide deposits of the Ducktown mining district, Tennessee, *in* Allard, G.O., and Carpenter, R.H., eds., *Exploration for metallic resources in the southeast*: Athens, Georgia, University of Georgia, p. 91–99.
- Stose, A.J., and Stose, G.W., 1957, Geology and mineral resources of the Gossan Lead district and adjacent areas in Virginia: *Virginia Division of Mineral Resources Bulletin* 72, 233 p.
- Wittington, D., 1982, Geology of the Stone Hill massive sulfide copper mine, Cleburne and Randolph Counties, Alabama: Tuscaloosa, University of Alabama, Unpublished M.Sc. Thesis, 143 p.

SA02**Massive Sulfide Deposits, Besshi Type**Tennessee
North Carolina

Descriptive Model 24b

Area = 1,830 km²[Model](#)*by* J.F. Slack**Rationale for Model Choice**

The southern Appalachians region contains several large Besshi massive sulfide deposits (Gair and Slack, 1980). These deposits are similar to other stratabound and commonly stratiform sulfide deposits within intercalated clastic metasedimentary rocks and metabasalt that form mainly by submarine hydrothermal processes (Franklin and others, 1981; Fox, 1984; Slack, 1993).

Rationale for Tract Delineation

The permissive tract, to the northeast of the Ducktown district, outlines areas of the Great Smoky Group that are permissive for the occurrence of Besshi deposits, but lack known deposits or prospects. No estimate of undiscovered deposits was made.

References

- Gair, J.E., and Slack, J.F., 1980, Stratabound massive sulfide deposits of the U.S. Appalachians, *in* Vokes, F.M., and Zachrisson, Ebbe, eds., *Review of Caledonian-Appalachian stratabound sulphides: Geological Survey of Ireland Special Paper No. 5*, p. 68–81.
- Fox, J.S., 1984, Besshi-type volcanogenic sulphide deposits—A review: *Canadian Institute of Mining Bulletin*, v. 77, no. 864, p. 57–68.
- Franklin, J.M., Lydon, J.W., and Sangster, D.F., 1981, Volcanic-associated massive sulfide deposits, *in* Skinner, B.J., ed., *Economic Geology Seventy-Fifth Anniversary Volume, 1905–1980*: Lancaster, Pennsylvania, Economic Geology Publishing Company, p. 485–627.
- Slack, J.F., 1993, Descriptive and grade-tonnage models for Besshi-type massive sulphide deposits, *in* Kirkham, R.V., Sinclair, W.D., Thorpe, R.I., and Duke, J.M., eds., *Mineral deposit modeling: Geological Association of Canada, Special Paper No. 40*, p. 343–371.

SA03**Massive Sulfide Deposits, Besshi Type**

Descriptive Model 24b • Mark3 Index 98

Area = 8,570 km²Tennessee
North Carolina
Georgia[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by J.F. Slack

Rationale for Model Choice

The southern Appalachians region contains several large Besshi massive sulfide deposits (Gair and Slack, 1980). These deposits are similar to other stratabound and commonly stratiform sulfide deposits within intercalated clastic metasedimentary rocks and metabasalt that form mainly by submarine hydrothermal processes (Franklin and others, 1981; Fox, 1984; Slack, 1993). The largest deposits of this type in the southern Appalachians were mined in the Ducktown district of southeastern Tennessee (Emmons and Laney, 1926; Magee, 1968; Slater, 1982), and produced major amounts of copper and pyrrhotite, the latter for manufacture of sulfuric acid, and minor amounts of zinc, gold, and silver. Smaller deposits of this type occur at Fontana and Ore Knob, North Carolina (Ross, 1935; Espenshade, 1963; Kinkel, 1967).

The Besshi grade-tonnage model of Slack (1993) was used in the calculation of undiscovered metal resources. This model (24b.1) is considered better than model 24b of Singer (1986), which only included data for Besshi deposits in Japan. The model of Slack (1993) incorporates grade and tonnage data for Besshi deposits throughout the world, including those in the United States Appalachians, and is therefore more comprehensive.

Rationale for Tract Delineation

The permissive tract contains the Ducktown district, Tennessee, within Late Proterozoic rift-facies metasedimentary rocks of the Great Smoky Group (Knoll and Keller, 1979), although in this tract, metabasalt is rare. This tract also contains the much smaller Fontana, North Carolina, deposit and several prospects.

Rationale for Numerical Estimate

Estimates of the number of undiscovered deposits were made by comparisons with the number of known deposits in other areas such as the Besshi district of Japan. The choices were influenced by the presence of mines, prospects, and mineral occurrences; by geochemical anomalies; and by the level of exploration interest. At 90th, 50th, and 10th percentiles, the estimated numbers of undiscovered deposits are 1, 3, and 5, respectively, consistent with the grade and tonnage model of Slack (1993).

References

- Emmons, W.H., and Laney, F.B., 1926, Geology and ore deposits of the Ducktown mining district, Tennessee: U.S. Geological Survey Professional Paper 139, 114 p.
- Fox, J.S., 1984, Besshi-type volcanogenic sulphide deposits—A review: Canadian Institute of Mining Bulletin, v. 77, no. 864, p. 57–68.
- Franklin, J.M., Lydon, J.W., and Sangster, D.F., 1981, Volcanic-associated massive sulfide deposits, in Skinner, B.J., ed., Economic Geology Seventy-Fifth Anniversary Volume, 1905–1980: Lancaster, Pennsylvania, Economic Geology Publishing Company, p. 485–627.

- Gair, J.E., and Slack, J.F., 1979, Map showing lithostratigraphic and structural setting of stratabound (massive) sulfide deposits of the U.S. Appalachians: U.S. Geological Survey Open-File Report 79-1517, scale 1:1,000,000 [four oversize sheets].
- Gair, J.E., and Slack, J.F., 1980, Stratabound massive sulfide deposits of the U.S. Appalachians, *in* Vokes, F.M., and Zachrisson, Ebbe, eds., Review of Caledonian-Appalachian stratabound sulphides: Geological Survey of Ireland Special Paper No. 5, p. 68–81.
- Knoll, A.H., and Keller, F.B., 1979, Late Precambrian microfossils from the Walden Creek Group, Ocoee Supergroup, Tennessee: Geological Society of America, Abstracts with Programs, v. 11, p. 185.
- Magee, Maurice, 1968, Geology and ore deposits of the Ducktown district, Tennessee, *in* Ridge, J.D., ed., Ore deposits of the United States, 1933–1967 (Graton-Sales Volume): New York, American Institute of Mining, Metallurgical, and Petroleum Engineers, v. I, p. 207–241.
- Ross, C.S., 1935, Origin of the copper deposits of the Ducktown type in the southern Appalachian region: U.S. Geological Survey Professional Paper 179, 165 p.
- Shearer, H.K., and Hull, J.P.D., 1918, A preliminary report on a part of the pyrite deposits of Georgia: Georgia Geological Survey Bulletin 33, 229 p.
- Slack, J.F., 1993, Descriptive and grade-tonnage models for Besshi-type massive sulphide deposits, *in* Kirkham, R.V., Sinclair, W.D., Thorpe, R.I., and Duke, J.M., eds., Mineral deposit modeling: Geological Association of Canada, Special Paper No. 40, p. 343–371.
- Slater, Randy, 1982, Massive sulfide deposits of the Ducktown mining district, Tennessee, *in* Allard, G.O., and Carpenter, R.H., eds., Exploration for metallic resources in the southeast: Athens, Georgia, University of Georgia, p. 91–99.
- Stose, A.J., and Stose, G.W., 1957, Geology and mineral resources of the Gossan Lead district and adjacent areas in Virginia: Virginia Division of Mineral Resources Bulletin 72, 233 p.

SA04**Massive Sulfide Deposits, Kuroko Type**

Maryland

Descriptive Model 28a • Mark3 Index 104

Virginia

Area = 3,490 km²

District of Columbia

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by T.L. Klein

Rationale for Model Choice

The Chopawamsic Formation of central and northern Virginia contains dozens of base-metal rich or pyritic kuroko massive sulfide deposits over the 175 km length of the Virginia gold-pyrite belt. Gossans from these deposits were first mined for iron. Later, their deeper unweathered parts were mined for base-metals and sulfur. Massive sulfide deposits are mostly restricted to three distinct stratigraphic intervals separated by more than 900 m of barren rock (Pavlidis and others, 1982). Metamorphic grade increases from greenschist-facies to amphibolite facies southward in the belt. The early Cambrian volcanic rocks in the Chopawamsic Formation consist of equal proportions of mafic, intermediate, and felsic compositions with minor amounts of iron formation and sedimentary rocks comprising the remainder of the stratigraphic section (Pavlidis, 1981). Several low-K granitoids intrude the Chopawamsic Formation. The transitional tholeiitic to calc-alkaline geochemistry of the volcanic rocks suggest that the belt was formed in an island-arc setting. Based on stratigraphic considerations, the arc is thought to have developed on the eastern margin of a continent (Pavlidis, 1981). At least seven deposits are present in the Mineral district that contains the largest volume (resources) of sulfide ore (>9 million metric tons) in the belt. The other deposits in the belt are thought to contain from 3 to 3.5 million tons of massive sulfide (Pavlidis and others, 1982). Other deposits, the Valzinco mine, located near the Mineral district, the London and Virginia mine, and deposits in the Andersonville district and Cabin Branch contain significant-sized sulfide bodies. However, many of these sulfide bodies (Cabin Branch, London and Virginia, and most deposit in the Andersonville district) contain principally pyrite or pyrrhotite, with minor base-metal sulfide minerals. Grades and tonnages of kuroko massive sulfide deposits in the tract are given below:

Site	State	Metric tons (millions)	Cu %	Zn %	Pb %	Ag (g/t)	Au (g/t)	Source
Mineral district	Va	9.	1	2.5		34		Duke, 1985.
Valzinco	Va	0.26		10	4.4			Duke, 1985.
London and Virginia	Va	0.66	5.8	3.2	0.92	25	4	Duke, 1985.
Andersonville district	Va	1.4	1	5		34	0.2	Duke, 1985.
Cabin Branch	Va	1.4*						Duke, 1985.

*No base metals were recovered during pyrite production.

In the Virginia gold-pyrite belt, kyanite-quartz deposits occur near massive sulfide deposits and may represent metamorphosed hydrothermal alteration assemblages associated with the submarine hot-spring systems. Base and precious metals, pyrite, kyanite, and barite have been mined from various deposits in this area. The deposits are invariably characterized by the presence of large volumes of felsic volcanic rocks, many in bimodal volcanic suites, and fine-

grained immature volcanic-related sedimentary rocks that were probably formed in a convergent arc tectonic setting, perhaps in rift basins related to convergence (Duke, 1985; Neathery and Hollister, 1985; Long, 1979).

The massive sulfide districts and deposits in the Chopawamsic Formation exhibit geologic characteristics similar to those of the kuroko deposits of Japan (Franklin and others, 1981) and those of kuroko massive sulfide deposits (model 28a) (Singer and Mosier, 1986). The typical kuroko lithologic association of substantial thicknesses of felsic volcanic rocks, chemical sedimentary rocks (barite, manganese and iron formation), and massive sulfides is present in every district.

Because the lead contents of Precambrian and Phanerozoic kuroko massive sulfide deposits are significantly different (Franklin and others, 1981), the grade and tonnage model of Singer and Mosier (1986), which combines deposits of all ages, did not seem appropriate for the Phanerozoic kuroko deposits in the southeastern United States. A new model for Phanerozoic kuroko deposits (Mark3 index 104) was used.

Rationale for Tract Delineation

This permissive tract is comprised of the rocks of the central Virginia volcanic-plutonic belt (Pavilides, 1981) and extends northeastward to include favorable rocks in the James Run Formation in Maryland (Pavilides and others, 1982). Because most rocks in the Maryland part of this favorable tract are poorly exposed or buried beneath Coastal Plain sedimentary deposits, the extent and character of these subsurface rocks has not been fully established.

Rationale for Numerical Estimate

Recent exploration has been moderately extensive in the Virginia gold-pyrite belt where several small deposits were defined by exploration drilling in the 1970s and 1980s (Duke, 1983). The numbers of undiscovered deposits estimated at the 90th, 50th, and 10th percentiles respectively, are 4, 8, and 12 deposits consistent with the Phanerozoic kuroko model.

References

- Duke, N.A., 1983, A metallogenic study of the central Virginia gold-pyrite belt: Winnipeg, Manitoba, University of Manitoba, unpublished Ph.D. thesis.
- Duke, N.A., 1985, The metallogeny of base and precious metal deposits in paleorift setting of the south-central Appalachians, *in* Misra, K.C., ed., *Volcanogenic sulfide and precious metal mineralization in the southern Appalachians*: Knoxville, University of Tennessee, *Studies in Geology* 16, p. 3–21.
- Franklin, J.M., Lydon, J.W., and Sangster, D.F., 1981, Volcanic-associated massive sulfide deposits, *in* Skinner, B.J., ed., *Economic Geology Seventy-Fifth Anniversary Volume, 1905–1980*: Lancaster, Pennsylvania, Economic Geology Publishing Company, p. 485–627.
- Pavilides, L., Gair, J.E., and Cranford, S.L., 1982, Central Virginia volcanic-plutonic belt as host for massive sulfide deposits: *Economic Geology*, v. 77, no. 2, p. 233–272.
- Pavilides, L., 1981, The central Virginia volcanic-plutonic belt—An island arc of Cambrian(?) age: U.S. Geological Survey Professional Paper 1231A, 44 p.
- Singer, D.A., and Mosier, D.L., 1986, Grade and tonnage model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 190–197.

SA05**Descriptive Model 28a****Area = 62,500 km²****Massive Sulfide Deposits, Kuroko Type****Virginia
North Carolina
South Carolina
Georgia**[Model](#)*by* T.L. Klein**Rationale for Model Choice**

Volcanic rocks of the northern Carolina slate belt and crystalline rocks buried beneath Coastal Plain sedimentary deposits in southeastern Virginia, eastern North and South Carolina, and east-central Georgia that contain volcanic rocks, as inferred from airborne magnetic surveys and limited drilling are permissive for kuroko massive sulfide deposits.

Rationale for Tract Delineation

Buried crystalline rocks in southeastern Virginia, eastern North and South Carolina, and central Georgia are included in this tract to the point where the bedrock is buried by up to 1 km of Coastal plain sedimentary deposits. No estimate of undiscovered deposits was made because of the poorly known geologic framework for most of these rocks and the small amount of mineral exploration that has been undertaken.

SA06**Descriptive Model 28a****Area = 29,600 km²****Massive Sulfide Deposits, Kuroko Type****North Carolina****South Carolina****Georgia****Alabama**[Model](#)*by* T.L. Klein**Rationale for Model Choice**

Volcanic rocks in the Charlotte belt, Belair belt, the high-grade Ashland-Wedowee terranes of Alabama and parts of the Carolina slate belt, are considered permissive for the occurrence of kuroko massive sulfide deposits, although they contain few examples.

Rationale for Tract Delineation

The permissive tract includes volcanic rocks in the Carolina slate belt, Charlotte belt, Belair belt, and the high-grade Ashland-Wedowee terranes of Alabama, exclusive of areas with known deposits. No estimate of undiscovered deposits was made.

SA07**Massive Sulfide Deposits, Kuroko Type**

Descriptive Model 28a • Mark3 Index 104

Area = 4,420 km²

North Carolina

South Carolina

Georgia

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by T.L. Klein

Rationale for Model Choice and Deposit Examples

Rocks of the Albemarle Group, in the Carolina slate belt of central North Carolina, host the kuroko massive sulfide deposits of the Gold Hill and Cid districts. The massive sulfide deposits in the Cid district, and probably those at Gold Hill, are within the Flat Swamp Member of the Cid Formation (Indorf, 1981; Feiss and others, 1991). The Flat Swamp bimodal volcanic rocks can be traced over an area of 2,400 square kilometers along the Troy anticlinorium and may be as much as 1,400 m thick in some places (Butler and Secor, 1991). The volcanic rocks are calc-alkaline in character, and were probably deposited in either an island arc or volcanic arc developed on thin continental crust (see, Butler and Secor, 1991). The age of the sequence is somewhat problematic but it is younger than 586 Ma, the age of the underlying Uwharrie Formation (Wright and Seiders, 1980). The small, zinc-rich deposits of the Cid district are located along a sedimentary-volcanic rock transition zone over a strike length greater than 30 km. Examples of concordant massive sulfide lenses up to 5 m thick and discordant stringer zone deposits are found in the abandoned mines of the district. Lead, silver, and zinc have been produced principally from the Silver Hill mine where the amount of production is poorly known, the production grades unknown, and the results of exploration drilling unavailable. The Gold Hill district, located within the Gold Hill fault zone, which forms the boundary between the Charlotte and Carolina slate belt, contains at least one copper-rich massive sulfide deposit at the Union Copper mine (Unger, 1982). This small deposit (probably less than 0.5 million metric tons), is highly deformed and is associated with several, nearby, low-sulfide Au-quartz vein deposits.

Grades and tonnages of kuroko massive sulfide deposits in this tract are given below:

Site	State	Metric tons (millions)	Cu %	Zn %	Pb%	Ag (g/t)	Au (g/t)	Source
Gold Hill district	NC	0.46	2.6	NA	NA	48	0.85	Calculated from data of Pardee and Park, 1948.
Cid district	NC	0.46	NA	NA	NA	NA	NA	Feiss and others, 1991.
Barite Hill	SC	1.4	NA	NA	NA	NA	1.4	Clark and others, 1992.

NA, not available.

The dominantly felsic volcanic rocks of the Persimmon Fork Formation, and the related, informally named, lower Cambrian Lincolnton metadacite contain base- and precious-metal deposits at Barite Hill and the Dorn mine in the Lincolnton-McCormick district in South Carolina (Bell and others, 1980; Carpenter and others, 1982). Although the Barite Hill mine, which began gold production in 1991, and the abandoned Dorn mine are principally gold mines, their high base-metal content and (or) abundant barite suggest that they are closely related to kuroko massive sulfide deposits. Kyanite deposits, probably also related to these massive sulfide deposits, were mined at Graves Mountain the Lincolnton-McCormick district. Similar small base- and precious-metal deposits, and kyanite and barite deposits occur in the Kings

Mountain belt of North and South Carolina, which is composed of bimodal volcanic rocks and chemical and epiclastic sedimentary rocks (see Butler and Secor, 1991).

Stratabound barite deposits in the Kings Mountain belt near the North and South Carolina border associated with base-metal sulfide accumulations and iron formation are similar to deposits in the Lincolnton-McCormick district and are considered to be related to kuroko massive sulfide deposits.

In the Kings Mountain belt, as in the Lincolnton-McCormick district and Virginia gold-pyrite belt, kyanite-quartz deposits occur near massive sulfide deposits and may represent metamorphosed hydrothermally altered rocks associated with the submarine hot-spring systems that formed them. Base and precious metals, pyrite, kyanite, and barite have been mined from various deposits in these areas that are invariably characterized by the presence of large volumes of felsic volcanic rocks, many in bimodal volcanic suites, and fine-grained immature volcanic-related sedimentary rocks that were probably formed in convergent arc tectonic settings, many perhaps in rift basins related to convergence (Duke, 1985; Neathery and Hollister, 1985; Long, 1979).

The massive sulfide districts and deposits in the Carolina slate belt exhibit geologic characteristics similar to the kuroko deposits of Japan (see Franklin and others, 1981) and those of kuroko massive sulfide deposits (model 28a) (Singer and Mosier, 1986). The typical kuroko lithologic association of substantial thicknesses felsic volcanic rocks, chemical sedimentary rocks (barite, bedded manganese and iron formation), and massive sulfides is present in every district.

Because the lead contents of Precambrian and Phanerozoic kuroko massive sulfide deposits are significantly different (Franklin and others, 1981), the grade and tonnage model of Singer and Mosier (1986), which combines deposits of all ages, did not seem appropriate for the Phanerozoic kuroko deposits in the southeastern United States. A new Phanerozoic kuroko model (Mark3 index 104) was used.

Rationale for Tract Delineation

Low-grade metamorphosed volcanic rocks in three areas, the Lincolnton-McCormick area of southern South Carolina, the Kings Mountain belt along the North and South Carolina border, and the area underlain by rocks of the Albemarle Group in the western part of the Carolina slate belt in central North Carolina are included in the permissive tract. In North Carolina, one of the three component areas contain two major districts (Cid, Gold Hill). Several base- and precious-metal mines thought to be kuroko deposits (Barite Hill, Dorn), as well as barite and kyanite occurrences, in the Lincolnton-McCormick district of South Carolina and Georgia and the Kings Mountain belt, also indicate that these areas are permissive for kuroko massive sulfide deposits.

Rationale for Numerical Estimate

For the 90th, 50th, and 10th percentiles, respectively, the team estimated 3, 7, and 12 undiscovered deposits consistent with the Phanerozoic kuroko model (Mark3 index 104) are present in the three districts that make up the tract.

References

- Bell, Henry, III, Carpenter, R.H., and Feiss, P.G., 1980, Volcanogenic ore deposits of the Carolina slate belt, *in* Frey, R.W., ed., *Excursions in southeastern geology*, Volume 1, Field trip guidebook for the Geological Society 1980 Annual Meeting, Atlanta, Georgia: Falls Church, Virginia, American Geological Institute, p. 149–178.

- Butler, J.R., and Secor, D.T., Jr., 1991, The central Piedmont, *in* Horton, J.W., and Zullo, V.A., eds., *The geology of the Carolinas*: Knoxville, University of Tennessee Press, p. 59–78.
- Carpenter, R.H., Odom, A.L., and Hartley, M.E., 1982, Geochronological investigations of the Lincolnton metadacite, Georgia and South Carolina: Geological Society of America Special Paper 191, p. 145–152.
- Clark, S.H.B., Grieg, D.D., and Bryan, N.L., 1992, A preliminary report on the geology of the volcanic rock-hosted Barite Hill gold deposit, Carolina slate belt: Geological Society of America Abstracts with Programs, v. 24, no. 2, p. 8.
- Duke, N.A., 1985, The metallogeny of base and precious metal deposits in paleorift setting of the south-central Appalachians, *in* Misra, K.C., ed., *Volcanogenic sulfide and precious metal mineralization in the southern Appalachians*: Knoxville, University of Tennessee, Studies in Geology 16, p. 3–21.
- Feiss, P.G., 1982, Ore deposits of the northern parts of the Carolina slate belt, North Carolina: Geological Society of America Special Paper 191, p. 153–164.
- Feiss, P.G., Maybin, A.H., III, Riggs, S.R., and Grosz, A.E., 1991, Mineral resources of the Carolinas, *in* Horton, J.R., Jr., and Zullo, V.A., eds., *The geology of the Carolinas*: Knoxville, University of Tennessee Press, p. 319–345.
- Franklin, J.M., Lydon, J.W., and Sangster, D.F., 1981, Volcanic-associated massive sulfide deposits, *in* Skinner, B.J., ed., *Economic Geology Seventy-Fifth Anniversary Volume, 1905–1980*: Lancaster, Pennsylvania, Economic Geology Publishing Company, p. 485–627.
- Indorf, C.P., 1981, The Silver Hill zinc deposit and associated deposits, central North Carolina: *Economic Geology*, v. 76, no. 5, p. 1170–1185.
- Long, L.T., 1979, The Carolina slate belt—Evidence of a continental rift zone: *Geology*, v. 7, p. 180–184.
- Neathery, T.L., and Hollister, V.F., 1985, Models for volcanogenic sulfide exploration in the southernmost Appalachians, *in* Misra, K.C., ed., *Volcanogenic sulfide and precious metal mineralization in the southern Appalachians*: Knoxville, University of Tennessee, Studies in Geology 16, p. 97–112.
- Pardee, J.T., and Park, C.F., Jr., 1948, Gold deposits of the southern Piedmont: U.S. Geological Survey Professional Paper 213, 156 p.
- Singer, D.A., and Mosier, D.L., 1986, Grade and tonnage model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 190–197.
- Unger, H.E., 1982, Geology of the Union copper mine, Gold Hill district, central North Carolina: Chapel Hill, North Carolina, University of North Carolina, unpublished M.S. thesis, 86 p.
- Wright, J.E., and Seiders, V.M., 1980, Age of zircons from volcanic rocks of the central North Carolina Piedmont and tectonic implications for the Carolina volcanic belt: Geological Society of America Bulletin, pt. 1, v. 91, p. 287–294.

SA08**Massive Sulfide Deposits, Kuroko Type**Georgia
Alabama

Descriptive Model 28a • Mark3 Index 104

Area = 2,780 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by T.L. Klein

Rationale for Model Choice and Deposit Examples

In the western Georgia Piedmont, the New Georgia Group is host to a large number of massive sulfide deposits (Abrams and McConnell, 1984; German 1989). This unit consists of a bimodal amphibolite-grade metavolcanic sequence that has both tholeiitic and calc-alkaline geochemical affinities interbedded with iron formation and immature epiclastic sedimentary rocks.

McConnell and Abrams (1984) suggest that these rocks formed in a back-arc basin that was underlain by continental crust. As in the Virginia gold-pyrite belt, many of these deposits were mined primarily for sulfur and some are nearly barren of base metals. The Tallapoosa mine, in Haralson County and the Chestatee mine in Lumpkin County were probably the largest base-metal-bearing deposits of at least eight massive sulfide deposits that were exploited in the belt. This belt of rocks contains some small, possible kuroko massive sulfide deposits where it continues into Alabama and is part of the Ashland-Wedowee terrane.

Grades and tonnages of kuroko massive sulfide deposits in the tract are given below:

Site	State	Metric tons (millions)	Cu %	Zn %	Pb%	Ag (g/t)	Au (g/t)	Source
Tallapoosa	Ga	0.043	3.3	2.9	NA	NA	NA	Shearer and Hull, 1918; Neathery and Hollister, 1985.
Chestatee	Ga	1.1	1.7	0.7	NA	NA	NA	Shearer and Hull, 1918; Gair and Slack, 1980.

NA, not available.

In the Ashland-Wedowee terrane, kyanite-quartz deposits occur near massive sulfide deposits and may represent metamorphosed hydrothermal alteration associated with the submarine hot-spring systems that formed them. Base and precious metals, pyrite, kyanite, and barite have been mined from various deposits in this area that is characterized by the presence of large volumes of felsic volcanic rocks, many in bimodal volcanic suites, and fine-grained immature volcanic-related sedimentary rocks that were probably formed in convergent arc tectonic settings, many perhaps in rift basins related to convergence (Neathery and Hollister, 1985).

The massive sulfide districts and deposits in the New Georgia Group exhibit geologic characteristics similar to those of the kuroko deposits of Japan (Franklin and others, 1981) and those of kuroko massive sulfide deposits (model 28a) (Singer and Mosier (1986). The typical kuroko lithologic association (substantial thicknesses of felsic volcanic rocks, chemical sedimentary rocks containing barite, manganese and iron formation, and massive sulfides) is present in every district in southeastern United States except for the Pyriton district where, locally, thick stratigraphic intervals are missing due to thrusting.

Because the lead contents of Precambrian and Phanerozoic kuroko massive sulfide deposits are significantly different (Franklin and others, 1981), the grade and tonnage model of Singer and

Mosier (1986), which combines deposits of all ages, did not seem appropriate for the Phanerozoic kuroko deposits in the southeastern United States. A new Phanerozoic kuroko model (Mark3 index 104) was used.

Rationale for Tract Delineation

West-central Georgia and a small part of the east-central Alabama Piedmont contain massive sulfide deposits in the New Georgia and Sandy Springs Groups. These two rock units are dominated by volcanic rocks, immature volcanic-derived sedimentary rocks, and iron formation (Abrams and McConnell, 1984); they underlie the Dahlonega and Carroll County gold belts, and they define this permissive tract in Georgia and Alabama (see German, 1989). These multiply-deformed rock units, retrograded to greenschist-facies from amphibolite metamorphic-grade, were last deformed in a transpressive structural setting between the high-grade metamorphic rocks of the Richard Russell and Tallulah Falls thrust sheets (Albino, 1989). Approximately a dozen abandoned mines that produced primarily pyrite occur in this tract.

Rationale for Numerical Estimate

For the 90th, 50th, and 10th percentiles, respectively, the team estimated 2, 5, and 10 deposits consistent with the Phanerozoic kuroko model.

References

- Abrams, C.E., and McConnell, K.I., 1984, Geologic setting of volcanogenic base and precious metal deposits of the West Georgia Piedmont—A multiply deformed metavolcanic terrain: *Economic Geology*, v. 79, no. 7, p. 1521–1539.
- Albino, G.V., 1989, Gold deposits of the Dahlonega belt, northeastern Georgia, *in* Cook, R.B., ed., *Economic mineral deposits of the southeast—Metallic ore deposits: Georgia Geologic Survey Bulletin* 117, p. 85–120.
- Franklin, J.M., Lydon, J.W., and Sangster, D.F., 1981, Volcanic-associated massive sulfide deposits, *in* Skinner, B.J., ed., *Economic Geology Seventy-Fifth Anniversary Volume, 1905–1980*: Lancaster, Pennsylvania, Economic Geology Publishing Company, p. 485–627.
- Gair, J.E., and Slack, J.F., 1980, Stratabound massive sulfide deposits of the U.S. Appalachians, *in* Vokes, F.M., and Zachrisson, Ebbe, eds., *Review of Caledonian-Appalachian stratabound sulphides: Geological Survey of Ireland Special Paper No. 5*, p. 68–81.
- German, J.M., 1989, Geologic setting and genesis of gold deposits of the Dahlonega and Carroll County gold belts, Georgia: *Economic Geology*, v. 84, no. 4, p. 903–923.
- McConnell, K.I., and Abrams, C.E., 1984, Geology of the greater Atlanta region: *Georgia Geologic Survey Bulletin* 96, 150 p.
- Neathery, T.L., and Hollister, V.F., 1985, Models for volcanogenic sulfide exploration in the southernmost Appalachians, *in* Misra, K.C., ed., *Volcanogenic sulfide and precious metal mineralization in the southern Appalachians*: Knoxville, University of Tennessee, *Studies in Geology* 16, p. 97–112.
- Shearer, H.K., and Hull, J.P.D., 1918, A preliminary report on a part of the pyrites deposits of Georgia: *Georgia Geologic Survey Bulletin* 33, 229 p.
- Singer, D.A., and Mosier, D.L., 1986, Grade and tonnage model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., *Mineral deposit models: U.S. Geological Survey Bulletin* 1693, p. 190–197

SA09**Massive Sulfide Deposits, Kuroko Type**

Alabama

Descriptive Model 28a • Mark3 Index 104

Area = 187 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by T.L. Klein

Rationale for Model Choice

The Talladega terrane of the eastern Alabama Piedmont is host to several massive sulfide districts that occur within a Devonian(?) bimodal volcanic sequence, the Hillabee Greenstone. The felsic volcanic rocks are calc-alkaline in character, whereas the mafic volcanic rocks are tholeiitic, suggesting that the sequence may have developed in an arc setting over continental crust (Tull and Stow, 1982). In the Pyriton district, discontinuous pyrite-rich lenses ranging from 2–10 m thick extend 2.5 km along strike within the lower mafic part of the Hillabee Greenstone. At Pyriton, the upper felsic volcanic rocks, present elsewhere, have been removed by faulting. Production from the district was relatively small, probably about 100,000 metric tons of pyritic ore averaging 1.25 percent copper. Drilling in the district during exploration for pyrite has indicated that substantial low-grade copper resources (5.9 million metric tons at 0.3 percent copper and 0.06 percent zinc) may be present (see Stow and Tull, 1982).

Because the lead contents of Precambrian and Phanerozoic kuroko massive sulfide deposits are significantly different (Franklin and others, 1981), the grade and tonnage model of Singer and Mosier (1986), which combines deposits of all ages, did not seem appropriate for the Phanerozoic kuroko deposits in the southeastern United States. A new Phanerozoic kuroko model (Mark3 index 104) was used.

Rationale for Tract Delineation

Volcanic rocks of the Hillabee Greenstone in the Devonian Talladega terrane of east-central Alabama define the permissive tract. These dominantly mafic volcanic rocks occur in a narrow zone (up to 2.5 km wide) within a faulted nappe (Tull and Stow, 1982). Several massive sulfide districts and prospects occur along the 170-km-long belt; the largest deposits, those at Pyriton and in the Hatchet Creek-Millerville district, have produced pyrite.

Rationale for Numerical Estimate

The numbers of undiscovered deposits were estimated individually for favorable tract using the consensus method. The numbers of undiscovered deposits estimated at the 90th, 50th, and 10th percentiles respectively, are 0, 1, and 3 deposits consistent with the Phanerozoic kuroko model (Mark3 index 104). This estimate is low because of the small size of the tract and the apparent low base-metal content of the known deposits relative to the grade and tonnage model.

References

- Franklin, J.M., Lydon, J.W., and Sangster, D.F., 1981, Volcanic-associated massive sulfide deposits, *in* Skinner, B.J., ed., Economic Geology Seventy-Fifth Anniversary Volume, 1905–1980: Lancaster, Pennsylvania, Economic Geology Publishing Company, p. 485–627.
- Singer, D.A., and Mosier, D.L., 1986, Grade and tonnage model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p.190–197
- Stow, S.H., and Tull, J.F., 1982, Geology and geochemistry of the strata-bound sulfide deposits of the Pyriton district, Alabama: Economic Geology, v. 77, no. 2, p. 322–334.

Tull, J.F., and Stow, S.H., 1982, Geologic setting of the Hillabee metavolcanic complex and associated strata-bound sulfide deposits in the Appalachian Piedmont of Alabama: *Economic Geology*, v. 77, no. 2, p. 312–321.

SA10**Epithermal Vein Deposits, Quartz-alunite Type**

Descriptive Model 25e • Mark3 Index 38

Area = 25,100 km²Virginia
North Carolina
South Carolina
Georgia[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by T. L. Klein

Rationale for Model Choice

Quartz-pyrophyllite or quartz-andalusite-pyrophyllite deposits that are the result of extreme leaching by acidic, high-sulfur hydrothermal fluids are common in the metamorphosed, dominantly andesitic volcanic rocks of the northern and eastern parts of the Carolina slate belt (CSB) (Feiss, 1982; Klein and Criss, 1988; Schmidt, 1985; Sykes and Moody, 1981). These deposits of aluminous minerals, which provide nearly all the pyrophyllite and andalusite produced in the United States, are thought to be metamorphosed analogs of acid-sulfate or quartz-alunite alteration zones (see Hayba and others, 1985; Berger, 1986). More than 50 of these aluminous alteration zones are known in the CSB. Gold deposits or prospects are associated with more than 10 percent of these zones and enrichments of copper sulfide minerals (chalcopyrite, enargite), and geochemically anomalous Mo, Sn, and Te are common. Minor amounts of alunite have been preserved in several deposits (see Lu and others, 1993; Schreyer, 1987). The oxygen isotope signature of many of the andesitic volcanic host rocks and minerals from many of the gold deposits strongly suggest that they were deposited in a subaerial environment (Klein and Criss, 1988; Feiss and others, 1993). The high-alumina alteration is equivalent to that in quartz-alunite gold deposits (see Berger, 1986) because of the character of the alteration (e.g., intense acid leaching), the widespread involvement of high-temperature meteoric water in alteration, the character of their host rocks, and their distinctive chemistry. These deposits are thought to have formed over a wide range of paleo depth from subvolcanic to near-surface (Klein and Criss, 1988; Powers, 1988; Schmidt, 1985; Scheetz and others, 1991). Some are stratabound gold-bearing zones formed in the near-surface hot-spring environment whereas others may be discordant, linear or pipe-like fracture-controlled deposits originally emplaced at shallow depths below the surface of these paleo-hot-spring systems. .

The best-studied example of this type is the Brewer mine in South Carolina (Butler and others, 1985; Lu and others, 1993). It along with several other small abandoned deposits of this type (e.g., Nesbit mine, N.C.; Brassington mine, S.C.) and several hot-spring deposits (e.g., Haile mine) are clustered in the CSB near the North Carolina-South Carolina border. The gold deposit at the Brewer mine is localized in felsic volcanoclastic rocks along a crescent-shaped breccia zone that has a highly siliceous matrix containing abundant enargite, pyrite and free gold. The ore zone is located within an advanced argillic (pyrophyllite, andalusite, sericite, topaz) alteration zone that is surrounded by a zone of sericitic alteration (Butler and others, 1988; Lu and others, 1993). Geochemical enrichments of Cu, Mo, As, Hg, Sn, and Te coincide roughly with the mineralized zone. The system is overlain by laminated mudstones.

Other examples, such as the abandoned gold deposits in the Robbins district, N.C. and the Nesbit mine, S.C., are associated with massive and (or) foliated pyrophyllite bodies, devoid of the high-temperature aluminosilicate minerals (andalusite and topaz), and their surrounding sericite-rich alteration zones. Gold is associated with disseminated pyrite and quartz or pyrite veinlets. Most have geochemically anomalous Mo, As, or Sn. Several are interpreted to have

formed from hydrothermal fluids dominated by meteoric water. These tend to occur along linear zones several kilometers in length, perhaps reflecting the fault control.

Several prospects in central North Carolina, including Pilot Mountain and Snow Camp, are somewhat ellipsoidal in shape and may be related to alteration caused by shallow-level, porphyritic dacitic intrusions (Klein and Criss, 1988). The area of the alteration systems associated with these prospects is thought to extend over several tens of square kilometers. Eight major alteration systems have been described in the northern CSB, including the Brewer mine, South Carolina and, the Robbins-Glendon, Pilot-Fox Mountain, Staley, Montgomery County, Saxapahaw-Snow Camp, and the Oxford-Stovall areas of North Carolina (Espenshade and Potter, 1960; Stuckey, 1967; Schmidt, 1985; and McKee and Butler, 1985).

We consider the Brewer deposit and the other cited examples to be quartz-alunite gold deposits because of the subaerial character of many of the intermediate and felsic volcanic host rocks, the similarities of their ore and alteration mineralogy and geochemistry, associated metals, and rock textures with those typical of quartz-alunite gold deposits. The apparent widespread involvement of meteoric water in the hydrothermal fluids also is consistent with a subaerial origin. Extreme leaching by acidic, high-temperature hydrothermal fluids produces the relatively unique mineral assemblage found in Tertiary or younger quartz-alunite deposits elsewhere and in the CSB analogs. These assemblages are not typical of other types of epithermal or mesothermal gold deposits.

Information on resources and grade are only available for the recently-mined Brewer mine in South Carolina. The estimates of historic and recent production total approximately 5 t of gold, most of which was extracted from oxidized ore. Mining was suspended in 1991 when the oxidized ore was exhausted. However, Farmer (1991) indicates that 7.5 t of gold may remain in the unmined sulfide-rich part of the deposit. The grade for the sulfide-rich part of the deposit is reported to be 1.4 g/t (Farmer, 1991). Total tonnage estimates of 5.7 million t for ore at the Brewer mine (12.4 t Au) plot within the upper 20th percentile for tonnage and below the lowest grade intercept on the grade and tonnage curves for quartz-alunite deposits (Mosier and Menzie, 1985).

Rationale for Tract Delineation

The permissive tract consists of the late Precambrian to Cambrian volcanic and sedimentary rocks of the CSB, eastern CSB, Charlotte belt, and Kings Mountain belt and their equivalents that extend toward the southwest. This tract includes areas that have the greatest potential for the presence of undiscovered quartz-alunite gold deposits based on the presence of probable subaerially deposited, metamorphosed volcanic and sedimentary host rocks and quartz-alunite alteration in the CSB.

Rationale for Numerical Estimate

For the 90th, 50th, and 10th percentiles, the team (T.W. Offield, T.L. Klein, and R.P. Koeppen) estimated 2, 5, and 10 or more epithermal quartz-alunite gold deposits consistent with the grade and tonnage model of Mosier and Menzie (1986) (Mark3 index 38). Because high-alumina alteration centers are thought to represent metamorphosed quartz-alunite alteration centers, the number of undiscovered deposits was calculated by assuming that each of the eight major known high-alumina alteration centers has a surface area of approximately 10 square kilometers, resulting in an estimate of 80 square kilometers total area of high-alumina alteration in the CSB. The areal size, number of deposits and deposit density in other quartz-alunite gold districts is given below:

Deposit	Size (km)	No. of known deposits	Density (deposits/km ²)	Reference
Kalimantan, Indonesia	2 x 400	6	0.008	van Leeuwen and others, 1990.
North Sulawesi, Indonesia	20 x 160	11	0.003	Carlile and others, 1990.
Baguio district, Philippines	7 x 25	12	0.07	Mitchell and Balce, 1990.

Because we consider the well-explored Baguio district in the Philippines to be an analog for quartz-alunite districts in the CSB, the number of deposits at the 50th percentile (5) in the tract was calculated by multiplying the deposit density of 0.07 deposits/square km, the density of deposits in the Baguio district, by the total area of the high-alumina alteration centers in the tract. One mine, the Brewer, was subtracted from the calculated total because it is the only significant producer of this type in the CSB. We used the resulting average number of deposits to guide our probabilistic estimate.

References

- Berger, B.R., 1986, Descriptive model of epithermal quartz-alunite Au, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 158.
- Butler, J.R., Scheetz, J.W., Stonehouse, J.M., Taylor, D.R., and Callaway, R.Q., 1988, The Brewer gold mine, Chesterfield County, South Carolina: Chapel Hill, University of North Carolina, Guidebook for Field Trip, April 5, 1988, Southeastern Section, Geological Society of America, 22 p.
- Carlile, J.C., Digdowirogo, S., and Darius, K., 1990, Geological setting, characteristics, and regional exploration for gold in the volcanic arcs of North Sulawesi, Indonesia, *in* Hedenquist, J.W., White, N.C., and Siddeley, G., eds., Epithermal gold mineralization of the Circum-Pacific I: Association of Exploration Geochemists Special Publication No. 16a, p. 105–140.
- Espenshade, G.H. and Potter, D.B., 1960, Kyanite, sillimanite, and andalusite deposits of the southeastern States: U.S. Geological Survey Professional Paper 336, 121 p.
- Farmer, A., 1991, Proposed acquisition of Brewer Gold Company: Vancouver Stockwatch, July 16, p. 13–14.
- Feiss, P.G., 1982, Ore deposits of the northern parts of the Carolina slate belt, North Carolina: Geological Society of America Special Paper 191, p. 153–164.
- Feiss, P.G., Vance, R.K., and Wesolowski, D.J., 1993, Volcanic rock-hosted gold and base-metal mineralization associated with Neoproterozoic—Early Paleozoic back-arc extension in the Carolina terrane, southern Appalachian Piedmont: *Geology*, v. 21, p. 439–442.
- Hayba, D. O., Bethke, P.M., Heald, P., and Foley, N.K., 1985, Geologic, mineralogic, and geochemical characteristics of volcanic-hosted epithermal precious-metal deposits, *in* Berger, B.R., and Bethke, P.M., eds., *Geology and geochemistry of epithermal systems*: Society of Economic Geologists, Reviews in Economic Geology, v. 2, p. 129–167.
- Klein, T.L., and Criss, R.E., 1988, An oxygen isotope and geochemical study of the meteoric-hydrothermal systems at Pilot Mountain and selected other localities, Carolina slate belt: *Economic Geology*, v. 83, no. 4, p. 801–821.
- Lu, C., Misra, K.C., Stonehouse, J.M., and Zwaschka, M.R., 1993, Geochemical signature of alteration at the Brewer gold mine, Jefferson, South Carolina: *South Carolina Geology*, v. 35, p. 37–54.

- McKee, L.H., and Butler, J.R., 1985, Hydrothermal alteration and mineralization at four gold mines in southern Union County, North Carolina, *in* Misra, K.C., ed., Volcanogenic sulfide and precious metal mineralization in the southern Appalachians: Knoxville, University of Tennessee, Studies in Geology 16, p. 113–123.
- Mitchell, A.H.G., and Balce, G.R., 1990, Geological features of some epithermal gold systems, Philippines, *in* Hedenquist, J.W., White, N.C., and Siddeley, G., eds., Epithermal gold mineralization of the Circum-Pacific I: Association of Exploration Geochemists Special Publication No. 16a, p. 241–296.
- Mosier, D.L., and Menzies, W.D., 1985, Grade and tonnage model of epithermal quartz-alunite Au, *in* Cox, D.P., and Singer, D.A., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 159–161.
- Powers, J.A., 1988, Gold mineralization and high alumina alteration in the Robbins district of the Carolina slate belt, Moore County, North Carolina: Geological Society of America Abstracts with Programs, v. 20, p. 309.
- Scheetz, J.W., Stonehouse, J.M., and Zwaschka, M.R., 1991, Geology of the Brewer gold mine in South Carolina: Mining Engineering, v. 43, no.1, p. 38–42.
- Schmidt, R.G., 1985, High-alumina hydrothermal systems in volcanic rocks and their significance to mineral prospecting in the Carolina slate belt: U.S. Geological Survey Bulletin 1562, 59 p.
- Schreyer, W., 1987, Pre- or syn-metamorphic minerals in peraluminous metamorphic rocks?, *in* Helgeson, H.C., ed., Chemical transport in metasomatic processes: D. Reidel Publishing Co., p. 265–296.
- Stuckey, J.L., 1967, Pyrophyllite deposits in North Carolina: North Carolina Division of Mineral Resources Bulletin 80, 38 p.
- Sykes, M.L., and Moody, J.B., 1981, Pyrophyllite and metamorphism in the Carolina slate belt: American Mineralogist, v. 63, p. 96–108.
- van Leeuwen, T.M., Leach, T., Hawke, A.A., and Hawke, M.M., 1990, The Kelian disseminated gold deposit, East Kalimantan, Indonesia, *in* Hedenquist, J.W., White, N.C., and Siddeley, G., eds., Epithermal gold mineralization of the Circum-Pacific I: Association of Exploration Geochemists Special Publication No. 16a, p. 1–62.

SA11**Epithermal Vein Deposits, Quartz-alunite Type****Descriptive Model 25e****Area = 43,200 km²**

Virginia
North Carolina
South Carolina
Georgia

[Model](#)*by* T. L. Klein**Rationale for Model Choice**

Quartz-pyrophyllite or quartz-andalusite-pyrophyllite deposits that are the result of extreme leaching by acidic, high-sulfur hydrothermal fluids are common in the metamorphosed, dominantly andesitic volcanic rocks of the northern and eastern parts of the Carolina slate belt (CSB) (Feiss, 1982; Klein and Criss, 1988; Schmidt, 1985; Sykes and Moody, 1981). These deposits of aluminous minerals, which provide nearly all the pyrophyllite and andalusite produced in the United States, are thought to be metamorphosed analogs of acid-sulfate or quartz-alunite alteration zones (see Hayba and others, 1985; Berger, 1986). More than 50 of these aluminous alteration zones are known in the CSB. Gold deposits or prospects are associated with more than 10 percent of these zones and enrichments of copper sulfide minerals (chalcopyrite, enargite), and geochemically anomalous Mo, Sn, and Te are common. Minor amounts of alunite have been preserved in several deposits (see Lu and others, 1993; Schreyer, 1987). The oxygen isotope signature of many of the andesitic volcanic host rocks and minerals from many of the gold deposits strongly suggest that they were deposited in a subaerial environment (Klein and Criss, 1988; Feiss and others, 1993). The high-alumina alteration is equivalent to that in quartz-alunite gold deposits (see Berger, 1986) because of the character of the alteration (e.g., intense acid-leaching), the widespread involvement of high-temperature meteoric water in alteration, the character of their host rocks, and their distinctive chemistry. These deposits are thought to have formed over a wide range of paleodepths from subvolcanic to near-surface (Klein and Criss, 1988; Powers, 1988; Schmidt, 1985; Scheetz and others, 1991). Some are stratabound gold-bearing zones formed in the near-surface hot-spring environment whereas others may be discordant, linear or pipe-like fracture-controlled deposits originally emplaced at shallow depths below the surface of these paleo-hot-spring systems. .

The best-studied example of this type is the Brewer mine in South Carolina (Butler and others, 1985; Lu and others, 1993). It along with several other small abandoned deposits of this type (e.g. Nesbit mine, N.C.; Brassington mine, S.C.) and several hot-spring deposits (e.g. Haile mine) are clustered in the CSB near the North Carolina-South Carolina border. The gold deposit at the Brewer mine is localized in felsic volcanoclastic rocks along a crescent-shaped breccia zone that has a highly siliceous matrix containing abundant enargite, pyrite and free gold. The ore zone is located within an advanced argillic (pyrophyllite, andalusite, sericite, topaz) alteration zone that is surrounded by a zone of sericitic alteration (Butler and others, 1988; Lu and others, 1993). Geochemical enrichments of Cu, Mo, As, Hg, Sn, and Te coincide roughly with the mineralized zone. The system is overlain by laminated mudstones.

Other examples, such as the abandoned gold deposits in the Robbins district, N.C. and the Nesbit mine, S. C., are associated with massive and (or) foliated pyrophyllite bodies, devoid of the high-temperature aluminosilicate minerals (andalusite and topaz), and their surrounding sericite-rich alteration zones. Gold is associated with disseminated pyrite and quartz or pyrite veinlets. Most have geochemically anomalous Mo, As, or Sn. Several are interpreted to have

formed from hydrothermal fluids dominated by meteoric water. These tend to occur along linear zones several kilometers in length, perhaps reflecting the fault control.

Several prospects in central North Carolina, including Pilot Mountain and Snow Camp are somewhat ellipsoidal in shape and may be related to alteration caused by shallow-level, porphyritic dacitic intrusions (Klein and Criss, 1988). The area of the alteration systems associated with these prospects is thought to extend over several tens of square kilometers. Eight major alteration systems have been described in the northern CSB, including the Brewer mine, South Carolina and, the Robbins-Glendon, Pilot-Fox Mountain, Staley, Montgomery County, Saxapahaw-Snow Camp, and the Oxford-Stovall areas of North Carolina (Espenshade and Potter, 1960; Stuckey, 1967; Schmidt, 1985; and McKee and Butler, 1985).

We consider the Brewer deposit and the other cited examples to be quartz-alunite gold deposits because of the subaerial character of many of the intermediate and felsic volcanic host rocks, the similarities of their ore and alteration mineralogy and geochemistry, associated metals, and rock textures with those typical of quartz-alunite gold deposits. The apparent widespread involvement of meteoric water in the hydrothermal fluids also is consistent with a subaerial origin. Extreme leaching by acidic, high-temperature hydrothermal fluids produces the relatively unique mineral assemblage found in Tertiary or younger quartz-alunite deposits elsewhere and in the CSB analogs. These assemblages are not typical of other types of epithermal or mesothermal gold deposits.

Rationale for Tract Delineation

This permissive tract for epithermal quartz-alunite gold districts consist of the metamorphosed late Precambrian to Cambrian volcanic and sedimentary rocks of the CSB and eastern CSB, and their equivalents that extend toward the southwest. The tract is the eastward extension of the CSB, eastern CSB, and other possible metavolcanic terranes, where the cover of Coastal Plain sedimentary deposits is less than approximately 1 km deep. No numerical estimate was made because the bedrock of this tract is relatively unexplored, and the geologic framework of much of the belt is poorly known.

References

- Berger, B.R., 1986, Descriptive model of epithermal quartz-alunite Au, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 158.
- Butler, J.R., Scheetz, J.W., Stonehouse, J.M., Taylor, D.R., and Callaway, R.Q., 1988, The Brewer gold mine, Chesterfield County, South Carolina: Chapel Hill, University of North Carolina, Guidebook for Field Trip, April 5, 1988, Southeastern Section, Geological Society of America, 22 p.
- Espenshade, G.H. and Potter, D.B., 1960, Kyanite, sillimanite, and andalusite deposits of the southeastern States: U.S. Geological Survey Professional Paper 336, 121 p.
- Feiss, P.G., 1982, Ore deposits of the northern parts of the Carolina slate belt, North Carolina: Geological Society of America Special Paper 191, p. 153–164.
- Feiss, P.G., Vance, R.K., and Wesolowski, D.J., 1993, Volcanic rock-hosted gold and base-metal mineralization associated with Neoproterozoic-Early Paleozoic back-arc extension in the Carolina terrane, southern Appalachian Piedmont: *Geology*, v. 21, p. 439–442.
- Hayba, D. O., Bethke, P.M., Heald, P., and Foley, N.K., 1985, Geologic, mineralogic, and geochemical characteristics of volcanic-hosted epithermal precious-metal deposits, *in* Berger, B.R., and Bethke, P.M., eds., *Geology and geochemistry of epithermal systems*: Society of Economic Geologists, Reviews in Economic Geology, v. 2, p. 129–167.
- Klein, T.L., and Criss, R.E., 1988, An oxygen isotope and geochemical study of the meteoric-hydrothermal systems at Pilot Mountain and selected other localities, Carolina slate belt: *Economic Geology*, v. 83, no. 4, p. 801–821.

- Lu, C., Misra, K.C., Stonehouse, J.M., and Zwaschka, M.R., 1993, Geochemical signature of alteration at the Brewer gold mine, Jefferson, South Carolina: *South Carolina Geology*, v. 35, p. 37–54.
- McKee, L.H. and Butler, J.R., 1985, Hydrothermal alteration and mineralization at four gold mines in southern Union County, North Carolina, *in* Misra, K.C., ed., *Volcanogenic sulfide and precious metal mineralization in the southern Appalachians*: Knoxville, University of Tennessee, *Studies in Geology* 16, p. 113–123.
- Powers, J.A., 1988, Gold mineralization and high alumina alteration in the Robbins district of the Carolina slate belt, Moore County, North Carolina: *Geological Society of America Abstracts with Programs*, v. 20, p. 309.
- Scheetz, J.W., Stonehouse, J.M., and Zwaschka, M.R., 1991, Geology of the Brewer gold mine in South Carolina: *Mining Engineering*, v. 43, no. 1, p. 38–42.
- Schmidt, R.G., 1985, High-alumina hydrothermal systems in volcanic rocks and their significance to mineral prospecting in the Carolina slate belt: *U.S. Geological Survey Bulletin* 1562, 59 p.
- Stuckey, J.L., 1967, Pyrophyllite deposits in North Carolina: *North Carolina Division of Mineral Resources Bulletin* 80, 38 p.
- Sykes, M.L., and Moody, J.B., 1981, Pyrophyllite and metamorphism in the Carolina slate belt: *American Mineralogist*, v. 63, p. 96–108.

SA12**Descriptive Model 25e****Area = 18,400 km²****Epithermal Vein Deposits, Quartz-alunite Type****South Carolina****North Carolina****Georgia**[Model](#)*by* T. L. Klein**Rationale for Model Choice**

Quartz-pyrophyllite or quartz-andalusite-pyrophyllite deposits that are the result of extreme leaching by acidic, high-sulfur hydrothermal fluids are common in the metamorphosed, dominantly andesitic volcanic rocks of the northern and eastern parts of the Carolina slate belt (CSB) (Feiss, 1982; Klein and Criss, 1988; Schmidt, 1985; Sykes and Moody, 1981). These deposits of aluminous minerals, which provide nearly all the pyrophyllite and andalusite produced in the United States, are thought to be metamorphosed analogs of acid-sulfate or quartz-alunite alteration zones (see Hayba and others, 1985; Berger, 1986). More than 50 of these aluminous alteration zones are known in the CSB. Gold deposits or prospects are associated with more than 10 percent of these zones and enrichments of copper sulfide minerals (chalcopyrite, enargite), and geochemically anomalous Mo, Sn, and Te are common. Minor amounts of alunite have been preserved in several deposits (see Lu and others, 1993; Schreyer, 1987). The oxygen isotope signature of many of the andesitic volcanic host rocks and minerals from many of the gold deposits strongly suggest that they were deposited in a subaerial environment (Klein and Criss, 1988; Feiss and others, 1993). The high-alumina alteration is equivalent to that in quartz-alunite gold deposits (see Berger, 1986) because of the character of the alteration (e.g., intense acid-leaching), the widespread involvement of high-temperature meteoric water in alteration, the character of their host rocks, and their distinctive chemistry. These deposits are thought to have formed over a wide range of paleodepths from subvolcanic to near-surface (Klein and Criss, 1988; Powers, 1988; Schmidt, 1985; Scheetz and others, 1991). Some are stratabound gold-bearing zones formed in the near-surface hot-spring environment whereas others may be discordant, linear or pipe-like fracture-controlled deposits originally emplaced at shallow depths below the surface of these paleo-hot-spring systems. .

The best-studied example of this type is the Brewer mine in South Carolina (Butler and others, 1985; Lu and others, 1993). It along with several other small abandoned deposits of this type (e.g., Nesbit mine, N.C.; Brassington mine, S.C.) and several hot-spring deposits (e.g., Haile mine) are clustered in the CSB near the North Carolina-South Carolina border. The gold deposit at the Brewer mine is localized in felsic volcanoclastic rocks along a crescent-shaped breccia zone that has a highly siliceous matrix containing abundant enargite, pyrite and free gold. The ore zone is located within an advanced argillic (pyrophyllite, andalusite, sericite, topaz) alteration zone that is surrounded by a zone of sericitic alteration (Butler and others, 1988; Lu and others, 1993). Geochemical enrichments of Cu, Mo, As, Hg, Sn, and Te coincide roughly with the mineralized zone. The system is overlain by laminated mudstones.

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We consider the Brewer deposit and the other cited examples to be quartz-alunite gold deposits because of the subaerial character of many of the intermediate and felsic volcanic host rocks, the similarities of their ore and alteration mineralogy and geochemistry, associated metals, and rock textures with those typical of quartz-alunite gold deposits. The apparent widespread involvement of meteoric water in the hydrothermal fluids also is consistent with a subaerial origin. Extreme leaching by acidic, high-temperature hydrothermal fluids produces the relatively unique mineral assemblage found in Tertiary or younger quartz-alunite deposits elsewhere and in the CSB analogs. These assemblages are not typical of other types of epithermal or mesothermal gold deposits.

Rationale for Tract Delineation

This permissive tract consist of the late Precambrian to Cambrian volcanic and sedimentary rocks of the CSB, eastern CSB, Charlotte belt, and Kings Mountain belt and their equivalents that extend toward the southwest. No numerical estimate was made because of the rare occurrence of deposits of this type in the tract and the poor understanding of the depositional environment of the metavolcanic and metasedimentary rocks.

References

- Berger, B.R., 1986, Descriptive model of epithermal quartz-alunite Au, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 158.
- Butler, J.R., Scheetz, J.W., Stonehouse, J.M., Taylor, D.R., and Callaway, R.Q., 1988, The Brewer gold mine, Chesterfield County, South Carolina: Chapel Hill, University of North Carolina, Guidebook for Field Trip, April 5, 1988, Southeastern Section, Geological Society of America, 22 p.
- Espenshade, G.H., and Potter, D.B., 1960, Kyanite, sillimanite, and andalusite deposits of the southeastern States: U.S. Geological Survey Professional Paper 336, 121 p.
- Feiss, P.G., 1982, Ore deposits of the northern parts of the Carolina slate belt, North Carolina: Geological Society of America Special Paper 191, p. 153–164.
- Feiss, P.G., Vance, R.K., and Wesolowski, D.J., 1993, Volcanic rock-hosted gold and base-metal mineralization associated with Neoproterozoic-Early Paleozoic back-arc extension in the Carolina terrane, southern Appalachian Piedmont: *Geology*, v. 21, p. 439–442.
- Hayba, D. O., Bethke, P.M., Heald, P., and Foley, N.K., 1985, Geologic, mineralogic, and geochemical characteristics of volcanic-hosted epithermal precious-metal deposits, *in* Berger, B.R., and Bethke, P.M., eds., *Geology and geochemistry of epithermal systems*: Society of Economic Geologists, Reviews in Economic Geology, v. 2, p. 129–167.
- Klein, T.L., and Criss, R.E., 1988, An oxygen isotope and geochemical study of the meteoric-hydrothermal systems at Pilot Mountain and selected other localities, Carolina slate belt: *Economic Geology*, v. 83, no. 4, p. 801–821.
- Lu, C., Misra, K.C., Stonehouse, J.M., and Zwaschka, M.R., 1993, Geochemical signature of alteration at the Brewer gold mine, Jefferson, South Carolina: *South Carolina Geology*, v. 35, p. 37–54.

- McKee, L.H. and Butler, J.R., 1985, Hydrothermal alteration and mineralization at four gold mines in southern Union County, North Carolina, *in* Misra, K.C., ed., Volcanogenic sulfide and precious metal mineralization in the southern Appalachians: Knoxville, University of Tennessee, Studies in Geology 16, p. 113–123.
- Powers, J.A., 1988, Gold mineralization and high alumina alteration in the Robbins district of the Carolina slate belt, Moore County, North Carolina: Geological Society of America Abstracts with Programs, v. 20, p. 309.
- Scheetz, J.W., Stonehouse, J.M., and Zwaschka, M.R., 1991, Geology of the Brewer gold mine in South Carolina: Mining Engineering, v. 43, no. 1, p. 38–42.
- Schmidt, R.G., 1985, High-alumina hydrothermal systems in volcanic rocks and their significance to mineral prospecting in the Carolina slate belt: U.S. Geological Survey Bulletin 1562, 59 p.
- Stuckey, J.L., 1967, Pyrophyllite deposits in North Carolina: North Carolina Division of Mineral Resources Bulletin 80, 38 p.
- Sykes, M.L., and Moody, J.B., 1981, Pyrophyllite and metamorphism in the Carolina slate belt: American Mineralogist, v. 63, p. 96–108.

SA13**Descriptive Model 25a****Area = 7,700 km²****Hot-spring Au-Ag Deposits****Virginia
North Carolina**[Model](#)*by* T. L. Klein**Rationale for Model Choice**

The compositionally-bimodal, metamorphosed, late Precambrian to Cambrian volcanic terrain of the Central Carolina slate belt (CSB) contains examples of epithermal precious metal deposits. Extensive accumulations of felsic volcanic rocks, ranging in composition from dacite to rhyolite, are associated with volcanic centers that are found in the area between the North Carolina-Virginia border southward to the north-central part of South Carolina, just north of Columbia, with the greatest felsic volcanic accumulations occurring in the area between the cities of Asheboro and Troy, North Carolina. The relationship of gold deposits to the waning stages of felsic volcanism was first suggested by Worthington and Kiff (1970) after they observed that many gold deposits in this region were found along the contact between a dominantly felsic volcanic unit (the Uwharrie Formation) and overlying mudstones. The application of the hot-spring model to explain the origin of some gold deposits in the CSB was proposed by Spence (1975); Spence and others (1980); and Worthington and others (1980); and has been supported by subsequent studies (Feiss, 1988; Butler and others, 1988; Koeppen and Klein, 1989).

Rationale for Tract Delineation

The permissive tract includes parts of the northern CSB where the composition of the volcanic rocks is mostly mafic to intermediate, and the adjacent Charlotte belt where more highly metamorphosed equivalent of the CSB volcanic rocks may be present.

Rationale for Numerical Estimate

No estimates were made for this permissive tract because, even though it may contain some areas of favorable host rocks, the tract is not known to contain deposits of this type and it has been much less well explored than the favorable areas.

References

- Butler, J.R., Scheetz, J.W., Stonehouse, J.M., Taylor, D.R., and Callaway, R.Q., 1988, The Brewer gold mine, Chesterfield County, South Carolina: Chapel Hill, University of North Carolina, Guidebook for Field Trip, April 5, 1988, Southeastern Section, Geological Society of America, 22 p.
- Feiss, P.G., 1988, Gold mineralization in the southern Appalachian Piedmont—Pardee and Park redivivus, *in* Kisvarsanyi, G., and Grant, S.K., eds., Tectonic controls of ore deposits and the vertical and horizontal extent of ore systems, Proceedings volume: Rolla, University of Missouri, p. 491–500.
- Koeppen, R.P., and Klein, T.L., 1989, Caraway-Back Creek volcanic center, central slate belt, North Carolina—Newly recognized thermal source for precious- and base-metal mineralization, *in* Schindler, K.S., ed., USGS research on mineral resources—1989 program and abstracts, fifth annual V.E. McKelvey Forum on Mineral and Energy Resources: U.S. Geological Survey Circular 1035, p. 40–41.
- Spence, W.H., 1975, A model for the origin of the pyrophyllite deposits in the Carolina slate belt: Geological Society of America Abstracts with Programs, v. 7, no. 4, p. 536–537.
- Spence, W.H., Worthington, J.E., Jones, E.M., and Kiff, I.T., 1980, Origin of the gold mineralization at the Haile mine, Lancaster County, South Carolina: Mining Engineering, v. 32, no. 1, p. 70–73.

- Worthington, J.E., and Kiff, I.T., 1970, A suggested volcanogenic origin for certain gold deposits in the slate belt of the North Carolina Piedmont: *Economic Geology*, v. 65, no. 5, p. 529–537.
- Worthington, J.E., Kiff, I.T., Jones, E.M., and Chapman, P.E., 1980, Applications of the hot springs or fumarolic model in prospecting for lode gold deposits: *Mining Engineering*, v. 32, no. 1, p. 73–79.

SA14**Descriptive Model 25a****Area = 43,200 km²****Hot-spring Au-Ag Deposits**

Virginia
North Carolina
South Carolina
Georgia

Model*by T.L.Klein***Rationale for Model Choice**

The compositionally-bimodal, metamorphosed, late Precambrian to Cambrian volcanic terrain of the Central Carolina slate belt (CSB) contains examples of epithermal precious metal deposits. Extensive accumulations of felsic volcanic rocks, ranging in composition from dacite to rhyolite, are associated with volcanic centers that are found in the area between the North Carolina-Virginia border southward to the north-central part of South Carolina, just north of Columbia, with the greatest felsic volcanic accumulations occurring in the area between the cities of Asheboro and Troy, North Carolina. The relationship of gold deposits to the waning stages of felsic volcanism was first suggested by Worthington and Kiff (1970) after they observed that many gold deposits in this region were found along the contact between a dominantly felsic volcanic unit (the Uwharrie Formation) and overlying mudstones. The application of the hot-spring model to explain the origin of some gold deposits in the CSB was proposed by Spence (1975); Spence and others (1980); and Worthington and others (1980); and has been supported by subsequent studies (Feiss, 1988; Butler and others, 1988; Koeppen and Klein, 1989).

Rationale for Tract Delineation

This tract defines the permissive area for hot-spring deposits in the southeastern U.S, although there are no known occurrences. It consists of the late Precambrian to Cambrian metamorphosed volcanic and sedimentary rocks of the CSB and eastern CSB, and includes the eastward extension of the eastern CSB and other possible volcanic terranes, where they are covered by less than 1 km of Coastal Plain sedimentary deposits.

Rationale for Numerical Estimate

No estimates were made for this permissive tract because even though it may contain some areas of favorable host rocks. It is not known to contain deposits of this type, it has been much less well explored than the favorable areas, and much of the eastern part is beneath the sedimentary cover.

References

- Butler, J.R., Scheetz, J.W., Stonehouse, J.M., Taylor, D.R., and Callaway, R.Q., 1988, The Brewer gold mine, Chesterfield County, South Carolina: Chapel Hill, University of North Carolina, Guidebook for Field Trip, April 5, 1988, Southeastern Section, Geological Society of America, 22p.
- Feiss, P.G., 1988, Gold mineralization in the southern Appalachian Piedmont—Pardee and Park redivivus, *in* Kisvarsanyi, G., and Grant, S.K., eds., Tectonic controls of ore deposits and the vertical and horizontal extent of ore systems, Proceedings volume: Rolla, University of Missouri, p. 491–500.
- Klein, T.L., 1988, Geochemical and alteration studies of gold deposits in the central Carolina slate belt: Geological Society of America Abstract with Programs, v. 20, no. 4, p. 274.
- Koeppen, R.P., and Klein, T.L., 1989, Caraway-Back Creek volcanic center, central slate belt, North Carolina—Newly recognized thermal source for precious- and base-metal mineralization, *in* K.S. Schindler, K.S., ed., USGS research on mineral resources—1989 program and abstracts, fifth annual

- V.E. McKelvey Forum on Mineral and Energy Resources: U.S. Geological Survey Circular 1035, p. 40–41.
- Spence, W.H., 1975, A model for the origin of the pyrophyllite deposits in the Carolina slate belt: Geological Society of America Abstracts with Programs, v. 7, no. 4, p. 536–537.
- Spence, W.H., Worthington, J.E., Jones, E.M., and Kiff, I.T., 1980, Origin of the gold mineralization at the Haile Mine, Lancaster County, South Carolina: Mining Engineering, v. 32, no. 1, p. 70–73.
- Worthington, J.E., and Kiff, I.T., 1970, A suggested volcanogenic origin for certain gold deposits in the slate belt of the North Carolina Piedmont: Economic Geology, v. 65, no. 5, p. 529–537.
- Worthington, J.E., Kiff, I.T., Jones, E.M., and Chapman, P.E., 1980, Applications of the hot springs or fumarolic model in prospecting for lode gold deposits: Mining Engineering, v. 32, no. 1, p. 73–79.

SA15**Hot-spring Au-Ag Deposits**

Descriptive Model 25a • Mark3 Index 45

Area = 18,700 km²

North Carolina

South Carolina

Georgia

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by T.L. Klein

Rationale for Model Choice

The compositionally-bimodal, metamorphosed, late Precambrian to Cambrian volcanic terrain of the Central Carolina slate belt (CSB) contains many examples of epithermal precious metal deposits. Extensive accumulations of felsic volcanic rocks, ranging in composition from dacite to rhyolite, are associated with volcanic centers that are found in the area between the North Carolina-Virginia border southward to the north-central part of South Carolina, just north of Columbia, with the greatest felsic volcanic accumulations occurring in the area between the cities of Asheboro and Troy, North Carolina. The relationship of gold deposits to the waning stages of felsic volcanism was first suggested by Worthington and Kiff (1970) after they observed that many gold deposits in this region were found along the contact between a dominantly felsic volcanic unit (the Uwharrie Formation) and overlying mudstones. The application of the hot-spring model to explain the origin of some gold deposits in the CSB was proposed by Spence (1975); Spence and others (1980); and Worthington and others (1980); and has been supported by subsequent studies (Feiss, 1988; Butler and others, 1988; Klein, 1988; Koeppen and Klein, 1989).

Volcanic textures and the oxygen isotope signature of many of these felsic volcanic rocks and some of the gold deposits strongly suggest that they were deposited in a subaerial environment (Klein and Criss, 1988). Several of these deposits are thought to be deformed and metamorphosed stratabound gold-bearing zones related to paleo-hot-spring systems (e.g., Haile). Others may be discordant, fracture-controlled deposits originally emplaced at shallow depths below the surface in a paleo-hot-spring hydrothermal system (e.g., Hoover Hill) (Koeppen and Klein, 1989). Metamorphosed epithermal quartz-alunite gold deposits are also thought to occur in the CSB but are generally restricted to the more intermediate-composition volcanic rocks.

Three of the four producing or recently producing gold deposits and many abandoned mines and prospects in the CSB are thought to be epithermal in origin, and some were formed at shallow levels in hot-spring systems. Recent mineral exploration in the CSB has resulted in the renewed mining activity at the Haile mine and the discovery of a large, new deposit at Ridgeway in South Carolina. In addition, several abandoned mines and prospects have been recently explored in central North Carolina that contain substantial inferred reserves (e.g., Russell) and persistent ore zones that are only partially constrained by drilling. The most productive area has been in north-central South Carolina, where recent mining has exploited probable metamorphosed hot-spring deposits (Haile, Ridgeway).

Three of the known deposits (Haile, Ridgeway, Russell) are found near the contact of large accumulations of dominantly felsic, bimodal volcanic rocks with overlying epiclastic rocks, probably of marine origin. All are characterized by steeply dipping ore zones that consist of disseminated sulfide minerals (predominantly pyrite) that have been intensely silicified and sericitized and contain few, if any, well-defined mineralized quartz veins. All three deposits are slightly enriched in Cu, Zn, As, and Mo. Ore zones at the Haile mine also contain gold and

silver telluride minerals. Gold at the Portis mine, in the eastern CSB, is concentrated in pyrite-quartz stockworks within a shallow-level granitoid sill and is tentatively classified as a hot-spring gold deposit.

The Haile, Ridgeway, and Russell mines are considered to be hot-spring gold deposits because of the subaerial character of some of their felsic volcanic host rocks, the similarities of their ore and alteration mineralogy and host rock textures with those of hot-spring deposits (Model 25a of Berger, 1986), and the apparent widespread involvement of meteoric water in the hydrothermal fluids. However, an alternative origin as shear zone-controlled deposits has been proposed by investigators at the Haile and Ridgeway deposits (see Tomkinson, 1985). Although these deposits are locally highly deformed and gold may be controlled by small-scale, shear-related structures, this control is probably due mainly to local remobilization during metamorphism. The overall character, including typical grades and size, of these CSB deposits is similar to hot-spring deposits, elsewhere, and not at all typical of low-sulfide Au-quartz veins.

Laminated mudstones, some of which contain marine fossils, are commonly associated with CBS deposits. This seems to be inconsistent with a simple, subaerial hot-spring origin, however, the evidence for meteoric water-dominated hydrothermal fluids from oxygen-isotope studies and the absence of substantial quantities of base-metals in these deposits suggest that marine waters were not the principal source of fluids. The apparent conflict can be rationalized if a subaerial hot-spring system, related to coastal volcanism, was subsequently covered by marine sediments or formed in subsiding coastal fresh water lakes that eventually became marine.

Other types of epithermal deposit (e.g., Creede, Comstock, and Sado deposits of Cox and Singer (1986) are found in similar environments but are formed at deeper levels within epithermal systems. Although deposits of this type are present in the CSB (see Klein, 1988), most of the ore in CSB deposits is disseminated rather than in veins and is not characteristically as silver-rich as the deeper epithermal vein deposits.

Grade and tonnages of the three mines for which information is available (Haile, 9.1 million metric tons, 3 g/t; Ridgeway, 51 million metric tons, 1 g/t; and Russell, 3.7 million metric tons, 2 g/t), plot between the 20th and 80th percentile for tonnage and between the 10th and 80th percentiles on the grade curves for hot-spring deposits (see Berger and Singer, 1992). In general, these three CSB deposits appear to be typical of hot-spring deposits in their grade and tonnage characteristics and lower in grade and of greater tonnage than other types of epithermal deposits. Even the smallest CSB deposit, the Russell mine, is larger than 70 percent of the Creede deposits and the Ridgeway deposit is larger than all but one example suggesting that these deposits do not belong to this deposit tonnage population. The results are even more convincing when the same comparison is made to the Comstock and Sado deposits. Not only are all three CSB deposits larger than 80 percent of the Comstock and all but one Sado deposit but all of the three CSB deposit gold grades are lower than approximately 90 percent those of both deposit types. When a similar comparison is made to low-sulfide gold deposits (Bliss, 1986) the three CSB deposit are larger than more than 95 percent of all low-sulfide gold deposits and their grades lower more than 99 percent of these deposits, indicating that they are not likely to belong, as has been proposed, to any known type of shear-zone controlled, low-sulfide gold deposits.

Rationale for Tract Delineation

The permissive tract encloses the exposed area of the CSB and eastern CSB and includes areas that contain evidence for significant amounts of felsic volcanism. This tract includes the Haile and the Ridgeway deposits. Even though much of the volcanism in the CSB was submarine, we

cannot reliably discriminate, in many cases, between submarine and subaerial felsic volcanic centers using the present geologic framework. Therefore, we have included in this tract those parts of the slate belt that are known to contain bimodal (rhyolitic-basaltic) volcanism and where the depositional environment is incompletely known. As more information is made available concerning the distribution of subaerial versus submarine volcanic centers, a significant part of this tract where submarine volcanism dominates could be reclassified.

Rationale for Numerical Estimate

The following calculations, based on deposit densities observed in other hot-spring Au-Ag districts were used to estimate the number of undiscovered deposits in the favorable areas at the 50th percentile by using the product of the area of the favorable tracts and the deposit density:

District	Size, km	No.of deposit s	Density (deposits/km ²)	Reference
Surigao del Norte, Philippines	30 x 700	20	0.001	Mitchell and Balce, 1990.
Paracales, Philippines	10 x 20	20	0.10	Mitchell and Balce, 1990.
Round Mountain, Nevada	20 x 20	6	0.015	Mills and others, 1988.
Coromandel peninsula, New Zealand	10 x 30	10	0.033	Irvine and Smith, 1990.
Humboldt Range, Nevada	10 x 40	5	0.012	Hastings and others, 1988.

The tract contains the two largest examples (Haile, Ridgeway) and has a large surface area. A low density of 0.001 deposits/km² was used to calculate a first pass at the mean number of deposits in the tract because much of the geologic framework is not well known. This calculation yielded 18.66 deposits. Six hot-spring deposits consistent with the grade and tonnage model are known in this tract, leading to a net estimate of 12.66 mean undiscovered deposits. The team believed that the number of deposits calculated in this manner was too large by a factor of about two, and the final probabilistic estimate used a mean number of 6.3 as a guide. For the 90th, 50th, and 10th percentiles, the team estimated 3, 5, and 12 or more hot-spring Au-Ag deposits consistent with the grade and tonnage model of Berger and Singer (1992).

References

- Berger, B.R., 1986, Descriptive model of hot-spring Au-Ag, *in* Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, p.143
- Berger, B.R., and Singer, D.A., 1992, Grade and tonnage model of hot-spring Au-Ag, *in* Bliss, J.D., ed., Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, p. 23–25.
- Bliss, J.D., 1986, Grade and tonnage model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239–243.
- Butler, J.R., Scheetz, J.W., Stonehouse, J.M., Taylor, D.R., and Callaway, R.Q., 1988, The Brewer gold mine, Chesterfield County, South Carolina: Chapel Hill, University of North Carolina, Guidebook for Field Trip, April 5, 1988, Southeastern Section, Geological Society of America, 22 p.
- Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, 379 p.

- Feiss, P.G., 1988, Gold mineralization in the Southern Appalachian Piedmont—Pardee and Park redivivus, *in* Kisvarsanyi, G., and Grant, S.K., eds., Tectonic controls of ore deposits and the vertical and horizontal extent of ore systems, Proceedings volume: Rolla, University of Missouri, p. 491–500.
- Hastings, J.S., Burkhart, T.H., and Richardson, R.E., 1988, Geology of the Florida Canyon gold deposit, Pershing County, Nevada, *in* Schafer, R.W., Cooper, J.J., and Vikre, P.G., eds., Bulk mineable precious metal deposits of the western United States, symposium proceedings: Geological Society of Nevada, p. 433–452.
- Klein, T.L., 1988, Geochemical and alteration study of gold deposits in the central Carolina slate belt: Geological Society of America Abstracts with Programs, v. 20, no. 4, p. 274.
- Klein, T.L., and Criss, R.E., 1988, An oxygen isotope and geochemical study of the meteoric-hydrothermal systems at Pilot Mountain and selected other localities, Carolina slate belt: *Economic Geology*, v. 83, no. 4, p. 801–821.
- Koeppen, R.P., and Klein, T.L., 1989, Caraway-Back Creek volcanic center, central slate belt, North Carolina—Newly recognized thermal source for precious- and base-metal mineralization: *in* K.S. Schindler, K.S., ed., USGS research on mineral resources—1989 program and abstracts, fifth annual V.E. McKelvey Forum on Mineral and Energy Resources: U.S. Geological Survey Circular 1035, p. 40–41.
- Mills, B.A., Boden, D.R., Sander, M.V., 1988, Alteration and precious metal mineralization associated with the Toquima caldera complex, Nye County, Nev., *in* Schafer, R.W., Cooper, J.J., and Vikre, P.G., eds., Bulk mineable precious metal deposits of the western United States, symposium proceedings: Geological Society of Nevada.
- Mitchell, A.H.G., and Balce, G.R., 1990, Geological features of some epithermal gold systems, Philippines, *in* Hedenquist, J.W., White, N.C., and Siddeley, G., eds., Epithermal gold mineralization of the Circum-Pacific I: Association of Exploration Geochemists Special Publication No. 16a, p. 241–296.
- Spence, W.H., 1975, A model for the origin of the pyrophyllite deposits in the Carolina slate belt: Geological Society of America Abstracts with Programs, v. 7, no. 4, p. 536–537.
- Spence, W.H., Worthington, J.E., Jones, E.M., and Kiff, I.T., 1980, Origin of the gold mineralization at the Haile mine, Lancaster County, South Carolina: *Mining Engineering*, v. 32, no. 1, p. 70–73.
- Tomkinson, M.J., 1988, Gold mineralization in phyllonites at the Haile mine, South Carolina: *Economic Geology*, v. 83, no. 7, p. 1392–1400.
- Worthington, J.E., and Kiff, I.T., 1970, A suggested volcanogenic origin for certain gold deposits in the slate belt of the North Carolina Piedmont: *Economic Geology*, v. 65, no. 5, p. 529–537.
- Worthington, J.E., Kiff, I.T., Jones, E.M., and Chapman, P.E., 1980, Applications of the hot springs or fumarolic model in prospecting for lode gold deposits: *Mining Engineering*, v. 32, no. 1, p. 73–79.

SA16**Hot-spring Au-Ag Deposits**

North Carolina

Descriptive Model 25a • Mark3 Index 45

Area = 2,920 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by T. L. Klein

Rationale for Model Choice

The compositionally-bimodal, metamorphosed, late Precambrian to Cambrian volcanic terrain of the Central Carolina slate belt (CSB) contains many examples of epithermal precious metal deposits. Extensive accumulations of felsic volcanic rocks, ranging in composition from dacite to rhyolite, are associated with volcanic centers that are found in the area between the North Carolina-Virginia border southward to the north-central part of South Carolina, just north of Columbia, with the greatest felsic volcanic accumulations occurring in the area between the cities of Asheboro and Troy, North Carolina. The relationship of gold deposits to the waning stages of felsic volcanism was first suggested by Worthington and Kiff (1970) after they observed that many gold deposits in this region were found along the contact between a dominantly felsic volcanic unit (the Uwharrie Formation) and overlying mudstones. The application of the hot-spring model to explain the origin of some gold deposits in the CSB was proposed by Spence (1975); Spence and others (1980); and Worthington and others (1980); and has been supported by subsequent studies (Feiss, 1988; Butler and others, 1988; Klein, 1988; Koeppen and Klein, 1989).

Volcanic textures and the oxygen isotope signature of many of these felsic volcanic rocks and some of the gold deposits strongly suggest that they were deposited in a subaerial environment (Klein and Criss, 1988). Several of these deposits are thought to be deformed and metamorphosed stratabound gold-bearing zones related to paleo-hot-spring systems (e.g., Haile). Others may be discordant, fracture-controlled deposits originally emplaced at shallow depths below the surface in a paleo-hot-spring hydrothermal system (e.g., Hoover Hill) (Koeppen and Klein, 1989). Metamorphosed epithermal quartz-alunite gold deposits are also thought to occur in the CSB but are generally restricted to the more intermediate-composition volcanic rocks.

Three of the four producing or recently producing gold deposits and many abandoned mines and prospects in the CSB are thought to be epithermal in origin, and some were formed at shallow levels in hot-spring systems. Recent mineral exploration in the CSB has resulted in the renewed mining activity at the Haile mine and the discovery of a large, new deposit at Ridgeway in South Carolina. In addition, several abandoned mines and prospects have been recently explored in central North Carolina that contain substantial inferred reserves (e.g., Russell) and persistent ore zones that are only partially constrained by drilling. The most productive area has been in north-central South Carolina, where recent mining has exploited probable metamorphosed hot-spring deposits (Haile, Ridgeway).

Three of the known deposits (Haile, Ridgeway, Russell) are found near the contact of large accumulations of dominantly felsic, bimodal volcanic rocks with overlying epiclastic rocks, probably of marine origin. All are characterized by steeply dipping ore zones that consist of disseminated sulfide minerals (predominantly pyrite) that have been intensely silicified and sericitized and contain few, if any, well-defined mineralized quartz veins. All three deposits are slightly enriched in Cu, Zn, As, and Mo. Ore zones at the Haile mine also contain gold and

silver telluride minerals. Gold at the Portis mine, in the eastern CSB, is concentrated in pyrite-quartz stockworks within a shallow-level granitoid sill and is tentatively classified as a hot-spring gold deposit.

The Haile, Ridgeway, and Russell mines are considered to be hot-spring gold deposits because of the subaerial character of some of their felsic volcanic host rocks, the similarities of their ore and alteration mineralogy and host rock textures with those of hot-spring deposits (Model 25a, Berger, 1986), and the apparent widespread involvement of meteoric water in the hydrothermal fluids. However, an alternative origin as shear zone-controlled deposits has been proposed by investigators at the Haile and Ridgeway deposits (see Tomkinson, 1985). Although these deposits are locally highly deformed and gold may be controlled by small-scale, shear-related structures, this control is probably due mainly to local remobilization during metamorphism. The overall character, including typical grades and size, of these CSB deposits is similar to hot-spring deposits, elsewhere, and not at all typical of low-sulfide Au-quartz veins.

Laminated mudstones, some of which contain marine fossils, are commonly associated with CBS deposits. This seems to be inconsistent with a simple, subaerial hot-spring origin, however, the evidence for meteoric water-dominated hydrothermal fluids from oxygen-isotope studies and the absence of substantial quantities of base-metals in these deposits suggest that marine waters were not the principal source of fluids. The apparent conflict can be rationalized if a subaerial hot-spring system, related to coastal volcanism, was subsequently covered by marine sediments or formed in subsiding coastal fresh water lakes that eventually became marine.

Other types of epithermal deposit (e.g., Creede, Comstock, and Sado deposits of Cox and Singer (1986) are found in similar environments but are formed at deeper levels within epithermal systems. Although deposits of this type are present in the CSB (see Klein, 1988), most of the ore in CSB deposits is disseminated rather than in veins and is not characteristically as silver-rich as the "deep" epithermal vein deposits.

Grade and tonnages of the three mines for which information is available (Haile, 9.1 million metric tons, 3g/t; Ridgeway, 51 million metric tons, 1 g/t; and Russell, 3.7 million metric tons, 2 g/t), plot between the 20th and 80th percentile for tonnage and between the 10th and 80th percentiles on the grade curves for hot-spring deposits (see Berger and Singer, 1992). In general, these three CSB deposits appear to be typical of hot-spring deposits in their grade and tonnage characteristics and lower in grade and of greater tonnage than other types of epithermal deposits. Even the smallest CSB deposit, the Russell mine, is larger than 70 percent of the Creede deposits and the Ridgeway deposit is larger than all but one example suggesting that these deposits do not belong to this deposit tonnage population. The results are even more convincing when the same comparison is made to the Comstock and Sado deposits. Not only are all three CSB deposits larger than 80 percent of the Comstock and all but one Sado deposit but all of the three CSB deposit gold grades are lower than approximately 90 percent those of both deposit types. When a similar comparison is made to low-sulfide gold deposits (Bliss, 1986) the three CSB deposit are larger than more than 95 percent of all low-sulfide gold deposits and their grades lower more than 99 percent of these deposits, indicating that they are not likely to belong, as has been proposed, to any known type of shear-zone controlled, low-sulfide gold deposits.

Rationale for Tract Delineation

The eastern part of this tract is, in large part, composed of subaerial felsic volcanic rocks that are favorable host rocks for hot-spring Au-Ag deposits. To the west, there is a transition into intermingled subaerial and subaqueous volcanic rocks, only some of which might be favorable. The distinction between subaerial and submarine rocks cannot be reliably made in the western

part of this tract at this time. The tract contains the Russell mine and several other probable epithermal deposits.

Rationale for Numerical Estimate

The following calculations, based on deposit densities observed in other hot-spring Au-Ag districts were used to estimate the number of undiscovered deposits in the favorable areas at the 50th percentile by using the product of the area of the favorable tracts and the deposit density:

District	Size, km	No.of deposits	Density (deposits/km ²)	Reference
Surigao del Norte, Philippines	30 x 700	20	0.001	Mitchell and Balce, 1990.
Paracales, Philippines	10 x 20	20	0.10	Mitchell and Balce, 1990.
Round Mountain, Nevada	20 x 20	6	0.015	Mills and others, 1988.
Coromandel peninsula, New Zealand	10 x 30	10	0.033	Irvine and Smith, 1990.
Humboldt Range, Nevada	10 x 40	5	0.012	Hastings and others, 1988.

For the 90th, 50th, and 10th percentiles, the team estimated 2, 5, and 8 or more hot-spring Au-Ag deposits consistent with the grade and tonnage model of Berger and Singer (1992) (Mark3 index 45). A deposit density of 0.001 deposits/km², like that of the Surigao del Norte district in the Philippines was used as a guide for estimates for this tract because of the size of the Surigao del Norte district. Thus, 2.9 mean deposits were predicted in this 2900 square kilometer tract. In addition, approximately 24 probable hot-spring prospects and occurrences with small known production totals of less than 2 metric tons of gold occur in the tract. Probably no more than 2 of these 24 might be typical of the grade and tonnage model, given further exploration and development. When added to the 2.9 mean undiscovered deposits, the total mean estimate is about 4.9 deposits, a number that we used to guide our probabilistic estimate.

References

- Berger, B.R., 1986, Descriptive model of hot-spring Au-Ag, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p.143
- Berger, B.R., and Singer, D.A., 1992, Grade and tonnage model of hot-spring Au-Ag: *in* Bliss, J.D., ed., Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, p. 23–25.
- Bliss, J.D., 1986, Grade and tonnage model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239–243.
- Butler, J.R., Scheetz, J.W., Stonehouse, J.M., Taylor, D.R., and Callaway, R.Q., 1988, The Brewer gold mine, Chesterfield County, South Carolina: Chapel Hill, University of North Carolina, Guidebook for Field Trip, April 5, 1988, Southeastern Section, Geological Society of America, 22 p.
- Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, 379 p.
- Feiss, P.G., 1988, Gold mineralization in the Southern Appalachian Piedmont—Pardee and Park redivivus, *in* Kisvarsanyi, G., and Grant, S.K., eds., Tectonic controls of ore deposits and the vertical and horizontal extent of ore systems, Proceedings volume: Rolla, University of Missouri, p. 491–500.

- Hastings, J.S., Burkhart, T.H., and Richardson, R.E., 1988, Geology of the Florida Canyon gold deposit, Pershing County, Nevada, *in* Schafer, R.W., Cooper, J.J., and Vikre, P.G., eds., Bulk mineable precious metal deposits of the western United States, symposium proceedings: Geological Society of Nevada, p. 433–452.
- Klein, T.L., 1988, Geochemical and alteration study of gold deposits in the central Carolina slate belt: Geological Society of America Abstracts with Programs, v. 20, no. 4, p. 274.
- Klein, T.L., and Criss, R.E., 1988, An oxygen isotope and geochemical study of the meteoric-hydrothermal systems at Pilot Mountain and selected other localities, Carolina slate belt: *Economic Geology*, v. 83, no. 4, p. 801–821.
- Koeppen, R.P., and Klein, T.L., 1989, Caraway-Back Creek volcanic center, central slate belt, North Carolina—Newly recognized thermal source for precious- and base-metal mineralization, *in* SSchindler, K.S., ed., USGS research on mineral resources—1989 program and abstracts, fifth annual V.E. McKelvey Forum on Mineral and Energy Resources: U.S. Geological Survey Circular 1035, p. 40–41.
- Mills, B.A., Boden, D.R., Sander, M.V., 1988, Alteration and precious metal mineralization associated with the Toquima caldera complex, Nye County, Nevada, *in* Schafer, R.W., Cooper, J.J., and Vikre, P.G., eds., Bulk mineable precious metal deposits of the western United States, symposium proceedings, Geological Society of Nevada.
- Mitchell, A.H.G., and Balce, G.R., 1990, Geological features of some epithermal gold systems, Philippines, *in* Hedenquist, J.W., White, N.C., and Siddeley, G., eds., Epithermal gold mineralization of the Circum-Pacific I, Association of Exploration Geochemists Special Publication No. 16a, p. 241–296.
- Spence, W.H., 1975, A model for the origin of the pyrophyllite deposits in the Carolina slate belt: Geological Society of America Abstracts with Programs, v. 7, no. 4, p. 536–537.
- Spence, W.H., Worthington, J.E., Jones, E.M., and Kiff, I.T., 1980, Origin of the gold mineralization at the Haile mine, Lancaster County, South Carolina: *Mining Engineering*, v. 32, no. 1, p. 70–73.
- Tomkinson, M.J., 1988, Gold mineralization in phyllonites at the Haile mine, South Carolina: *Economic Geology*, v. 83, no. 7, p. 1392–1400.
- Worthington, J.E., and Kiff, I.T., 1970, A suggested volcanogenic origin for certain gold deposits in the slate belt of the North Carolina Piedmont: *Economic Geology*, v. 65, no. 5, p. 529–537.
- Worthington, J.E., Kiff, I.T., Jones, E.M., and Chapman, P.E., 1980, Applications of the hot springs or fumarolic model in prospecting for lode gold deposits: *Mining Engineering*, v. 32, no. 1, p. 73–79.

SA17**Descriptive Model 25a****Area = 18,000 km²****Hot-spring Au-Ag Deposits****North Carolina****South Carolina****Georgia**[Model](#)[Mineral Deposits](#)*by* T.L. Klein**Rationale for Model Choice**

The compositionally-bimodal, metamorphosed, late Precambrian to Cambrian volcanic terrain of the Central Carolina slate belt (CSB) contains many examples of epithermal precious metal deposits. Extensive accumulations of felsic volcanic rocks, ranging in composition from dacite to rhyolite, are associated with volcanic centers that are found in the area between the North Carolina-Virginia border southward to the north-central part of South Carolina, just north of Columbia, with the greatest felsic volcanic accumulations occurring in the area between the cities of Asheboro and Troy, North Carolina. The relationship of gold deposits to the waning stages of felsic volcanism was first suggested by Worthington and Kiff (1970) after they observed that many gold deposits in this region were found along the contact between a dominantly felsic volcanic unit (the Uwharrie Formation) and overlying mudstones. The application of the hot-spring model to explain the origin of some gold deposits in the CSB was proposed by Spence (1975); Spence and others (1980); and Worthington and others (1980); and has been supported by subsequent studies (Feiss, 1988; Butler and others, 1988; Klein, 1988; Koeppen and Klein, 1989).

Rationale for Tract Delineation

This tract defines the permissive area for hot-spring deposits in the southeastern United States. It consists of the metamorphosed late Precambrian to Cambrian volcanic and sedimentary rocks of the CSB, Charlotte belt and Kings Mountain belt, and their equivalents that extend toward the southwest. There are no known occurrences of hot-spring mineralization.

Rationale for Numerical Estimate

No estimates were made for this permissive tract because even though it may contain some areas of favorable host rocks; (1) it is not known to contain deposits of this type, and (2) it has been much less well explored than the favorable areas.

References

- Butler, J.R., Scheetz, J.W., Stonehouse, J.M., Taylor, D.R., and Callaway, R.Q., 1988, The Brewer gold mine, Chesterfield County, South Carolina: Chapel Hill, University of North Carolina, Guidebook for Field Trip, April 5, 1988, Southeastern Section, Geological Society of America, 22 p.
- Feiss, P.G., 1988, Gold mineralization in the Southern Appalachian Piedmont—Pardee and Park redivivus, *in* Kisvarsanyi, G., and Grant, S.K., eds., Tectonic controls of ore deposits and the vertical and horizontal extent of ore systems, proceedings volume: Rolla, University of Missouri, p. 491–500.
- Klein, T.L., 1988, Geochemical and alteration studies of gold deposits in the central Carolina slate belt: Geological Society of America Abstract with Programs, v. 20, no. 4, p. 274.
- Koeppen, R.P., and Klein, T.L., 1989, Caraway-Back Creek volcanic center, central slate belt, North Carolina—Newly recognized thermal source for precious- and base-metal mineralization, *in* Schindler, K.S., ed., USGS research on mineral resources—1989 program and abstracts, fifth annual V.E. McKelvey Forum on Mineral and Energy Resources: U.S. Geological Survey Circular 1035, p. 40–41.

Spence, W.H., 1975, A model for the origin of the pyrophyllite deposits in the Carolina slate belt: Geological Society of America Abstracts with Programs, v. 7, no. 4, p. 536–537.

Spence, W.H., Worthington, J.E., Jones, E.M., and Kiff, I.T., 1980, Origin of the gold mineralization at the Haile mine, Lancaster County, South Carolina: Mining Engineering, v. 32, no. 1, p. 70–73.

Worthington, J.E., and Kiff, I.T., 1970, A suggested volcanogenic origin for certain gold deposits in the slate belt of the North Carolina Piedmont: Economic Geology, v. 65, no. 5, p. 529–537.

Worthington, J.E., Kiff, I.T., Jones, E.M., and Chapman, P.E., 1980, Applications of the hot springs or fumarolic model in prospecting for lode gold deposits: Mining Engineering, v. 32, no. 1, p. 73–79.

SA18**Sediment-Hosted Copper Deposits**

Pennsylvania

Descriptive Model 30b • Mark3 Index 63

Maryland, Virginia

Area = 11,600 km²

New Jersey, New York

[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Gilpin R. Robinson, Jr.**Rationale for Model Choice**

Numerous copper occurrences are known in the early Mesozoic basins of the eastern United States (Robinson and Sears, 1988). Many of these copper deposits and occurrences are sediment-hosted deposit types occurring in Mesozoic red-bed strata (Smoot and Robinson, 1988, table 1A). However, the estimated sizes of most of these occurrences are smaller than the general range of the tonnage curves for sediment-hosted copper, model 30b (Mosier and others, 1986).

The assessment was made using the sediment-hosted copper model 30b of Cox and Singer (1986); this model includes deposits from both red-bed and reduced-facies hosts. The model may not be completely appropriate for assessment of the early Mesozoic basin region for the following reason. A number of deposits in the model have metal grades and tonnages that are enlarged by processes of supergene enrichment, a process not likely to be significant in the eastern region from northern Virginia to Connecticut. Hence the tonnages of copper in the simulation results might be larger than the actual undiscovered tonnage.

Rationale for Tract Delineation

Because of the wide distribution of thick red-bed sequences and numerous small copper occurrences, the Culpeper basin in Virginia, the Gettysburg basin in Pennsylvania, and the Newark basin in New Jersey, and New York are considered to be permissive for small red-bed copper deposits.

In addition, recent work has identified significant occurrences of copper concentrated in reduced lacustrine mudstone units within the sequences of red sandstone and siltstones deposited in the basins (Smoot and Robinson, 1988; Robinson and Smoot, 1989) and the basins are believed to have potential for additional sediment-hosted copper deposits in these reduced-lacustrine facies rocks. Two favorable areas have been postulated for reduced facies sediment-hosted deposits.

In the Culpeper basin, Virginia, two black mudstone intervals, each containing zones of 0.5 to 2 percent copper ranging from 10 cm to more than 1 m in thickness, have been identified (Smoot and Robinson, 1988; Robinson and Smoot, 1989). Indications of mineralization in these beds have been traced along strike for approximately 6 km. Additional favorable host horizons occur in intervals throughout the cyclic stratigraphic section in the tract. This part of the Culpeper basin is underlain by basement rocks containing oxidized continental tholeiitic basalt, a potential source of copper.

Metal-rich mudstones resemble unmineralized mudstones, outcrop exposures in the region are sparse, and the deep humid weathering tends to greatly reduce copper contents in soils and saprolites. These factors suggest that more extensive sediment-hosted copper deposits may have gone unrecognized.

Rationale for Numerical Estimate

For the 90th, 50th, and 10th percentiles, the team estimated 1, 2, and 3 or more sediment-hosted copper deposits consistent with the grade and tonnage model of Mosier and others (1986) (Mark3 index 63). The permissive tract is large, poorly exposed, and inadequately explored for reduced facies deposits.

References

- Mosier, D.L., Singer, D.A., and Cox, D.P., 1986, Grade and tonnage model for sediment-hosted copper, *in* Cox, D.P. and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 205–208.
- Cox, D.P., 1986, Descriptive model for sediment-hosted copper, *in* Cox, D.P. and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 205.
- Robinson, G.R., Jr., and Sears, C.M., 1988, Inventory of metal mines and occurrences associated with the early Mesozoic basins of the eastern United States—Summary tables, *in* Froelich A.J., and Robinson, G.R., Jr., Studies of the early Mesozoic basins of the eastern United States: U.S. Geological Survey Bulletin 1776, p. 265–303.
- Robinson, G.R., Jr., and Smoot, J.P., 1989, Stratabound copper and zinc mineralization in Triassic lacustrine beds of the Culpeper basin, Virginia [abs.], *in* Schindler, K.S., ed., USGS research on mineral resources—1989 program and abstracts, fifth annual V.E. McKelvey Forum on Mineral and Energy Resources: U.S. Geological Survey Circular 1035, p. 57–59.
- Smoot, J.P., and Robinson, G.R. Jr., 1988, Sedimentology of stratabound base-metal occurrences in the Newark Supergroup, *in* Froelich, A.J., and Robinson, G.R., Jr., eds., Studies of the early Mesozoic basins of the eastern United States: U.S. Geological Survey Bulletin 1776, p. 356–376.

SA19**Mississippi Valley Deposits, Appalachian Zn****North Carolina****Descriptive Model 32b****Area = 279 km²**[Model](#)*by* Sandra H.B. Clark, Joseph A. Briskey, Jr., and Dennis P. Cox**Rationale for Model Choice**

Large resources of zinc occur in the Central Tennessee district in deposits like Elmwood and Gordonsville that have many similarities to major stratabound Appalachian Zn or Mississippi Valley (MVT) districts that extend from Tennessee to Newfoundland. Because of the distinctive geological features and importance of the eastern United States deposits, they are the basis for definition of the worldwide Appalachian Zn model (Briskey, 1986a). This differentiation of Appalachian Zn as a subtype of MVT is supported by recent studies of lead isotopes, which indicate that the Appalachian sulfides have unusually homogeneous compositions, distinctly different from the arrays typical of MVT deposits in the mid-continent of the United States (Kesler and others, 1994; Carlson, 1994). Known Appalachian Zn districts in east-central United States are stratabound within Lower Cambrian to Lower Ordovician dolostones and limestones that formed as platform carbonate deposits in the Appalachian basin sedimentary sequence. Host rocks for known deposits are the Lower Ordovician Beekmantown and Knox Groups (East and Central Tennessee, Shenandoah Valley, and Friedensville districts) and the Lower Cambrian Shady Dolomite (Austinville-Ivanhoe district).

Rationale for Tract Delineation

This small tract is based on the exposure of lower Paleozoic shelf carbonate rocks in the Grandfather Mountain window where the Blue Ridge crystalline rocks were thrust over the shelf rocks during the Alleghenian Orogeny (Rankin and others, 1991). These rocks are similar to those that contain Appalachian Zn deposits to the west, however, no examples of deposits or prospects are known in the tract.

Rationale for Numerical Estimate

Because of the small size of the tract and low probability of undiscovered deposits, no estimate of undiscovered deposits was made.

References

- Briskey, J.A., 1986a, Descriptive model of Appalachian Zn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 222.
- Carlson, E.H., 1983, The occurrence of Mississippi Valley-type mineralization in northwestern Ohio, *in* Kisvarsanyi, Geza, Grant, S.K., Pratt, W.P., and Koenig, J.W., ed., International conference on Mississippi Valley type lead-zinc deposits: Rolla, University of Missouri, p. 424-435.
- Kesler, S.E., Cumming, G.L., Kristic, Dragan, and Appold, M.S., 1994, Lead isotopic geochemistry of Mississippi Valley-type deposits of the southern Appalachians: *Economic Geology*, v. 89, no.2, p. 307-321.
- Rankin, D.W., Dillon, W.P., Black, D.F.B., Boyer, S.E., Daniels, D.L., Goldsmith, R., Grow, J.A., Horton, J.W., Jr., Hutchinson, D.R., Klitgord, R.C., McDowell, R.C., Miltop, D.J., Owens, J.P., and Phillips, J.D., 1991, E-4, Central Kentucky to Carolina Trough: Boulder, Colo., Geological Society of America Centennial Continent-Ocean Transect No. 16, 2 sheets, scale 1:500,000.

SA20**Descriptive Model 36a****Area = 191,000 km²****Low-sulfide Au-quartz Vein Deposits**

Pennsylvania
 New Jersey, Delaware
 Maryland, Virginia
 North Carolina, Tennessee
 South Carolina, Georgia
 Alabama

[Model](#)*by* T.L. Klein**Rationale for Model Choice**

Many of the gold deposits of the southeastern United States are analogous to the low-sulfide Au-quartz vein deposit model (Berger, 1986). There are broad similarities in ore controls (i.e., veins controlled by regional fault systems or folds), in vein and alteration mineralogy, and in their host rocks. Although low-sulfide gold deposits are typically found in low-grade metamorphic terrains, we feel that the metamorphic grade is probably a less important criteria than the character of the protolith and alteration assemblage and the presence of appropriate regional structures. Therefore, the deposits in the Alabama, Dahlonga, and South Mountain districts are classified as low-sulfide Au-quartz veins deposits (model 36a, Berger, 1986), even though they are found in high-grade metamorphic rocks.

Rationale for Tract Delineation

Because gold occurrences are found in nearly every major pre-Mesozoic lithotectonic terrane in the southeastern United States, the entire area of metamorphosed igneous and sedimentary rocks in the southern Appalachian Mountains and Piedmont is considered to be permissive for the occurrence of low-sulfide Au-quartz vein deposits. This tract consists of the area remaining after more favorable areas were assigned to tracts SA21–SA27. After the more favorable tracts were removed, the team members believed that the number of undiscovered deposits remaining in this larger permissive tract was small and they were unable to make a numerical estimate.

Reference

Berger, B.R., 1986, Descriptive model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds. Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239.

SA21**Low-sulfide Au-quartz Vein Deposits**Maryland
Virginia

Descriptive Model 36a • Mark3 Index 27

Area = 5,400 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by T.L. Klein

Rationale for Model Choice

Many of the gold deposits of the southeastern United States are thought to be low-sulfide Au-quartz vein deposits because of their similarity in ore controls (i.e., veins controlled by regional fault systems or folds), the mineralogy of their veins, alteration halos, and associated sulfides, and their host rocks to those of model 36a (Berger, 1986). Grade and tonnage of low-sulfide Au-quartz vein deposits for which information is available are as follows: Creighton, Ga., 140,000 metric tons, 10 g/t; Franklin, Va., 88,000 metric tons, 20.5 g/t; Gold Hill, N.C., 1.3 million metric tons, 4.1 g/t; Hog Mountain, Ala., 2.7 million metric tons, 2.7 g/t; Howie, N.C., 310,000 metric tons, 10 g/t; Iola, N.C., 220,000 metric tons, 7 g/t; Rudisil, N.C., 140,000 metric tons, 14 g/t; Vacluse, Va., 160,000 metric tons, 14 g/t. These eight deposits are larger in tonnage than 60 percent of the low-sulfide Au-quartz vein deposits that make up the grade and tonnage model (Bliss, 1986), plotting between the 10th and 40th percentile. Grades for these deposits are lower than 30 percent of low-sulfide Au-quartz vein deposits in the model, plotting between the 30th and 90th percentiles. In general, the low-sulfide gold deposits in the southeastern United States, for which we have grade and tonnage information, appear somewhat larger but of similar grade when compared with low-sulfide gold deposits elsewhere.

One of the most laterally-extensive gold belt in the southeastern United States is the gold-pyrite belt of northern and central Virginia that averages about 30 km wide and is more than 144 km long. Most of the deposits are gold-bearing quartz-carbonate veins and lenses, or wide zones of disseminations or veinlets of quartz in the moderately- to highly-deformed, metavolcanic and metasedimentary rocks of the Cambrian central Virginia volcanic-plutonic belt (Pavlidis, 1981). Several of these deposits contain veins as thick as 5 m; some mineralized zones containing disseminated gold are up to 20 m wide (Pardee and Park, 1948). This belt of rocks is distinctive because of a strong metamorphic gradient with mid-greenschist facies rocks grading into mid-amphibolite facies rocks in a west to east direction.

Rationale for Tract Delineation and Significant Examples

This tract is comprised of the rocks of the Central Virginia Volcanic-Plutonic belt (Pavlidis, 1981) and is extended northeastward to include the gold deposits near the Great Falls in southern Maryland. Three deposits in this tract, Franklin, Whitehall, and Vacluse, are probably the largest in Virginia, although production records for most mines in Virginia are incomplete or not available. More than 150 other small gold prospects and occurrences are found in the northeast-trending belt, which also includes several dozen small- to moderate-size kuroko massive sulfide deposits. Other significant abandoned mines in this tract include the Moss-Tellurium, Melville, and Eagle mines.

Rationale for Numerical Estimate

A mean predicted number of deposits for the permissive tract was calculated using its area multiplied by a deposit density factor derived from four well-characterized, major low-sulfide Au-quartz vein regions (i.e., the Meguma area, Nova Scotia; the central Victoria area, Australia;

Klamath Mountains, Oregon; the Sierra Nevada foothills, California) (Bliss and others, 1987). The deposit densities for these four regions are within 12 percent of their mean of 0.0048 deposits per square kilometer. This mean density when multiplied by the area of the permissive tract gives a predicted number of deposits that the team believed to be too large. This large tract has a relatively small number of known deposits, even though it has been well explored for both gold veins and kuroko massive sulfide deposits. For this reason, the team used a reduced density factor of 0.0014 deposits per square kilometer. This number when multiplied by the area of the permissive tract gives a predicted mean number of 7.56 deposits. The number of known deposits in the tract with grade and tonnage consistent with the deposit model is 3. This was subtracted from the predicted number to obtain a net of 4.56. Using this number as a guide, a geologically reasonable distribution of the number of deposits was selected: at the 90th, 50th, and 10th percentiles, respectively, 2, 5, and 8 or more low-sulfide Au-quartz vein deposits in the tract consistent with the grade and tonnage model of Bliss (1986).

References

- Bliss, J.D., 1986, Grade and tonnage model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 239–243.
- Bliss, J.D., Menzie, W.D., Orris, G.J., and Page, N.J., 1987, Mineral deposit density—A useful tool for mineral-resource assessment [abs.], *in* Sachs, J.S., ed., *USGS research on mineral resources, 1987 program and abstracts, third annual V.E. McKelvey Forum on Mineral and Energy Resources*: U.S. Geological Survey Circular 995, p. 6.
- Pardee, J.T., and Park, C.F., Jr., 1948, *Gold deposits of the southern Piedmont*: U.S. Geological Survey Professional Paper 213, 156 p.
- Pavrides, L., 1981, The central Virginia volcanic-plutonic belt—An island arc of Cambrian(?) age: U.S. Geological Survey Professional Paper 1231-A, 34 p.

SA22**Low-sulfide Au-quartz Vein Deposits**

Descriptive Model 36a • Mark3 Index 27

Area = 92,400 km²Virginia
North Carolina
South Carolina
Georgia[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* T.L. Klein**Rationale for Model Choice**

Many of the gold deposits in the southeastern United States are thought to be low-sulfide Au-quartz vein deposits because of their similarity in ore controls (i.e., veins controlled by regional fault systems or folds), the mineralogy of their veins, alteration halos, and associated sulfides, and their host rocks to those of model 36a (Berger, 1986). A cluster of low-sulfide Au-quartz vein deposits that includes the Rudisil mine occurs in the Charlotte district (Pardee and Park, 1948) just west of the southern end of the Gold Hill fault. The cluster is associated with mafic and granitic intrusions. Elsewhere in the Carolina slate belt, the largest mine is the Iola, located near Candor, North Carolina. The Iola, and two smaller deposits nearby, discovered in the early 1900's, are the most recently discovered gold deposits in North Carolina. They have produced approximately 1.5 metric tons of gold (Pardee and Park, 1948). These deposits are in northeast-trending quartz-carbonate veins in a poorly exposed area of intermediate volcanic rocks. Their structural setting is poorly known.

Grade and tonnage of low-sulfide Au-quartz vein deposits for which information is available are as follows: Creighton, Ga., 140,000 metric tons, 10 g/t; Franklin, Va., 88,000 metric tons, 20.5 g/t; Gold Hill, N.C., 1.3 million metric tons, 4.1 g/t; Hog Mountain, Ala., 2.7 million metric tons, 2.7 g/t; Howie, N.C., 310,000 metric tons, 10 g/t; Iola, N.C., 220,000 metric tons, 7 g/t; Rudisil, N.C., 140,000 metric tons, 14 g/t; Vaucluse, Va., 160,000 metric tons, 14 g/t. These eight deposits are larger in tonnage than 60 percent of the low-sulfide Au-quartz vein deposits that make up the grade and tonnage model (Bliss, 1986), plotting between the 10th and 40th percentile. Grades for these deposits are lower than 30 percent of low-sulfide Au-quartz vein deposits in the model, plotting between the 30th and 90th percentiles. In general, the low-sulfide gold deposits in the southeastern United States, for which we have grade and tonnage information, appear somewhat larger but of similar grade when compared with low-sulfide gold deposits elsewhere.

Rationale for Tract Delineation and Significant Examples

Areas of the Charlotte belt, Carolina slate belt, eastern Carolina slate belt, the Belair belt and low-grade metamorphic rocks buried beneath the Cretaceous and Eocene Coastal Plain sedimentary rocks that have not been otherwise included in other favorable areas are included in this permissive tract. Several inactive mines, the Iola and Rudisil mines and the Capps-McGinn, Carter-Star, and Barringer mines are found in this tract.

Rationale for Numerical Estimate

A mean predicted number of deposits for the permissive tract was calculated using its area times a deposit density factor derived from four well-characterized, major low-sulfide Au-quartz vein regions (i.e., the Meguma area, Nova Scotia; the central Victoria area, Australia; Klamath Mountains, Oregon; the Sierra Nevada foothills, California) (Bliss and others, 1987). The deposit densities for these four regions are within 12 percent of their mean of 0.0048

deposits per square kilometer. This mean density when multiplied by the area of the permissive tract gives a predicted number of deposits that is unreasonably large. Because the tract included a large amount of unexplored, covered bedrock that may include large areas of nonpermissive rocks and structures, the assessment team used a deposit density factor reduced to 0.0001. This factor gives a predicted mean number of undiscovered deposits of 9.2. The number of known deposits in the tract with grade and tonnage consistent with the deposit model is 2. This was subtracted from the predicted number to obtain a net of 7.2. Using this number as a guide, a geologically reasonable distribution of the number of deposits was selected: at the 90th, 50th, 10th, and 5th percentiles, respectively, 4, 7, 11, and 13 or more low-sulfide Au-quartz vein deposits in the tract consistent with the grade and tonnage model of Bliss (1986).

References

- Berger, B.R., 1986, Descriptive model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239.
- Bliss, J.D., 1986, Grade and tonnage model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239–243.
- Bliss, J.D., Menzie, W.D., Orris, G.J., and Page, N.J., 1987, Mineral deposit density—A useful tool for mineral-resource assessment [abs.], *in* Sachs, J.S., ed., USGS research on mineral resources, 1987 program and abstracts, third annual V.E. McKelvey Forum on Mineral and Energy Resources: U.S. Geological Survey Circular 995, p. 6.
- Pardee, J.T., and Park, C.F., Jr., 1948, Gold deposits of the southern Piedmont: U.S. Geological Survey Professional Paper 213, 156 p.

SA23**Low-sulfide Au-quartz Vein Deposits**

North Carolina

Descriptive Model 36a • Mark3 Index 27

South Carolina

Area = 1,860 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by T.L. Klein

Rationale for Model Choice

Many of the gold deposits of the southeastern United States are thought to be low-sulfide Au-quartz vein deposits because of their similarity in ore controls (i.e., veins controlled by regional fault systems or folds), the mineralogy of their veins, alteration halos, and associated sulfides, and their host rocks to those of model 36a (Berger, 1986). Grade and tonnage of low-sulfide Au-quartz vein deposits for which information is available are as follows: Creighton, Ga., 140,000 metric tons, 10 g/t; Franklin, Va., 88,000 metric tons, 20.5 g/t; Gold Hill, N.C., 1.3 million metric tons, 4.1 g/t; Hog Mountain, Ala., 2.7 million metric tons, 2.7 g/t; Howie, N.C., 310,000 metric tons, 10 g/t; Iola, N.C., 220,000 metric tons, 7 g/t; Rudisil, N.C., 140,000 metric tons, 14 g/t; Vaucluse, Va., 160,000 metric tons, 14 g/t. These eight deposits are larger in tonnage than 60 percent of the low-sulfide Au-quartz vein deposits that make up the grade and tonnage model (Bliss, 1986), plotting between the 10th and 40th percentile. Grades for these deposits are lower than 30 percent of low-sulfide Au-quartz vein deposits in the model, plotting between the 30th and 90th percentiles. In general, the low-sulfide gold deposits in the southeastern United States, for which we have grade and tonnage information, appear somewhat larger but of similar grade when compared with low-sulfide gold deposits elsewhere.

The northwest-trending Gold Hill fault zone controls a group of gold deposits, along the boundary between the Charlotte and Carolina slate belts in North Carolina. The host rocks are typically low-grade, thin-bedded mudstones, felsic and mafic volcanic rocks, and granitoids. Mineralized quartz-carbonate veins and pods occur in this fault zone over a distance of approximately 96 km. Four of the most developed deposits in this belt include the Reed mine, the first gold mine in the United States, that was discovered in 1799. Two deposits with the largest combined production and reserves, the Gold Hill group and Whitney mine (Pardee and Park, 1948), are located near the north-south midpoint of the fault zone, near a kuroko massive sulfide deposit at Gold Hill, North Carolina. The Howie mine, the most recently and extensively explored deposit of this type in North Carolina, is found near the southern end of the belt, southeast of Charlotte. More than 100 additional small gold deposits and occurrences are found over the length of the belt.

Rationale for Tract Delineation and Significant Deposits

A northwest-trending 3–5 km-wide zone surrounding the Gold Hill fault is defined as the permissive tract. This tract contains deformed and sericitically-altered metasedimentary and metaigneous rocks along the boundary of the Charlotte and Carolina slate belts. The four major abandoned mines (Whitney, Gold Hill, Reed, and Howie) and approximately 100 small mines and occurrences in the tract account for at least 9 metric tons of the estimated 36 metric tons of gold production from North Carolina (Koschmann and Berdendahl, 1968). Other significant past-producing mines in the tract are the Phoenix mine and the Lewis group.

Rationale for Numerical Estimate

A mean predicted number of deposits for the permissive tract was calculated using its area times a deposit density factor derived from four well-characterized, major low-sulfide Au-quartz vein regions (i.e., the Meguma area, Nova Scotia; the central Victoria area, Australia; Klamath Mountains, Oregon; the Sierra Nevada foothills, California) (Bliss and others, 1987). The deposit densities for these four regions are within 12 percent of their mean of 0.0048 deposits per square kilometer. This mean density when multiplied by the area of the permissive tract gives a predicted mean number of undiscovered deposits of 8.9. The number of known deposits in the tract with grade and tonnage consistent with the deposit model is 5. This was subtracted from the predicted number to obtain a net of 3.9. Using this number as a guide, a geologically reasonable distribution of the number of deposits was selected: at the 90th, 50th, and 10th percentiles, respectively, 2, 3, and 8 or more low-sulfide Au-quartz vein deposits in the tract consistent with the grade and tonnage model of Bliss (1986).

References

- Berger, B.R., 1986, Descriptive model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239.
- Bliss, J.D., 1986, Grade and tonnage model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239–243.
- Bliss, J.D., Menzie, W.D., Orris, G.J., and Page, N.J., 1987, Mineral deposit density—A useful tool for mineral-resource assessment [abs.], *in* Sachs, J.S., ed., USGS research on mineral resources, 1987 program and abstracts, third annual V.E. McKelvey Forum on Mineral and Energy Resources: U.S. Geological Survey Circular 995, p. 6.
- Koschmann, A.H., and Bergendahl, M.H., 1968, Principal gold-producing districts of the United States: U.S. Geological Survey Professional Paper 610, 283 p.
- Pardee, J.T., and Park, C.F., Jr., 1948, Gold deposits of the southern Piedmont: U.S. Geological Survey Professional Paper 213, 156 p.

SA24**Low-sulfide Au-quartz Vein Deposits**

North Carolina

Descriptive Model 36a • Mark3 Index 27

South Carolina

Area = 744 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by T.L. Klein

Rationale for Model Choice

Many of the gold deposits of the southeastern United States are thought to be low-sulfide Au-quartz vein deposits because of their similarity in ore controls (i.e., veins controlled by regional fault systems or folds), the mineralogy of their veins, alteration halos, and associated sulfides, and their host rocks to those of model 36a (Berger, 1986). Grade and tonnage of low-sulfide Au-quartz vein deposits for which information is available are as follows: Creighton, Ga., 140,000 metric tons, 10 g/t; Franklin, Va., 88,000 metric tons, 20.5 g/t; Gold Hill, N.C., 1.3 million metric tons, 4.1 g/t; Hog Mountain, Ala., 2.7 million metric tons, 2.7 g/t; Howie, N.C., 310,000 metric tons, 10 g/t; Iola, N.C., 220,000 metric tons, 7 g/t; Rudisil, N.C., 140,000 metric tons, 14 g/t; Vaucluse, Va., 160,000 metric tons, 14 g/t. These eight deposits are larger in tonnage than 60 percent of the low-sulfide Au-quartz vein deposits that make up the grade and tonnage model (Bliss, 1986), plotting between the 10th and 40th percentile. Grades for these deposits are lower than 30 percent of low-sulfide Au-quartz vein deposits in the model, plotting between the 30th and 90th percentiles. In general, the low-sulfide gold deposits in the southeastern United States, for which we have grade and tonnage information, appear somewhat larger but of similar grade when compared with low-sulfide gold deposits elsewhere.

The Kings Mountain-Smyrna district, located in south-central North Carolina and northwestern South Carolina, contains at least 75 small abandoned gold mines and prospects (Horton and Butler, 1981; Butler, 1981). Most of these are low-sulfide gold deposits and are found in sericitically-altered metasedimentary and metavolcanic rocks and metatonalite along a regional northwest-trending anticline (Butler, 1981) and several shear zones. However, several gold deposits in the district may be related to kuroko massive sulfides or some other type of submarine hot-spring system. The district also contains abundant iron formation and barite beds and lenses. Gold production was at least 2 metric tons of Au. However, most of the recorded production was from the Kings Mountain mine, a probable hot-spring deposit (LaPoint, 1992).

Rationale for Tract Delineation

Sericitically-altered metaigneous and metasedimentary rocks of the Kings Mountain belt that lie between the compositionally-varied intrusive rocks of the Charlotte belt on the east and high-grade metasedimentary and metaigneous rocks on the west define the permissive tract. The boundaries between the belts are the ductile Boogertown and Kings Mountain shear zones, respectively. The northern and southern boundaries, although not well defined, are in part along intrusive contacts. This tract contains up to 75 small abandoned mines in the Kings Mountain-Smyrna district along the North and South Carolina border. The distribution of a few mines is controlled by the internal shear zones, the Kings Creek and Long Creek zones (Gair, 1989). Those in the Smyrna district occur along the axes of the South Fork anticline (Butler, 1981).

Rationale for Numerical Estimate

A mean predicted number of deposits for the permissive tract was calculated using its area times a deposit density factor derived from four well-characterized, major low-sulfide Au-quartz vein regions (i.e., the Meguma area, Nova Scotia; the central Victoria area, Australia; Klamath Mountains, Oregon; the Sierra Nevada foothills, California) (Bliss and others, 1987). The deposit densities for these four regions are within 12 percent of their mean of 0.0048 deposits per square kilometer. This mean density when multiplied by the area of the permissive tract gives a predicted mean number of 3.57 undiscovered deposits. No deposits with grade and tonnage consistent with the deposit model are known in the tract. Using the predicted number of undiscovered deposits as a guide, a geologically reasonable distribution of the number of deposits was selected: at the 90th, 50th, and 10th percentiles, respectively, 2, 3, and 7 or more low-sulfide Au-quartz vein deposits in the tract consistent with the grade and tonnage model of Bliss (1986).

References

- Berger, B.R., 1986, Descriptive model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239.
- Bliss, J.D., 1986, Grade and tonnage model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239–243.
- Bliss, J.D., Menzie, W.D., Orris, G.J., and Page, N.J., 1987, Mineral deposit density—A useful tool for mineral-resource assessment [abs.], *in* Sachs, J.S., ed., USGS research on mineral resources, 1987 program and abstracts, third annual V.E. McKelvey Forum on Mineral and Energy Resources: U.S. Geological Survey Circular 995, p. 6.
- Butler, J.R., 1981, Gold and related deposits of the Smyrna district, York and Cherokee Counties, South Carolina: South Carolina Geology, v. 25, no. 1, p. 9–20.
- Gair, J.E., 1989, Gold-quartz and gold-pyrite-quartz veins, *in* Gair, J.E., ed., Mineral resources of the Charlotte 1°x2° quadrangle, North Carolina and South Carolina: U.S. Geological Survey Professional Paper 1462, p. 61–64.
- Horton, J.W., and Butler, J.R., 1981, Geology and mining history of the Kings Mountain belt between Gaffney, South Carolina, and Lincolnton, North Carolina, *in* Horton, J.W., Butler, J.R., and Milton, D.M., eds., Geological investigations of the Kings Mountain belt and adjacent areas in the Carolinas: Carolina Geological Society Field Trip Guidebook 1981, p. 192–212.
- LaPoint, D.J., 1992, Geologic setting of the Kings Mountain gold mine, Cleveland County, North Carolina, *in* Dennison, J.M., and Stewart, K.G., eds., Geologic field trip guides to North Carolina and vicinity: Chapel Hill, University of North Carolina, Geologic Guidebook No. 1, p. 35–48.

SA25**Low-sulfide Au-quartz Vein Deposits**

North Carolina

Descriptive Model 36a • Mark3 Index 27

Area = 629 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)

by T.L. Klein

Rationale for Model Choice

Many of the gold deposits of the southeastern United States are thought to be low-sulfide Au-quartz vein deposits because of their similarity in ore controls (i.e., veins controlled by regional fault systems or folds), the mineralogy of their veins, alteration halos, and associated sulfides, and their host rocks to those of model 36a (Berger, 1986). Although low-sulfide gold deposits are typically found in low-grade metamorphic terrains, we feel that the metamorphic grade is probably a less important criteria than the character of the protolith and alteration assemblage and the presence of appropriate regional structures. Therefore, the deposits in the Alabama, Dahlonga, and South Mountain districts are classified as low-sulfide Au-quartz veins deposits (model 36a, Berger, 1986), even though they are found in high-grade metamorphic rocks.

Grade and tonnage of low-sulfide Au-quartz vein deposits for which information is available are as follows: Creighton, Ga., 140,000 metric tons, 10 g/t; Franklin, Va., 88,000 metric tons, 20.5 g/t; Gold Hill, N.C., 1.3 million metric tons, 4.1 g/t; Hog Mountain, Ala., 2.7 million metric tons, 2.7 g/t; Howie, N.C., 310,000 metric tons, 10 g/t; Iola, N.C., 220,000 metric tons, 7 g/t; Rudisil, N.C., 140,000 metric tons, 14 g/t; Vaucluse, Va., 160,000 metric tons, 14 g/t. These eight deposits are larger in tonnage than 60 percent of the low-sulfide Au-quartz vein deposits that make up the grade and tonnage model (Bliss, 1986), plotting between the 10th and 40th percentile. Grades for these deposits are lower than 30 percent of low-sulfide Au-quartz vein deposits in the model, plotting between the 30th and 90th percentiles. In general, the low-sulfide gold deposits in the southeastern United States, for which we have grade and tonnage information, appear somewhat larger but of similar grade when compared with low-sulfide gold deposits elsewhere.

The South Mountain area of western North Carolina contains 5 small bedrock gold-quartz vein deposits (Gair, 1989; Nitze and Hanna, 1896). The host rocks are medium to high-grade metasedimentary and meta-igneous rocks typical of the Inner Piedmont region. Thin quartz veins are present in five east-northeast-trending, subparallel belts. Gold production has been minor from this district, probably no more than 2 metric tons, most of it from extensive alluvial placer deposits derived from the quartz-vein gold deposits.

Rationale for Tract Delineation

The South Mountain district of western North Carolina as known from the distribution of alluvial placer gold and bedrock deposit (Gair, 1989) defines the permissive tract. Approximately 5 small bedrock deposits were exploited in this tract. Little is known about these deposits.

Rationale for Numerical Estimate

A mean predicted number of deposits for the permissive tract was calculated using its area times a deposit density factor derived from four well-characterized, major low sulfide Au-quartz vein regions (i.e., the Meguma area, Nova Scotia; the central Victoria area, Australia; Klamath Mountains, Oregon; the Sierra Nevada foothills, California) (Bliss and others, 1987).

The deposit densities for these four regions are within 12 percent of their mean of 0.0048 deposits per square kilometer. This mean density when multiplied by the area of the permissive tract gives a predicted number of 3.02 mean undiscovered deposits. This mean density when multiplied by the area of the permissive tract gives a predicted number of deposits that the team believed to be too large. This tract has been moderately well explored, and no significant deposits have been found. For this reason, the team used a reduced density factor of 0.0014 deposits per square kilometer. This number when multiplied by the area of the permissive tract gives a predicted mean number of 0.88 deposits. Using this number as a guide, a geologically reasonable distribution of the number of deposits was selected: at the 90th, 50th, and 10th percentiles, respectively, 0, 1, and 2 or more low-sulfide Au-quartz vein deposits in the tract consistent with the grade and tonnage model of Bliss (1986).

References

- Berger, B.R., 1986, Descriptive model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239.
- Bliss, J.D., 1986, Grade and tonnage model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239–243.
- Gair, J.E., 1989, Gold-quartz and gold-pyrite-quartz veins, *in* Gair, J.E., ed., Mineral resources of the Charlotte 1°x2° quadrangle, North Carolina and South Carolina: U.S. Geological Survey Professional Paper 1462, p. 61–64.
- Nitze, H.B.L., and Hanna, G.B., 1896, Gold deposits of North Carolina: North Carolina Geological Survey Bulletin 3, 200 p.

SA26**Low-sulfide Au-quartz Vein Deposits**

Georgia

Descriptive Model 36a • Mark3 Index 27

Area = 1,110 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by T.L. Klein

Rationale for Model Choice

Many of the gold deposits of the southeastern United States are thought to be low-sulfide Au-quartz vein deposits because of their similarity in ore controls (i.e., veins controlled by regional fault systems or folds), the mineralogy of their veins, alteration halos, and associated sulfides, and their host rocks to those of model 36a (Berger, 1986). Although low-sulfide gold deposits are typically found in low-grade metamorphic terrains, we feel that the metamorphic grade is probably a less important criteria than the character of the protolith and alteration assemblage and the presence of appropriate regional structures. Therefore, the deposits in the Alabama, Dahlonge, and South Mountain districts are classified as low-sulfide Au-quartz veins deposits (model 36a, Berger, 1986), even though they are found in high-grade metamorphic rocks.

Grade and tonnage of low-sulfide Au-quartz vein deposits for which information is available are as follows: Creighton, Ga., 140,000 metric tons, 10 g/t; Franklin, Va., 88,000 metric tons, 20.5 g/t; Gold Hill, N.C., 1.3 million metric tons, 4.1 g/t; Hog Mountain, Ala., 2.7 million metric tons, 2.7 g/t; Howie, N.C., 310,000 metric tons, 10 g/t; Iola, N.C., 220,000 metric tons, 7 g/t; Rudisil, N.C., 140,000 metric tons, 14 g/t; Vaucluse, Va., 160,000 metric tons, 14 g/t. These eight deposits are larger in tonnage than 60 percent of the low-sulfide Au-quartz vein deposits that make up the grade and tonnage model (Bliss, 1986), plotting between the 10th and 40th percentile. Grades for these deposits are lower than 30 percent of low-sulfide Au-quartz vein deposits in the model, plotting between the 30th and 90th percentiles. In general, the low-sulfide gold deposits in the southeastern United States, for which we have grade and tonnage information, appear somewhat larger but of similar grade when compared with low-sulfide gold deposits elsewhere.

The Dahlonge gold belt and its southwestward extension, the Carroll County gold belt, extend for more than 160 km. The Carroll County belt is separated from the Dahlonge belt by a gap of a few miles that contains no known gold deposits or occurrences. The belt contains metamorphosed clastic and chemical sedimentary, volcanic, and intrusive rocks. Retrogressive metamorphism of sillimanite-grade mineral assemblages to lower-grade kyanite- and staurolite-bearing assemblages is typical in this belt where kinematic indicators in this high strain zone show an overall dextral sense of movement. Gold deposits are typically in well developed quartz-carbonate veins or zones of quartz-calcite pods (Albino, 1990). Many kuroko massive sulfide deposits (Model 28a) are found in the volcanic-rich parts of this belt. Much of the production was from hundreds small deposits many of which were alluvial placers or hydraulically-mined saprolite deposits derived from weathering of quartz vein deposits.

Rationale for Tract Delineation and Significant Deposits

The Dahlonge gold belt and the Carroll County gold belt at its southwestern end define this permissive tract. This highly-deformed, 1-2 km-wide, rock package was retrograded to the greenschist facies from the staurolite metamorphic grade, and was last deformed in a transpressive structural setting between the high-grade metamorphic rocks of the Richard Russell and Tallulah Falls thrust sheets (Albino, 1989). The few moderate-sized and hundreds

of small deposits from this area have accounted for an estimated 19 metric tons of the 27 metric tons of gold produced from Georgia (Koschmann and Bergendahl, 1968; Albino, 1989). The tract includes the Creighton mine. Other mines with significant past production in this tract are the Battle Branch, Barlow, Cherokee, Findley Ridge, Sixes, Royal-Vindicator, and the Dahlonega-Consolidated.

Rationale for Numerical Estimate

A mean predicted number of deposits for the permissive tract was calculated using its area, times a deposit density factor derived from four well-characterized, major low-sulfide Au-quartz vein regions (i.e., the Meguma area, Nova Scotia; the central Victoria area, Australia; Klamath Mountains, Oregon; the Sierra Nevada foothills, California) (Bliss and others, 1987). The deposit densities for these four regions are within 12 percent of their mean of 0.0048 deposits per square kilometer. This mean density when multiplied by the area of the permissive tract gives a predicted mean number of 5.34 undiscovered deposits. The number of known deposits in the tract with grade and tonnage consistent with the deposit model is 3. This was subtracted from the predicted number to obtain a net of 2.34. Using this number as a guide, a geologically reasonable distribution of the number of deposits was selected: at the 90th, 50th, and 10th percentiles, respectively, 1, 2, and 4 or more low-sulfide Au-quartz vein deposits in the tract consistent with the grade and tonnage model of Bliss (1986).

References

- Albino, G.V., 1989, Gold deposits of the Dahlonega belt, northeastern Georgia, *in* Cook, R.B., ed., Economic mineral deposits of the southeast: metallic ore deposits: Georgia Geologic Survey Bulletin 117, p. 85–120.
- Berger, B.R., 1986, Descriptive model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds. Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239.
- Bliss, J.D., 1986, Grade and tonnage model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239–243.
- Bliss, J.D., Menzie, W.D., Orris, G.J., and Page, N.J., 1987, Mineral deposit density—A useful tool for mineral-resource assessment [abs.], *in* Sachs, J.S., ed., USGS research on mineral resources, 1987 program and abstracts, third annual V.E. McKelvey Forum on Mineral and Energy Resources: U.S. Geological Survey Circular 995, p. 6.
- German, J.M., 1989, Geologic setting and genesis of gold deposits of the Dahlonega and Carroll County gold belts, Georgia: *Economic Geology*, v. 84, no. 4, p. 903–923.
- Koschmann, A.H., and Bergendahl, M.H., 1968, Principal gold-producing districts of the United States: U.S. Geological Survey Professional Paper 610, 283 p.

SA27**Low-sulfide Au-quartz Vein Deposits****Alabama****Descriptive Model 36a • Mark3 Index 27****Area = 756 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* T.L. Klein**Rationale for Model Choice**

Many of the gold deposits of the southeastern United States are thought to be low-sulfide Au-quartz vein deposits because of their similarity in ore controls (i.e., veins controlled by regional fault systems or folds), the mineralogy of their veins, alteration halos, and associated sulfides, and their host rocks to those of model 36a (Berger, 1986). Although low-sulfide gold deposits are typically found in low-grade metamorphic terrains, we feel that the metamorphic grade is probably a less important criteria than the character of the protolith and alteration assemblage and the presence of appropriate regional structures. Therefore, the deposits in the Alabama, Dahlonga, and South Mountain districts are classified as low-sulfide Au-quartz veins deposits (model 36a, Berger, 1986), even though they are found in high-grade metamorphic rocks.

Grade and tonnage of low-sulfide Au-quartz vein deposits for which information is available are as follows: Creighton, Ga., 140,000 metric tons, 10 g/t; Franklin, Va., 88,000 metric tons, 20.5 g/t; Gold Hill, N.C., 1.3 million metric tons, 4.1 g/t; Hog Mountain, Ala., 2.7 million metric tons, 2.7 g/t; Howie, N.C., 310,000 metric tons, 10 g/t; Iola, N.C., 220,000 metric tons, 7 g/t; Rudisil, N.C., 140,000 metric tons, 14 g/t; Vaucluse, Va., 160,000 metric tons, 14 g/t. These eight deposits are larger in tonnage than 60 percent of the low-sulfide Au-quartz vein deposits that make up the grade and tonnage model (Bliss, 1986), plotting between the 10th and 40th percentile. Grades for these deposits are lower than 30 percent of low-sulfide Au-quartz vein deposits in the model, plotting between the 30th and 90th percentiles. In general, the low-sulfide gold deposits in the southeastern United States, for which we have grade and tonnage information, appear somewhat larger but of similar grade when compared with low-sulfide gold deposits elsewhere.

Several small districts in the eastern Alabama Piedmont have produced small amounts of gold from low-sulfide Au-quartz deposits, perhaps as much as 2 metric tons (Dean, 1989). The districts include the Cragford, Devil's Backbone, Eagle Creek, Goldville, Gold Ridge, Hog Mountain, and Riddles Mill. Host rocks are typically amphibolite-grade metasedimentary rocks with minor metavolcanic rocks and metamorphosed tonalite intrusions (Guthrie and Leshner, 1989). The Devils Backbone and Eagle Creek districts are located along the Brevard zone, where amphibolite-grade metasedimentary rocks have been retrograded to greenschist-grade. Most deposits are found in discontinuous, folded, quartz veins and pods. Production at Hog Mountain, the largest gold mine in Alabama, was estimated by Pardee and Park (1948) to have been 0.75 metric tons Au. Calculations by Paris (1985) based on data of Pardee and Park (1948) suggest that up to 7.5 metric tons of gold may be present to moderate depths.

Rationale for Tract Delineation and Significant Deposits

Three separate small areas in Alabama were evaluated together as one permissive tract. The southernmost area includes the Eagle Creek and Devils Backbone districts in the Brevard zone and a thin belt of rocks located between them. The Gold Ridge, Cragford, Goldville, Hog Mountain districts and the rocks located between them, in the Ashland-Wedowee belt comprise the middle area of the three. An area containing small gold deposits in the Riddle's Mill district

in the rocks of the Talladega Group, along the Talladega fault defines the small, northern most area in Alabama. The Hog Mountain mine is located within this tract.

Rationale for Numerical Estimate

A mean predicted number of deposits for the permissive tract was calculated using its area times a deposit density factor derived from four well-characterized, major low-sulfide Au-quartz vein regions (i.e., the Meguma area, Nova Scotia; the central Victoria area, Australia; Klamath Mountains, Oregon; the Sierra Nevada foothills, California) (Bliss and others, 1987). The deposit densities for these four regions are within 12 percent of their mean of 0.0048 deposits per square kilometer. This mean density when multiplied by the area of the permissive tract gives a predicted mean number of undiscovered deposits of 3.63. The number of known deposits in the tract with grade and tonnage consistent with the deposit model is 1. This was subtracted from the predicted number to obtain a net of 2.63. Using this number as a guide, a geologically reasonable distribution of the number of deposits was selected: at the 90th, 50th, and 10th percentiles, respectively, 1, 3, and 4 or more low-sulfide Au-quartz vein deposits in the tract consistent with the grade and tonnage model of Bliss (1986).

References

- Berger, B.R., 1986, Descriptive model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239.
- Bliss, J.D., 1986, Grade and tonnage model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239–243.
- Bliss, J.D., Menzie, W.D., Orris, G.J., and Page, N.J., 1987, Mineral deposit density—A useful tool for mineral-resource assessment [abs.], *in* Sachs, J.S., ed., USGS research on mineral resources, 1987 program and abstracts, third annual V.E. McKelvey Forum on Mineral and Energy Resources: U.S. Geological Survey Circular 995, p. 6.
- Dean, L.S., 1989, A review of gold mining and exploration in Alabama, *in* Leshner, C.M., Cook, R.B., and Dean, L.S., eds., Gold deposits of Alabama: Geological Survey of Alabama Bulletin 136, p. 1–10.
- Guthrie, G.M., and Leshner, C.M., 1989, Geologic setting of lode gold deposits in the northern Piedmont and Brevard zone, Alabama, *in* Leshner, C.M., Cook, R.B., and Dean, L.S., eds., Gold deposits of Alabama: Geological Survey of Alabama Bulletin 136, p. 11–32.
- Pardee, J.T., and Park, C.F., Jr., 1948, Gold deposits of the southern Piedmont: U.S. Geological Survey Professional Paper 213, 156 p.
- Paris, T.A., 1985, The Goldville project—Results from an exploration project for gold in the northern Alabama Piedmont, *in* Misra, K.C., ed., Volcanogenic sulfide and precious metal mineralization in the southern Appalachians: University of Tennessee, Studies in Geology 16, p. 182–205.

SB01**Skarn Cu Deposits**

California

Descriptive Model 18b • Mark3 Index 8

Area = 11,500 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Steve Ludington, Dennis P. Cox, and Michael F. Diggles**Rationale for Model Choice**

Skarn deposits form where intermediate to felsic intrusive rocks, which are the principal sources of the metals, are emplaced into carbonate rocks. In the Mojave Desert, the deposits are mainly Mesozoic in age.

Rationale for Tract Delineation

The plutons of the southern Basin and Range include Jurassic or Cretaceous felsic rocks that, in places, intrude carbonate rocks, mostly of Paleozoic age. The tract is defined to be those parts of the area underlain by carbonate rocks of any age that are in close proximity to Mesozoic plutons. Some skarns in the New York Mountains may be Proterozoic in age. The Clark Mountains have prominent skarns along their west flank, including Copper World.

Important Examples of Deposit Type

There are 26 known skarn Cu deposits, prospects, and occurrences in the eastern Mojave Desert, most of which are quite small, and none were included as significant deposits in this study. An example is the Copper World deposit from which more than 2,400 metric tons of copper was produced, along with additional Pb, Ag, Au, and Zn.

Rationale for Numerical Estimate

Although no significant deposits of this type are known for the Mojave, the region is permissive in terms of the overall geological environment. Only a few of the known deposits have sizes similar to those that belong to the grade and tonnage models of Jones and Menzie (1986). For the 90th, 50th, and 10th, percentiles, the team estimated 1, 2, and 4 or more skarn Cu deposits consistent with the grade and tonnage model of Jones and Menzie (1986).

References

- Cox, D.P., and Theodore, T.G., 1986, Descriptive model of Cu skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 86.
- Hodges, C.A., and Ludington, Steve, 1991, Quantitative assessment of undiscovered metallic mineral resources in the East Mojave National Scenic Area, southern California: U.S. Geological Survey Open-File Report 91-0551, 18 p.
- Jones, G.M., and Menzie, W.D., 1986, Grade and tonnage model of Cu skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 86-89.
- U.S. Geological Survey, 1991, Evaluation of metallic mineral resources and their geologic controls in the East Mojave National Scenic Area, San Bernardino County, California: U.S. Geological Survey Open-File Report 91-0427, 278 p., 6 plates.

SB02**Skarn Cu Deposits****Nevada****Descriptive Model 18b • Mark3 Index 8****Area = 1,610 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Dennis P. Cox**Rationale for Model Choice**

Although no copper skarn deposits are known in southern Nevada, intrusion of plutons into the widespread carbonate rocks in this area represent permissive conditions for this deposit type.

Rationale for Tract Delineation

Copper skarn deposits can occur where plutons intrude carbonate rocks. Paleozoic sedimentary rocks are hidden by a thin veneer of sediment in many parts of the area. The permissive tract was defined as an area 10 km in radius around all plutons where they intrude Proterozoic and younger carbonate rocks. There are no known deposits or prospects in the tract.

Rationale for Numerical Estimate

Undiscovered copper skarn deposits might exist under cover of Cenozoic rocks and sedimentary deposits, but the likelihood is small because of the limited size of the permissive tract. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 1, and 1 or more deposits consistent with the grade and tonnage model of Jones and Menzie (1986).

Reference

Jones, G.W., and Menzie, W.D., 1986, Grade-tonnage model of Cu skarns, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 86-89.

SB03**Skarn Cu Deposits**

Arizona

Descriptive Model 18b • Mark3 Index 8

Area = 61,700 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* Leslie J. Cox**Rationale for Model Choice**

Copper skarns form where carbonate rocks are intruded by felsic plutons. The model considered here is the simple skarn model as exemplified by Oracle Ridge-Marble Peak. Many copper skarns in Arizona are closely related to large porphyry copper systems and are assigned to a different deposit model (porphyry Cu, skarn-related). Skarn deposits associated with intrusions with Cu grades lower than 0.2 percent were referred to this model (Jones and Menzie, 1986; Mark3 index 8).

Rationale for Tract Delineation

The permissive tract was delineated by modifying the tracts for porphyry Cu deposits, and including Late Cretaceous to early Tertiary muscovite-garnet-bearing peraluminous granite and associated pegmatite (unit TKgm, Reynolds, 1988). We then outlined areas within that modified tract that are known to contain limestone and other carbonate rocks. The tract also includes all pertinent known mineral districts.

Important Examples of Deposit Type

Oracle Ridge (Marble Peak), in the Santa Catalina Mountains, is the most important copper skarn deposit in Arizona. Other deposits are in the Coyote district in the Baboquivari Mountains, the Johnson Camp district (the Mammoth, Burro, and Republic-Cyprus deposits) in the Little Dragoon Mountains, the Helvetia district (Elgin and Copper Chief deposits) of the northern Santa Rita Mountains and the Middle Pass district.

Rationale for Numerical Estimate

In the Middle Pass district alone, there are many small Cu skarn ore bodies, but few would individually make as much as a half million metric tons of ore. We would expect a similar distribution of deposits at depth, however, unexposed deposits of this type are very difficult to explore for. Some estimators felt that 90 percent of the Cu skarns in exposed rocks had been discovered, but at 500 m depth, only 10 percent have been discovered. We arrived at individual probabilities for districts that contain one or more skarn deposits as follows: Middle Pass (0.50), Empire, (0.10), the Turquoise area drilled by Newmont (0.90), the remainder of Turquoise, (0.33), Pima, Redington, Growler, and Apache Pass (0.01 each), and Papago (0.002). These individual probabilities sum to an expected value of about 2 undiscovered deposits in known districts which was used to constrain the lower limit for the 90th percentile estimate. Many more deposits were estimated to occur in the permissive tract at depths between 500 m and 1000 m. For the 90th, 50th, 10th, and 5th percentiles, the team estimated 3, 30, 50, and 60 or more deposits consistent with the grade and tonnage model of Jones and Menzie (1986).

References

- Brant, A.A., 1966, Geophysics in the exploration for Arizona porphyry coppers, *in* Titley, S.R., and Hicks, C.L., eds., *Geology of the porphyry copper deposits*: Tucson, University of Arizona Press, p. 189-203.
- Cox, D.P., and Theodore, T.G., 1986, Descriptive model of Cu skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 86.
- Einaudi, M.T., Meinert, L.D., and Newberry, R.J., 1981, Skarn deposits, *in* Skinner, B.J., ed., *Economic Geology Seventy-Fifth Anniversary Volume, 1905-1980*: Lancaster, Pennsylvania, Economic Geology Publishing Company, p. 317-392.
- Jones, G.M., and Menzie, W.D., 1986, Grade and tonnage model of Cu skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 86-89.
- Reynolds, S.J., 1988, Geologic map of Arizona: Arizona Geological Survey Map 26, scale 1:1,000,000.
- Titley, S.R., and Anthony, E.Y., 1989, Laramide mineral deposits in Arizona *in* Jenney, J.P., and Reynolds, S.J., eds., *Geologic evolution of Arizona*: Tucson, Arizona Geological Society Digest 17, p. 485-514.

SB04**Skarn Cu Deposits****New Mexico****Descriptive Model 18b • Mark3 Index 8****Area = 20,900 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* Steve Ludington**Rationale for Model Choice**

In southwestern New Mexico, copper-rich skarn deposits occur in carbonate rocks adjacent to Laramide intermediate to felsic intrusive rocks that are not related to known porphyry copper deposits.

Rationale for Tract Delineation

Skarn deposits form where intermediate to felsic intrusive rocks, which are the principal sources of the metals, are emplaced into carbonate rocks. Therefore, the permissive tract for Laramide copper skarn deposits is that broad area where Laramide intrusive rocks are coincident with carbonate units. This permissive tract occurs in southwestern New Mexico and is contiguous with the Arizona porphyry copper province.

Important Examples of Deposit Type

The most important copper skarn deposit in southwestern New Mexico is the Continental mine (Richter and Lawrence, 1983).

Rationale for Numerical Estimate

Whereas the permissive area is relatively small, and there is only one known deposit, the team emphasized the substantial area (>50 percent of the tract) of covered permissive rocks. In addition, the area has yielded significant production from porphyry copper and polymetallic deposits of Laramide age. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 1, 2, and 3 or more deposits consistent with the grade and tonnage model for copper skarns of Jones and Menzie (1986).

References cited

- Jones, G.M., and Menzie, W.D., 1986, Grade and tonnage model for Cu skarns, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 86-89.
- Richter, D.H., and Lawrence, V.A., 1978, Mineral deposit map of the Silver City 1°x 2° quadrangle, New Mexico-Arizona: U.S. Geological Survey Miscellaneous Field Investigations Map I-1310-B, scale 1:250,000.

SB05**Skarn Zn-Pb Deposits****New Mexico****Descriptive Model 18c • Mark3 Index 22****Area = 20,900 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Steve Ludington**Rationale for Model Choice**

Southwestern New Mexico contains an important Laramide skarn Zn-Pb deposit, characterized by the replacement of carbonate rocks by calc-silicate minerals and base-metal sulfides.

Rationale for Tract Delineation

Skarn Zn-Pb deposits form where intermediate to felsic intrusive rocks, which are the principal sources of the metals, are emplaced into carbonate rocks. The general rule for delineation of the permissive tract was to exclude all areas that show no evidence for Laramide plutonism. In addition, areas where erosion has left Precambrian igneous and metamorphic rocks exposed at the surface were excluded, as were areas inferred to be covered by surficial deposits thicker than 1 km.

Important Examples of Deposit Type

The Groundhog mine (Meinert, 1987) is an important zinc-lead skarn deposit, and other Laramide plutonic systems could have given rise to concealed skarn deposits.

Rationale for Numerical Estimate

Whereas the permissive area is relatively small, and has only one known deposit, the team placed a major emphasis on productive related deposits in the area and the substantial proportion (>50 percent) of covered permissive rocks. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 1, 2, and 3 or more deposits consistent with the grade and tonnage model of Mosier (1986).

References

- Meinert, L.D., 1987, Skarn zonation and fluid evolution in the Groundhog Mine, Central mining district, New Mexico: *Economic Geology*, v. 82, no. 3, p. 523-545.
- Mosier, D.L., 1986, Grade and tonnage model of Zn-Pb skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 90-93.

SB06**Porphyry Cu Deposits**

California

Descriptive Model 17 • Mark3 Index 4

Area = 70,200 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Dennis P. Cox**Rationale for Model Choice**

Plutons, mainly of Mesozoic age, intrude Precambrian metamorphic and Paleozoic sedimentary rocks in many localities in southeastern California. Porphyry-style alteration and mineralization occurs at the Crescent Peak prospect 7 km to the east of the tract in Nevada and in the northern Ivanpah Mountains (T.G. Theodore, written commun., 1994). A porphyry copper prospect, Red Hill, is known in the Ord Mountains. It contains 3.6 million metric tons of rock that average 0.305 percent copper and 0.155 percent molybdenum in two shear zones cutting granitic rock (U.S. Geological Survey, 1992). Large alteration zones in the Mojave mining district may indicate a buried porphyry copper system.

Rationale for Tract Delineation

The permissive tract is a nearly continuous area marked by small plutons that intrude Precambrian metamorphic and Paleozoic sedimentary rocks. Small areas covered by basin fill more than 1 km in depth are excluded.

Rationale for Numerical Estimate

For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 2, and 3 or more porphyry copper deposits consistent with the grade and tonnage model of Singer and others (1986) (Mark3 index 4). This estimate was guided by the combination of estimates for the West Mojave Management Area (U.S. Geological Survey, 1992) and East Mojave National Scenic Area (Hodges and Ludington, 1991).

References

- Hodges, C.A., and Ludington, Steve, 1991, Quantitative assessment of undiscovered metallic mineral resources in the East Mojave National Scenic Area, southern California: U.S. Geological Survey Open-File Report 91-0551, 18 p.
- Singer, D.A., Mosier, D.L., and Cox, D.P., 1986, Grade-tonnage model of porphyry copper, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 77-81.
- U.S. Geological Survey, 1992, Evaluation of selected metallic and nonmetallic mineral resources, West Mojave Management Area, southern California: U.S. Geological Survey Open-File Report 92-595, 89 p.

SB07**Porphyry Cu Deposits****Nevada****Descriptive Model 17 • Mark3 Index 4****Area = 4,680 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Dennis P. Cox**Rationale for Model Choice**

The association of base- and precious-metal vein and replacement deposits with Mesozoic plutons suggests a favorable environment for porphyry copper deposits. No well defined examples are known, but alteration and mineralization that strongly resembles a porphyry system was described by Longwell and others (1965) around a Cretaceous pluton at Crescent Peak.

Rationale for Tract Delineation

High-level plutons and their sedimentary and volcanic country rocks are permissive for porphyry copper deposits. The permissive tract includes a 10 km-wide area around all Mesozoic plutons.

Rationale for Numerical Estimate

We estimate that there is a 10 percent chance that the Crescent Peak prospect has sufficient tonnage and grade to be classed as a deposit consistent with the grade and tonnage model of Singer and others (1986). For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 1, 1, and 2 or more deposits consistent with that model.

References

- Singer, D.A., Mosier, D.L., and Cox, D.P., 1986, Grade-tonnage model of porphyry copper, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 77-81.
- Longwell, C.R., Pampeyan, B.B., and Roberts, R.J., 1965, Geology and mineral deposits of Clark County, Nevada: Nevada Bureau of Mines and Geology Bulletin 62, 218 p.

SB08**Porphyry Cu Deposits****Nevada****Descriptive Model 17 • Mark3 Index 4****Area = 4,680 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Dennis P. Cox**Rationale for Model Choice**

Tertiary andesite that is intruded by high-level plutons and accompanied by areas of widespread alunite alteration is a favorable scenario for porphyry copper deposits (Wallace, 1979; Hudson, 1983). Alunite alteration occurs in the Alunite district (Longwell and others, 1965) near Boulder City and may represent the uppermost extent of a porphyry system. Polymetallic veins of the Searchlight district are weakly suggestive of the presence of a porphyry system.

Rationale for Tract Delineation

Tertiary volcanic rocks and plutons and their inferred subsurface extent define the permissive tract. Small areas covered by basin fill more than 1 km in depth are excluded.

Rationale for Numerical Estimate

Because of the rarity of porphyry mineralization of Tertiary age in southern Nevada and bordering States, our estimate is low. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 1, and 2 or more deposits consistent with the grade and tonnage model of Singer and others (1986).

References

- Hudson, D.M., 1983, Alteration and geochemical characteristics of the upper parts of selected porphyry systems, Western Nevada: Reno, University of Nevada, unpub. Ph.D. dissertation, 229 p.
- Wallace, A.B., 1979, Possible signatures of buried porphyry copper deposits in middle to late Tertiary volcanic rocks of Western Nevada, *in* Ridge, J.D., ed., Proceedings of the Fifth Quadrennial IAGOD Symposium: Reno, University of Nevada, Mackay School of Mines, v. 2, p. 69-76.
- Singer, D.A., Mosier, D.L., and Cox, D.P., 1986, Grade-tonnage model of porphyry copper, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 77-81.

SB09**Porphyry Cu Deposits****Arizona****Descriptive Model 17 • Mark3 Index 4****Area = 12,400 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* Leslie J. Cox**Rationale for Model Choice**

The choice of the worldwide porphyry-copper model of Cox (1986) to assess for porphyry copper deposits in Arizona was based on the close fit between geological and mineralogical features of the known Arizona deposits (Titley, 1982) and the description of the deposit model. Of 208 deposits located worldwide, 32 deposits are in Arizona. Most of the porphyry stocks in Arizona that are considered to be the source of large copper ore bodies were probably emplaced in the cores of voluminous fields of andesitic-dacitic to rhyolitic volcanic rocks erupted during Laramide time (Titley and Anthony, 1989).

Rationale for Tract Delineation

The permissive terrane delineated for the Arizona part of the Southern Basin and Range province includes all volcanic and igneous rocks of Jurassic and younger ages as identified on Reynolds' (1988) geologic map of Arizona with the exception of the Early Tertiary to Late Cretaceous muscovite-garnet-bearing peraluminous granites. Igneous rocks of Jurassic age are included because the Bisbee deposit is Jurassic; igneous rocks of the Laramide age are included because almost all of the known porphyry copper deposits in Arizona are generally associated with porphyritic intrusions of the Laramide calc-alkaline series; and igneous rocks of Tertiary age are included because deposits outside of Arizona are associated with Tertiary intrusions.

Areas extending 10 km outward from the Mesozoic and Tertiary plutons, as identified on the geologic maps of Reynolds (1988) and Keith (1984), are also included in the permissive terrane with the following exclusions: areas in which the bedrock is under more than 1 km of cover using a geophysical depth-to-bedrock map for which bedrock was defined as being middle Miocene or older (Oppenheimer and Sumner, 1980). A geophysical depth-to-bedrock map for which bedrock was defined as being Laramide or older (Saltus, 1991) was used to identify covered areas unfavorable for the occurrence of porphyry copper deposits, but these areas were not excluded from the permissive terrane.

The permissive terrane also includes areas where magnetic and gravity expressions indicate shallowly buried permissive bedrock (M.E. Gettings, written commun., 1993), known deposits and districts of this and associated models, and all areas identified in previous U.S. Geological Survey mineral assessments such as for U.S. Bureau of Land Management Wilderness Study Areas and CUSMAP (W.S. Updegrove and M.F. Diggles, written commun., 1993).

Titley and Anthony (1989) defined geologic terranes in Arizona on the basis of underlying basement rocks. This tract is the subset of permissive terrane in Arizona within their subdivision IV, the Granite-Gneiss Terrane.

Important Examples of Deposit Type

The single major deposit in the tract is the Mineral Park porphyry Cu-Mo deposit in the Wallapai district (Wilkinson and others, 1982).

Rationale for Numerical Estimate

Information supplied to the team included the State geologic map (Reynolds, 1988); mylar overlays emphasizing the distributions of igneous rocks of Jurassic, Laramide, and middle Tertiary ages (Keith, 1984, and Reynolds, 1988); deep cover as identified by gravity studies for which basement was defined as middle Tertiary (Oppenheimer and Sumner, 1980), and as Laramide (Saltus, 1991); magnetic anomalies (Gettings, written commun., 1991); distribution of anomalies of Sb, Ag, As, Mo, Cu, Pb, and Zn (S.E. Church, written commun., 1993); and the distribution of known deposits (Keith and others, 1983a, and MRDS), all at the scale of 1:1,000,000. In general, consideration was given to the fact that exploration activity in Arizona in the 1960s and 1970s led to the discovery of many new porphyry copper deposits. The team concluded that some areas should be re-examined in light of discoveries about Arizona tectonics in the last 18 years. Some team members felt that some of the districts of middle Tertiary age, particularly in the southeast part of the State, should also be re-examined.

This tract contains one known porphyry copper deposit and three other mineral districts classified 1a (copper and porphyry) by Keith and others (1983a); all have Laramide ages. It was also noted that there are 30 other metallic mineral districts within this tract that are middle Tertiary in age according to Keith and others (1983a). Estimators noted that fewer porphyry copper deposits, geophysical extensions of Laramide rock beneath cover, and geochemical anomalies occur in this tract than in eastern Arizona.

The estimators thought that nearly all exposed systems have been discovered and that most of the undiscovered deposits are hidden under cover. We attempted to determine the deposit density beneath shallow cover. We assumed that the maximum number of deposits beneath cover would be equal to the number of known porphyry copper deposits in exposed areas times a multiplier: the ratio of the area of shallow cover to the area of exposed rock. In an early stage of the assessment, before we divided southern Arizona into six permissive tracts, we had estimated the ratio of shallow cover to exposed favorable rock in the southern half of the State to be about 2.8, where shallow cover was defined as rocks of middle Tertiary and younger ages 0–1 km thick and the area of favorable exposed rocks was defined as the area 2.5 km beyond and including all igneous rocks of Laramide and Jurassic ages. The definitions of exposed rock and cover were made with the expectation that the undiscovered deposits would have Laramide or older ages. This expectation conflicts somewhat with the parameters used to draw the permissive tract, which allow for the possibility of undiscovered porphyry copper deposits of middle Tertiary age. In retrospect, the construction of separate tracts, one for undiscovered Laramide and one for undiscovered Tertiary deposits, would have facilitated more accurate estimations of deposit densities. The deposit density multiplier determined for all of southern Arizona was understood to be a very crude guideline, to be adjusted in accord with how similar the rocks beneath cover might be to the rock exposed in each tract. Most estimators reduced the guideline multiplier by more than half for this tract where only about one-third of the exposed rocks are considered favorable and the gravity maps of Saltus (1991) show that nearly 10 percent of the shallow cover would be deep cover (>1 km thick) if basement was defined as Laramide rather than as middle Tertiary.

For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 1, 2, 2, and 3 or more deposits consistent with the grade and tonnage model of Singer and others (1986).

References

- Cox, D.P., 1986, Descriptive model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 76.
- Keith, S.B., 1984, Map of outcrops of Laramide (Cretaceous-Tertiary) rocks in Arizona and adjacent regions: Arizona Bureau of Geology and Mineral Technology Map 19, 1:1,000,000.

- Keith, S.B., Gest, D.E., and DeWitt, Ed, 1983a, Metallic mineral districts of Arizona: Arizona Bureau of Geology and Mineral Technology Map 18, scale 1:1,000,000.
- Keith, S.B., Schnabel, Lorraine, DeWitt, Ed, Gest, D.E., and Wilt, Jan, 1983b, Map, description and bibliography of the mineralized areas of the Basin and Range province in Arizona: U.S. Geological Survey Open-File Report 84-0086, 129 p.
- Oppenheimer, J.M., and Sumner, J.S., 1980, Depth-to-bedrock map, Basin and Range province, Arizona: Tucson, University of Arizona, Laboratory of Geophysics.
- Reynolds, S.J., 1988, Geologic map of Arizona: Arizona Geological Survey Map 26, scale 1:1,000,000.
- Saltus, R.W., 1991, Gravity and heat flow constraints on Cenozoic tectonics of the Western United States cordillera: Stanford University, Ph.D. dissertation, 245 p., 66 figs.
- Singer, D.A., Mosier, D.L., and Cox, D.P., 1986, Grade and tonnage model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 77-81.
- Titely, S.R., 1982, The style and progress of mineralization and alteration and alteration in porphyry copper systems, *in* Titely, S.R., ed., Advances in geology of the porphyry copper deposits: Tucson, University of Arizona Press, p. 93-116.
- Titely, S.R., and Anthony, E.Y., 1989, Laramide mineral deposits in Arizona *in* Jenney, J.P., and Reynolds, S.J., eds., Geologic evolution of Arizona: Tucson, Arizona Geological Society Digest 17, p. 485-514.
- U.S. Bureau of Mines, 1993, The mineral industry of Arizona in 1992: Washington, D.C., U.S. Bureau of Mines, Mineral Industry Surveys, 4 p.
- Wilkinson, W.H., Jr., Vega, L.A., and Titely, S.R., 1982 Geology and ore deposits at Mineral Park, Mohave County, Arizona, *in* Titely, S.R., ed., Advances in geology of the porphyry copper deposits: Tucson, University of Arizona Press, p. 523-542.

SB10**Porphyry Cu Deposits**

Arizona

Descriptive Model 17 • Mark3 Index 4

Area = 9,620 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Leslie J. Cox

Rationale for Model Choice

The choice of the worldwide porphyry-copper model of Cox (1986) to assess for porphyry copper deposits in Arizona was based on the close fit between geological and mineralogical features of the known Arizona deposits (Titley, 1982) and the description of the deposit model. Of 208 deposits located world-wide, 32 deposits are in Arizona. Most of the porphyry stocks in Arizona that are considered to be the source of large copper ore bodies were probably emplaced in the cores of voluminous fields of andesitic-dacitic to rhyolitic volcanic rocks erupted during Laramide time (Titley and Anthony, 1989).

Rationale for Tract Delineation

The permissive terrane delineated for the Arizona part of the Southern Basin and Range province includes all volcanic and igneous rocks of Jurassic and younger ages as identified on Reynolds' (1988) geologic map of Arizona with the exception of the Early Tertiary to Late Cretaceous muscovite-garnet-bearing peraluminous granites. Igneous rocks of Jurassic age are included because the Bisbee deposit is Jurassic; igneous rocks of the Laramide age are included because almost all of the known porphyry copper deposits in Arizona are generally associated with porphyritic intrusions of the Laramide calc-alkaline series; and igneous rocks of Tertiary age are included because deposits outside of Arizona are associated with Tertiary intrusions.

Areas extending 10 km outward from the Mesozoic and Tertiary plutons, as identified on the geologic maps of Reynolds (1988) and Keith (1984), are also included in the permissive terrane with the following exclusions: areas in which the bedrock is under more than 1 km of cover using a geophysical depth-to-bedrock map for which bedrock was defined as being middle Miocene or older (Oppenheimer and Sumner, 1980). A geophysical depth-to-bedrock map for which bedrock was defined as being Laramide or older (Saltus, 1991) was used to identify covered areas unfavorable for the occurrence of porphyry copper deposits, but these areas were not excluded from the permissive terrane.

The permissive terrane also includes areas where magnetic and gravity expressions indicate shallowly buried permissive bedrock (M.E. Gettings, written commun., 1993), known deposits and districts of this and associated models, and all areas identified in previous U.S. Geological Survey mineral assessments such as for U.S. Bureau of Land Management Wilderness Study Areas and CUSMAP (W.S. Updegrove and M.F. Diggles, written commun., 1993).

Titley and Anthony (1989) defined geologic terranes in Arizona on the basis of underlying basement rocks. This tract is the subset of permissive terrane in Arizona within their subdivision III, the Yavapai Terrane.

Important Examples of Deposit Type

The largest deposit in the tract is Bagdad (Anderson and others, 1955). Copper Basin is a smaller deposit, and Sheep Mountain is a prospect.

Rationale for Numerical Estimate

Information supplied to the team included the State geologic map (Reynolds, 1988); mylar overlays emphasizing the distributions of igneous rocks of Jurassic, Laramide, and middle Tertiary ages (Keith, 1984, and Reynolds, 1988); deep cover as identified by gravity studies for which basement was defined as middle Tertiary (Oppenheimer and Sumner, 1980), and as Laramide (Saltus, 1991); magnetic anomalies (Gettings, written commun., 1991); distribution of anomalies of Sb, Ag, As, Mo, Cu, Pb, and Zn (S.E. Church, written commun., 1993); and the distribution of known deposits (Keith and others, 1983a, and MRDS), all at the scale of 1:1,000,000. In general, consideration was given to the fact that exploration activity in Arizona in the 1960s and 1970s led to the discovery of many new porphyry copper deposits. The team concluded that some areas should be re-examined in light of discoveries about Arizona tectonics in the last 18 years. Some team members felt that some of the districts of middle Tertiary age, particularly in the southeast part of the State, should also be re-examined.

This tract contains three known porphyry copper deposits and six other mineral districts classified 1a (copper and porphyry) by Keith and others (1983a); all but one fall within districts having Laramide ages; Keith and others (1983a) list the Castle Creek district, the location of the Sheep Mountain porphyry copper deposit, as middle Tertiary in age. In addition, there are 21 other middle Tertiary metallic mineral districts according to Keith and others (1983a). Estimators noted that fewer porphyry copper deposits, geophysical extensions of Laramide rock beneath cover, and geochemical anomalies occur in this tract than in eastern Arizona.

The estimators thought that nearly all exposed systems have been discovered and that most of the undiscovered deposits are hidden under cover. We attempted to determine the deposit density beneath shallow cover. We assumed that the maximum number of deposits beneath cover would be equal to the number of known porphyry copper deposits in exposed areas times a multiplier: the ratio of the area of shallow cover to the area of exposed rock. In an early stage of the assessment, before we divided southern Arizona into six permissive tracts, we had estimated the ratio of shallow cover to exposed favorable rock in the southern half of the State to be about 2.8, where shallow cover was defined as rocks of middle Tertiary and younger ages 0–1 km thick and the area of favorable exposed rocks was defined as the area 2.5 km beyond and including all igneous rocks of Laramide and Jurassic ages. The definitions of exposed rock and cover were made with the expectation that the undiscovered deposits would have Laramide or older ages. This expectation conflicts somewhat with the parameters used to draw the permissive tract, which allow for the possibility of undiscovered porphyry copper deposits of middle Tertiary age. In retrospect, the construction of separate tracts, one for undiscovered Laramide and one for undiscovered Tertiary deposits, would have facilitated more accurate estimations of deposit densities. The deposit density multiplier determined for all of southern Arizona was understood to be a very crude guideline, to be adjusted in accord with how similar the rocks beneath cover might be to the rock exposed in each tract. Most estimators reduced the guideline multiplier by about half for this tract where about half of the exposed rocks are considered favorable and the gravity maps of Saltus (1991) show that an insignificant amount of the shallow cover would be deep cover (>1 km thick) if basement was defined as Laramide rather than as middle Tertiary.

For the 90th, 50th, 10th, and 5th percentiles, the team estimated 1, 2, 5, and 10 or more deposits consistent with the grade and tonnage model of Singer and others (1986).

References

Anderson, C.A., Scholz, E.A., and Strobell, J.D., Jr., 1955, Geology and ore deposits of the Bagdad area, Yavapai County, Arizona: U.S. Geological Survey Professional Paper 278, 103 p.

- Cox, D.P., 1986, Descriptive model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 76.
- Keith, S.B., 1984, Map of outcrops of Laramide (Cretaceous-Tertiary) rocks in Arizona and adjacent regions: Arizona Bureau of Geology and Mineral Technology Map 19, 1:1,000,000.
- Keith, S.B., Gest, D.E., and DeWitt, Ed, 1983a, Metallic mineral districts of Arizona: Arizona Bureau of Geology and Mineral Technology Map 18, scale 1:1,000,000.
- Keith, S.B., Schnabel, Lorraine, DeWitt Ed, Gest, D.E., and Wilt, Jan, 1983b, Map, description and bibliography of the mineralized areas of the Basin and Range province in Arizona: U.S. Geological Survey Open-File Report 84-0086, 129 p.
- Oppenheimer, J.M., and Sumner, J.S., 1980, Depth-to-bedrock map, Basin and Range province, Arizona: Tucson, University of Arizona, Laboratory of Geophysics.
- Reynolds, S.J., 1988, Geologic map of Arizona: Arizona Geological Survey Map 26, scale 1:1,000,000.
- Saltus, R.W., 1991, Gravity and heat flow constraints on Cenozoic tectonics of the Western United States cordillera: Stanford University, Ph.D. dissertation, 245 p., 66 figs.
- Singer, D.A., Mosier, D.L., and Cox, D.P., 1986, Grade and tonnage model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 77-81.
- Titley, S.R., 1982, The style and progress of mineralization and alteration and alteration in porphyry copper systems, *in* Titley, S.R., ed., Advances in geology of the porphyry copper deposits: Tucson, University of Arizona Press, p. 93-116.
- Titley, S.R., and Anthony, E.Y., 1989, Laramide mineral deposits in Arizona, *in* Jenney, J.P., and Reynolds, S.J., eds., Geologic evolution of Arizona: Tucson, Arizona Geological Society Digest 17, p. 485-514.
- U.S. Bureau of Mines, 1993, The mineral industry of Arizona in 1992: Washington, D.C., U.S. Bureau of Mines, Mineral Industry Surveys, 4 p.

SB11**Porphyry Cu Deposits****Arizona****Descriptive Model 17 • Mark3 Index 4****Area = 29,900 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Leslie J. Cox**Rationale for Model Choice**

The choice of the worldwide porphyry-copper model of Cox (1986) to assess for porphyry copper deposits in Arizona was based on the close fit between geological and mineralogical features of the known Arizona deposits (Titley, 1982) and the description of the deposit model. Of 208 deposits located world-wide, 32 deposits are in Arizona. Most of the porphyry stocks in Arizona that are considered to be the source of large copper ore bodies were probably emplaced in the cores of voluminous fields of andesitic-dacitic to rhyolitic volcanic rocks erupted during Laramide time (Titley and Anthony, 1989).

Rationale for Tract Delineation

The permissive terrane delineated for the Arizona part of the Southern Basin and Range province includes all volcanic and igneous rocks of Jurassic and younger ages as identified on Reynolds' (1988) geologic map of Arizona with the exception of the Early Tertiary to Late Cretaceous muscovite-garnet-bearing peraluminous granites. Igneous rocks of Jurassic age are included because the Bisbee deposit is Jurassic; igneous rocks of the Laramide age are included because almost all of the known porphyry copper deposits in Arizona are generally associated with porphyritic intrusions of the Laramide calc-alkaline series; and igneous rocks of Tertiary age are included because deposits outside of Arizona are associated with Tertiary intrusions.

Areas extending 10 km outward from the Mesozoic and Tertiary plutons, as identified on the geologic maps of Reynolds (1988) and Keith (1984), are also included in the permissive terrane with the following exclusions: areas in which the bedrock is under more than 1 km of cover using a geophysical depth-to-bedrock map for which bedrock was defined as being middle Miocene or older (Oppenheimer and Sumner, 1980). A geophysical depth-to-bedrock map for which bedrock was defined as being Laramide or older (Saltus, 1991) was used to identify covered areas unfavorable for the occurrence of porphyry copper deposits, but these areas were not excluded from the permissive terrane.

The permissive terrane also includes areas where magnetic and gravity expressions indicate shallowly buried permissive bedrock (M.E. Gettings, written commun., 1993), known deposits and districts of this and associated models, and all areas identified in previous U.S. Geological Survey mineral assessments such as for U.S. Bureau of Land Management Wilderness Study Areas and CUSMAP (W.S. Updegrove and M.F. Diggles, written commun., 1993).

Titley and Anthony (1989) defined geologic terranes in Arizona on the basis of underlying basement rocks. This tract is the subset of permissive terrane in Arizona within their subdivision V, the Mesozoic Terrane of the Western Desert.

Important Examples of Deposit Type

There are no major deposits in the tract. The lesser extent of Laramide rocks under cover indicated by geophysical evidence suggests that there are only a small number of undiscovered deposits here as well.

Rationale for Numerical Estimate

Information supplied to the team included the State geologic map (Reynolds, 1988); mylar overlays emphasizing the distributions of igneous rocks of Jurassic, Laramide, and middle Tertiary ages (Keith, 1984, and Reynolds, 1988); deep cover as identified by gravity studies for which basement was defined as middle Tertiary (Oppenheimer and Sumner, 1980), and as Laramide (Saltus, 1991); magnetic anomalies (Gettings, written commun., 1991); distribution of anomalies of Sb, Ag, As, Mo, Cu, Pb, and Zn (S.E. Church, written commun., 1993); and the distribution of known deposits (Keith and others, 1983a, and MRDS), all at the scale of 1:1,000,000. In general, consideration was given to the fact that exploration activity in Arizona in the 1960s and 1970s led to the discovery of many new porphyry copper deposits. The team concluded that some areas should be re-examined in light of discoveries about Arizona tectonics in the last 18 years. Some team members felt that some of the districts of middle Tertiary age, particularly in the southeast part of the State, should also be re-examined.

This tract contains only three mineral districts classified 1a (copper and porphyry) by Keith and others (1983a); two have Laramide ages and the other a queried Laramide age. There was much uncertainty about the number, size, and characteristics of deposits in the 1a districts. In addition, there are at least 40 other metallic mineral districts within this tract that are middle Tertiary in age (Keith and others, 1983a). Estimators noted that geophysical extensions of Laramide rock beneath cover and geochemical anomalies are fewer here than in the rest of Arizona.

The estimators thought that nearly all exposed systems have been discovered and that most of the undiscovered deposits are hidden under cover. We attempted to determine the deposit density beneath shallow cover. We assumed that the maximum number of deposits beneath cover would be equal to the number of known porphyry copper deposits in exposed areas times a multiplier: the ratio of the area of shallow cover to the area of exposed rock. In an early stage of the assessment, before we divided southern Arizona into six permissive tracts, we had estimated the ratio of shallow cover to exposed favorable rock in the southern half of the State to be about 2.8, where shallow cover was defined as rocks of middle Tertiary and younger ages 0–1 km thick and the area of favorable exposed rocks was defined as the area 2.5 km beyond and including all igneous rocks of Laramide and Jurassic ages. The definitions of exposed rock and cover were made with the expectation that the undiscovered deposits would have Laramide or older ages. This expectation conflicts somewhat with the parameters used to draw the permissive tract, which allow for the possibility of undiscovered porphyry copper deposits of middle Tertiary age. In retrospect, the construction of separate tracts, one for undiscovered Laramide and one for undiscovered Tertiary deposits, would have facilitated more accurate estimations of deposit densities.

The deposit density multiplier determined for all of southern Arizona was understood to be a very crude guideline, to be adjusted in accord with how similar the rocks beneath cover might be to the rock exposed in each tract. Most estimators reduced the guideline multiplier by about half for this tract where more than half of the exposed rocks are considered favorable and the gravity maps of Saltus (1991) show that more than 10 percent of the shallow cover would be deep cover (>1 km thick) if basement was defined as Laramide rather than as middle Tertiary.

For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 1, 2, and 5 or more deposits consistent with the grade and tonnage model of Singer and others (1986).

References

Cox, D.P., 1986, Descriptive model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 76.

- Keith, S.B., 1984, Map of outcrops of Laramide (Cretaceous-Tertiary) rocks in Arizona and adjacent regions: Arizona Bureau of Geology and Mineral Technology Map 19, 1:1,000,000.
- Keith, S.B., Gest, D.E., and DeWitt, Ed, 1983a, Metallic mineral districts of Arizona: Arizona Bureau of Geology and Mineral Technology Map 18, scale 1:1,000,000.
- Keith, S.B., Schnabel, Lorraine, DeWitt Ed, Gest, D.E., and Wilt, Jan, 1983b, Map, description and bibliography of the mineralized areas of the Basin and Range province in Arizona: U.S. Geological Survey Open-File Report 84-0086, 129 p.
- Oppenheimer, J.M., and Sumner, J.S., 1980, Depth-to-bedrock map, Basin and Range province, Arizona: Tucson, University of Arizona, Laboratory of Geophysics.
- Reynolds, S.J., 1988, Geologic map of Arizona: Arizona Geological Survey Map 26, scale 1:1,000,000.
- Saltus, R.W., 1991, Gravity and heat flow constraints on Cenozoic tectonics of the Western United States cordillera: Stanford University, Ph.D. dissertation, 245 p., 66 figs.
- Singer, D.A., Mosier, D.L., and Cox, D.P., 1986, Grade and tonnage model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 77-81.
- Titely, S.R., 1982, The style and progress of mineralization and alteration and alteration in porphyry copper systems, *in* Titely, S.R., ed., Advances in geology of the porphyry copper deposits: Tucson, University of Arizona Press, p. 93-116.
- Titely, S.R., and Anthony, E.Y., 1989, Laramide mineral deposits in Arizona *in* Jenney, J.P., and Reynolds, S.J., eds., Geologic evolution of Arizona: Tucson, Arizona Geological Society Digest 17, p. 485-514.
- U.S. Bureau of Mines, 1993, The mineral industry of Arizona in 1992: Washington, D.C., U.S. Bureau of Mines, Mineral Industry Surveys, 4 p.

SB12**Porphyry Cu Deposits****Arizona****Descriptive Model 17****Area = 2,400 km²**[Model](#)*by* Leslie J. Cox**Rationale for Model Choice**

The choice of the worldwide porphyry-copper model of Cox (1986) to assess for porphyry copper deposits in Arizona was based on the close fit between geological and mineralogical features of the known Arizona deposits (Titley, 1982) and the description of the deposit model. Of 208 deposits located world-wide, 32 deposits are in Arizona. Most of the porphyry stocks in Arizona that are considered to be the source of large copper ore bodies were probably emplaced in the cores of voluminous fields of andesitic-dacitic to rhyolitic volcanic rocks erupted during Laramide time (Titley and Anthony, 1989).

Rationale for Tract Delineation

The permissive terrane delineated for the Arizona part of the Southern Basin and Range province includes all volcanic and igneous rocks of Jurassic and younger ages as identified on Reynolds' (1988) geologic map of Arizona with the exception of the Early Tertiary to Late Cretaceous muscovite-garnet-bearing peraluminous granites. Igneous rocks of Jurassic age are included because the Bisbee deposit is Jurassic; igneous rocks of the Laramide age are included because almost all of the known porphyry copper deposits in Arizona are generally associated with porphyritic intrusions of the Laramide calc-alkaline series; and igneous rocks of Tertiary age are included because deposits outside of Arizona are associated with Tertiary intrusions.

Areas extending 10 km outward from the Mesozoic and Tertiary plutons, as identified on the geologic maps of Reynolds (1988) and Keith (1984), are also included in the permissive terrane with the following exclusions: areas in which the bedrock is under more than 1 km of cover using a geophysical depth-to-bedrock map for which bedrock was defined as being middle Miocene or older (Oppenheimer and Sumner, 1980). A geophysical depth-to-bedrock map for which bedrock was defined as being Laramide or older (Saltus, 1991) was used to identify covered areas unfavorable for the occurrence of porphyry copper deposits, but these areas were not excluded from the permissive terrane.

The permissive terrane also includes areas where magnetic and gravity expressions indicate shallowly buried permissive bedrock (M.E. Gettings, written commun., 1993), known deposits and districts of this and associated models, and all areas identified in previous U.S. Geological Survey mineral assessments such as for U.S. Bureau of Land Management Wilderness Study Areas and CUSMAP (W.S. Updegrove and M.F. Diggles, written commun., 1993).

Titley and Anthony (1989) defined geologic terranes in Arizona on the basis of underlying basement rocks. This tract is the subset of permissive terrane in Arizona within their subdivision II, the Mazatzal Terrane.

Important Examples of Deposit Type

There are no major deposits in the tract.

Rationale for Numerical Estimate

Information supplied to the team included the State geologic map (Reynolds, 1988); mylar overlays emphasizing the distributions of igneous rocks of Jurassic, Laramide, and middle Tertiary ages (Keith, 1984, and Reynolds, 1988); deep cover as identified by gravity studies for which basement was defined as middle Tertiary (Oppenheimer and Sumner, 1980), and as Laramide (Saltus, 1991); magnetic anomalies (Gettings, written commun., 1991); distribution of anomalies of Sb, Ag, As, Mo, Cu, Pb, and Zn (S.E. Church, written commun., 1993); and the distribution of known deposits (Keith and others, 1983a, and MRDS), all at the scale of 1:1,000,000. In general, consideration was given to the fact that exploration activity in Arizona in the 1960s and 1970s led to the discovery of many new porphyry copper deposits. The team concluded that some areas should be re-examined in light of discoveries about Arizona tectonics in the last 18 years. Some team members felt that some of the districts of middle Tertiary age, particularly in the southeast part of the State, should also be re-examined.

Because this tract contains no known porphyry copper deposits, no metallic mineral deposits of Laramide age, and very few middle Tertiary and younger metallic mineral deposits, the team decided that the probable number of undiscovered deposits in this tract was very low and made no estimate.

References

- Cox, D.P., 1986, Descriptive model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 76.
- Keith, S.B., 1984, Map of outcrops of Laramide (Cretaceous-Tertiary) rocks in Arizona and adjacent regions: Arizona Bureau of Geology and Mineral Technology Map 19, 1:1,000,000.
- Keith, S.B., Gest, D.E., and DeWitt, Ed, 1983a, Metallic mineral districts of Arizona: Arizona Bureau of Geology and Mineral Technology Map 18, scale 1:1,000,000.
- Keith, S.B., Schnabel, Lorraine, DeWitt, Ed, Gest, D.E., and Wilt, Jan, 1983b, Map, description and bibliography of the mineralized areas of the Basin and Range province in Arizona: U.S. Geological Survey Open-File Report 84-0086, 129 p.
- Oppenheimer, J.M., and Sumner, J.S., 1980, Depth-to-bedrock map, Basin and Range province, Arizona: Tucson, Ariz., University of Arizona, Laboratory of Geophysics.
- Reynolds, S.J., 1988, Geologic map of Arizona: Arizona Geological Survey Map 26, scale 1:1,000,000.
- Saltus, R.W., 1991, Gravity and heat flow constraints on Cenozoic tectonics of the Western United States cordillera: Stanford University, Ph.D. dissertation, 245 p., 66 figs.
- Singer, D.A., Mosier, D.L., and Cox, D.P., 1986, Grade and tonnage model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 77-81.
- Titley, S.R., 1982, The style and progress of mineralization and alteration and alteration in porphyry copper systems, *in* Titley, S.R., ed., Advances in geology of the porphyry copper deposits: Tucson, University of Arizona Press, p. 93-116.
- Titley, S.R., and Anthony, E.Y., 1989, Laramide mineral deposits in Arizona *in* Jenney, J.P., and Reynolds, S.J., eds., Geologic evolution of Arizona: Tucson, Arizona Geological Society Digest 17, p. 485-514.
- U.S. Bureau of Mines, 1993, The mineral industry of Arizona in 1992: Washington, D.C., U.S. Bureau of Mines, Mineral Industry Surveys, 4 p.

SB13**Porphyry Cu Deposits****Arizona****Descriptive Model 17 • Mark3 Index 4****Area = 24,800 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* Leslie J. Cox**Rationale for Model Choice**

The choice of the worldwide porphyry-copper model of Cox (1986) to assess for porphyry copper deposits in Arizona was based on the close fit between geological and mineralogical features of the known Arizona deposits (Titley, 1982) and the description of the deposit model. Of 208 deposits located world-wide, 32 deposits are in Arizona. Most of the porphyry stocks in Arizona that are considered to be the source of large copper ore bodies were probably emplaced in the cores of voluminous fields of andesitic-dacitic to rhyolitic volcanic rocks erupted during Laramide time (Titley and Anthony, 1989).

Rationale for Tract Delineation

The permissive terrane delineated for the Arizona part of the Southern Basin and Range province includes all volcanic and igneous rocks of Jurassic and younger ages as identified on Reynolds' (1988) geologic map of Arizona with the exception of the Early Tertiary to Late Cretaceous muscovite-garnet-bearing peraluminous granites. Igneous rocks of Jurassic age are included because the Bisbee deposit is Jurassic; igneous rocks of the Laramide age are included because almost all of the known porphyry copper deposits in Arizona are generally associated with porphyritic intrusions of the Laramide calc-alkaline series; and igneous rocks of Tertiary age are included because deposits outside of Arizona are associated with Tertiary intrusions.

Areas extending 10 km outward from the Mesozoic and Tertiary plutons, as identified on the geologic maps of Reynolds (1988) and Keith (1984), are also included in the permissive terrane with the following exclusions: areas in which the bedrock is under more than 1 km of cover using a geophysical depth-to-bedrock map for which bedrock was defined as being middle Miocene or older (Oppenheimer and Sumner, 1980). A geophysical depth-to-bedrock map for which bedrock was defined as being Laramide or older (Saltus, 1991) was used to identify covered areas unfavorable for the occurrence of porphyry copper deposits, but these areas were not excluded from the permissive terrane.

The permissive terrane also includes areas where magnetic and gravity expressions indicate shallowly buried permissive bedrock (M.E. Gettings, written commun., 1993), known deposits and districts of this and associated models, and all areas identified in previous U.S. Geological Survey mineral assessments such as for U.S. Bureau of Land Management Wilderness Study Areas and CUSMAP (W.S. Updegrove and M.F. Diggles, written commun., 1993).

Titley and Anthony (1989) defined geologic terranes in Arizona on the basis of underlying basement rocks. This tract is the subset of permissive terrane in Arizona within the western part of their subdivision I, the Pinal-Paleozoic Terrane.

Important Examples of Deposit Type

Major deposits in the tract include Casa Grande West, Florence, Lake Shore, Mineral Butte, Mission-Pima-San Xavier, Silver Bell, Sacaton, Vekol Hills, Sierrita-Esperanza, and Twin Buttes.

Rationale for Numerical Estimate

Information supplied to the team included the State geologic map (Reynolds, 1988); mylar overlays emphasizing the distributions of igneous rocks of Jurassic, Laramide, and middle Tertiary ages (Keith, 1984, and Reynolds, 1988); deep cover as identified by gravity studies for which basement was defined as middle Tertiary (Oppenheimer and Sumner, 1980), and as Laramide (Saltus, 1991); magnetic anomalies (Gettings, written commun., 1991); distribution of anomalies of Sb, Ag, As, Mo, Cu, Pb, and Zn (S.E. Church, written commun., 1993); and the distribution of known deposits (Keith and others, 1983a, and MRDS), all at the scale of 1:1,000,000. In general, consideration was given to the fact that exploration activity in Arizona in the 1960s and 1970s led to the discovery of many new porphyry copper deposits. The team concluded that some areas should be re-examined in light of discoveries about Arizona tectonics in the last 18 years. Some team members felt that some of the districts of middle Tertiary age, particularly in the southeast part of the State, should also be re-examined.

This tract contains eleven known porphyry copper deposits of Laramide age that have a wide range of grades and tonnages, however more deposits have copper grades that are above than are below the median. At least 2 of those deposits are located more than 2.5 km from outcrop. There are eleven 1a (copper and porphyry) districts of Keith (1983a), all of which have Laramide ages, except for one that is queried and one that is Jurassic. Estimators noted that geophysical extensions of Laramide rock beneath cover and geochemical anomalies are more numerous here than in western Arizona. There are at least 14 geophysical anomalies of various sizes that indicate extension of Laramide bedrock beneath cover.

The estimators thought that nearly all exposed systems have been discovered and that most of the undiscovered deposits are hidden under cover. We attempted to determine the deposit density beneath shallow cover. We assumed that the maximum number of deposits beneath cover would be equal to the number of known porphyry copper deposits in exposed areas times a multiplier: the ratio of the area of shallow cover to the area of exposed rock. In this permissive tract, we estimated the ratio of shallow cover to exposed favorable rock to be about 5, where shallow cover was defined as rocks of middle Tertiary and younger ages 0–1 km thick and the area of favorable exposed rocks was defined as the area 2.5 km beyond and including all igneous rocks of Laramide and Jurassic ages. Most estimators reduced this multiplier by less than half because only about two-thirds of the of the exposed rocks in this permissive tract are considered favorable. Further adjustment of the multiplier was dependent upon the estimators' interpretations of how similar the rocks beneath cover might be to the rock exposed. The definitions of exposed rock and cover were made with the expectation that the undiscovered deposits would have Laramide or older ages. This expectation conflicts somewhat with the parameters used to draw the permissive tract, which allow for the possibility of undiscovered porphyry copper deposits of middle Tertiary age. In retrospect, the construction of separate tracts, one for undiscovered Laramide and one for undiscovered Tertiary deposits, would have facilitated more accurate estimations of deposit densities.

For the 90th, 50th, and 10th percentiles, the team estimated 3, 15, and 40 or more undiscovered deposits consistent with the grade and tonnage model of Singer and others (1986).

References

- Cox, D.P., 1986, Descriptive model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 76.
- Keith, S.B., 1984, Map of outcrops of Laramide (Cretaceous-Tertiary) rocks in Arizona and adjacent regions: Arizona Bureau of Geology and Mineral Technology Map 19, 1:1,000,000.

- Keith, S.B., Gest, D.E., and DeWitt, Ed, 1983a, Metallic mineral districts of Arizona: Arizona Bureau of Geology and Mineral Technology Map 18, scale 1:1,000,000.
- Keith, S.B., Schnabel, Lorraine, DeWitt, Ed, Gest, D.E., and Wilt, Jan, 1983b, Map, description and bibliography of the mineralized areas of the Basin and Range province in Arizona: U.S. Geological Survey Open-File Report 84-0086, 129 p.
- Oppenheimer, J.M., and Sumner, J.S., 1980, Depth-to-bedrock map, Basin and Range province, Arizona: Tucson, University of Arizona, Laboratory of Geophysics.
- Reynolds, S.J., 1988, Geologic map of Arizona: Arizona Geological Survey Map 26, scale 1:1,000,000.
- Saltus, R.W., 1991, Gravity and heat flow constraints on Cenozoic tectonics of the Western United States cordillera: Stanford University, Ph.D. dissertation, 245 p., 66 figs.
- Singer, D.A., Mosier, D.L., and Cox, D.P., 1986, Grade and tonnage model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 77-81.
- Titely, S.R., 1982, The style and progress of mineralization and alteration and alteration in porphyry copper systems, *in* Titely, S.R., ed., Advances in geology of the porphyry copper deposits: Tucson, University of Arizona Press, p. 93-116.
- Titely, S.R., and Anthony, E.Y., 1989, Laramide mineral deposits in Arizona, *in* Jenney, J.P., and Reynolds, S.J., eds., Geologic evolution of Arizona: Tucson, Arizona Geological Society Digest 17, p. 485-514.
- U.S. Bureau of Mines, 1993, The mineral industry of Arizona in 1992: Washington D.C., U.S. Bureau of Mines, Mineral Industry Surveys, 4 p.

SB14**Porphyry Cu Deposits****Arizona****Descriptive Model 17 • Mark3 Index 4****Area = 38,500 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* Leslie J. Cox**Rationale for Model Choice**

The choice of the worldwide porphyry-copper model of Cox (1986) to assess for porphyry copper deposits in Arizona was based on the close fit between geological and mineralogical features of the known Arizona deposits (Titley, 1982) and the description of the deposit model. Of 208 deposits located world-wide, 32 deposits are in Arizona. Most of the porphyry stocks in Arizona that are considered to be the source of large copper ore bodies were probably emplaced in the cores of voluminous fields of andesitic-dacitic to rhyolitic volcanic rocks erupted during Laramide time (Titley and Anthony, 1989).

Rationale for Tract Delineation

The permissive terrane delineated for the Arizona part of the Southern Basin and Range province includes all volcanic and igneous rocks of Jurassic and younger ages as identified on Reynolds' (1988) geologic map of Arizona with the exception of the Early Tertiary to Late Cretaceous muscovite-garnet-bearing peraluminous granites. Igneous rocks of Jurassic age are included because the Bisbee deposit is Jurassic; igneous rocks of the Laramide age are included because almost all of the known porphyry copper deposits in Arizona are generally associated with porphyritic intrusions of the Laramide calc-alkaline series; and igneous rocks of Tertiary age are included because deposits outside of Arizona are associated with Tertiary intrusions.

Areas extending 10 km outward from the Mesozoic and Tertiary plutons, as identified on the geologic maps of Reynolds (1988) and Keith (1984), are also included in the permissive terrane with the following exclusions: areas in which the bedrock is under more than 1 km of cover using a geophysical depth-to-bedrock map for which bedrock was defined as being middle Miocene or older (Oppenheimer and Sumner, 1980). A geophysical depth-to-bedrock map for which bedrock was defined as being Laramide or older (Saltus, 1991) was used to identify covered areas unfavorable for the occurrence of porphyry copper deposits, but these areas were not excluded from the permissive terrane.

The permissive terrane also includes areas where magnetic and gravity expressions indicate shallowly buried permissive bedrock (M.E. Gettings, written commun., 1993), known deposits and districts of this and associated models, and all areas identified in previous U.S. Geological Survey mineral assessments such as for U.S. Bureau of Land Management Wilderness Study Areas and CUSMAP (W.S. Updegrove and M.F. Diggles, written commun., 1993).

Titley and Anthony (1989) defined geologic terranes in Arizona on the basis of underlying basement rocks. This tract is the subset of permissive terrane in Arizona within the eastern part their subdivision I, the Pinal-Paleozoic Terrane.

Important Examples of Deposit Type

Major porphyry copper deposits in the tract include Bisbee, Carlota-Cactus, Chilito, Castle Dome-Pinto Valley, Christmas, Copper Cities, Copper Creek, Cyprus Miami (Inspiration), Helvetia, I-10, Lone Star, Miami East, Morenci-Metcalf, Ray, Red Mountain, Rosemont, San Juan, and San Manuel (Kalamazoo).

The Ray deposit and Morenci complex are in the billion-ton-plus class of ore reserves; the only other deposit of this size in the United States is Bingham Canyon in Utah (U.S. Bureau of Mines, 1993). The Dos Pobres deposit, in the Lone Star Mining district near Safford, Arizona, contains reserves of more than 300 million metric tons at 0.72 percent copper and about 0.3 grams gold per metric ton. This deposit and Sanchez are classified as porphyry copper-gold deposits (Lowell, 1989).

Rationale for Numerical Estimate

Information supplied to the team included the State geologic map (Reynolds, 1988); mylar overlays emphasizing the distributions of igneous rocks of Jurassic, Laramide, and middle Tertiary ages (Keith, 1984, and Reynolds, 1988); deep cover as identified by gravity studies for which basement was defined as middle Tertiary (Oppenheimer and Sumner, 1980), and as Laramide (Saltus, 1991); magnetic anomalies (Gettings, written commun., 1991); distribution of anomalies of Sb, Ag, As, Mo, Cu, Pb, and Zn (S.E. Church, written commun., 1993); and the distribution of known deposits (Keith and others, 1983a, and MRDS), all at the scale of 1:1,000,000. In general, consideration was given to the fact that exploration activity in Arizona in the 1960s and 1970s led to the discovery of many new porphyry copper deposits. The team concluded that some areas should be re-examined in light of discoveries about Arizona tectonics in the last 18 years. Some team members felt that some of the districts of middle Tertiary age, particularly in the southeast part of the State, should also be re-examined.

This tract contains 20 known deposits and 18 other mineral districts classified 1a (porphyry and copper) by Keith (1983a); all are Laramide or Jurassic in age. Estimators noted that geochemical anomalies are more numerous here than in western Arizona and that this area also has more magnetic anomalies that indicate extensions of Laramide rocks beneath cover.

The estimators thought that nearly all exposed systems have been discovered and that most of the undiscovered deposits are hidden under cover. We attempted to determine the deposit density beneath shallow cover. We assumed that the maximum number of deposits beneath cover would be equal to the number of known porphyry copper deposits in exposed areas times a multiplier: the ratio of the area of shallow cover to the area of exposed rock. In this permissive tract, we estimated the ratio of shallow cover to exposed favorable rock to be about 2, where shallow cover was defined as rocks of middle Tertiary and younger ages 0–1 km thick and the area of favorable exposed rocks was defined as the area 2.5 km beyond and including all igneous rocks of Laramide and Jurassic ages. Most estimators reduced this multiplier by about half because about half of the exposed rocks in this permissive tract are considered favorable. Further adjustment of the multiplier was dependent upon the estimators' interpretations of how similar the rocks beneath cover might be to the rock exposed. The definitions of exposed rock and cover were made with the expectation that the undiscovered deposits would have Laramide or older ages. This expectation conflicts somewhat with the parameters used to draw the permissive tract, which allow for the possibility of undiscovered porphyry copper deposits of middle Tertiary age. In retrospect, the construction of separate tracts, one for undiscovered Laramide and one for undiscovered Tertiary deposits, would have facilitated more accurate estimations of deposit densities.

For the 90th, 50th, and 10th percentiles, the team estimated 2, 5, and 15 or more undiscovered deposits consistent with the grade and tonnage model of Singer and others (1986).

References

Cox, D.P., 1986, Descriptive model of porphyry Cu, in Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 76.

- Keith, S.B., 1984, Map of outcrops of Laramide (Cretaceous-Tertiary) rocks in Arizona and adjacent regions: Arizona Bureau of Geology and Mineral Technology Map 19, 1:1,000,000.
- Keith, S.B., Gest, D.E., and DeWitt, Ed, 1983a, Metallic mineral districts of Arizona: Arizona Bureau of Geology and Mineral Technology Map 18, scale 1:1,000,000.
- Keith, S.B., Schnabel, Lorraine, DeWitt, Ed, Gest, D.E., and Wilt, Jan, 1983b, Map, description and bibliography of the mineralized areas of the Basin and Range province in Arizona: U.S. Geological Survey Open-File Report 84-0086, 129 p.
- Lowell, J.D., 1989, Gold mineralization in porphyry copper deposits discussed: Mining Engineering, v. 41, no. 4, p. 227-231.
- Oppenheimer, J.M., and Sumner, J.S., 1980, Depth-to-bedrock map, Basin and Range province, Arizona: Tucson, University of Arizona, Laboratory of Geophysics.
- Reynolds, S.J., 1988, Geologic map of Arizona: Arizona Geological Survey Map 26, scale 1:1,000,000.
- Saltus, R.W., 1991, Gravity and heat flow constraints on Cenozoic tectonics of the Western United States cordillera: Stanford University, Ph.D. dissertation, 245 p., 66 figs.
- Singer, D.A., Mosier, D.L., and Cox, D.P., 1986, Grade and tonnage model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 77-81.
- Titely, S.R., 1982, The style and progress of mineralization and alteration and alteration in porphyry copper systems, *in* Titely, S.R., ed., Advances in geology of the porphyry copper deposits: Tucson, University of Arizona Press, p. 93-116.
- Titely, S.R., and Anthony, E.Y., 1989, Laramide mineral deposits in Arizona, *in* Jenney, J.P., and Reynolds, S.J., eds., Geologic evolution of Arizona: Tucson, Arizona Geological Society Digest 17, p. 485-514.
- U.S. Bureau of Mines, 1993, The mineral industry of Arizona in 1992: Washington, D.C., U.S. Bureau of Mines, Mineral Industry Surveys, 4 p.

SB15**Porphyry Cu Deposits****New Mexico****Descriptive Model 17 • Mark3 Index 4****Area = 23,100 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* Steve Ludington and Virginia McLemore**Rationale for Model Choice**

Southwestern New Mexico contains numerous Laramide calc-alkaline plutons, part of a cluster of intrusions of this age that lies mostly in neighboring Arizona. In addition, there are known deposits that are type examples of porphyry copper deposits in North America. Some of these intrusive rocks also exhibit a halo of polymetallic veins that might reflect a concealed porphyry copper deposit associated with the intrusive bodies.

Rationale for Tract Delineation

The permissive tract in southwestern New Mexico is contiguous with a large permissive area in Arizona that contains numerous Laramide porphyry copper deposits. Geologic constraints on the occurrence of porphyry copper deposits in this area are discussed in detail in the descriptions of the Arizona tracts. In southwestern New Mexico, the amount of covered area is approximately equal to that exposed. The general rule for delineation was to exclude all areas that show no evidence for Laramide plutonism. In addition, areas of plutonism that are overwhelmingly gabbroic or granitic, or strongly alkaline, were excluded. Manifestation of plutonism may include exposed plutonic terranes, known polymetallic vein, skarn, and/or replacement deposits, unexposed plutons, inferred to exist by geophysical or other means, and any other inferred magmatic trends.

Important Examples of Deposit Type

Southwestern New Mexico contains two producing Laramide porphyry copper deposits, Santa Rita (Chino) and Tyrone, and one explored but inactive deposit, Copper Flat (Hillsboro). In addition, there are at least seven known porphyry copper prospects in the area.

Rationale for Numerical Estimate

The team evaluated the seven known prospects individually. Then, considering the extent of exploration and the amount of area covered by thin surficial deposits, we extrapolated those judgments to the entire permissive tract. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 2, 3, 4, 6, and 9 or more deposits consistent with the worldwide porphyry copper grade and tonnage model (Singer and others, 1986).

Reference

Singer, D.A., Mosier, D.L., and Cox, D.P., 1986, Grade and tonnage model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 77-81.

SB16**Porphyry Cu Deposits****New Mexico****Descriptive Model 17 • Mark3 Index 4****Area = 23,100 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Alan R. Wallace, Steve Ludington, and Virginia McLemore**Rationale for Model Choice**

Southwestern New Mexico contains several Tertiary porphyry copper prospects, as well as calc-alkaline plutons. In addition, some of these intrusive rocks have a halo of polymetallic veins that might reflect a concealed porphyry copper deposit associated with the intrusive bodies. Immediately east of the permissive area, porphyry copper-gold deposits are associated with a sequence of alkaline plutons that, although slightly older, are part of the same magmatic sequence as the rocks in southwestern New Mexico. Thus, assuming the two deposit types are related, southwestern New Mexico may contain undiscovered porphyry copper deposits related to calc-alkaline plutonism like those described by Cox (1986).

Rationale for Tract Delineation

The general rule for delineating permissive areas for porphyry copper deposits of middle Tertiary and younger age was to exclude all areas that show no evidence for plutonism of this age. In addition, areas of plutonism that are overwhelmingly gabbroic or granitic, or strongly alkaline, were excluded. Manifestation of plutonism may include exposed plutonic terranes, known polymetallic vein, skarn, and(or) replacement deposits, unexposed plutons, inferred to exist by geophysical or other means, and any other inferred magmatic trends.

Important Examples of Deposit Type

No significant deposits are known in southwestern New Mexico, but at least 5 prospects—White Signal, Alum Mountain, Bitter Creek, Cooperas Creek, and Steins Creek—are known that are probably middle Tertiary in age.

Rationale for Numerical Estimate

Much of the permissive area for deposits of this age in southwestern New Mexico is not deeply eroded, and deposits that might be present could easily be covered by younger materials. The area concealed is at least half the total. The known prospects have not been explored very thoroughly, and the assessment team was hampered by a distinct lack of information. Nevertheless, exploration in the area for several decades has failed to discover a viable Tertiary deposit. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 1, and 2 or more deposits consistent with the worldwide porphyry copper grade and tonnage model (Singer and others, 1986).

References

- Cox, D.P., 1986, Descriptive model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 76.
- Singer, D.A., Mosier, D.L., and Cox, D.P., 1986, Grade and tonnage model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 77-81.

SB17**Porphyry Cu-Au Deposits**

Arizona

Descriptive Model 20c • Mark3 Index 34

Area = 117,600 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Leslie J. Cox and Michael F. Diggles

Rationale for Model Choice

The rationale for the choice of the porphyry copper-gold model of Cox and Singer (1992) was based on our ability to identify characteristics in the known Arizona deposits that are unique to the porphyry Cu-Au deposit model and on our ability to distinguish a geologic setting for gold-rich porphyries that is different from the general porphyry-copper environment. It is argued that gold-rich porphyries tend to be associated with alkaline igneous rocks (Gilmour, 1982, Lowell, 1989). Wilt (1993), however, contends that gold-rich porphyry deposits occur in calc-alkaline settings as well, but possesses an oxidation state that is determined by the rocks through which the magma rises: the gold-poor porphyries are oxidized, whereas the gold-rich porphyries are weakly oxidized. Our estimates for undiscovered porphyry Cu-Au deposits were guided by Wilt's delineation of oxidized versus weakly oxidized calc-alkaline rocks in Arizona.

Rationale for Tract Delineation

The tract for porphyry copper-gold consists of all six of the general porphyry copper tracts for Arizona. The most favorable rocks consist of porphyritic igneous rocks of Laramide age in the Basin and Range and Transition Zone of Arizona and their interpreted geophysical extensions beneath cover. The team identified and excluded areas that would not be permissive for the occurrence of porphyry copper deposits because of parameters such as geologic setting, rock composition, and depth of cover.

Important Examples of Deposit Type

Only a few of the many significant Arizona porphyry copper deposits are gold-rich: Dos Pobres (Langton and Williams, 1982), Ajo-New Cornelia (Hagstrom and others, 1987), and Sanchez. Of the three known deposits, all have tonnages below the median for the porphyry Cu-Au model (Singer and Cox, 1986).

Rationale for Numerical Estimate

Estimates for porphyry Cu-Au deposits were weighted toward areas characterized by weakly oxidized calc-alkaline intrusions as defined by ferric:ferrous ratios in unaltered plutons. In southwestern Arizona, the potential for Laramide Cu-Au porphyries in the identified weakly oxidized area is relatively small, because the shallow Laramide intrusions have been largely destroyed by erosion. This is indicated by the fact that volcanic rocks of Oligocene age rest unconformably upon eroded plutons of Laramide age. Only a small part of the tract is favorable for porphyry Cu-Au deposits.

The theory that porphyry Cu-Au deposits are emplaced close to the surface and should be situated within their associated volcanic rocks was considered and Laramide intrusions adjacent to volcanic rocks of the same age were examined. To arrive at estimates of undiscovered porphyry Cu-Au deposits, the team considered first the probability of there being zero deposits, the maximum number likely, and the most likely number. Using this estimation technique, the team reached a consensus of an expected value of about 1 undiscovered porphyry Cu-Au deposit. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated

0, 1, 2, 3, and 4 or more deposits consistent with the grade and tonnage model of Singer and Cox (1986).

References

- Cox, D.P., and Singer, D.A., 1992, Distribution of gold in porphyry copper deposits, *in* DeYoung, J.H., Jr., and Hammarstrom, J.M., eds., Contributions to commodity geology research: U.S. Geological Survey Bulletin 1877, p. C1-C14.
- Gilmour, Paul, 1982, Grades and tonnages of porphyry copper deposits *in* Titley, S.R., ed., Advances in geology of the porphyry copper deposits: Tucson, University of Arizona Press, p. 7-36.
- Hagstrum, J.T., Cox, D.P., and Miller, R.J., 1987, Structural reinterpretation of the Ajo Mining District, Pima County Arizona based on paleomagnetic and geochronologic studies: *Economic Geology*, v. 82, no. 4, p. 1348-1361.
- Langton, J.M., and Williams, S.A., 1982, Structural petrological, and mineralogical controls for the Dos Pobres ore body, *in* Titley, S.R., ed., Advances in geology of the porphyry copper deposits, southwestern North America: Tucson, University of Arizona Press, p. 335-352.
- Lowell, J.D., 1989, Gold mineralization in porphyry copper deposits discussed: *Mining Engineering*, v. 41, no. 4, p. 227-231.
- Singer, D.A., and Cox, D.P., 1986, Grade and tonnage model of porphyry Cu-Au, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 110-114.
- Wilt, J.C., 1993, Geochemical patterns of hydrothermal mineral deposits associated with calc-alkalic and alkali-calcic igneous rocks as evaluated with neural networks: Tucson, University of Arizona, Ph.D. dissertation, 721 p.

SB18 **Polymetallic Replacement and Skarn Zn-Pb Deposits** **California**
Descriptive Model 19a + 18c • Mark3 Index 92
Area = 11,500 km²

[Cumulative Distribution](#)

[Histogram](#)

[Table](#)

[Model](#)

[Mineral Deposits](#)

by Dennis P. Cox

Rationale for Model Choice

Plutons mainly of Cretaceous age intrude Paleozoic carbonate sedimentary rocks in the Ivanpah district and elsewhere in this tract. Intrusive contacts of such altered plutons with carbonate rocks are permissive environments for zinc-lead skarn and polymetallic replacement deposits. Because zinc-lead skarn deposits are possible in the same environment as polymetallic replacement deposits, a model that combines the zinc-lead skarn (Mosier, 1986) and polymetallic replacement (Mosier and others, 1986) was used to represent the undiscovered districts (Mark 3 no. 92).

Rationale for Tract Delineation

Skarn Zn-Pb and polymetallic replacement deposits can be present where plutons intrude carbonate rocks. The proximity of Mesozoic plutons and their inferred subsurface extents to areas underlain by Proterozoic and younger carbonate rocks defines the permissive tract. Small areas covered by basin fill more than 1 km deep are excluded.

Important Examples of Deposit Type

The Shoshone district is the only significant example of this deposit type in the tract. Although galena-rich veins are numerous in the Ivanpah district, skarn and replacement ore bodies are unknown (Hewett, 1956, p.143).

Rationale for Numerical Estimate

Although few deposits of this type have been discovered in the past, large parts of the tract are covered by a thin veneer of sediment. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 1, 2, 5, and 7 or more districts consistent with the combined grade and tonnage model of zinc-lead skarn and polymetallic replacement districts of Singer (Mark3 index 92). This estimate was guided by estimates for the West Mojave Management Area (U.S. Geological Survey, 1992) and East Mojave National Scenic Area (Hodges and Ludington, 1991).

References

- Cox, D.P., 1986, Descriptive model of Zn-Pb skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 90.
- Hewett, D.F., 1956, Geology and ore deposits of the Ivanpah quadrangle, Nevada: U.S. Geological Survey Professional Paper 275, 172 p.
- Hodges, C.A., and Ludington, Steve, 1991, Quantitative assessment of undiscovered metallic mineral resources in the East Mojave National Scenic Area, southern California: U.S. Geological Survey Open-File Report 91-0551, 18 p.
- Morris, H.T., 1986, Descriptive model of polymetallic replacement deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 99-100.
- Mosier, D.L., 1986, Grade and tonnage model of Zn-Pb skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 90-93.

Mosier, D.L., Morris, H.T., and Singer, D.A., 1986, Grade and tonnage model of polymetallic replacement deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 101-104.

U.S. Geological Survey, 1992, Evaluation of selected metallic and nonmetallic mineral resources, West Mojave Management Area, southern California: U.S. Geological Survey Open-File Report 92-595, 89 p.

SB19 **Polymetallic Replacement and Skarn Zn-Pb Deposits** **Nevada**
Descriptive Model 19a + 18c • Mark3 Index 92
Area = 1,610 km²

[Cumulative Distribution](#)

[Histogram](#)

[Table](#)

[Model](#)

[Mineral Deposits](#)

by Dennis P. Cox

Rationale for Model Choice

The deposits in the Goodsprings or Yellow Pine district occur in Devonian and Mississippian strata and are related to poorly exposed granodiorite porphyry bodies that are noted for their very large feldspar crystals (Hewitt, 1931). Radiometric ages of these intrusions show that they are Late Triassic to Early Jurassic in age (Carr and others, 1986; Garside and others, 1993). The Goodsprings district is unique in Nevada in that a small proportion of the deposits in the district diverge markedly from typical polymetallic replacement deposits. The Boss Mine, for example, is a high-grade, oxidized copper deposit with an interior zone rich in platinum group metals. Other examples resemble Mississippi Valley deposits in their ore textures and extreme distance from a possible causative pluton, as first suggested by Hewitt (1931). Because zinc-lead skarn deposits are possible in the same environment as polymetallic replacement deposits, a model that combines the zinc-lead skarn (Mosier, 1986) and polymetallic replacement (Mosier and others, 1986) was used to represent the undiscovered districts (Mark 3 no. 92).

Rationale for Tract Delineation

Skarn Zn-Pb and polymetallic replacement deposits can be present where plutons intrude carbonate rocks. Paleozoic sedimentary rocks are hidden by a thin veneer of sediment in many parts of the area. The permissive tract was defined as an area 10 km in radius around all plutons where they intrude Proterozoic and younger carbonate rocks.

Rationale for Numerical Estimate

An undiscovered zinc-lead skarn or polymetallic replacement district might exist under cover of Cenozoic rocks and sedimentary deposits but the likelihood is small because of the limited size of the permissive area. For the 90th, 50th, and 10th percentiles, the team estimated 0, 1, and 2 or more deposits consistent with the combined grade and tonnage model (Mark 3 no. 92).

References

- Carr, M.D., Evans K.V., Fleck, J.R., Frizzell, R.J., Ort, K.M., and Zartman, R.E., 1986, Early Middle Jurassic upper limit for the movement on the Keystone thrust, southern Nevada: Geological Society of America, Abstracts with Program, v. 18, no. 5, p. 345.
- Garside, L.J., Bonham, H.F., Jr., Tingley, J.V., and McKee, E.H., 1993, Potassium-argon ages of igneous rocks and alteration minerals associated with mineral deposits, western and southern Nevada: Isochron West, no. 59, p. 17-23.
- Hewett, D.F., 1931, Geology and ore deposits of the Goodspings quadrangle, Nevada: U.S. Geological Survey Professional Paper 162, 171 p.
- Mosier, D.L., 1986, Grade-tonnage model of Zn-Pb skarns, in Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 90-93.
- Mosier, D.L., Morris, H.T., and Singer, D.A., 1986, Grade-tonnage model of polymetallic replacement deposits, in Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 101-104.

SB20 **Polymetallic Replacement and Skarn Zn-Pb Deposits** **Arizona**
Descriptive Model 19a + 18c • Mark3 Index 92
Area = 61,700 km²

[Cumulative Distribution](#)

[Histogram](#)

[Table](#)

[Model](#)

[Mineral Deposits](#)

by Leslie J. Cox

Rationale for Model Choice

Polymetallic replacement and skarn Zn-Pb deposits are formed in similar environments. Both are due to metasomatism that results from the intrusion of calcareous rocks by magma. In Arizona, the ore in replacement deposits is rich in sulfur, pyrite is the dominant sulfide, and silica occurs as jasperoid, rather than in calc-silicate minerals. In skarn deposits, ore minerals are disseminated, not massive, and iron is fixed in calc-silicate minerals rather than in pyrite. These differences are difficult to predict on a regional scale, and we estimated these deposits together, using a grade and tonnage model that combines the two types (Mark3 index 92).

Rationale for Tract Delineation

The permissive tract was delineated by modifying the tracts for porphyry Cu deposits, and including Late Cretaceous to early Tertiary muscovite-garnet-bearing peraluminous granite and associated pegmatite (unit TKgm, Reynolds, 1988). We then outlined areas within that modified tract that are known to contain limestones and other carbonate rocks. The tract also includes all pertinent known mineral districts.

Important Examples of Deposit Type

For polymetallic replacement deposits, there are 6 to 9 Arizona examples with tonnages distributed about the median of the grade-tonnage model of Mosier and others (1986); of the 3 above the median in tonnage, two are very large, the Superior deposit in the Pioneer district (Hammer and Peterson, 1968) and the Copper Queen deposit in the Warren district at Bisbee. Two skarn Zn-Pb deposits in Arizona, Aravaipa, and Washington Camp are listed as examples in the grade and tonnage model of Mosier (1986), but there are no world-class skarn deposits of this type.

Rationale for Numerical Estimate

The quantitative estimate was made considering the distribution and size of the known deposits of each type. The Pearce, Pioneer (Superior and Belmont deposits), Oro Blanco (American Mine), Turquoise, Waterman, Slate, Swisshelm, Harshaw (French Flux deposit), and Copper Queen-Bisbee districts are all consistent with the worldwide grade tonnage curves. In addition, there are a dozen or so smaller deposits about which we do not know a great deal. To arrive at estimates, we considered first the probability of there being zero deposits, the maximum number likely, and the most likely number. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 1, 3, 5, 7, and 10 or more deposits consistent with the combined grade and tonnage models of Mosier (1986) and Mosier and others (1986).

References

Hammer, D.F., and Peterson, D.W., 1968, Geology of the Magma mine area, Arizona, *in* Ridge, J.D., ed., Ore deposits of the United States, 1933-1967 (Graton-Sales volume): New York, American Institute of Mining, Metallurgy and Petroleum Engineers, v. 2, p. 1282-1310.

- Mosier, D.L., 1986, Grade and tonnage model of Zn-Pb skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 90-93.
- Mosier, D.L., Morris, H.T., and Singer, D.A., 1986, Grade and tonnage model of polymetallic replacement deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 101-104.
- Reynolds, S.J., 1988, Geologic map of Arizona: Arizona Geological Survey Map 26, scale 1:1,000,000.

SB21**Polymetallic Replacement Deposits****New Mexico****Descriptive Model 19a • Mark3 Index 47****Area = 20,900 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* Alan R. Wallace and Virginia McLemore**Rationale for Model Choice**

Southwestern New Mexico contains known Laramide polymetallic replacement districts, characterized by the replacement of carbonate rocks by base-metal sulfides, precious metals, and related gangue minerals.

Rationale for Tract Delineation

Polymetallic replacement deposits form where intermediate to felsic intrusive rocks, which are the principal sources of the metals, are emplaced into carbonate rocks. The general rule for delineation of the permissive tract was to exclude all areas that show no evidence of Laramide plutonism. In addition, areas where erosion has left Precambrian igneous and metamorphic rocks exposed at the surface were excluded, as were areas inferred to be covered by surficial deposits thicker than 1 km.

Important Examples of Deposit Type

Three Laramide polymetallic replacement districts are known—Chloride Flat, Georgetown, and Fierro-Hanover—and four other prospective areas.

Rationale for Numerical Estimate

Whereas the permissive area is relatively small, the number of known prospects is substantial. The team also placed a major emphasis on the productive nature of exposed areas and the substantial area (>50 percent of the permissive terrain) of covered permissive rocks. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 4, 5, 6, 8, and 10 or more undiscovered districts consistent with the grade and tonnage model for polymetallic replacement deposits of Mosier and others (1986).

Reference

Mosier, D.L., Morris, H.T., and Singer, D.A., 1986, Grade and tonnage model of polymetallic replacement deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 101-104.

SB22**Polymetallic Replacement Deposits****New Mexico****Descriptive Model 19a • Mark3 Index 47****Area = 20,900 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Alan R. Wallace, Steve Ludington, and Virginia McLemore**Rationale for Model Choice**

Southwestern New Mexico contains several known middle Tertiary polymetallic replacement prospects, characterized by the replacement of carbonate rocks by base-metal sulfides, precious metals, and related gangue minerals.

Rationale for Tract Delineation

Polymetallic replacement deposits form where intermediate to felsic intrusive rocks, which are the principal sources of the metals, are emplaced into carbonate rocks. The general rule for delineation of the permissive tract was to exclude all areas that show no evidence of middle Tertiary plutonism. In addition, areas where erosion has left Precambrian igneous and metamorphic rocks exposed at the surface were excluded, as were areas inferred to be covered by surficial deposits thicker than 1 km.

Important Examples of Deposit Type

There are no districts with known production large enough to qualify as significant for the purposes of this study, although several are close. We identified 11 areas—Granite Gap, McGhee Peak, Victorio, Cookes Peak, Lake Valley west, Apache, Carpenter, North Cookes Range, Rincon, Tres Hermanos, and Tierra Blanca—where rock mineralized in this style is known, but where recorded production is unknown, incomplete, or small.

Rationale for Numerical Estimate

This area contains a remarkable concentration of poorly-known prospects. We believe that the known prospects are not fully explored and that further exploration could result in several of them advancing to the status of districts consistent with the grade and tonnage model for polymetallic replacement deposits of Mosier and others (1986). The team evaluated each of the known prospects and extrapolated the judgments to the entire tract, including a large covered area that is at least as large as the exposed area. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 3, 7, 12, 14, and 18 or more deposits consistent with the grade and tonnage model for polymetallic replacement deposits of Mosier, Morris, and Singer (1986).

Reference

Mosier, D.L., Morris, H.T., and Singer, D.A., 1986, Grade and tonnage model of polymetallic replacement deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 101-104.

SB23**Distal Disseminated Ag-Au Deposits**

Nevada

Descriptive Model Bull. 2004 • Mark3 Index 18

Area = 1,610 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Dennis P. Cox**Rationale for Model Choice**

Although no distal disseminated Ag-Au deposits are known, intrusion of plutons into the widespread carbonate rocks in this area represent permissive conditions for this deposit type.

Rationale for Tract Delineation

Distal disseminated Ag-Au deposits can be present where plutons intrude sedimentary rocks. Paleozoic sedimentary rocks are hidden by a thin veneer of sediment in many parts of the area. The permissive tract was defined as an area 10 km in radius around all plutons except where the plutons intrude Precambrian igneous and metamorphic rocks.

Important Examples of Deposit Type

There are no known deposits or prospects in the tract.

Rationale for Numerical Estimate

An undiscovered distal disseminated Ag-Au deposits might exist under cover of Cenozoic rocks and sedimentary deposits, but the likelihood is small because of the limited size of the permissive area. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 1, 1, and 2 or more deposits consistent with the grade and tonnage model of Cox and Singer (1992).

Reference

Cox, D.P., and Singer, D.A., 1992, Descriptive and grade and tonnage model of distal-disseminated Ag-Au, *in* Bliss, J.D., ed., *Developments in deposit modeling: U.S. Geological Survey Bulletin 2004*, p. 20-22.

SB24**Distal Disseminated Ag-Au Deposits**

Arizona

Descriptive Model Bull. 2004 • Mark3 Index 18

Area = 61,700 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Leslie J. Cox

Rationale for Model Choice

Distal disseminated Ag-Au deposits form in sedimentary rocks distal to plutons. The deposits are somewhat similar to sediment-hosted Au deposits, but have significantly higher Ag grades and base-metal contents. They are associated with hypabyssal or subvolcanic intrusions. Arizona has at least two known distal disseminated Ag-Au deposits.

Rationale for Tract Delineation

The permissive tract was delineated by modifying the tracts for porphyry Cu deposits, and including Late Cretaceous to early Tertiary muscovite-garnet-bearing peraluminous granite and associated pegmatite (unit TKgm, Reynolds, 1988). We then outlined areas within that modified tract that are known to contain limestones and other carbonate rocks. The tract also includes all pertinent known mineral districts.

Important Examples of Deposit Type

Two deposits in Arizona, Hardshell and Tombstone, are part of the grade and tonnage models (Cox and Singer, 1992), but both are below the median tonnage. Tombstone is classified as a distal disseminated Ag-Au deposit rather than as a polymetallic replacement deposit because it contains no massive replacement bodies and lacks a clear relationship to a plutonic contact. The Vekol district might be classified as distal disseminated Ag-Au, but it produced less than 100,000 metric tons of ore and is not a significant deposit.

Rationale for Numerical Estimate

Estimators thought that deposits of this type might be both commonly formed and readily concealed in Arizona, because they are low in sulfide content and relatively inconspicuous. This type of mineralization was not widely recognized as ore until the 1970s, because of its low-grade, disseminated nature. For the 50th percentile, estimators noted that the number of known distal-disseminated deposits is near that of polymetallic-replacement deposits: about 2 to 7. Therefore, some argued that there should be perhaps 4 to 10 total known plus undiscovered (the estimate for undiscovered polymetallic-replacement deposits at the 50th percentile is 3). For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 1, 2, 5, 7, and 10 or more deposits consistent with the grade and tonnage model of Cox and Singer (1992).

References

- Cox, D.P., 1992, Descriptive model of distal disseminated Ag-Au, *in* Bliss, J.D., ed., Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, p. 19.
- Cox, D.P., and Singer, D.A., 1992, Grade and tonnage model of distal disseminated Ag-Au, *in* Bliss, J.D., ed., Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004, p. 20-22.
- Reynolds, S.J., 1988, Geologic map of Arizona: Arizona Geological Survey Map 26, scale 1:1,000,000.

SB25**Massive Sulfide Deposits, Kuroko Type**

Arizona

Descriptive Model 28a • Mark3 Index 93

Area = 3,560 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Eric R. Force and Leslie J. Cox

Rationale for Model Choice

The known Arizona massive sulfide deposits closely resemble the kuroko deposit model of Singer (1986); they are located in metamorphosed rocks of Early Proterozoic age that represent volcanic-arc marine environments. There are at least 41 deposits and occurrences in 13 districts (Donnelly and Conway, 1988) in the Yavapai, Mohave, and Mazatzal terranes in Arizona's Transition Zone.

Rationale for Tract Delineation

Permissive rock units were delineated using the geologic map of Arizona (Reynolds, 1988). Marine felsic to intermediate volcanic rocks of known volcanic-arc association appear to occur only in the Proterozoic rocks of the Yavapai, Mohave, and Mazatzal terranes in Arizona's Transition Zone, and they constitute the permissive tract. Rock assemblages of Jurassic age in southwestern Arizona that would otherwise be permissive are not marine in origin, and, therefore, massive sulfide deposits probably do not occur in them. In addition to areas that outcrop, part of the permissive area was delineated where the geophysical interpretation (M.E. Gettings, written commun., 1991) of gravity and magnetic data (Saltus, 1991) indicated extensions of Early Proterozoic metamorphic bedrock beneath cover materials less than 1 km thick

Important Examples of Deposit Type

In the Verde district near Jerome (Anderson and Creasey, 1958), the world-class United Verde deposit produced over 30 million metric tons of ore, averaging 4.8 percent copper (Donnelly and Conway, 1988). The United Verde deposit is approximately five times larger than the next larger deposit in Arizona, the Iron King mine, and 22 times larger than the Old Dick-Bruce mine. Two smaller deposits are the Binghamton and the Antler. Of the 41 deposits and occurrences listed by Donnelly and Conway (1988), more than half had production of less than 5,000 metric tons of ore (E.H. DeWitt, written commun., 1993).

Some deposits in the Bagdad district are difficult to classify. If the granitic sills were to be removed from the section, the Bagdad deposits would be enclosed in pillow basalt lavas on oceanic crust (C.M. Conway, written commun., 1992), a setting more appropriate to Cyprus deposits. Until more work is done to better define this environment, these deposits are considered to be kuroko deposits.

Rationale for Numerical Estimate

Our estimate is based on the existence of five deposits closely approximating the tonnage distribution of the kuroko deposit model (Singer and Mosier, 1986). During estimation of undiscovered deposits, much discussion centered around the estimators' beliefs about the possible existence or non-existence of another deposit the size of the United Verde in this tract. Using the grade and tonnage models, one of about 10 estimated undiscovered deposits would have to be the size of the United Verde. Other important considerations included the density of occurrence of known deposits, the belief that many of the Arizona deposits have been

tectonically deformed to vertical orientations, beliefs about the intensity of exploration, and the belief that the upper 500 m was fairly well explored by drilling and electromagnetic methods and that the lower 500 m might contain undiscovered deposits. This belief influenced a minority of estimators to postulate that the same number was yet to be found as had already been discovered.

Two separate sets of estimates were made for undiscovered kuroko deposits in Arizona. However, the results of the estimates made using a local Arizona grade and tonnage model provided by Ed DeWitt, of the U.S. Geological Survey, are not included in this report. Estimates based on the worldwide model converged on an expected value of about 2 undiscovered deposits. For the 90th, 50th, 10th, and 5th percentiles, the team estimated 0, 1, 3, and 7 or more deposits consistent with the grade and tonnage model of Singer and Mosier (1986).

References

- Anderson, C.A., and Creasey, S.C., 1958, Geology and ore deposits of the Jerome area, Yavapai County, Arizona: U.S. Geological Survey Professional Paper 308, 185 p.
- Donnelly, M.E., and Conway, C.M., 1988, Metallogenic map of volcanogenic massive-sulfide occurrences in Arizona: U.S. Geological Survey Map MF-1853-B, scale 1:1,000,000.
- Reynolds, S.J., 1988, Geologic map of Arizona: Arizona Geological Survey Map 26, scale 1:1,000,000.
- Saltus, R.W., 1991, Gravity and heat flow constraints on Cenozoic tectonics of the Western United States cordillera: Stanford University, Ph.D. dissertation, 245 p., 66 figs.
- Singer, D.A., 1986, Descriptive model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 189-190.
- Singer, D.A., and Mosier, D.L., 1986, Grade and tonnage model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 190-197.

SB26**Massive Sulfide Deposits, Kuroko Type****New Mexico****Descriptive Model 28a • Mark3 Index 93****Area = 1,740 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Steve Ludington and Miles Silberman**Rationale for Model Choice**

Metamorphosed Proterozoic volcanic rocks, especially felsic volcanic rocks in greenstone terranes often contain stratabound polymetallic massive sulfide deposits. The presence of kuroko deposits and prospects in other parts of New Mexico suggests they might occur in the Basin and Range province.

Rationale for Tract Delineation

The criteria for tract delineation include submarine island-arc volcanic host rocks of felsic composition and exhalative zones within the supracrustal sequence associated with the volcanic rocks (e.g., iron-formations or cherty zones) that provide evidence for submarine hydrothermal hot spring activity during volcanism. Greenstone belts make up a significant part of Proterozoic terranes in New Mexico; Robertson and others (1986) indicate areas where felsic and mafic rocks occur within Precambrian greenstone belts, thus defining the permissive tracts for kuroko massive sulfide deposits.

Important Examples of Deposit Type

Significant deposits or prospects are not known in southwestern New Mexico.

Rationale for Numerical Estimate

The presence of several deposits and smaller prospects indicates that the mineralizing process took place in New Mexico. The permissive tract in the Basin and Range part of the State is, however, quite small, and there is little direct evidence for kuroko deposits. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 0, 0, and 1 or more deposits consistent with the grade and tonnage model for kuroko massive sulfide deposits (Singer and Mosier, 1986).

References

- Robertson, J.M., Fulp, M.S., and Daggett, M.D., III, 1986, Metallogenic map of volcanogenic massive sulfide deposit occurrences in New Mexico: U.S. Geological Survey Miscellaneous Field Studies Map MF-1853-A, scale 1:1,000,000.
- Singer, D.A., and Mosier, D.L., 1986, Grade and tonnage model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 190-197.

SB27**Epithermal Vein Deposits, Comstock Type**

California

Descriptive Model 25c • Mark3 Index 16

Area = 39,700 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* James J. Rytuba**Rationale for Model Choice**

Miocene volcanic centers and associated subvolcanic intrusive rocks of intermediate to felsic composition are present in the Mojave part of the southern Basin and Range province. These volcanic centers consist of dacite to rhyolite dome, flow, and ash-flow fields. The volcanic centers host several Comstock-type deposits as well as several epithermal gold deposits and prospects of other types with their associated areas of alteration. Most of the deposits and prospects are hosted in volcanic rocks but some ore occurs in the crystalline basement rocks and sedimentary rocks deposited in middle Tertiary basins. Not enough is known about the geology of the basement beneath the volcanic rocks to clearly support a Comstock classification following Mosier and others (1986a). The model was chosen because of the high silver content of the known deposits. Associated mineral deposits include hot-spring and quartz-alunite gold deposits and barite vein deposits.

Rationale for Tract Delineation

The permissive tract for Comstock deposits was delineated on the basis of areas of known silver, gold, and barite prospects and deposits, Miocene volcanic centers, and areas of shallow cover where buried extensions of volcanic centers may occur.

Important Examples of Deposit Type

The Calico mining district located in this tract is an example of this deposit type. The very large silver resource in the Waterloo and Langtry deposits located in the western part of the Calico mining district are Comstock type deposits that are hosted by middle Tertiary lacustrine sedimentary deposits and water-laid tuffs (Fletcher, 1986).

Rationale for Numerical Estimate

Three factors contributed to the numerical estimate for undiscovered resources. One is the presence of several prospects with alteration and mineralization characteristics of this deposit type. The second factor is the presence of Comstock type deposits, and the third factor is the presence of large volcanic centers, parts of which are buried beneath a thin veneer of alluvium or sedimentary rocks that covers parts of the permissive tract. Based upon these factors, the team estimated for the 90th, 50th, and 10th percentiles, respectively, 0, 1, and 2 or more deposits consistent with the grade and tonnage model of (Mosier and others, 1986).

References

- Fletcher, D.I., 1986, Geology and genesis of the Waterloo and Langtry silver-barite deposits, California: Stanford University Ph.D. dissertation, 202 p.
- Mosier, D.L., Singer, D.A., and Berger, B.R., 1986, Descriptive model of Comstock epithermal veins, in Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 150.

Mosier, D.L., Sato, Takeo, and Singer, D.A., 1986, Grade-tonnage model of Comstock epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 151-153.

SB28**Epithermal Vein Deposits, Comstock Type****Nevada****Descriptive Model 25c • Mark3 Index 16****Area = 4,170 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Dennis P. Cox**Rationale for Model Choice**

Although no districts as defined by the grade and tonnage model of Mosier and others (1986) are known, permissive conditions exist for epithermal vein deposits. The tract is contiguous to permissive tracts in Arizona and California, where Comstock districts and hot-spring deposits occur near the Nevada border.

Rationale for Tract Delineation

All Tertiary volcanic rocks and their extensions under less than one km of cover are permissive.

Rationale for Numerical Estimate

Based on the broad area of covered Tertiary volcanic rocks permissive for this deposit type, the team estimated, for the 90th, 50th, 10th, 5th, and 1st percentiles, 0, 1, 1, 2, and 2 or more deposits consistent with the grade and tonnage model of Mosier and others (1986).

Reference

Mosier, D.L., Sato, Takeo, and Singer, D.A., 1986, Grade-tonnage model of Comstock epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 151-153.

SB29**Epithermal Vein Deposits, Comstock Type**

Arizona

Descriptive Model 25c • Mark3 Index 16

Area = 59,699 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by Robert J. Kamilli and Leslie J. Cox

Rationale for Model Choice

The rationale for the choice of Comstock epithermal veins as analogues for most of the epithermal gold districts in Arizona was based on the reasonable fit between geological and mineralogical features of the known Arizona districts and the description of the model by Mosier and others (1986a). Of 41 districts located worldwide, 3 districts in Arizona are included in the model. Of the 15 districts with pre-production sizes sufficient to be deemed significant, the Kofa, Oatman, Turquoise, Union Pass, and Vulture are above the median of the tonnage distribution. The question of whether the deposits in Arizona are evenly distributed about the means of the tonnage curve remains a matter of debate, although the initial perception that perhaps 60 to 70 districts might lie below the 90th percentile shifted to an acceptance that perhaps only 12 or so of the smaller districts might properly be classified as Comstock type, with the rest better classed as polymetallic or other types.

Gold-silver vein deposits near Prescott are problematic because they occur in Precambrian rocks, yet have many characteristics in common with epithermal vein deposits. These deposits were classified as "Congress-type" in a preassessment of the Prescott quadrangle (Conway and others, 1987).

Arizona epithermal districts generally are all in volcanic rocks of approximately the same age as mineralization. The veins bottom within a few hundred feet and do not connect with larger base-metal deposits at depth. The districts are related to volcanic centers rather than to large intrusions. In Arizona, many of the districts fall in an area south of the Colorado Plateau in a belt that is in line with the Colorado mineral belt.

South of the northeast-trending Holbrook Lineament (Titley and Anthony, 1989, p. 489), gold is generally produced from silver-rich polymetallic deposits whereas between the Holbrook and Bright Angel-Mesa Butte lineament to the north, gold is generally produced from gold-rich quartz veins (Titley, oral commun., 1993).

Examination of the production reported in Keith and others (1983) for approximately 70 districts shown as Type 3 (gold districts with or without copper or lead) shows that for more than half, the ratio of base to precious metal is above 100 (S. Richard, Arizona Geological Survey, written commun., 1993). Some of these were significant gold producers. However, there is no way to discern which of the districts are composed of more than one deposit type; some of them may contain mostly base metals and may not be of the Comstock type at all.

Rationale for Tract Delineation

The permissive tract was compiled using the 1988 Geologic Map of Arizona (Reynolds, 1988, Map 26). The rocks included Triassic and Jurassic through Quaternary andesites through rhyolites as well as associated subvolcanic intrusions and volcano-sedimentary rocks that are the products of both calc-alkaline and bimodal volcanism. These volcanic fields delineate the permissive tract for epithermal mineral deposits.

The permissive tract was extended under younger units where justified by geologic interpretation of the State map. More speculative extensions were made by assuming a 10° dip and extending the unit either to the point where it would be 1 km deep (a lateral distance of about 6 km) or to a point halfway between the volcanic outcrop and another, nonvolcanic unit. In general, pre-Tertiary units are too discontinuous to extend with confidence under cover. Rocks are not delineated permissive where depth to bedrock is greater than 1 km, based on the Depth-to-bedrock map for Arizona (Oppenheimer and Sumner, 1980). The resulting tract is essentially a map of volcanic rocks, but also includes those parts of epithermal districts that do not plot precisely in the volcanic terranes.

Important Examples of Deposit Type

Kofa, Oatman, Turquoise, Union Pass, and Vulture are the most important of the known historic districts in Arizona (Keith and others, 1983). The development in the 1980s of the Frisco deposit raised the Union Pass (McConico) district above the median of the tonnage curve. The Newsboy deposit in the Vulture district, is a new discovery in the 1980s.

Rationale for Numerical Estimate

Information that was available for participants to determine the favorability of areas within the permissive tract included maps showing the distribution of some of the volcanic centers, maps showing the distribution of As, Sb, and Hg geochemical anomalies, maps showing the distribution of placer gold deposits, and gravity and magnetic anomaly data at sub-regional scales.

The group discussed the perception that exploration activity for gold has been greater in Nevada than in Arizona since the early 1980s. It was estimated that of the 60 or so small districts (both Comstock and polymetallic vein), no more than about half had been looked at three times or more, and thus, some of the districts may be under-explored.

Some estimators thought the potential for undiscovered districts in the upper 1 km of the basins was about the same, area for area, as the number of districts presently exposed.

There are approximately 15,000 km² of exposed Tertiary volcanic rocks within the permissive tract. The maximum ratio of the area of covered permissive area to exposed area was estimated to be about 0.7.

To promote a detailed analysis, the permissive tract south of the Colorado Plateau was divided into two terranes, southeastern Arizona and northwestern Arizona because of crustal differences in silver-to-gold ratios recognized by Titley (1991). The northwestern area contains ores relatively rich in gold whereas the southeastern area contains ores relatively enriched in silver.

Factors important to the estimators included: (1) the distribution and number of Arizona districts known to be similar in size and grade to those in the Comstock model; (2) amounts of pre- and post-basin volcanic cover; (3) concealment by cover, in that the northwestern area has 3 times as much cover as the southeastern area, and thus, there may be more undiscovered deposits in the northwestern part; (4) the perception that there has been relatively low exploration intensity of exposed volcanic rocks; (5) the fact that unlike Nevada, Arizona is not chiefly known as an important precious metal region; (6) the possibility of the existence of deposits older than Tertiary in age, given that there is apparently a Jurassic epithermal deposit just across the border in Mexico; and (7) the difficulty in finding veins not exposed at the surface.

There remain some differences of opinion among the team members. Some think the possibility of finding deposits having ages older than Tertiary was likely. They believe there is sufficient

room in the broadly defined permissive tract to hold the numbers estimated. A more cautious point of view holds that perhaps half of the known districts are mis-classified and that there is not much remaining to be discovered in the rocks now exposed at surface. The final consensus was that for the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 1, 5, 7, 10, and 15 or more deposits consistent with the grade and tonnage model of Mosier and others (1986b).

References

- Conway, C., Hanna, W.F., Hendicks, J.D., Hoover, D.B., Knepper, D.H., Jr., McCarthy, J.H., Jr., Mosier, D., Page, N.J., Pitkin, J.A., and Southworth, C.S., 1987, Planning document for the mineral resource assessment of the Prescott 1° x 2° quadrangle, Arizona: U.S. Geological administrative report, unpublished, 130 msp.
- Keith, S.B., Gest, D.E., and DeWitt, Ed, 1983a, Metallic mineral districts of Arizona: Arizona Bureau of Geology and Mineral Technology Map 18, scale 1:1,000,000.
- Mosier, D.L., Singer, D.A., and Berger, B.R., 1986, Descriptive model of Comstock epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 150.
- Mosier, D.L., Sato, Takeo, and Singer, D.A., 1986, Grade-tonnage model of Comstock epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 151-153.
- Oppenheimer, J.M., and Sumner, J.S., 1980, Depth-to-bedrock map, Basin and Range province, Arizona: Tucson, Ariz., University of Arizona, Laboratory of Geophysics.
- Titley, S.R., 1991, Correspondence of ores of silver and gold with basement terranes in the American southwest: *Mineralium Deposita*, v. 26, p. 66-71.
- Titley, S.R., and Anthony, E.Y., 1989, Laramide mineral deposits in Arizona, *in* Jenney, J.P., and Reynolds, S.J., eds., Geologic evolution of Arizona: Tucson, Arizona Geological Society Digest 17, p. 485-514.

SB30**Epithermal Vein Deposits, Quartz-adularia Type****New Mexico****Descriptive Model 25c + 25d • Mark3 Index 25****Area = 13,500 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* Alan R. Wallace and Virginia McLemore**Rationale for Model Choice**

Numerous known quartz-adularia precious-metal veins occur in felsic to intermediate volcanic rocks in southwest New Mexico. The general lack of information on grades and tonnages precluded classifying known deposits and potential undiscovered deposits into separate Creede, Comstock, and Sado deposit models. Therefore, a general volcanic-hosted quartz-adularia model was adopted, which is a combination of the Comstock and Sado data (Mark3 index 25).

Rationale for Tract Delineation

Extensive felsic to intermediate Tertiary volcanic fields in the area contain known quartz-adularia deposits. These volcanic fields are variably cut by younger intrusive rocks, and faults and caldera ring fractures are common. Therefore, permissive tracts were delineated to include areas of volcanic rocks of intermediate to felsic composition. The absence of faults or other fluid-focusing structures on maps was not considered a negative criteria for assessment.

Important Examples of Deposit Type

Mogollon is a known district, and Steeple Rock is a significant prospect that exhibits characteristics of both quartz-adularia and quartz-alunite deposits. In addition, six additional prospects—Wilcox, Kimball/Steins, San Francisco, Gila Fluorspar, Carrizalillo, and Gillespie,—were identified in southwestern New Mexico.

Rationale for Numerical Estimate

The team assessed each of the seven prospects and first arrived at an expected value of about 1.3, including 1 deposit represented by unannounced but known reserves at Steeple Rock. Additional estimates for the greater Steeple Rock district and for the covered area in Hidalgo County added 0.4 deposits for a total expected value of about 1.7. The team reviewed the size of the known deposits and prospects and the extent of volcanic rocks, decided that the estimates were uniformly between 50 and 100 percent too low, and further revised the estimates. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 2, 3, 6, 7, and 8 or more districts consistent with the grade and tonnage model for the generalized quartz-adularia deposit type.

SB31**Epithermal Vein Deposits, Sado Type**

California

Descriptive Model 25d • Mark3 Index 28

Area = 39,700 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)

by James J. Rytuba

Rationale for Model Choice

Miocene volcanic centers and associated subvolcanic intrusive rocks of intermediate to felsic composition are present in the west Mojave part of the south Basin and Range province. These consist of dacite to rhyolite dome fields and lava flow and ash-flow fields with similar compositions. Active geothermal systems are present in the Coso Range. The prevolcanic basement is made up largely of plutonic igneous rocks. These environments are permissive for Sado gold deposits (Mosier and others, 1986). One Sado gold deposit has been mined but is now inactive. Several epithermal gold prospects and deposits and large areas of alteration are present in all of the volcanic centers. Most of these deposits and prospects occur in areas of subvolcanic Miocene intrusive rocks and vein mineralization occurs in these rocks as well as in the crystalline basement rocks. Associated mineral deposits include quartz-alunite gold deposits, Comstock epithermal veins, and hot spring Au-Ag deposits.

Rationale for Tract Delineation

The permissive tract for Sado gold deposits was delineated on the basis of areas of known gold prospects and deposits, Miocene volcanic centers, and areas of shallow cover where buried extensions of volcanic centers may occur. Included within the tract are three known gold deposits of this type. Only one, the Yellow Aster deposit, is currently active.

Important Examples of Deposit Type

There are several examples of this type of deposit within the three gold districts located in the permissive tract, including the Soledad gold deposit in the Soledad Mountain volcanic center, and the Kelly and Yellow Aster mines in the Randsburg district, all of which have been major producers of gold and silver in California.

Rationale for Numerical Estimate

Three factors contributed to the numerical estimate for undiscovered resources. One is the presence of one mine developed for this deposit type and the presence of several prospects and deposits with alteration and mineralization characteristics of this deposit type. The second factor is the presence of quartz-alunite type deposits and prospects which are associated with this deposit type. The third factor is the presence of several large volcanic centers, parts of which are buried beneath a thin veneer of alluvium or sedimentary rock that underlies parts of the permissive terrane. For the 90th, 50th, 10th, 5th, and 1st percentiles, the team estimated 0, 0, 1, 1, and 2 or more deposits consistent with the grade and tonnage model of Mosier and Sato (1986).

References

- Mosier, D.L., and Sato, Takeo, 1986, Grade and tonnage model of Sado epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 155-157.
- Mosier, D.L., Berger, B.R., and Singer, D.A., 1986, Descriptive model of Sado epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 154.

SB32**Epithermal Vein Deposits, Quartz-alunite Type**

California

Descriptive Model 25e • Mark3 Index 38

Area = 39,700 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* James J. Rytuba**Rationale for Model Choice**

Miocene volcanic centers and associated subvolcanic intrusive rocks of intermediate to felsic composition are present in the west Mojave part of the southern Basin and Range province. These consist of dacite to rhyolite dome fields, and lava flow and ash-flow fields of similar composition. These environments are permissive for quartz-alunite gold deposits (Berger, 1986). Four quartz-alunite-type deposits have been mined but are now inactive. Several epithermal gold prospects and deposits of other types, and large areas of alteration are present in the volcanic centers. Most of the deposits and prospects occur in the volcanic centers but some mineralization occurs in the crystalline basement rocks. Associated mineral deposits include hot-spring and quartz-adularia gold deposits.

Rationale for Tract Delineation

The permissive tract for quartz-alunite deposits was delineated on the basis of areas of known gold prospects and deposits, Miocene volcanic centers, and areas of shallow cover where buried extensions of volcanic centers may occur. Included within the terrane are four deposits at the Middle Buttes volcanic center which had a pre-mining reserve of about 2.4 metric tons of gold (Blaske and others, 1991) and several epithermal gold prospects and quartz-adularia type gold deposits which can be associated with quartz-alunite deposits.

Important Examples of Deposit Type

There are several examples of this type of deposit within the Mojave mining district located in the permissive tract. These include four deposits in the Middle Buttes volcanic center, and the Tropico deposit in the Soledad Mountain volcanic center, all of which have been major producers of gold in California (Blaske and others, 1991).

Rationale for Numerical Estimate

Three factors contributed to the numerical estimate for undiscovered resources. One is the presence of four mines developed for this deposit type and the presence of several prospects with alteration and mineralization characteristics of this deposit type. The second factor is the presence of quartz-adularia type deposits and prospects which are associated with quartz-alunite deposits. The third factor is the presence of large volcanic centers with pervasive alteration, parts of which are buried beneath a thin veneer of alluvium or sedimentary rock that covers parts of the permissive tract. Estimates were guided by results of two previous assessments in this area: the East Mojave National Scenic Area (Hodges and Ludington, 1991), and the West Mojave Management Area (U.S. Geological Survey, 1992). For the 90th, 50th, 10th, 5th and 1st percentiles, the team estimated 0, 0, 2, 3, and 4 or more epithermal quartz-alunite Au deposits consistent with the grade and tonnage model of Mosier and Menzie (1986).

References

Berger, B.R., 1986, Descriptive model of epithermal quartz-alunite Au, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 158.

- Blaske, A.R., Bornhorst, T.J., Brady, J.M., Marsh, T.M., and McKittrick, S.A., 1991, The Shumake volcanic dome-hosted epithermal precious metal deposit, western Mojave Desert, California: *Economic Geology*, v. 86, no. 8, p. 1646-1656.
- Hodges, C.A., and Ludington, Steve, 1991, Quantitative assessment of undiscovered metallic mineral resources in the East Mojave National Scenic Area, southern California: U.S. Geological Survey Open-File Report 91-0551, 18 p.
- Mosier, D.L., and Menzie, W.D., 1986, Grade and tonnage model of epithermal quartz-alunite Au, *in* Cox, D.P., and Singer, D.A., eds., *Mineral deposit models*: U.S. Geological Survey Bulletin 1693, p. 159.
- U.S. Geological Survey, 1992, Evaluation of selected metallic and nonmetallic mineral resources, West Mojave Management Area, southern California: U.S. Geological Survey Open-File Report 92-595, 89 p.

SB33**Epithermal Vein Deposits, Quartz-alunite Type****Nevada****Descriptive Model 25e • Mark3 Index 38****Area = 4,170 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Dennis P. Cox**Rationale for Model Choice**

Alunite alteration occurs in the Alunite district near Las Vegas, in Tertiary andesites. Although production from the associated gold deposits was very small (Longwell and others, 1965), and no districts as defined by the grade and tonnage model of Mosier and Menzie (1986) are known, the coexistence of epithermal mineralization and hydrothermal alteration in volcanic rocks indicates that the area is permissive for undiscovered quartz-alunite districts.

Rationale for Tract Delineation

All Tertiary volcanic rocks and their extensions under less than 1 km of cover are permissive.

Rationale for Numerical Estimate

Based on the broad area of covered Tertiary volcanic rocks permissive for this deposit type, and the presence of known deposits to the west, in rocks of the same age in California, the team estimated, for the 90th, 50th, 10th, 5th, and 1st percentiles, 0, 1, 2, 4, and 5 or more deposits consistent with the grade and tonnage model of Mosier and Menzie (1986).

References

- Mosier, D.L., and Menzie, W.D., 1986, Grade-tonnage model of epithermal quartz-alunite veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 159-161.
- Longwell, C.R., Pampeyan, B.B., and Roberts, R. J., 1965, Geology and mineral deposits of Clark County, Nevada: Nevada Bureau of Mines and Geology Bulletin 62, 218 p.

SB34**Epithermal Vein Deposits, Quartz-alunite Type**

Arizona

Descriptive Model 25e

Area = 59,600 km²[Model](#)*by* Dennis P. Cox**Rationale for Model Choice**

The Tertiary volcanic rocks in Arizona are considered permissive for quartz-alunite gold deposits. Although there are no known occurrences of quartz-alunite gold mineralization in the tract, deposits of this type are known in neighboring parts of California (Mojave district), and Nevada, (Alunite district), and occurrences of alunite alteration are known in nearby New Mexico (Steeplerock district).

Rationale for Tract Delineation

The permissive tract was compiled using the 1988 Geologic Map of Arizona (Reynolds, 1988, map 26). The rocks included Triassic and Jurassic through Quaternary andesites through rhyolites as well as associated subvolcanic intrusions and volcano-sedimentary rocks that are the products of both calc-alkaline and bimodal volcanism. These volcanic fields delineate the permissive tract for epithermal mineral deposits.

The permissive tract was extended under younger units where justified by geologic interpretation of the State map. More speculative extensions were made by assuming a 10° dip and extending the unit either to the point where it would be 1 km deep (a lateral distance of about 6 km) or to a point halfway between the volcanic outcrop and another, nonvolcanic unit. In general, pre-Tertiary units are too discontinuous to extend with confidence under cover. Rocks are not delineated permissive where depth to bedrock is greater than 1 km, based on the Depth to Bedrock Map for Arizona (Oppenheimer and Sumner, 1980). The resulting tract is essentially a map of volcanic rocks, but also includes those parts of epithermal districts that do not plot precisely in the volcanic terrains.

Rationale for Numerical Estimate

Because of the lack of known deposits in the tract, we considered that the probability of occurrence of hot-spring gold deposits was less than 0.01 percent, and we made no estimate.

References

- Oppenheimer, J.M., and Sumner, J.S., 1980, Depth-to-bedrock map, Basin and Range province, Arizona: Tucson, University of Arizona, Laboratory of Geophysics.
- Reynolds, S.J., 1988, Geologic map of Arizona: Arizona Geological Survey Map 26, scale 1:1,000,000.

SB35**Epithermal Vein Deposits, Quartz-alunite Type****New Mexico****Descriptive Model 25e • Mark3 Index 38****Area = 13,500 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Alan R. Wallace and Virginia McLemore**Rationale for Model Choice**

Quartz-alunite gold deposits are related to felsic volcanic and subvolcanic rocks, which are abundant in southwestern New Mexico. Based on the characteristics of known occurrences and prospects, we used the descriptive model of Berger (1986) and the grade-tonnage model of Mosier and Menzie (1986).

Rationale for Tract Delineation

Felsic volcanic rocks are common in southwestern New Mexico, and acid-sulfate alteration has been reported in these rocks. Felsic to intermediate volcanic and related subvolcanic rocks and their shallow extensions make up the permissive tract.

Important Examples of Deposit Type

Alum Mountain north of Silver City and prospects in the Steeple Rock district are quartz-alunite prospects. In addition, quartz-alunite deposits were recognized by industry in the Wilcox district (J.C. Ratté, oral commun., 1994) and the Cooke's Range (V.T. McLemore, written commun., 1993).

Rationale for Numerical Estimate

Although the permissive tract is not large, acid-sulfate alteration is evident in at least four districts, several prospects are present, and exploration companies have specifically looked for this type of deposit here. Most districts in New Mexico have not been adequately explored at depth, and drilling and other exploration programs are needed to better evaluate the potential for undiscovered deposits (V.T. McLemore, written commun., 1993). For the 90th, 50th, 10th, 5th, and 1st percentiles, the team made estimates of 0, 0, 1, 2, and 4 or more deposits consistent with the grade and tonnage model for quartz-alunite deposits of Mosier and Menzie (1986).

References

- Berger, B.R., 1986, Descriptive model of epithermal quartz-alunite Au, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 158.
- Mosier, D.L., and Menzie, W.D., 1986, Grade and tonnage model of epithermal quartz-alunite Au, *in* Cox, D.P., and Singer, D. A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 159-161.

SB36**Hot-spring Au-Ag Deposits**

California

Descriptive Model 25a • Mark3 Index 45

Area = 39,700 km²[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* James J. Rytuba**Rationale for Model Choice**

Miocene volcanic centers and associated subvolcanic intrusive rocks of intermediate to felsic composition are present in the Mojave Desert part of the southern Basin and Range province. These consist of andesite to rhyolite dome fields, intermediate lava flow and ash-flow fields, and one large caldera structure. Active geothermal systems are present in the Coso Range. These environments are permissive for hot spring Au-Ag deposits (Berger, 1986). Two hot-spring deposits have been mined recently, but are now inactive. In the East Mojave National Scenic Area, one large hot-spring Au-Ag deposit is being mined and epithermal gold prospects and associated alteration are present in several of the volcanic centers. Several epithermal gold prospects and deposits and large areas of alteration are present in all of the volcanic centers. Most of the deposits and prospects occur in the volcanic centers but some mineralization occurs in the crystalline basement rocks. Associated mineral deposits include epithermal quartz-alunite and quartz-adularia deposits.

Rationale for Tract Delineation

The permissive tract for hot spring Au-Ag deposits was delineated on the basis of areas of known gold prospects and deposits, Miocene volcanic centers, areas of shallow cover where buried extensions of volcanic centers may occur, and areas of active geothermal systems. Included within the tract are known deposits, one of which, the Castle Mountain deposit, in the Hart district, is currently being mined, and several epithermal gold prospects and quartz-alunite and quartz-adularia gold deposits which can be associated with hot spring Au-Ag deposits.

Important Examples of Deposit Type

The Standard gold deposit in the Soledad Mountain volcanic center, the Shumake and Cactus Queen deposits in the Middle Buttes volcanic center, and deposits in the Randsburg district have all been major producer of gold and silver in California. The Castle Mountain gold deposit in the Hart district near the Nevada-California border is hosted in a Miocene dome and flow field. It is a major producer of gold in California (Burnett, 1990), and recent exploration has defined a large new reserve amenable to open-pit mining methods.

Rationale for Numerical Estimate

Four factors contributed to the numerical estimate for undiscovered resources. One is the presence of five mines developed for this deposit type and the presence of several prospects with alteration and mineralization characteristics of this deposit type. The second factor is the presence of quartz-alunite and quartz-adularia type deposits and prospects which are associated with hot spring Au-Ag deposits. Third is the presence of several large volcanic centers, parts of which are buried beneath a thin veneer of alluvium or sedimentary rock that covers parts of the permissive tract. Finally, there is an active geothermal system in the permissive tract. Estimates were guided by results of two previous assessments in this area: the East Mojave National Scenic Area (Hodges and Ludington, 1991), and the West Mojave Management Area (U.S. Geological Survey, 1992). For the 90th, 50th, 10th, and 5th percentiles,

the team estimated 0, 2, 4, 6, and 8 or more deposits consistent with the worldwide hot spring Au-Ag grade and tonnage model (Berger and Singer, 1992).

References

- Berger, B.R., and Singer, D.A., 1992, Grade and tonnage model of hot-spring Au-Ag, *in* Bliss, J.D., ed., *Developments in mineral deposit modeling*: U.S. Geological Survey Bulletin 2004, p. 23-25.
- Burnett, J.L., 1990, 1989 California mining review: *California Geology*, v. 43, no. 10, p. 219-224.
- Hodges, C.A., and Ludington, Steve, 1991, Quantitative assessment of undiscovered metallic mineral resources in the East Mojave National Scenic Area, southern California: U.S. Geological Survey Open-File Report 91-0551, 18 p.
- Schantz, Radford, Wetzel, Nicholas, Adams, Robert, and Raney, R.G., 1990, Minerals in the East Mojave National Scenic Area, California—An economic analysis, volume II: U.S. Bureau of Mines Open-File Report MLA 6-90, v. 2, 252 p.
- U.S. Bureau of Mines, 1990, Minerals in the East Mojave National Scenic Area, California—A minerals investigation, volume I: U.S. Bureau of Mines Open-File Report MLA 6-90, v. 1, 356 p.
- U.S. Bureau of Mines, 1992, Economic analysis of the minerals potential of the East Mojave National Scenic Area, California, executive summary: U.S. Bureau of Mines Open-File Report 55-92, 12 p.
- U.S. Bureau of Mines, 1992, Economic analysis of the minerals potential of the East Mojave National Scenic Area, California: U.S. Bureau of Mines Open-File Report 56-92, 43 p. plus attachments.
- U.S. Geological Survey, 1991, Evaluation of metallic mineral resources and their geologic controls in the East Mojave National Scenic Area, San Bernardino County, California: U.S. Geological Survey Open-File Report 91-0427, 278 p., 6 plates.
- U.S. Geological Survey, 1992, Permissive terranes for metallic and selected non-metallic mineral resources, West Mojave Management Area, southern California: U.S. Geological Survey Administrative Report, 21 p., 1 plate.
- U.S. Geological Survey, 1992, Evaluation of selected metallic and nonmetallic mineral resources, West Mojave Management Area, southern California: U.S. Geological Survey Open-File Report 92-595, 89 p.

SB37**Hot-spring Au-Ag Deposits****California****Descriptive Model 25a • Mark3 Index 45****Area = 7,110 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)[Mineral Deposits](#)*by* Richard M. Tosdal**Rationale for Model Choice**

The southeast corner of California contains widely distributed volcanic rocks that unconformably overlie metamorphic and igneous rocks; subvolcanic and epizonal calc-alkaline dikes and stocks intrude the crystalline rocks. These environments are permissive for hot-spring Au-Ag deposits. In addition, numerous epithermal gold prospects and deposits are present. Some of these deposits have been classified as hot-spring Au-Ag type deposits. Most deposits or prospect occur in crystalline rocks that underlie the volcanic rocks.

Rationale for Tract Delineation

Included in this permissive tract for hot-spring Au-Ag deposits are areas of known gold prospects, Tertiary volcanic rocks that might conceal one of these deposits, and areas of shallow cover on the extensive pediments on the flanks of the ranges. The two known deposits, currently being mined, and two prospects are included within the tract.

Important Examples of Deposit Type

There are two examples of this deposit type within the permissive tract. One is the Mesquite deposit, a major producer of gold in California (Burnett, 1990; Willis and Tosdal, 1992), and the second is the Picacho deposit, which is also actively being mined. Both are north of Yuma, Arizona. Another example of this type of deposit in the Great Basin part of southern California is the Hart deposit, near the Nevada-California border.

Rationale for Numerical Estimate

Two factors are especially important to the numerical estimate for undiscovered deposits. One is the presence of two developed mines of this type, as well as the two other prospects that have been explored but are of too low grade or tonnage to be mined at present. Second is the wide expanse of pediment buried beneath thin veneer of alluvium or sedimentary rock that underlies most of the permissive tract. Based upon these two factors, for the 90th, 50th, and 10th percentiles, the team estimated 1, 3, and 5 or more deposits consistent with the worldwide hot-spring Au-Ag grade and tonnage model (Berger and Singer, 1992).

References

- Berger, B.R., and Singer, D.A., 1992, Grade and tonnage model of hot-spring Au-Ag, *in* Bliss, J.D., ed., *Developments in mineral deposit modeling: U.S. Geological Survey Bulletin* 2004, p. 23-25.
- Burnett, J.L., 1990, 1989 California mining review: *California Geology*, v. 43, no. 10, p. 219-224.
- Willis, G.F., and Tosdal, R.M., 1992, Formation of gold veins and breccias during dextral strike-slip faulting in the Mesquite mining district, southwestern California: *Economic Geology*, v. 87, no. 8, p. 2002-2022.

SB38**Hot-spring Au-Ag Deposits****Nevada****Descriptive Model 25a • Mark3 Index 45****Area = 4,170 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Dennis P. Cox**A nearby example, and Rationale for Model Choice**

Although no deposits as defined by the grade and tonnage model of Berger and Singer (1986) are known in Nevada, a major deposit is known in the Hart district, Castle Mountains, in California 7 km from the border (Ausburn, 1991; Capps and Moore, 1991) The same permissive conditions exist for undiscovered districts of this type in Nevada.

Rationale for Tract Delineation

All Tertiary volcanic rocks and their extensions under less than 1 km of cover are permissive.

Rationale for Numerical Estimate

Based on the broad area of covered Tertiary volcanic rocks permissive for this deposit type, the team estimated, for the 90th, 50th, 10th, 5th, and 1st percentiles, 0, 1, 1, 1, and 2 or more deposits consistent with the grade and tonnage model of Berger and Singer (1992).

References

- Ausburn, K.E., 1991, Ore-petrogenesis of Tertiary volcanic-hosted epithermal gold mineralization at the Hart mining district, Castle Mountains, NE San Bernardino County, California, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., *Geology and ore deposits of the Great Basin--Symposium proceedings: Reno, Geological Society of Nevada*, v. 2, April 1990, p. 1147-1188.
- Berger, B.R., and Singer, D.A., 1992, Grade and tonnage model of hot-spring Au-Ag, *in* Bliss, J.D., ed., *Developments in deposit modeling: U.S. Geological Survey Bulletin 2004*, p. 23-25.
- Capps, R.C., and Moore, J.A., 1991, Geologic setting of mid-Miocene gold deposits in the Castle Mountains, San Bernardino County, California, and Clark County Nevada, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., *Geology and ore deposits of the Great Basin--Symposium proceedings: Reno, Geological Society of Nevada*, v. 2, April 1990, p. 1195-1220.

SB39**Descriptive Model 25a****Area = 74,300 km²****Hot-spring Au-Ag Deposits****Arizona
New Mexico**[Model](#)*by* Robert J. Kamilli and Leslie J. Cox**Rationale for Model Choice**

The Tertiary volcanic rocks in Arizona are considered permissive for quartz alunite gold deposits. Although there are no known occurrences of hot-spring gold mineralization in Arizona, deposits of this type are known in the Mojave region in California (Hart district).

Rationale for Tract Delineation

The permissive tract was compiled using the 1988 Geologic Map of Arizona (Reynolds, 1988, map 26). The rocks included Triassic and Jurassic through Quaternary andesites through rhyolites as well as associated subvolcanic intrusions and volcano-sedimentary rocks that are the products of both calc-alkaline and bimodal volcanism. These volcanic fields delineate the permissive tract for epithermal mineral deposits.

The permissive tract was extended under younger units where justified by geologic interpretation of the State map. More speculative extensions were made by assuming a 10 degree dip and extending the unit either to the point where it would be 1 km deep (a lateral distance of about 6 km) or to a point halfway between the volcanic outcrop and another, nonvolcanic unit. In general, pre-Tertiary units are too discontinuous to extend with confidence under cover. Rocks are not delineated permissive where depth to bedrock is greater than 1 km, based on the Depth to Bedrock Map for Arizona (Oppenheimer and Sumner, 1980). The resulting tract is essentially a map of volcanic rocks, but also includes those parts of epithermal districts that do not plot precisely in the volcanic terrains.

Rationale for Numerical Estimate

Because of the lack of known deposits in the tract, we considered that the probability of occurrence of hot-spring gold deposits was less than 0.01 percent, and we made no estimate.

References

- Oppenheimer, J.M., and Sumner, J.S., 1980, Depth-to-bedrock map, Basin and Range province, Arizona: Tucson, University of Arizona, Laboratory of Geophysics.
- Reynolds, S.J., 1988, Geologic map of Arizona: Arizona Geological Survey Map 26, scale 1:1,000,000.

SB40**Sediment-hosted Au Deposits****Nevada
California****Descriptive Model 26a • Mark3 Index 17****Area = 18,700 km²**[Cumulative Distribution](#)[Histogram](#)[Table](#)[Model](#)*by* Dennis P. Cox**Rationale for Model Choice**

Although no sediment-hosted gold deposits are known, shales and carbonate rocks in sedimentary sequences thickened by thrust faulting are permissive conditions for undiscovered deposits of this type.

Rationale for Tract Delineation

Paleozoic sedimentary rocks that were folded and thrust faulted during Mesozoic or earlier orogenies constitute the permissive tract. There are no known deposits or prospects.

Rationale for Numerical Estimate

Because of the lack of known deposits and the fact that this area is a great distance from the well-recognized deposits in northern Nevada, the team made a low estimate. For the 90th, 50th, 10th, 5th, and 1st percentiles, we estimated 0, 0, 0, 0, 1 or more deposits consistent with the grade and tonnage model of Mosier and others (1992).

Reference

Mosier, D.L., Singer, D.A., Bagby, W.C., and Menzie, W. D., 1992, Grade and tonnage model of sediment-hosted Au, *in* Bliss, J.D., ed., Developments in deposit modeling: U.S. Geological Survey Bulletin 2004, p. 26-28.

Overlook-type Gold Deposits**Washington****Mineral Deposits**

by Stephen E. Box and Arthur A. Bookstrom

General Description

Three Au deposits (Overlook, Key East and West, Lame Foot), located in northeastern Washington, are hosted in the Quesnellia oceanic accreted terrane. The gold deposits are associated with stratiform bodies of massive magnetite that is in sharp contact with Permian limestone on one side, and in fault contact with siltite-argillite on the other side. The deposits contain two types of ore: massive and veinlet. The massive ore consists of silicified, gold-bearing magnetite ± pyrrhotite ± pyrite ± hematite. The veinlet ore consists of gold-bearing quartz-pyrite-chalcopyrite veinlets and disseminated sulfides, in silicified argillite-siltite (Tschauder, 1989; Carden and others, 1992; Derkey, 1993; Rasmussen, 1993). The massive and veinlet ores commonly are in fault contact, and much of the massive ore is brecciated. Contacts of massive ore with unmineralized limestone are sharp and cusped, and the limestone appears unaltered. Quartz-veined argillite-siltite is silicified, sericitized, and bleached. Gold grade is about 5 g Au/metric ton in both ore types, and at Lame Foot the gold resource is about evenly divided between the two ore types. In both types of ore, gold is closely associated with sulfides, quartz veinlets, and pervasively silicified host rocks (silicified massive ore, brecciated and silicified massive ore, and silicified argillite-siltite).

The origin of these deposits is controversial. In one model, massive magnetite-pyrrhotite-pyrite deposits are interpreted as epigenetic replacement deposits, hosted in limestone; and quartz-sulfide veinlets are interpreted as hydrothermal fracture fillings, hosted in argillite-siltite (Tschauder, 1989). In the other model, the massive magnetite-pyrrhotite-pyrite bodies are interpreted as sea-floor volcanogenic massive oxide-sulfide deposits, similar to Australian deposits described by Davidson (1992), and the quartz-sulfide veinlets are interpreted as epigenetic veinlets, superimposed during a later hydrothermal event (Rasmussen, 1993).

Descriptive and grade-tonnage models have not been compiled for Overlook-type gold deposits. Therefore, no estimates were made for undiscovered mineral resources of this type.

References

- Carden, J.R., Wendland, D.W., and Rasmussen, M.G., 1992, The discovery and geology of the Lame Foot gold deposit, Ferry County, Washington [abs]: Abstracts, New world of minerals, Northwest Mining Association 98th Annual Convention, p. 26.
- Davidson, G.J., 1992, Hydrothermal geochemistry and ore genesis of sea-floor volcanogenic copper-bearing oxide ores: *Economic Geology*, v. 87, no. 3, p. 889-912.
- Derkey, R.E., 1993, Metallic mineral deposits, in Derkey, R.E., Gulick, C.W., and Lingley, W.S., Jr., eds., *Washington's mineral industry—1992: Washington Geology*, v. 21, no. 1, p. 4-30.
- Rasmussen, M.G., 1993, The geology and origin of the Overlook gold deposit, Ferry County, Washington: Seattle, University of Washington, Unpub. Ph.D. dissertation, 153 p.
- Tschauder, R.J., 1989, Gold deposits in northern Ferry County, Washington, in Joseph, N.L., and others, eds., *Geologic guidebook for Washington and adjacent areas: Washington Division of Geology and Earth Resources Information Circular 86*, p. 241-253.

National Assessment 1998
Alaska
Known Deposits

Layer	Tract	Map No.	Deposit	District	Quadrangle 250K Scale	Lat	Long	Deposit Type	Alternative Deposit Type
AKPL	AK-WC17	04	Koyuk District	Koyuk	Candle	65.000	-161.330	Placer Au-PGE	
AKPL	AK-WC17	05	Council District	Council	Solomon	64.750	-163.500	Placer Au-PGE	
AKPL	AK-WC17	06	Nome District	Nome	Nome	64.500	-165.500	Placer Au-PGE	
AKPL	AK-WC17	07	Ruby District	Ruby	Ruby	64.417	-154.333	Placer Au-PGE	
AKPL	AK-WC17	08	Innoko District	Innoko	Ophir	63.500	-156.500	Placer Au-PGE	
AKPL	AK-WC17	09	McGrath District	McGrath	McGrath	62.750	-155.000	Placer Au-PGE	
AKPV	AK-WC22	01	Illinois Creek	Kaiyuh	Nulato	64.080	-158.000	Vein, polymetallic	Polymetallic replacement
AKPV	AK-WC22	02	Win-Won (Cloudy Mountain)	Innoko	Medfra	63.220	-156.070	Vein, polymetallic, Ag-Sn	
AKSK	AK-WC24	01	Nixon Fork	Innoko	Medfra	63.236	-154.758	Skarn, Cu	

Polymetallic Veins, Au-Ag-bearing

Idaho Batholith

Mineral Deposits

by Arthur A. Bookstrom and Stephen E. Box

General Description

Clusters of polymetallic quartz veins, containing gold and silver, are widely distributed within and around the Idaho batholith. Many significant placer gold deposits of the region were derived from them. Most of these veins occupy steeply dipping faults and fissures, and many of them are localized within or near roof pendants or inclusions of metasedimentary rocks in the Idaho batholith. These veins generally are quartz-rich, and commonly contain less than 5 percent of a wide variety of fine-grained ore minerals. Arsenopyrite, pyrite, galena, sphalerite, chalcopyrite, tetrahedrite, and stibnite are common. Bournonite, proustite, argentite, and electrum are sparse. Heubnerite, scheelite, hessite, cinnabar, and zinc-mercury sulfides are rare, but are characteristic of some veins. These veins commonly show evidence of multiple episodes of fracturing and healing by multiple generations of quartz, and various assemblages of ore minerals (Kiilsgaard and Bennett, 1987; Gammons, 1988). The composition of an individual vein depends on its particular history of fracturing and healing, during multiple pulses of mineralization in hydrothermal systems that changed with time. Wall rocks of some veins are pervasively silicified and sericitized, and contain disseminated ore minerals. Wall rocks of other veins are relatively unaltered. Free gold is more common in oxidized parts of the veins, than in reduced parts (below the water table), where much of the gold is contained in other ore minerals.

Polymetallic veins of the Atlanta district have significant known production and reserves of silver and gold; veins of the Hailey gold belt, and of the Rocky Bar, Elk City, and Warren districts have produced significant amounts of gold, and veins of the Yellow Jacket district have produced lead, copper, silver, and gold, and have significant reserves of gold (Table of Known Deposits, this report).

No estimates were made of the resources of undiscovered Au-Ag polymetallic veins of the Idaho batholith, because appropriate grade-tonnage models were not available when the estimation team met. However, Bliss (1994) has recently compiled tonnage-grade models for mixed base- and precious-metal veins of the Idaho batholith. Six different components of mineralization were modeled, as follows: (1) gold veins with byproduct silver, copper, and lead \pm zinc; (2) silver veins with byproduct gold, copper, and lead \pm and(or) zinc; (3) Ag-Pb veins with byproduct copper, and gold \pm zinc; (4) copper veins with byproduct gold, and silver \pm zinc; (5) copper-lead-zinc veins with byproduct gold \pm primary silver; and (6) simple antimony deposits with byproduct gold \pm silver. Deposits may contain one to three components, but most contain only one component, and most are gold veins. Geometric mean deposit size is 13,000 metric tons. Geometric mean gold grade in gold veins is 13 g Au/metric ton; in other components, gold grade is commonly less than 10 g Au/metric ton. Silver grades vary from 1 to 10,000 g Ag/metric ton. The median size of the area with mines is 2.9 square km (Bliss, 1994).

References

- Bliss, J.D., 1994, Mineral deposit modeling using components for complex mineral deposits—Mixed base- and precious-metal veins of the Idaho batholith, Idaho: U.S. Geological Survey Open-File Report 94-690, 53 p.
- Gammons, C.H., 1988, Studies in hydrothermal phenomena—1. The solubility of silver sulfide in aqueous sulfide solutions to 300° C., 2. A paragenesis and fluid inclusion study of polymetallic

mineralization in the Big Creek mining district, central Idaho: University Park, Pennsylvania, The Pennsylvania State University, Ph.D. dissertation, 337 p.

Kiilgaard, T.H., and Bennett, E.H., 1987, Mixed base- and precious-metal veins, *in* Fisher F.S., and Johnson, K.M., eds., Preliminary manuscript for "Mineral-Resource Potential and Geology of the Challis 1° x 2° Quadrangle, Idaho": U.S. Geological Survey Open-File Report 87-480, p. 126-133.

Polymetallic Veins, Au-Ag-bearing

Blue Mountains
Northeastern Oregon

Mineral Deposits

by Arthur A. Bookstrom and Stephen E. Box

General Description

According to Brooks and Ramp (1968), about 75 percent of the gold produced in Oregon has come from lode and placer deposits of the Blue Mountains, in the northeastern part of the State. "The lode-gold deposits in the Blue Mountains are predominantly narrow, quartz-rich fissure veins, breccia fillings, and associated replacement bodies along faults and shear zones" in argillite and granodiorite (Brooks and Ramp, 1968, p. 51). Quartz, pyrite, sphalerite, galena, chalcopyrite, tetrahedrite, and arsenopyrite are common in these veins. Pyrargyrite, proustite, stephanite, stibnite, cinnabar, petzite, and hessite are sparse to rare. Vein textures indicate mineral deposition by replacement and open-space filling. Veins are most abundant near contacts of Jurassic and Cretaceous plutons. Mineral assemblages of some vein sets are zoned with respect to the margins of such plutons (Hewett, 1931). Free gold is more common in oxidized parts of the veins than in reduced parts (below the water table), where much of the gold is contained in other ore minerals.

At the beginning of this study, gold-bearing veins of the Blue Mountains were tentatively classified as either low-sulfide Au-quartz veins, as described by Berger (1986), or as gold-silver polymetallic veins, as described by Cox (1986). However, most veins in the Cracker Creek, Cornucopia, Greenhorn, Granite, and Rock Creek mining districts of the Blue Mountains have produced much more silver than is typical for low-sulfide Au-quartz veins (table of Known Deposits of this report). Furthermore, the Blue Mountain veins are distinguished from base-metal polymetallic veins, and from other Au-Ag polymetallic veins, by their relatively high gold, and low base-metal contents (Bliss, 1994).

Because no appropriate grade-tonnage model was available when the estimation team met, no estimates were made for undiscovered resources of Blue Mountain-type polymetallic veins. However, a new grade-tonnage model for Blue Mountain-type Au-Ag polymetallic veins has been completed recently by Bliss (1994). According to that model, the geometric mean deposit size is 76,000 metric tons, and most of the known deposits have gold grades between 13 and 23 g Au per metric ton, and between 2 and 300 g Ag per metric ton. The median size of the area with mines is 95 hectares (Bliss, 1994, p. 2).

References

- Berger, B.R., 1986, Descriptive model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239.
- Bliss, J.D., 1994, Grade, tonnage, and other models of Blue Mountain-type Au-Ag polymetallic veins, Blue Mountains, Oregon, for use in resource and environmental assessment: U.S. Geological Survey Open-File Report 94-677, 33 p.
- Brooks, H.C., and Ramp, Len, 1968, Gold and silver in Oregon: State of Oregon Department of Geology and Mineral Industries Bulletin 61, 337 p.
- Cox, D.P., 1986, Descriptive model of polymetallic veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 125.
- Hewett, D.F., 1931, Zonal relations of the lodes of the Sumpter quadrangle: A.I.M.E. Transactions, v. 5, p. 305-346.

Polymetallic Disseminated, Au-Ag

Idaho

Mineral Deposits

by Arthur A. Bookstrom and Stephen E. Box

General Description

Polymetallic disseminated gold-silver deposits are like polymetallic veins of the gold-silver subset, but they are large-tonnage, low-grade deposits that can be mined in-bulk for gold and silver. These deposits consist of multiple sets of veins, mineralized breccias, and stockworks of veinlets, in silicified and sericitized host rocks that contain disseminated ore minerals. They occur along broad fault zones that show evidences of repeated breakage, movement, and hydrothermal mineralization. Host rocks are granitic rocks of the Idaho batholith, roof pendants or inclusions of metasedimentary rocks within the batholith, and metamorphic rocks surrounding it. Large-tonnage, low-grade pyritic gold deposits of the Mackinaw district lie along the regional, northeast-trending Trans-Challis fault zone. Polymetallic gold-silver vein and disseminated deposits of the Atlanta district lie along a northeast-trending fault-vein system that is south of and en-echelon to the Trans-Challis fault zone. Polymetallic vein, stockwork, and disseminated deposits of the Stibnite district lie within dilational northeast-striking fault jogs and splays, along north-striking right-lateral shear zones. Multiple generations of quartz, with different combinations of ore minerals, indicate complicated histories of recurrent fracturing and mineralization within long-lived hydrothermal systems that changed from mesothermal to epithermal over time (Cookro and others, 1988; Bartels and others, 1990).

The mineralogy of polymetallic disseminated gold-silver deposits is similar to that of polymetallic veins of the gold-silver subset. Veinlets and disseminations commonly contain arsenopyrite, pyrite, galena, sphalerite, chalcopyrite, tetrahedrite, and electrum. Stibnite and scheelite were abundant in the Yellow Pine deposit, and cinnabar also is present in and around the Yellow Pine deposit. Free gold is more common in the oxidized parts of these deposits than in reduced parts (below the water table), where much of the gold is contained in other ore minerals.

Significant known polymetallic disseminated gold-silver deposits are: (1) the Yellow Pine, Homestake, and West End deposits in the Stibnite district (Cookro and others, 1988); the Beartrack deposit in the Mackinaw district, (Bartels and others, 1990); bulk-tonnage deposits in the Atlanta district (Kiilsgaard and Bacon, in press); and bulk-tonnage deposits in the Elk City district (Table of Known Deposits, this report). Gold grades typically are on the order of 2 g/metric ton. The Yellow Pine mine was a major producer of antimony and tungsten, as well as gold and silver. Arsenic and mercury are relatively widely dispersed around some deposits of this type, and may therefore be useful in exploration for hidden deposits.

Descriptive and tonnage-grade models have not been compiled for polymetallic disseminated gold-silver deposits. Therefore, no estimates were made of the resource potential of undiscovered deposits of this type.

References

- Bartels, Ed, Douglas, I., Van Huffer, G., and Busby, S., 1990 [abstract and road log] , Beartrack project, Mackinaw mining district, Lemhi County, Idaho, in Moye, F.J., ed., Geology and ore deposits of the trans-Challis fault system/Great Falls tectonic zone: Tobacco Root Geological Society, 15th Annual Field Conference, p. 31-35.
- Cookro, T.M., Silberman, M.L., and Berger, B.R., 1988, Gold-tungsten-bearing hydrothermal deposits in the Yellow Pine mining district, Idaho, in Schafer, R.W., Cooper, J.J., and Vikre, P.G., eds., Bulk

mineable precious metal deposits of the western United States: Reno, Geological Society of Nevada, p. 577-624.

Polymetallic Veins, Coeur d'Alene Type

Idaho, Montana

Mineral Deposits

by Arthur A. Bookstrom and Stephen E. Box

General Description

The Coeur d'Alene (CDA) mining district, located in northern Idaho, has the world's greatest recorded silver production, ranks as a major producer of lead and zinc, and has some of the largest, and deepest underground mines in North America (Bennett, undated). From 1886 through 1990, mines of the district have produced about 30,000 metric tons of silver, 7 million metric tons of lead, and 4 million metric tons of zinc, from 120 million metric tons of ore (Mitchell and Bennett, 1983; Bennett and Springer, 1990). Production and reserves of significant known deposits are given in the Table of Known Deposits (this report).

CDA-type polymetallic veins are mesothermal replacement veins that are localized along faults within regional metamorphic shear zones in clastic metasedimentary terranes (Frykland, 1964; Beaudoin and Sangster, 1992). Silver, lead, and zinc are the most important products derived from CDA veins. Copper, gold, antimony, arsenic, and cadmium are byproducts. Cobalt, uranium, and mercury also may be geochemically enriched. Galena, sphalerite, and tetrahedrite occur in various proportions. Typical gangue mineral assemblages include quartz + siderite \pm other carbonates \pm barite. Gangue minerals were deposited early, and continued to be deposited with the ore minerals. The typical sequence of ore-mineral deposition is: early magnetite, pyrrhotite, uraninite, and arsenopyrite, followed by intermediate galena, sphalerite, and tetrahedrite, and late chalcopyrite (Guilbert and Park, 1985, p. 486). Fluid inclusion data indicate that ore deposition occurred at about 350° to 250°C (at pressures in excess of 1 kbar), and that the mineralizing solutions were complex CO₂-CH₄-C_nH_m-N₂-H₂O-NaCl fluids, interpreted as metamorphic-hydrothermal in origin (Leach and others, 1988). Replacement textures are common, with carbonate minerals and quartz replacing wall rocks, and ore minerals replacing earlier gangue and ore minerals. According to Lindgren (1933, p. 573), "metasomatic action, indicated by the presence of siderite in the quartzite, often spreads for 100 ft or more beyond the ore." Disseminated ore minerals also are found in the wall rocks of some veins (White, 1989).

Veins of the CDA mining district commonly are 2 to 3 m thick, but range from 1 to 12 m thick; ore shoots within veins range from 0.1 to 1 km in strike length, and from 0.2 to 2 km in dip length (Lindgren, 1933; Hobbs and Frykland, 1968). Production records from significant mines of the CDA district indicate recovery-based ore grades in the following ranges: 25 to 860 g silver /metric ton; 0 to 13 percent lead; 0 to 11 percent zinc; and 0 to 6 percent copper (Table of Known Deposits, this report). According to Siems (1994) ore grades and metal ratios vary considerably between different vein sets, but vary little with depth. White (1989) noted that in the CDA district, dip-slip shearing during mineralization formed cleavage and lineation in argillic rocks, and caused alignment of flattened, elongate, disseminated grains of vein minerals in wall rock. Ore shoots tend to parallel the shear lineation (White 1989; Wavra and others, 1994). CDA-type districts generally show evidence of "repeated stages of hydraulic fracturing, mineral deposition, and dynamic metamorphism...and, sometimes, pluton emplacement" Siems (1994, p. 15).

Although CDA-type polymetallic veins are important sources of silver, lead, and zinc, there are insufficient data from which a tonnage-grade model can be assembled. Beaudoin and Sangster (1992) list five analogues: Kokanee Range, and Keno Hill in Canada, Harz Mountains and

Freiberg in Germany, and Příbram in Czechoslovakia. Production data from the European deposits are incomplete and the Canadian deposits are smaller than CDA by a factor of 5 or 10. Lacking a grade and tonnage model, a quantitative assessment could not be made, but some general statements about favorable areas for CDA deposits are possible. CDA-type veins of the northern Idaho and northwestern Montana are hosted mostly in quartzites and argillites of the Proterozoic Belt basin (Harrison (1972). Mesothermal veins are common in the Wallace 1° x 2° quadrangle, and in adjacent parts of the Spokane and Sandpoint 1° x 2° quadrangles. Harrison and others (1986) outlined tracts with 7 degrees of favorability for mesothermal polymetallic veins in the Wallace 1° x 2° quadrangle, based on their scoring of favorabilities of lithologies, structures, known mineral occurrences, and geochemical and geophysical characteristics.

"Almost half of this area (about 17,000 km²) shows evidence that is at least moderately suggestive of the presence of such veins" (Harrison and others, 1986, sheet 2). The greater CDA mineral belt extends east-southeast from Pinehurst, Idaho, to Superior, Montana, along the Lewis and Clark Line, a broad zone of deformed rocks that have undergone recurrent episodes of deformation since Proterozoic time (Harrison, 1972). The CDA mining district lies mostly in the upper CDA River basin, and extends from Pinehurst, east to Mullen, Idaho (a distance of nearly 40 km), and from Wallace, north to Murray, Idaho (a distance of nearly 20 km). CDA-type veins and associated geochemical anomalies are abundant in the CDA district (Gott and Cathrall, 1980). Clusters of CDA-like veins also are localized along the northwest-striking Hope fault zone, and in the upper plate of the north-striking Purcell detachment fault (in the Lakeview, Pend Oreille, and Clark Fork mining districts), located in northern Idaho, near Pend Oreille Lake.

References

- Beaudoin, Georges, and Sangster, D.F., 1992, A descriptive model for silver-lead-zinc veins in clastic metasedimentary terranes: *Economic Geology*, v. 87, no. 4, p. 1005-1021.
- Bennett, E.H., undated, The fabulous Coeur d'Alene mining district: Idaho Geological Survey GeoNote 07, 1 p.
- Bennett, E.H., and Springer, Donald, 1990, Mine production in the Coeur d'Alene district, 1981-1990: Idaho Geological Survey, GeoNote 20, 1 p.
- Frykland, V.C., Jr., 1964, Ore deposits of the Coeur d'Alene district, Shoshone County, Idaho, *with a section on The bleached rock in the Coeur d'Alene district by Paul L. Weis*: U.S. Geological Survey Professional Paper 445, 103 p.
- Gott, G.B., and Cathrall, J.B., 1980, Geochemical-exploration studies in the Coeur d'Alene district, Idaho and Montana: U.S. Geological Survey Professional Paper 1116, 63 p.
- Guilbert, J.M., and Park, C.F., Jr., 1985, Ore deposits: New York, W.H. Freeman and Co., 985 p.
- Harrison, J.E., 1972, Precambrian Belt basin of northwestern United States—Its geometry, sedimentation, and copper occurrences: *Geological Society of America Bulletin*, v. 83, p. 1215-1240.
- Harrison, J.E., Leach, D.L., and Kleinkopf, M.D., 1986, Resource appraisal maps for mesothermal base- and precious-metal veins of the Wallace 1° x 2° quadrangle, Montana and Idaho: U.S. Geological Survey Map I-1509-I, 2 sheets.
- Hobbs, S.W., and Fryklund, V.C., Jr., 1968, The Coeur d'Alene district, Idaho, *in* Ridge, J.D., ed., Ore deposits of the United States, 1933-1967 (The Graton-Sales Volume): New York, American Institute of Mining Metallurgical, and Petroleum Engineers, v. 2, p. 1418-1435.
- Leach, D.L., Landis, G.P., and Hofstra, A.H., 1988, Metamorphic origin of the Coeur d'Alene base- and precious-metal veins in the Belt basin, Idaho and Montana: *Geology*, v. 16, p. 122-125.
- Lindgren, Waldemar, 1933, Mineral deposits: New York and London, McGraw-Hill Book Co., 930 p.
- Mitchell, V.E., and Bennett, E.H., 1983, Production statistics for the Coeur d'Alene mining district, Shoshone County, Idaho—1884-1980: Idaho Geological Survey Technical Report 83-3, 33 p.

- Siems, P.L., 1994, Economic geology of Coeur d'Alene-type silver-lead-zinc deposits: Northwest Mining Association Abstract Book, p. 14-15.
- Wavra, C.S., Bond, W.D., and Reid, R.R., 1994, Evidence from the Sunshine mine for dip-slip movement during Coeur d'Alene district mineralization: *Economic Geology*, v. 89, no. 3, p. 515-527.
- White, B.G., 1989, Superposed map-scale folds and subsequent veins unrelated to Osburn strike-slip fault, Coeur d'Alene mining district, Shoshone Country, Idaho: Geological Society of America, Abstracts with Programs, v. 21, no. 5, p. 158.

Sedimentary Exhalative Copper-cobalt Deposits

Idaho, Montana

Mineral Deposits

by Arthur A. Bookstrom, Michael L. Zientek, and Stephen E. Box

General Description

Sedimentary exhalative copper-cobalt deposits in Idaho and Montana typically contain massive to disseminated pyrite \pm cobaltiferous pyrite \pm pyrrhotite \pm magnetite \pm arsenopyrite \pm chalcopyrite \pm cobaltite \pm gold, in association with quartz \pm tourmaline \pm siderite \pm barite, in stratabound layers, lenses, and stringers; and in concordant and discordant breccias. These deposits are interpreted as submarine sedimentary-exhalative in origin. Host rocks generally are fine-grained clastic metasedimentary rocks (argillite, siltite, and quartzite), which may have a basaltic pyroclastic component, and may contain mafic-alkalic intrusions that were emplaced before lithification of the sediments. Ore lenses may occur at multiple stratigraphic horizons, separated by barren metasedimentary rocks. They tend to be localized near basin-bounding fault zones that were active during sedimentation, as evidenced by growth faults, soft-sediment folds, dewatering structures, and (or) intraformational conglomerates (Earhart, 1986; Modreski, 1985; Nash and Hahn, 1989; Nisbet and others, 1994; and Himes and Petersen, 1990).

Sedimentary exhalative copper-cobalt deposits of Idaho and Montana are hosted in fine-grained clastic metasedimentary rocks of Middle Proterozoic age. Deposits of the Idaho cobalt belt are hosted in the Yellowjacket Formation, which was deposited in the Yellowjacket basin. Deposits of western Montana are hosted in the Newland formation, which was deposited in the Helena embayment of the Belt basin.

The Idaho cobalt belt is located in east-central Idaho. The belt extends northwesterly for about 55 km, along the strike of the Middle Proterozoic Yellowjacket Formation, which contains at least eleven sediment-hosted copper-cobalt occurrences, including the Blackbird, Blackpine, Salmon Canyon, and Iron Creek deposits. Lateral zonation within the Idaho Cobalt belt shows gradations from iron-bearing sulfides, to oxides, to carbonates, to silicates, as in banded iron-formation terranes (Nisbet and others, 1994). Rocks and ores of the Idaho cobalt belt are progressively metamorphosed toward the northwest, and some discordant ore textures are attributed to metamorphic remobilization (Nold, 1990).

The Blackbird deposit has known production and resources of about 90,000 metric tons of copper and 5,300 metric tons of cobalt, in ores that contain about 1.4 percent copper, 0.8 percent cobalt, and 0.5 g Au/metric ton (Table of Significant Known Deposits, this report). The Blackbird mine area contains at least 17 copper-cobalt-gold lodes, which are localized along eight stratigraphic horizons (Nash and others, 1987). The ore-bearing strata are characterized by biotitite (interpreted as mafic-alkalic metatuff) and metachert (interpreted as siliceous exhalite). The stratigraphically lower deposits consist of sub-massive to disseminated ore and gangue minerals--pyrite, pyrrhotite, chalcopyrite, cobaltite, quartz, and siderite--that fill syn-sedimentary disruption structures and veins. The stratigraphically higher deposits consist of metachert layers and lenses that contain finely laminated ore minerals--cobaltite, chalcopyrite, pyrite, native bismuth, and native gold (Nash and others, 1987). The Blackpine deposit is located about two km southeast of the Blackbird deposit. Nisbet and others (1994) reported 14 mineralized zones that consist of semi-massive chalcopyrite horizons ranging from 7 cm to 1.7 m thick, with grades of 1.0 to 16.4 percent copper and 1 g Au/metric ton; and disseminated chalcopyrite zones ranging from 15 to 100 m thick, with grades of 0.1 to 1.2 percent copper, 30 to 4,000 ppm cobalt. The Salmon Canyon deposit is located about 27 km northwest of the Blackbird mine. Its ore grades are comparable to those of the Blackbird and Blackpine deposits,

but it apparently is smaller and more strongly metamorphosed. The Iron Creek deposit is located about 30 km southeast of the Blackbird mine. It is a large, low-grade deposit that consists of several lenses of abundant cobaltiferous pyrite and scattered chalcopyrite, in a zone as much as 250 m wide and 1,500 m long (Nash, 1989).

The Sheep Creek deposit is located in west-central Montana, near the northeast margin of the Helena embayment of the Proterozoic Belt basin. Two zones of stratabound sulfide ore are separated by the Volcano Valley Fault zone (Himes and Petersen, 1990). The lower sulfide zone consists of stratabound silicified shale with disseminated clots and stringers of fine-grained pyrite, chalcopyrite, and dolomite. The lower zone contains a possible resource of 160,000 metric tons of copper in 4 million metric tons of ore with an average grade of 4 percent copper (Zieg and Leitch, 1993). The upper sulfide zone is a nearly continuous blanket of bedded, disseminated to massive pyrite that reaches over 90 m thick and extends over a strike length of 25 km. A stratabound copper horizon near the base of the upper sulfide zone reaches 12 m thick and contains disseminated chalcopyrite. It also contains barite-chalcopyrite veins and masses, tennantite, marcasite, and various cobalt minerals. In both zones significant amounts of cobalt, nickel, arsenic and copper are incorporated in pyrite rims (Himes and Petersen, 1990). The upper sulfide zone contains a possible resource of 112,500 metric tons of copper and 4,500 metric tons of cobalt in 4.5 million metric tons of ore with an average grade of 2.5 percent copper and 0.1 percent cobalt (Zieg and Leitch, 1993).

Metasedimentary rocks of the Yellowjacket Formation (in eastern Idaho), and of the Newland Formation (in western Montana) are considered permissive for the occurrence of sediment-hosted copper-cobalt deposits. No estimates were made of undiscovered resources, because no grade-tonnage model is available for deposits of this type.

References

- Briskey, J.A., 1986, Descriptive model of sedimentary exhalative Zn-Pb, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 211.
- Cox, D.P., 1986, Descriptive model of sediment-hosted Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 205.
- Earhart, R.L., 1986, Descriptive model of Blackbird Co-Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 142.
- Himes, M.D., and Petersen, E.U., 1990, Geological and mineralogical characteristics of the Sheep Creek copper-cobalt sediment-hosted stratabound sulfide deposit, Meagher County, Montana: Proceedings of the Gold '90 Symposium, p. 533-546.
- Menzie, W.D., and Mosier, D.L., 1986, Grade and tonnage models of sedimentary exhalative Zn-Pb, *in* Cox, D.P. and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 212-217.
- Modreski, P.J., 1985, Stratabound cobalt-copper deposits in the Middle Proterozoic Yellowjacket Formation in and near the Challis Quadrangle, *in* McIntyre, D.H., ed., Symposium on the geology and mineral deposits of the Challis 1° x 2° quadrangle, Idaho: U.S. Geological Survey Bulletin 1658 A- S, p. 203-220.
- Mosier, D.L., Singer, D.A., and Cox, D.P., 1986, Grade and tonnage model of sediment-hosted Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 306-208.
- Nash, J.T., 1989, Geology and geochemistry of synsedimentary cobaltiferous-pyrite deposits, Iron Creek, Lemhi County, Idaho: U.S. Geological Survey Bulletin 1882, 33 p.

- Nash, J.T., Hahn, G.A., and Saunders, J.A., 1987, The occurrence of gold in siliceous Co-Cu deposits of the Blackbird mining district, Lemhi County, Idaho: U.S. Geological Survey Open-File Report 87-410, 14 p.
- Nash, J.T., and Hahn, G.A., 1989, Stratabound Co-Cu deposits and mafic volcaniclastic rocks in the Blackbird mining district, Lemhi County, Idaho, *in* Boyle, R.W., Brown, A.C., Jefferson, C.W., Jowett, E.C., and Kirkham, R.V., eds., *Sediment-hosted stratiform copper deposits*: Geological Association of Canada Special Paper 36, p. 339-356.
- Nisbet, P.C., Scales, W.G., Honsinger, E.G., and Bending, J.S., 1994, The Blackpine mine, a Cu-Co-Au exhalative sulfide system, Idaho cobalt belt, Lemhi County, Idaho [abs]: *Mine Quest*, Pacific Northwest Metals and Minerals Conference Abstracts, Columbia Section, Society for Mining, Metallurgy, and Exploration, Inc., p. 18.
- Nold, J.L., 1990, The Idaho cobalt belt, northwestern United States—A metamorphosed Proterozoic exhalative ore district: *Mineralium Deposita*, v. 25, p. 163-168.
- Zieg, G.A., and Leitch, Craig H.B., 1993, The geology of the Sheep Creek copper deposits, Meagher County, Montana: *Belt Symposium III Program and Abstracts* (not paginated).

Synsedimentary/Diagenetic Gold Deposits in Sedimentary Rocks

Montana

Mineral Deposits

by James E. Elliott

General Description and Location of Deposits

The York property is located approximately 30 km northeast of Helena on the southwestern flank of the Big Belt Mountains. There, varied clastic sedimentary rocks of the Precambrian Greyson Formation are enriched in gold and mines in the area have produced minor amounts of gold.

Gold in the Greyson Formation occurs in two different geometries; in low grade but large, grossly stratabound "reefs" (described below) and in narrow, higher-grade veins (Baitis, 1988). The underground mines in the area (the Golden Messenger and Old Amber mines, both long inactive) apparently exploited areas of the Greyson Formation where the veins were particularly thick or abundant. The thick or abundant veins are perhaps due to the presence of the Late Proterozoic Golden Messenger dike which may have served as a heat source to concentrate low-grade gold present in the reefs. The reefs, however, probably contain the major gold resource.

The reefs are stratabound, resistant but laterally discontinuous horizons within the middle part of the Greyson Formation. In detail, they crosscut the stratigraphy at a shallow angle and are made up mainly of potassium feldspar, quartz, iron-magnesium carbonate, fine-grained disseminated pyrite, and accessory phyllosilicates (Baitis, 1988). Fine-grained orthoclase makes up 40 to 90 percent of the reef rock and apparently formed prior to, or at the same time as, the early diagenetic minerals in the reef (Baitis, 1988), although at some localities x-ray diffraction studies indicate that the K-feldspar is tending toward microcline; at one locality, the rock is made up almost entirely of albite, and is enriched in gold (G. Desborough, personal commun., 1993). Reefs range from less than a centimeter to approximately 100 m in thickness, the zone of reef-bearing Greyson Formation has been traced along strike for nearly 14 km, and the reefs contain on average about 0.5 g/metric ton Au although higher-grade, but unpredictable, zones also exist and the veins may contain as much as 15 g/metric ton Au.

A number of different hypotheses have been proposed for the formation of the mineralized reefs. At present, it seems most likely that the low-grade gold present in the reefs is syngenetic or diagenetic and is related to hydrothermal fluids, possibly associated with exhalative vents (J.W. Whipple, written commun., 1993). This hypothesis is supported, in part, by the necessity for some sort of heat source to transform orthoclase to microcline (G. Desborough, personal commun., 1993). The possibility that a thermal event may have concentrated low-grade, disseminated gold in the Greyson Formation into a minable, higher-grade orebody has been suggested previously (Foster, 1991).

Past Production and Undiscovered Resources

The area has produced roughly three metric tons of gold from placer operations (Pardee and Schrader, 1933) and probably less than one-half metric ton of lode gold from the Old Amber and Golden Messenger underground mines. Baitis (1988) quotes a mineral resource for the Bar Gulch and Cabin areas (using a cutoff of 0.7 g/metric ton Au) of 2.4 million metric tons of mineralized rock containing 3.8 metric tons of gold. The complete areal extent of gold-enriched

Greyson Formation is not known, but could be tens of square kilometers or more and the total gold resource could be very large. However, there is no descriptive model nor grade and tonnage models for this type of deposit.

References

- Baitis, H.W., 1988, York—A Proterozoic shale hosted gold system in Montana: Spokane, Washington, Northwest Mining Association 94th Annual Meeting, December 1988, Preprint No. 18, 22 p.
- Foster, Fess, 1991, Geology and general overview of the Golden Sunlight mine, Jefferson County, Montana, *in* Shafer, R.W., ed., Mineral deposits of Montana: Association of Exploration Geochemists, 15th, International Geochemical Exploration Symposium, p. 26-36.
- Pardee, J.T., and Schrader, F.C., 1933, Metalliferous deposits of the greater Helena mining region, Montana: U.S. Geological Survey Bulletin 842, 318 p.

Low-sulfide Au-quartz Veins**Montana***by* James E. Elliott**General Description and Location of Deposits**

In northwestern Montana, a number of small gold deposits and numerous gold showings are associated with quartz veins in the sedimentary rocks of the Belt Supergroup, commonly in the Prichard Formation (Gibson, 1948). The quartz veins range from a few centimeters to nearly two meters in width but average around one-half meter. Most veins are parallel to bedding, but some cut across bedding at shallow to steep angles and some are vertical. Quartz makes up 95 to 98 percent of the veins, the remainder being small quantities of sericite (probably residual from incompletely replaced country rock), siderite, dolomite, calcite, and traces of chlorite and epidote. Ore minerals present include pyrite, galena, sphalerite, pyrrhotite, and native gold; chalcopyrite is present in some veins but is never abundant. Arsenopyrite, tetrahedrite, magnetite, and scheelite are scarce and occur only locally. Productive veins have gold grades ranging from 10 to 85 g/t gold. Data on gold:silver ratios are scarce, but ores from the richest mines contained more gold than silver. The age of the veins is not known. Six mines developed on veins of this type that have produced significant quantities of gold (the Midas, Gloria, American Kootenai, Jumbo, Viking (Gold Hill), and Branagan mines) are clustered in an area of about 25 km² located 35 km south of Libby in northwestern Montana. Another, larger mine that may have been developed on a vein of this type, the Keystone-Goldflint mine, is located about 45 km northeast of Libby.

Past Production and Qualitative Estimate of Undiscovered Resources

Total production from this class of deposit is small, probably aggregating less than one metric ton of gold. If the deposits developed by the Keystone and Goldflint mines in the Yaak (or Yahk) district are of this type, past production probably exceeds one and may approach two metric tons of gold.

Remaining resources are unknown, but considering the small size of the deposits and the heavily vegetated and steep terrain in which they occur, the existence of undiscovered deposits is quite likely.

The descriptive model for low-sulfide Au-quartz veins (Berger, 1986) most closely matches these deposits. However, the model specifies deposition in continental-margin mobile belts or accreted terranes and notes an association with greenstone belts, oceanic metasedimentary rocks, serpentinites, and late granitic batholiths. The deposits present in Montana lack these features. The Montana low-sulfide Au-quartz veins do not occur in an accreted terrane and are associated with none of the rock types mentioned above. In addition, alteration assemblages do not match those described in the model, ore controls and geochemical signatures are different, and the only real similarity between the Montana deposits and the model is vein mineralogy (native gold, quartz, and minor sulfides).

References

- Berger, B. R., 1986, Descriptive model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239.
- Gibson, Russell, 1948, Geology and ore deposits of the Libby quadrangle, Montana: U.S. Geological Survey Bulletin 956, 131 p.

Polymetallic Vein Deposits

Montana

Mineral Deposits

by James E. Elliott

General Description and Location of Deposits

Vein deposits are scattered over most of southwestern Montana. Deposits classified as purely vein deposits or deposits (or districts) that are in part veins and in part replacement deposits extend from the Barker district in Judith Basin County in the central part of the State southwest to the Virginia City district in Madison County and the Argenta district in Beaverhead County. Numerous vein deposits occur to the northeast, west, and south of Helena and a single deposit (the Jack Waite Pb-Zn-Cu-Ag mine) occurs as far west as the Idaho border.

A general description of these deposits is not really possible, because the deposits grouped together here undoubtedly were formed in a variety of different ways. Deposits in the Virginia City district, for example, are characterized by relatively meager amounts of base metals, and commonly contain adularia. Of 36 deposits or districts thought to have some vein-like properties, two produced gold only, 20 others produced predominantly gold with subordinate silver \pm other commodities, eight produced predominantly silver along with either gold or lead, and the remainder produced primarily copper, lead, or manganese.

Past Production and Undiscovered Resources

Deposits of this type have been very productive. Vein deposits have produced about 125 metric tons of gold, 4,000 metric tons of silver, 240,000 metric tons of lead 100,000 metric tons of zinc and 17,500 metric tons of copper. Known reserves in vein deposits are mostly precious metal reserves, about 70 metric tons of gold and 1,450 metric tons of silver (including Butte).

The existence of undiscovered deposits is likely, however, there is no applicable descriptive model nor a grade-tonnage model for this type of deposit. The models of Cox (1986) and Bliss and Cox (1986) describe only Ag-Pb-Zn veins, but most of the vein deposits in Montana produced significant amounts of gold.

References

- Cox, D.P., 1986, Descriptive model of polymetallic veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 125.
- Bliss, J.D., and Cox, D.P., 1986, Grade and tonnage model of polymetallic veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 125-129.

Polymetallic Vein Deposits, Butte Type

Montana

Mineral Deposits

by James E. Elliott

General Description

At Butte Montana, a large polymetallic vein system, rich in copper and grading outward to zinc, lead silver, gold, and manganese, has yielded ore production that dwarfs other vein districts in the U.S. by at least an order of magnitude. This rich deposit resulted from a multistage process in which an early porphyry copper-molybdenum deposit was fractured and the metals remobilized by a later influx of hydrothermal fluids (Brimhall, 1979). This remobilization and vein deposition, which may have been driven by a later period of igneous intrusion, produced hydrothermal alteration minerals with ages about 5 m.y. younger than those of the porphyry Cu-Mo stage. The veins have a distinctive mineral assemblages in the central copper zone that include chalcocite-digenite-covellite-pyrite, and bornite-chalcocite-enargite, and have alteration halos of sericite, dickite, kaolinite, and pyrophyllite (Meyer and others, 1968).

There are insufficient analogues of vein systems of this type and no grade-tonnage model has been prepared. The Magma vein at Superior Arizona (Hammer and Peterson, 1968) and the Rosario veins in the Collahuasi district, Chile (Dick and others, 1994) have similar mineralogy and zoning characteristics

References

- Brimhall, G.H., Jr., 1979, Lithologic determination of mass transfer mechanisms of multiple-stage porphyry copper mineralization at Butte, Montana—Vein formation by hypogene leaching and enrichment of potassium-silicate protore: *Economic Geology*, v. 74, no. 3, p. 556-589.
- Dick, L.A., Chávez, W.X., Jr., Gonzales, Aquiles, and Bisso, Claudio, 1994, Geologic setting and mineralogy of the Cu-Ag-(As) Rosario vein system, Collahuasi District, Chile: *Society of Economic Geologists Newsletter*, no. 19, p. 1, 6-11.
- Hammer, D.F., and Peterson, D.W., 1968, Geology of the Magma mine area, Arizona, *in* Ridge, J.D., ed., *Ore deposits of the United States, 1933-1967* (Graton-Sales volume): New York, American Institute of Mining, Metallurgy and Petroleum Engineers, v. 2, p. 1282-1310.
- Meyer, Charles, Shea, E.P., Goddard, C.C., Jr., and staff, 1968, Ore deposits at Butte, Montana, *in* Ridge, J.D., *Ore deposits of the United States, 1933-1967* (Graton-Sales Volume): New York, American Institute of Mining and Metallurgical Engineers, v. 2, p. 1373-1416.

Diatreme-hosted Gold Deposits

Montana

Mineral Deposits

by James E. Elliott

General Description

The Montana Tunnels mine is a bulk-minable deposit south of Helena, hosted by the Eocene Lowland Creek Volcanics (Sillitoe and others, 1985). Although mined principally for gold and silver, the deposit contains high concentrations of zinc and lead, which are recovered during milling. The diatreme, which consists mainly of matrix-rich breccia, was emplaced during the waning stages of Lowland Creek volcanism into a dacite porphyry pluton and a sequence of welded tuffs. The mineralization is associated spatially with a swarm of dacite porphyry dikes that cut the diatreme. Ore minerals, consisting of pyrite, spalerite, galena, minor chalcopyrite, and rare electrum, occur as disseminations in the diatreme breccia and as widely spaced, multidirectional veinlets. Gangue minerals include manganocalcite, siderite, and quartz. Alteration consists of a central zone of sericitic alteration, which encloses the ore zone, and a peripheral zone of argillitic alteration.

A near-surface environment of deposition is indicated by the presence of foundered blocks of base-surge deposits and occasional pieces of carbonized wood in the diatreme. The Montana Tunnels deposit was probably emplaced a few hundred meters below a paleosurface upon which a maar volcano was constructed and then, subsequently, removed by erosion.

For the mineral resource assessment of the Butte 1° x 2° quadrangle, the Montana Tunnels deposit was classified as a stockwork/disseminated gold-silver deposit (Elliott and others, 1993). Several areas in the eastern and southeastern parts of the Butte quadrangle are favorable for the occurrence of stockwork and disseminated gold-silver deposits.

References

- Elliott, J.E., Wallace, C.A., Lee, G.K., Antweiler, J.C., Lidke, D.J., Rowan, L.C., Hanna, W.F., Trautwein, C.M., Dwyer, J.L., and Moll, S.H., 1993, Maps showing mineral resource assessment for porphyry and stockwork deposits of copper, molybdenum, and tungsten and for stockwork and disseminated deposits of gold and silver in the Butte 1° x 2° quadrangle, Montana: U.S. Geological Survey Map I-2050-E, scales 1:250,000 and 1:500,000.
- Sillitoe, R.H., Graubeger, G.L., and Elliott, J.E., 1985, A diatreme-hosted gold deposit at Montana Tunnels, Montana: *Economic Geology*, v. 80, no. 6, p. 1707-1721.

Porphyry Gold Deposits**Nevada***by* Dennis P. Cox

Porphyry gold deposits, as described by Villa and Sillitoe (1991), are related to plutons emplaced at high levels in the crust. No examples of porphyry gold deposits have been clearly demonstrated in Nevada. Some ores in the Bald Mountain district, particularly the Top deposit, mentioned by Sillitoe and Bonham (1990, p. 159), may exemplify this deposit type. It consists of veins and a pyritic stockwork within a Jurassic intrusion (Hitchborn and others, 1995). Other deposits may be associated with similar intrusions in eastern Nevada, and might be expected to occur with Tertiary mineral deposits in the Battle Mountain trend and elsewhere.

References

- Hitchborn, A.D., Arbonies, D.G., Peters, S.G., McKee, E.H., Noble, D.C., Larson, L.T., Connors, K.C., and Beebe, J.S., 1995, Geology and gold deposits of the Bald Mountain mining district, White Pine County, Nevada [abs.], *in* Geology and ore deposits of the American Cordillera, Program with abstracts, Geological Society of Nevada, U.S. Geological Survey, and Sociedad Geológica de Chile, (no pagination).
- Sillitoe, R.H. and Bonham, H.F., 1990, Sediment-hosted gold deposits—Distal products of magmatic-hydrothermal systems: *Geology*, v. 18, p. 157-161.
- Vila, Tomás and Sillitoe, R.H., 1991, Gold-rich porphyry systems in the Maricunga belt, northern Chile: *Economic Geology*, v. 86, no. 6, p. 1238-1260.

Low-sulfide Au-quartz Veins**Nevada***by* Dennis P. Cox**General Description**

Low-sulfide Au-quartz veins, although not widely recognized as a deposit type in Nevada, may occur in the western part of the State. Permissive rocks for this type of deposit are regionally metamorphosed marine volcanic rocks and volcanogenic sedimentary rocks. All of the allochthonous assemblages in Nevada are metamorphosed in part. We did not delineate a tract as permissive for low-sulfide gold quartz veins, but the combination of the Black Rock, Paradise, Pine Nut, Golconda, and Roberts Mountains assemblages approximates the permissive area. No major deposits of this type are known in Nevada, but a few occurrences of auriferous quartz veins with carbonate alteration haloes are known, mainly in metavolcanic rocks of the Black Rock assemblage. Page (1959) described carbonate alteration of serpentine in the Candelaria district (Golconda Allochthon), which is typical of the alteration that accompanies low-sulfide Au-quartz veins. No major ductile shear structures comparable to those of the Mother Lode belt in California are known in Nevada. Because of our uncertainty concerning the existence of low-sulfide Au-quartz veins in Nevada, and the low probability of deposits, no estimate of undiscovered deposits was made.

Reference

Page, B.M., 1959, Geology of the Candelaria mining district, Mineral County, Nevada: Nevada Bureau of Mines and Geology Bulletin 56, 67 p.

Mississippi Valley-type Deposits

Nevada
Utah
Arizona

by Dennis P. Cox

General Description

Thick, regionally extensive carbonate rocks are permissive for Southeast Missouri Pb-Zn and Appalachian Zn subtypes of Mississippi Valley-type deposits, but no clearly defined examples of such deposits are known in the Basin and Range or Colorado Plateau. Callahan (1977) pointed to similarities in geologic environments between the Cordilleran region and the Mississippi Valley and Appalachian miogeosyncline. Similarities in mineralization patterns between deposits in the Mississippi Valley and deposits in the Pioche district (James and Knight, 1979) suggest that parts of some polymetallic replacement districts in the Great Basin were formed by early diagenetic processes and later modified by igneous-related hydrothermal events. Some deposits in the Goodsprings district resemble Mississippi Valley-type deposits in their ore textures and distance from a possible causative pluton as suggested by Hewitt (1931).

As reviewed by Leach and Rowan (1986), Mississippi Valley deposits are believed to result from the deposition of metals carried in basinal brines that have migrated outward from fold belts containing deformed and uplifted sedimentary basins. In applying such a process model to Nevada, late Paleozoic and Mesozoic orogenies could be expected to have driven mineralizing fluids through much of the basal clastic, and lower and upper carbonate assemblages of eastern and southern Nevada. Appalachian Zn deposits are formed where fluid flow intersects with karsted terrane beneath regional unconformities. At least two such unconformities are believed to exist in Nevada: one preceding the Devonian Period and another preceding the Pennsylvanian Period (A.K. Armstrong, written comm., 1988). Existing geologic maps make it difficult, however, to delineate tracts in Nevada containing unconformities in carbonate rocks of these ages.

References

- Callahan, W.H., 1977, Some thoughts regarding premises and procedures for prospecting for base metal ores in carbonate rocks in the North American Cordillera: *Economic Geology*, v. 72, no. 1, p. 71-81.
- Hewitt, D.F., 1931, Geology and ore deposits of the Goodsprings quadrangle, Nevada: U.S. Geological Survey Professional Paper 162, 171 p.
- James, L.P., and Knight, L.H., 1979, Statabound lead-zinc-silver ores of the Pioche district, Nevada—Unusual Mississippi Valley deposits, *in* Newman, G.W., and Goode, H.D., eds., Basin and Range Symposium: Denver, Rocky Mountain Association of Geologists, p. 389-395.
- Leach, D.L., and Rowan, E.L., 1986, Genetic link between Ouachita foldbelt tectonism and Mississippi Valley lead-zinc deposits of the Ozarks: *Geology*, v. 14, p. 931-935.

Sediment-hosted Copper Deposits**Nevada
Utah***by* Dennis P. Cox**General Description**

Stratabound and pipe-like bodies of copper, silver and other metal-sulfides with high metal:sulfur ratios occur in sedimentary strata associated with evaporites (Kirkham, 1989). Evaporite environments indicated by gypsum deposits (Papke, 1987) may be considered to be sources of brine capable of leaching and transporting copper and other metals in oxidized sedimentary rocks. These metals may be deposited as sulfides where brines interact with reduced sedimentary beds. Sediment-hosted copper deposits may exist in the Jungo, Pine Nut, and Mesozoic carbonate assemblages in west-central Nevada formed by brines derived from these evaporites that acted as scavengers of copper and other metals from any oxidized sedimentary rocks in the vicinity and deposited copper in marine sedimentary deposits of the Mesozoic carbonate assemblage.

References

- Kirkham, R.V., 1989, Distribution, settings, and genesis of sediment-hosted stratiform copper deposits, *in* Boyle, R.W., Brown, A.C., Jefferson, C.W., Jowett, E.C., and Kirkham, R.V. eds., *Sediment-hosted stratiform copper deposits: Geological Association of Canada Special Paper 36*, p. 3-38.
- Papke, K.G., 1987, Gypsum deposits in Nevada: Nevada Bureau of Mines and Geology Bulletin 103, 26 p.

Peraluminous Granite Au Deposits

Nevada
California
Arizona

Mineral Deposits

by Dennis P. Cox, Steve Ludington, and Ed H. DeWitt

General Description

Peraluminous granite is related to gold quartz veins at the Mineral Ridge district near [Silver Peak](#), Nevada (Bercaw and others, 1987), the [Skidoo](#) district in Inyo County California (Fyfe, 1980), the Gold Basin-Lost Basin mining districts in Mojave County, Arizona (Theodore and others, 1987), and the [Vulture](#) mine in Maricopa County, Arizona (White, 1988). These veins resemble low-sulfide Au-quartz veins, but they occur in quartzofeldspathic rather than marine volcanogenic host rocks. Gold-quartz veins with pyrite and traces of base-metal sulfides are genetically associated with Late Cretaceous two-mica granite at these four localities, and, locally, gold is disseminated in the granite. Spurr (1906) noted the close association of the Mineral Ridge veins to dikes of mucovite-bearing alaskite, and hypothesized an ore magma that evolved from granite to pegmatite to gold-bearing quartz vein. Spurr's ideas were not widely accepted, but his observations suggest an uncommon process that warrants modern investigation. Questions to be addressed include: What is the regional relationship of peraluminous granites to gold deposits? And, are there petrologic differences between Late Cretaceous peraluminous granites associated with tungsten veins, on the one hand, and gold veins, on the other?

References

- Bercaw, L.B., Atkinson, W.W., and Nielson, R.L., 1987, Geology and gold deposits of central Mineral Ridge, Esmeralda County, Nevada: Geological Society of America Abstracts with Program, v. 19, no. 5, p. 260.
- Fyfe, D.L., 1980, Mesothermal gold mineralization at Skidoo-Del Norte mines, Death Valley, California, in Fife, D.L. and Brown, A.R., eds., Geology and mineral wealth of the California desert (Dibblee Volume): South Coast Geological Society, Inc., p. 318-329.
- Theodore, T.G., Blair, W.N., and Nash, J.T., 1987, Geology and gold mineralization of the Gold Basin-Lost Basin mining districts, Mojave County, Arizona: U.S. Geological Survey Professional Paper 1361, 167 p.
- Spurr, J.E., 1906, Ore deposits of the Silver Peak quadrangle, Nevada: U.S. Geological Survey Professional Paper 55, 174 p.
- White, D.C., 1988, Geology of the Vulture mine, Arizona: Phoenix, Arizona, Annual Meeting, Society of Mining Engineers, January 26-29, 1988, 5 p. (preprint).

Polymetallic Vein Deposits

Nevada
California

Mineral Deposits

by Maureen G. Sherlock and Dennis P. Cox

General Description

Polymetallic veins are the most abundant metallic mineral deposits in Nevada. They are characterized by quartz veins that contain diverse base- and precious-metal sulfide ore minerals, and that are found in proximity to granitoid intrusive rocks. Vein structure can be complex and multiphase with a variety of forms, characteristically with envelopes of sericitic or argillic alteration. Tetrahedrite (or tennantite) is a characteristic ore mineral, and sphalerite, galena, chalcopyrite, jamesonite, native bismuth, stibnite and arsenopyrite are present in varying amounts. Most of these veins were mined for their silver content, but lead, zinc, and copper were also recovered from some. Native gold and electrum is present in some deposits, and many small veins were mined just for their gold content. The veins in the Reese River ([Austin](#)) district were the most productive polymetallic veins in Nevada. Fifteen named veins and many smaller structures occur in a Jurassic pluton and in lower Paleozoic sedimentary rocks. The veins are up to 1 m in thick, and as much as 1,100 m long, and have down-dip extents as great as 520 m (Ross, 1953). They contain mainly quartz, locally abundant calcite and rhodochrosite, and sparsely distributed pyrite, base-metal sulfides, arsenopyrite, tetrahedrite, stibnite and proustite. The veins are believed to be genetically related to a Cretaceous pluton 8 km to the southeast. Other examples are in the Searchlight district in southern Nevada and the [Ivanpah](#) and Santa Rosa districts in southeastern California.

Reference

Ross, C.P., 1953, The geology and ore deposits of the Reese River district, Lander County, Nevada: U.S. Geological Survey Bulletin 997, 132 p.

Volcanic-hosted Cu-As-Sb Deposits**Nevada
California***by* Dennis P. Cox**General Description**

Massive replacements of volcanic rocks by metal sulfides and sulfosalts, commonly enargite, as described by Sillitoe (1983), are classified as volcanic-hosted copper-arsenic-antimony deposits by Cox (1986). Areas of widespread alunite alteration within the late Tertiary andesite belt in western Nevada and east central California are permissive for this deposit type. A probable example is the Leviathan deposit in the Monitor district in California (Clark, 1977). No grade and tonnage models have been prepared for this deposit type.

References

- Clark, W.B., 1977, Mines and mineral resources of Alpine County, California: California Division of Mines and Geology County Report 8, 48 p.
- Cox, D.P., 1986, Descriptive model of volcanic-hosted Cu-As-Sb, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 123.
- Sillitoe, R.H., 1983, Enargite-bearing massive sulfide deposits, high in porphyry copper systems: *Economic Geology*, v. 78, no. 2, p. 348-352.

Kipushi-type Deposits

Nevada
Utah
Arizona

Mineral Deposits

by Dennis P. Cox

General Description

High-grade deposits of copper, with variable amounts of lead, zinc, cobalt, arsenic, germanium, and gallium, that are associated with breccias in dolomitized limestone are called Kipushi deposits (Cox and Bernstein, 1986) after the type example in Zaire (DeMagnée and Francois, 1988). The [Apex](#) deposit (Bernstein, 1986) in southwestern Utah is an oxidized copper deposit rich in germanium and gallium that probably belongs to this deposit type. It is localized in the Pennsylvanian rocks of the Callville Limestone, and, because these deposits are formed by processes closely related to sedimentary diagenesis, we suspect that similar deposits might exist in extensions of the Callville in Utah, southern Nevada, and northwest Arizona. In a brief reconnaissance (Cox, unpub. data), we examined the Lincoln Mine and other gossans and oxidized copper outcrops in the Callville on Tramp Ridge, in southern Nevada, in 1988. These occurrences resemble the Kipushi type in the dolomitic host rocks, the abundance of copper, and the presence of germanium in amounts up to 30 ppm. They are localized on the flanks of irregular areas of brecciated dolomite, up to 500 m in diameter.

References

- Bernstein, L.R., 1986, Geology and mineralogy of the Apex germanium-gallium mine, Washington County, Utah: U.S. Geological Survey Bulletin 1577, 9 p.
- Cox, D.P., and Bernstein, L.R., 1986, Descriptive model of Kipushi Cu-Pb-Zn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 227.
- DeMagnée, I. and Francois, A., 1988, The origin of the Kipushi (Cu, Zn, Pb) deposit in direct relation with a Proterozoic salt diapir. Copperbelt of Central Africa, Shaba, Zaire, *in* Friedrich, G.H., and Herzig, P.M., eds., Base metal sulfide deposits: Springer-Verlag, Berlin, Heidelberg, p. 74-93.

Panamint Range Disseminated Au Deposits

California

Mineral Deposits

by Steve Ludington

General Description

In the northern Mojave Desert, along the west side of the Panamint Range, a number of gold deposits have been recently discovered and developed. The [Briggs](#) deposit is the largest known to date. Briggs is an enigmatic deposit, perhaps related to reverse faults related to uplift of the Panamint Range. Gold and pyrite are disseminated in a quartz-rich, Proterozoic muscovite gneiss, and in associated amphibolite. The alteration suite is quartz-sericite-ankerite-albite-pyrite, and fluid inclusions have been reported to contain abundant CO₂, suggesting affinity with the low-sulfide Au-quartz model. The deposits are believed by some to be related to Cretaceous peraluminous granites, which are present in the range.

The resource at Briggs is in excess of 19,000,000 metric tons at a grade of about 1 g/metric ton and growing. An interesting aspect of the deposit is the low toxic metal content of the ore. Limited sampling by the U.S. Geological Survey confirms this, as a bulk ore sample contained <30 ppm As, <25 ppm Pb, <100 ppm Zn, and <2 ppm Cd.

Some other deposits in the Panamint Range that appear to have similar characteristics include the Gold Bug-Anthony, Suitcase, and Cecil R.

Cargo Muchacho Mountains Au Deposits

California

Mineral Deposits

by Richard M. Tosdal

General Description

The Cargo Muchacho Mountains in southeasternmost California contain two historically important gold mining districts and are the site of present mining activity in the [American Girl](#) mine (Cargo Muchacho mining district) and future activity in the [Oro Cruz](#) property, formerly known as the Tumco mine (Tumco mining district). Lode gold is present in four different settings, none of which are amenable to classification.

(1) Gold is present in association with biotite-specularite/magnetite-quartz-feldspar metamorphic mineral assemblages which form rod-like bodies that lie parallel to the gently south-dipping foliation in the quartzofeldspathic metamorphic rocks. Trace amounts of scheelite, chalcopryrite, galena, pyrite, stibnite, cinnabar, fluorite and barite are also present. Gold is associated with areas of elevated copper content. Along strike and associated with the deposits are aluminous gneiss and schist which represent areas of hydrogen metasomatism (Owens and Hodder, 1993). Host rocks for the bodies included metamorphosed Jurassic volcanic or volcanoclastic rocks and Jurassic metagranitic rocks. These bodies form the Oro Cruz property and also the earliest stage of gold enrichment in the American Girl Mine. A minimum of 100,000 ounces of gold have been produced prior to 1942 from the Tumco Mine.

(2) Gold is present in ribboned milky quartz veins which parallel the metamorphic foliation. The veins lie subparallel to the foliation within retrograde ductile shear zones and are surrounded by a low greenschist-facies mineral assemblage of chlorite-epidote-quartz (Branham, 1988; Borrastero, 1990). Within the veins, gold is associated with base metal sulfides (chalcopryrite, galena, sphalerite) and scheelite (Henshaw, 1942). These veins represent the principal lodes in the American Girl Mine where they attain grades of 1.75-7.95 grams per metric ton.

(3) Gold is locally present and concentrated in brittle low- and high-angle shear zones particularly where these young faults intersect areas of prior gold concentration. Example include the Padre Madre Mine (Cargo Muchacho Mining District), several horizons of the American Girl Mine and surrounding area, and the old Sovereign Mine which now is included within the Oro Cruz property.

(4) Gold is present in quartz and pegmatoidal quartz veins in Jurassic metagranite. The La Colorado Mine, at the north end of the range, represents this type of occurrence. Only a few hundred tons of ore were produced from the deposit (Morton, 1977), and it represent a small resource in comparison to the other three occurrences.

There are numerous models for these deposits with the largest controversy stemming from the role, or roles, that different plutonic complexes play in the formation of the deposits. It is, however, generally accepted that metamorphism played a large role in the formation of the first two types of occurrence (listed above), which are also the most important economically. These models are listed as follows: (1) Syngenetic stratabound Fe-Au-rich sedimentary rocks that were subsequently metamorphosed to form the magnetite-specularite gold ore bodies; (2) Replacement and metasomatism or veining associated with intrusion of a Jurassic granite into an active ductile shear zone; (3) Genetically associated with peraluminous granite of Late Cretaceous or early Tertiary age; (4) Quartz vein formation along a retrograde ductile shear zone; (5) Low-temperature mineralization formed during brittle deformation associated with late Cenozoic extensional and transcurrent faulting.

References

- Borrastero, R.H., 1990, Gold mineralization at the American Girl B-Zone Mine, Cargo Muchacho Mountains, southeasternmost California: Missoula, University of Montana, M.S. thesis, 112 p.
- Branham, A.D., 1988, Gold mineralization in low angle faults, American Girl Valley, Cargo Muchacho Mountains, California: Pullman, Washington State University M.S. thesis, 144 p.
- Henshaw, P.C., 1942, Geology and mineral deposits of the Cargo Muchacho Mountains, Imperial County California: California Journal of Mines and Geology, Quarterly Report XXXVIII, p. 147-196.
- Morton, P.K., 1977, Geology and mineral resources of Imperial County, California: California Division of Mines and Geology, County Report 7, 104 p.
- Owens, E.O., and Hodder, R.W., 1994, Aluminosilicate mineral assemblages in the Cargo Muchacho Mountains, southern California—Metasomatism and gold concentration associated with magmatism and deformation in mesozonal environments: Canadian Journal of Earth Sciences, v. 31, p. 310-322.

Detachment-fault-related Au Deposits

Arizona
Nevada
California

Mineral Deposits

by Dennis P. Cox

General Description

Gold and base-metal deposits associated with detachment faults have been described by many authors including Wilkins (1984), and Spencer and others (1989) and descriptive models have been prepared by Bouley (1986) and Long (1992). The deposits are mainly found in the Colorado River Basin and are represented by the Newberry district, southern Nevada, the [Moon Mountains](#) district, western Arizona, and the Copper Basin district in the Whipple Mountains of California.

The deposits occur within the detachment fault or in steeply dipping faults in the hanging wall of the detachment. They have a distinctive mineralogy marked by specular hematite, chlorite, and traces of chalcopyrite. Reserve data are unavailable for most of the deposits and no grade and tonnage model has been prepared. The [Copperstone](#) deposit in Arizona, the largest deposit known, has reserves and production of about 13 metric tons of gold at grades of about 2.5 grams per metric ton (Long, 1992).

References

- Bouley, B.A., 1986, Descriptive model of gold on flat faults, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 251.
- Long, K.R., 1992, Preliminary descriptive model for detachment-fault-related minearalization *in* Bliss, J.D., ed., Developments in deposit modeling: U.S. Geological Survey Bulletin 2004, p. 52-62.
- Spencer, J.E., Grubensky, M.J., Duncan, J.T., Shenk, J.D., Yarnold, J.C., and Lombard, J.P., 1989, Geology and mineral deposits of the central Artillery Mountains, *in* Spencer, J.E., and Reynolds, S.J., eds., Geology and mineral resources of the Buckskin and Rawhide Mountains, west-central Arizona: Arizona Geological Survey Bulletin 198, p. 168-183.
- Wilkins, Joe, Jr., 1984, The distribution of gold- and silver-bearing deposits in the Basin and Range province, Western United States, *in* Wilkins, Joe, Jr., ed., Gold and silver deposits of the Basin and Range Province, Western USA: Arizona Geological Society Digest, v. 15, p. 1-27.

Cyprus (and Besshi) Massive Sulfide Deposits**Arizona**

by Eric R. Force

General Description

Most of the known Arizona massive sulfide deposits appear to be kuroko-type, but, in a few areas, Precambrian marine sedimentary rocks are associated with apparent oceanic crust, suggesting the possibility for Cyprus, or perhaps Besshi, massive sulfide deposits.

Two small areas of Precambrian marine sedimentary rocks associated with oceanic crust were identified. In the Payson area, pillow lavas and deep-marine sedimentary rocks of Early Proterozoic age overlie gabbros and sheeted dikes (Dann, 1991). In the Bagdad area, the Bridle Formation and other deep-marine mafic volcanic rocks overlie gabbros (Lindberg, 1989; Donnelly and Conway, 1988).

There are no examples in Arizona of deposits of these types, and, because of insufficient information, no resource estimates were made.

References

- Dann, J.C., 1991, Early Proterozoic ophiolite, central Arizona: *Geology*, v. 19, p. 590-593.
- Donnelly, M.E., and Conway, C.M., 1988, Metallogenic map of volcanogenic massive-sulfide occurrences in Arizona: U.S. Geological Survey Miscellaneous Field Studies Map MF-1853-B, scale 1:1,000,000.
- Lindberg, P.A., 1989, Precambrian ore deposits of Arizona, *in* Jenney, J.P., and Reynolds, S.J., eds., *Geologic evolution of Arizona: Arizona Geological Society Digest* 17, p. 187-210.

Low-sulfide Gold-quartz Veins**Arizona**

by Frederick S. Fisher

General Description

Mesothermal quartz veins and Mother Lode veins are both approximate synonyms for this type of deposit which is characterized by gold in massive persistent quartz veins mainly in regionally metamorphosed volcanic rocks and volcanic sedimentary rocks (Berger, 1986).

Deposits similar to low-sulfide Au-quartz veins were identified in the Ajo 1° x 2° quadrangle (Peterson and others, 1987). However these deposits do not fulfill the criteria for low-sulfide Au-quartz veins because they are associated with intrusions of Jurassic age and their Ag/Au ratios are higher than would be expected. Nevertheless, although no unequivocal deposits of this type are known in Arizona, there are sedimentary and volcanic assemblages that accumulated in a marine (reducing) environment.

Regionally metamorphosed volcanic rocks of Precambrian age in Arizona are part of the Yavapai Series which is described by Anderson and Siver (1976) as a greenstone belt comprised of metamorphosed volcanic and volcanoclastic rocks. In other areas of Arizona, undifferentiated metasedimentary, metavolcanic, and gneissic rocks could be permissive. The most favorable areas would be near large extensive fracture and fault systems and also where granitic plutonic intrusions cut the greenstones.

No estimations were made for numbers of undiscovered deposits of this type.

References

- Anderson, C.A., and Silver, L.T., 1976, Yavapai Series—A greenstone belt: Arizona Geological Society Digest, v. 10, p. 13–26.
- Berger, B.R., 1986, Descriptive model of low-sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 239.
- Peterson, J.A., Cox, D.P., and Gray, Floyd, 1987, Mineral resource assessment of the Ajo and Lukeville 1° x 2° quadrangle, Arizona: U.S. Geological Survey Miscellaneous Field Studies Map MF-1834b, scale 1:250,000 with text.

Volcanogenic Massive Sulfide Deposits**Utah***by* Steve Ludington**General Description**

Several outcropping areas of Precambrian rock in Utah are poorly known, and might contain volcanogenic massive sulfide deposits. The lower part of the Farmington Canyon Complex, east and north of Salt Lake City, may contain enough amphibolite and possible felsic metavolcanic rock to suggest volcanogenic massive sulfide deposits. There are no known deposits, only some minor prospects. Outcrops of the McCoy Creek group (Misch and Hazzard, 1962), in the western part of the State, near the Deep Creek Range, and also cannot be eliminated from consideration for volcanogenic massive sulfide deposits.

Reference

Misch, Peter, and Hazzard, J.C., 1962, Stratigraphy and metamorphism of Late Precambrian rocks in central northeastern Nevada and adjacent Utah: AAPG Bulletin, v. 46, p. 289–309.

Sedimentary Exhalative Zn-Pb Deposits**Utah***by* Alan R. Wallace**General Description**

Proterozoic sedimentary rocks of the McCoy Creek Group, Trout Creek sequence, and Raft River/Albion Group, and Archean sedimentary rocks of the Farmington Canyon Complex, were considered for possible sedex deposits. However, the available literature indicates that these Proterozoic sedimentary rocks were deposited as a terrigenous sequence in a passive subsiding continental-margin environment (Link, 1993). Only at the base of the sequence is there any record of volcanic activity, and the associated sedimentation was a glacial diamictite (Link, 1993), much different than that associated with typical sedex deposits. The available literature does not report any metal accumulation associated with any of these rocks. The only evidence of mineralization in the Farmington Canyon Complex consists of small, scattered polymetallic veins (Bryant, 1988). Therefore, undiscovered sedex deposits in these Precambrian sedimentary sequences were not estimated and a permissive tract was not delineated because the environment is not considered permissive.

References

- Bryant, Bruce, 1988, Geology of the Farmington Canyon Complex, Wasatch Mountains, Utah: U.S. Geological Survey Professional Paper 1476, 54 p.
- Link, P.K., ed., 1993, Middle and Late Proterozoic stratified rocks of the western U.S. Cordillera, Colorado Plateau, and Basin and Range province, *in* Reed, J.C., Jr., and others, eds., Precambrian—Conterminous United States: Boulder, Geological Society of America, The Geology of North America, v. C-2, p. 463-595.

Polymetallic Vein Deposits

Colorado
New Mexico
Texas

Mineral Deposits

by Steve Ludington

General Description

At the scale of this assessment, the areas permissive for the occurrence of polymetallic vein deposits may be taken to be the same as for porphyry copper deposits. These deposits are associated with a wide spectrum of igneous compositions and have been emplaced over a wide range of emplacement depths.

Although polymetallic vein deposits have provided a large portion of the past production of mineral wealth in the southern Rocky Mountains, there is, at present, no suitable grade and tonnage model for these deposits. The existing one with this title (Bliss and Cox, 1986) is simply not representative of the deposits in the southern Rocky Mountains. These deposits, like polymetallic replacement deposits, occur naturally in districts, often consisting of dozens of individual veins and(or) mines, whereas many of the deposits used in the Bliss and Cox model are individual mining entities, consisting of only a very small part of the district to which they belong. The sizes of deposits in the model are too small to be used reliably in the Southern Rocky Mountains, and thus, no quantitative estimates were made, even though we believe the remaining resource in these districts is substantial.

Because of the large size of polymetallic vein districts, the team believes that there are few undiscovered districts in exposed areas. Those that might exist are likely in areas covered by surficial sediments. Of more significance is the resource remaining in existing districts. Mining halted in nearly all these districts for economic or political reasons, not because of exhaustion of mineralized rock, and the remaining resource in these areas is probably as large or larger than the undiscovered resource, and may be as large or larger than past production.

In New Mexico, [Lordsburg](#) (Laramide) and [Piños Altos](#) (Laramide) have been the most important districts. In Colorado, [Central City](#) and [Idaho Springs](#) (Laramide), Alma and [Breckenridge](#) (mid-Tertiary), and [Telluride](#), [Animas](#), and [Red Mountain-Sneffels](#) (late Tertiary, formerly considered Creede-type epithermal deposits (Mosier, Sato, and Singer, 1986; Mosier and others, 1986) all produced more than 30 metric tons (approximately 1 million troy ounces) of gold.

References

- Bliss, J.D., and Cox, D.P., 1986, Grade and tonnage model of polymetallic veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 125–129.
- Mosier, D.L., Singer, D.A., Sato, T., and Page N.J., 1986, Relationship of grade, tonnage, and basement lithology in volcanic-hosted epithermal precious- and base-metal quartz-adularia-type districts: *Mining Geology*, v. 36, p. 245–264.
- Mosier, D.L., Sato, T., and Singer, D.A., 1986, Grade and tonnage model of Creede epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 146–149.

Prairie-type Au-Ag-Cu Deposits

Midcontinent Region
Rocky Mountain Region

by Dennis P. Cox and Steve Ludington

General Description

Disseminated micron-size particles of Au-Ag-Cu, Pb, Zn, Cd, Sb, W, Sn, Fe, Cr, Bi, and trace Pd in the form of native metals, alloys, metal chlorides, oxides and carbonates have been recently documented by Abercrombie and Feng (1994) in rocks of the Western Canada Sedimentary Basins. Hematite and iron oxyhydroxides, monazite and Ce carbonate, calcite, native sulfur, gypsum and barite are present. Metal sulfides are absent. Host rocks include Precambrian metaigneous rocks and sedimentary rocks as young as Cretaceous. The metals are believed to have been transported and deposited by brines originating from the Middle Devonian Prairie evaporite.

Similar mineralization may be present in Tertiary sedimentary rocks of the Green River Basin in Moffat County, Colorado as indicated by placer deposits of the Iron Springs Divide area described by Parker (1974). There are no obvious hydrothermal vein sources for these placers, and it is thought that the metals were derived from an erosion of an exposed deltaic fan in the Eocene Green River Formation (Parker, 1974, p.166). The presence of monazite as an associated mineral in these placers allows the interesting speculation that they may have been derived from mineral concentrations in the Green River that are similar to those described by Abercrombie. Evaporites that could have provided brines, acting as the transport medium proposed by Abercrombie, are present in the Green River Formation.

We do not know whether or not Prairie-type gold mineralization has, anywhere, sufficient grade or tonnage to be classified as a mineral deposit, nor do we have a sufficiently clear idea of the ore-forming process to delineate tracts where such deposits would be permissive in the United States.

References

- Abercrombie, H.J., and Feng, R., 1994, Prairie-type gold-silver-copper mineralization in the Western Canada Sedimentary Basin—Brine-associated native and alloyed metals, chlorides, oxides, and carbonates: Geological Society of America 1994 Annual Meeting, Abstracts with Program, v. 26, no. 7, p. A-83
- Parker, B.H., 1974, Gold placers of Colorado: Quarterly of the Colorado School of Mines, v. 69, no. 3, 224 p.

Placer Gold

Arizona, California
Colorado, Idaho
Montana, New Mexico
Nevada, Oregon
South Dakota, Utah
Washington

by Dennis P. Cox

General Description

Gold, commonly with appreciable silver content, is liberated during weathering of gold-bearing mineral deposits and transported in streams to form a variety of deposits collectively referred to as placers. Gold and silver in placer deposits was not assessed in this study because we believe that the existence of undiscovered districts consistent with our grade and tonnage model (Orris and Bliss, 1985) is unlikely. This belief is based on the fact that placer deposits are found quite efficiently by primitive prospecting methods and on the observation that, except for extensions to known districts, no new placer districts were discovered during the 1970s and 1980s when the price of gold increased ten fold. Major placer districts (those that produced 2 metric tons of gold or more) are shown in the KNOWNDEP file, however, because they have contributed in an important way to national gold production.

Reference

Orris, G.J., and Bliss, J.D., 1985, Geologic and grade-volume data on 330 gold placer deposits: U.S. Geological Survey Open-File Report 85-213, 172, p.

Olympic Dam Cu-Au-U-REE Deposits

Midcontinent Region

by Gary B. Sidder and Warren C. Day

General Description

Discovery of Olympic Dam, a new type of mineral deposit of major proportions in Australia, has prompted investigations as to whether such a deposit might exist in the United States. In the sections below, the Olympic Dam deposit and similar deposits in Missouri are described, and their similarities are discussed. A quantitative assessment of this deposit type was not made because of the lack of analogues for Olympic Dam from which a grade and tonnage model could be prepared.

The Olympic Dam Deposit

Olympic Dam, on the northern Stuart shelf of South Australia, is the world's largest uranium deposit and one of the largest deposits of copper and gold. At December 1994 prices, the Olympic Dam deposit contains more than \$130 billion worth of metals, with an inferred reserve of more than 2,000 million metric tons of ore that contain an estimated 32 million metric tons of copper at an average grade of 1.6 weight percent Cu, 1.2 million metric tons of uranium oxide at 0.6 kg U₃O₈/metric ton, 1.2 million kg of gold at a grade of 0.6 g Au/metric ton, and 10 million kg of silver at 3.5 g Ag/metric ton (Reeve and others, 1990). In addition, fluorine, barium, and rare-earth elements (REE; especially lanthanum and cerium) are enriched over crustal values. The REE constitute a resource of about 10 million metric tons at a grade of < 0.5 weight percent total REE; however, these metals cannot be recovered economically with current technology (Reeve and others, 1990). The deposit is in a large hematite-rich breccia complex, known as the Olympic Dam Breccia Complex (Reeve and others, 1990; Cross, 1991). The complex occurs entirely within a felsic rapakivi granite, the Roxby Downs Granite of the Hiltaba supersuite in the Burgoyne batholith, which is Middle Proterozoic, about 1.59 Ga, in age (Creaser and Cooper, 1993; Johnson and Hattori, 1994). The granitic host rocks are intrusive equivalents of the Gawler Range Volcanics, which are exposed to the south of the deposit. The breccia complex and the hydrothermal alteration and mineralization developed in a volcanic to subvolcanic environment as products of phreatomagmatic explosions in a maar-diatreme complex as an integral part of the Gawler Range Volcanics-Hiltaba volcano-plutonic episode at about 1.59 Ga (Reeve and others, 1990; Creaser and Cooper, 1993).

Southeast Missouri and the Midcontinent

The Middle Proterozoic (1.48-1.45 Ga) St. Francois granite-rhyolite terrane of southeast Missouri in the Midcontinent region of the United States hosts iron ± copper ± rare-earth element ± gold deposits, prospects, and occurrences. The ores occur as massive intrusive, vein, or replacement bodies within volcanic rocks of the St. Francois terrane. Late-stage aplite or granitic dikes cut some of the deposits, which indicates that the mineralization was synchronous with igneous activity in the terrane. The Missouri iron ores consist predominantly of magnetite and (or) hematite, with variable amounts of pyrite, chalcopyrite, and bornite. They have anomalous contents of the large-ion-lithophile elements such as tin, tungsten, niobium, yttrium, beryllium, lithium, rubidium, and barium, and some are enriched in phosphorous (Nuelle, and others, 1992; Sidder and Day, 1993).

Iron ore has been produced nearly continuously from southeast Missouri since 1815. Until 1963, Middle Proterozoic hematite deposits were the major source of iron ore in Missouri. Since the Pea Ridge mine in Washington County opened in 1964 and the Pilot Knob mine in Iron County in 1968, all Missouri iron ore production has been from subsurface magnetite deposits (Emery, 1968; Ryan, 1981). The Pilot Knob underground mine produced 20.3 million metric tons of usable iron ore at an average grade of about 37 weight percent iron before closing in 1980. Since

1980, the Pea Ridge mine has been Missouri's only iron ore producer, and it is the only remaining active underground iron mine in the U.S. to 1994, about 44 million metric tons of iron ore at a grade of about 55 weight percent iron have been produced from the Pea Ridge mine; it has a demonstrated resource of 131.4 million metric tons at a grade of 57 weight percent iron (Kisvarsanyi and Kisvarsanyi, 1989; Sidder and Day, 1993).

Four REE-bearing breccia pipes in the Pea Ridge deposit have been delineated along the footwall and eastern edge of the magnetite orebody. The pipes are enriched particularly in lanthanum and cerium (light REE) as well as in yttrium (Nuelle, and others, 1992). Total REE oxide (REO) concentrations from grab samples range from about 5 to 19 weight percent, with an average of 10 weight percent. Grades from bulk samples range from about 7 to 25 weight percent REO and average about 12 weight percent. Ore reserves of about 600,000 tons at 12 weight percent REO have been estimated for one breccia pipe at Pea Ridge (Whitten and Yancey, 1990). Thorium and uranium are present in minor quantities in the breccia pipes. The thorium concentration in grab samples averages about 3,320 ppm, and the uranium content averages about 190 ppm (Nuelle, and others, 1992). Precious metals are distributed erratically in the breccia pipes. Gold concentrations rarely exceed 1 ppm, but assays of some drill core and chip samples are as high as 371 ppm (Husman, 1989).

The Boss copper-iron deposit is unusual among the iron deposits of southeast Missouri in that copper is a potential resource. Total indicated reserves for multiple, fragmented orebodies are 36.3 million metric tons at a grade of 0.85 weight percent copper and 17.5 weight percent iron (Sidder and Day, 1993). In addition to magnetite and hematite, sulfide minerals that contain iron, copper, cobalt, zinc, lead, and molybdenum are present; silver-, titanium-, tungsten-, bismuth-, selenium-, and tellurium-bearing minerals as well as native gold also occur (Hagni and Brandom, 1989).

The St. Francois terrane is one of several epizonal granite-rhyolite terranes in the Midcontinent region of the U.S. Others include granite-rhyolite in central Wisconsin (1,835 Ma), rhyolite-granite in southern Wisconsin (1,760 Ma), and granite-rhyolite of the Spavinaw terrane in northeast Oklahoma, eastern Kansas, and southwest Missouri (1,400–1,350 Ma) (Hauck, 1990; Sims, 1990). Other Middle Proterozoic mesozonal granitic bodies in the Midcontinent include the Wolf River batholith in Wisconsin (1,500 Ma), the Wausau Syenite Complex in Wisconsin (1,450 Ma), and other smaller bodies (Sims, 1990). Except for the St. Francois terrane, none of these other areas have known iron, copper, or other metal occurrences. However, rocks in some of these areas are present only in a few small outcrops and are mostly known from drill hole data.

Similarities Between the Stuart Shelf and Midcontinent U.S. Environments

The Missouri iron deposits and their host rocks exhibit many similarities to deposits and host rocks at and near Olympic Dam on the Stuart shelf. For example, the Stuart shelf contains six major known iron deposits and numerous small magnetic anomalies that have not been drilled, and southeast Missouri contains six major and 26 lesser known iron deposits (Einaudi and Oreskes, 1990). The mineralogical associations at Olympic Dam and southeast Missouri are similar, with magnetite and hematite ore minerals, associated iron and copper-iron sulfide minerals such as pyrite (commonly cobalt-bearing), chalcopyrite, and bornite, REE-bearing minerals, and gangue minerals such as apatite, fluorite, quartz, sericite, and barite (Hagni and Brandom, 1989; Sidder, and others, 1993). Deposits on the Stuart shelf define a province 100 km long and 35 km wide, with 15 to 30 km between deposits. Those in Missouri form a province that is 125 km long, 46 km wide, and the deposits are 10 to 30 km apart. The distribution of deposits in each province also represents a vertical zonation from massive magnetite-apatite ore emplaced at a depth of about 2 km to bedded hematitic ore in systems that vented at the surface. The combined size of deposits in each province is more than 1 billion metric tons of greater than 20 weight percent iron, with associated copper, uranium, gold, rare-earth elements, fluorine, barium, and phosphorous. Middle Proterozoic (about 1.59 Ga at Olympic Dam, and 1.48 to 1.45 Ga in southeast Missouri), felsic to intermediate, subalkalic to

alkalic plutonic and volcanic rocks in both areas are crustally derived and are presumed to be anorogenic in origin (Kisvarsanyi, 1984; Kisvarsanyi and Kisvarsanyi, 1989a); however, recent isotopic studies indicate that both anorogenic (incipient rift) and post-orogenic tectonic environments are represented in both regions (Johnson and Cross, 1991; Swan and Keith, 1986; Patchett and Ruiz, 1989). Bull's-eye magnetic anomalies associated with long, linear gravity anomalies and steep gravity gradients are characteristic (Hoover and Cordell, 1992; Gow and others, 1993). In addition, the deposits are aligned with photolineaments that are possibly fault zones that focussed the ore-forming fluids (O'Driscoll, 1985; Rutter and Esdale, 1985).

Similarities in Ore Genesis Between Olympic Dam and Southeast Missouri Deposits

Mineralization at Olympic Dam and in nearby deposits on the Stuart Shelf as well as in the Precambrian iron deposits of southeast Missouri was intimately related to and concurrent with the volcano-plutonic activity in their respective terranes. Ore formation was apparently localized within and at the margins of calderas. Geochemical, isotopic, and fluid inclusion studies at Olympic Dam and related iron-rich deposits on the Stuart shelf indicate that two fluids were involved in mineralization (Gow and others, 1994; Haynes and others, 1995). At Olympic Dam, the early, high-temperature (600-400°C) mineralizing fluid was magmatic in origin and was in isotopic equilibrium with the host Roxby Downs Granite. This fluid deposited magnetite and altered the country rocks to a skarnlike calcium-iron-rich assemblage. Hematite and copper-, gold-, and REE-bearing minerals were deposited at lower temperatures (about 300-150°C) by a second, more oxidized fluid. The source of the second fluid is debatable. Some have suggested that it was a meteoric fluid and others that it was a magmatic fluid (Oreskes and Einaudi, 1990; Davidson and Large 1994). Most agree that the second fluid was derived from a provenance of mafic to ultramafic rocks (Knutson and others, 1992; Oreskes and Einaudi, 1992). Douglas W. Haynes (Western Mining Corporation Ltd., oral commun., 1994) concluded that economic copper, uranium, and gold ore at Olympic Dam was deposited when a near-surface reservoir of appropriately oxidized saline groundwater such as a playa lake mixed with hotter fluids during igneous activity.

Fluid-inclusion and stable-isotope studies at the Pea Ridge deposit in southeast Missouri indicate that it formed from highly saline, high-temperature hydrothermal fluids derived from a cooling magma. Homogenization in three-phase (L+V+halite) fluid inclusions and oxygen and sulfur isotopic analyses of mineral pairs indicate that temperatures varied from greater than 530° to about 400°C during deposition of the magnetite ore and associated alteration (Sidder, and others, 1993). REE-gold-bearing breccia pipes formed from boiling late-stage fluids derived from the magnetite ore system. The breccia pipes were rapidly and explosively emplaced at a temperature of about 300°C (Nuelle, and others, 1992; Sidder and others, 1993). The Pea Ridge ore system may have evolved as immiscible fluids from the source, or a derivative magma, of an iron-rich trachyte suite, which is present regionally as ring intrusions associated with the volcano-plutonic complex (Day and others, 1992; Sidder and others, 1993). Modelling of conditions of ore formation at other deposits in Missouri also indicates the dominance of a magmatic-derived fluid in mineralization (Burstein and others, 1992; Kisvarsanyi and Smith, 1988). Haynes (oral commun., 1994) suggested that the lack of significant copper, uranium, and gold ore in southeast Missouri was due to the lack of oxidized saline groundwater in the mineralizing system during ore formation. In addition, most of the breccia bodies identified to date in the iron deposits of the St. Francois terrane are relatively simple in that they show only one or two brecciation events, whereas the breccias at Olympic Dam have been brecciated multiple times. Hence, the mineralizing system at Olympic Dam was apparently longer lived and more energetic than those identified thus far in southeast Missouri.

References

- Burstein, I.B., Shelton, K.L., Hagni, R.D., and Brandom, R.T., 1992, Mobilization of copper by MVT fluids penetrating igneous basement rocks—Sulfur isotope studies of the Precambrian Boss-Bixby Fe-Cu deposits, southeast Missouri: Geological Society of America, Abstracts with Programs, v. 24, no. 7, p. A234.

- Creaser, R.A., and Cooper, J.A., 1993, U-Pb geochronology of Middle Proterozoic felsic magmatism surrounding the Olympic Dam Cu-U-Au-Ag and Moonta Cu-Au-Ag deposits, South Australia: *Economic Geology*, v. 88, no. 1, p. 186-197.
- Cross, K.C., 1991, The Olympic Dam deposit—Breccia-hosted Cu-U-Au-Ag-(REE) mineralisation in a high level volcano-plutonic setting: Geological Society of Australia, Victorian Division, Annual Selwyn Memorial Symposium, October 1991, University of Melbourne, 8 p.
- Davidson, G.J., and Large, R.R., 1994, Gold metallogeny and the copper-gold association of the Australian Proterozoic: *Mineralium Deposita*, v. 29, p. 208-223.
- Day, W.C., Sidder, G.B., Rye, R.O., Nuelle, L.M., and Kisvarsanyi, E.B., 1992, The Middle Proterozoic rhyolite-hosted Pea Ridge iron and rare-earth element deposit—A magmatic source for Olympic Dam-type deposits in the midcontinent region of the United States, *in* Brown, P.E., and Chappell, B.W., ed., *Proceedings of the Second Hutton Symposium on the origin of granites and related rocks: Transactions of the Royal Society of Edinburgh*, v. 83, pt. 1 and 2, p. 489.
- Einaudi, M.T., and Oreskes, Naomi, 1990, Progress toward an occurrence model for Proterozoic iron oxide deposits—A comparison between the ore provinces of South Australia and southeast Missouri, *in* Pratt, W.P., and Sims, P.K., eds., *The Midcontinent of the United States —Permissive terrane for an Olympic Dam deposit?: U.S. Geological Survey Bulletin 1932*, p. 58-69.
- Emery, J.A., 1968, Geology of the Pea Ridge iron ore body, *in* Ridge, J.D., *Ore deposits of the United States, 1933-1967 (The Graton-Sales Volume): New York, The American Institute of Mining, Metallurgical, and Petroleum Engineers*, v. 1, p. 359-369.
- Gow, P.A., Wall, V.J., and Valenta, R.K., 1993, The regional geophysical response of the Stuart Shelf, South Australia: *Exploration Geophysics*, v. 24, p. 513-520.
- Gow, P.A., Wall, V.J., Oliver, N.H.S., and Valenta, R.K., 1994, Proterozoic iron oxide (Cu-U-Au-REE) deposits—Further evidence of hydrothermal origins: *Geology*, v. 22, p. 633-636.
- Hagni, R.D., and Bandom, R.T., 1989, The mineralogy of the Boss-Bixby, Missouri copper-iron-cobalt deposit and a comparison to the Olympic Dam deposit at Roxby Downs, South Australia, *in* Brown, V.M., Kisvarsanyi, E.B., and Hagni, R.D., eds., “Olympic Dam-type” deposits and geology of Middle Proterozoic rocks in the St. Francois Mountains terrane, Missouri: *Society of Economic Geologists Guidebook Series*, v. 4, p. 82-92.
- Hauck, S.A., 1990, Petrogenesis and tectonic setting of Middle Proterozoic iron oxide-rich ore deposits—An ore deposit model fro Olympic Dam-type mineralization, *in* Pratt, W.P., and Sims, P.K., eds., *The Midcontinent of the United States-Permissive terrane for an Olympic Dam-type deposit?: U.S. Geological Survey Bulletin 1932*, p. 4-39.
- Haynes, D.W., Cross, K.C., Bills, R.T., and Reed, M.H., 1995, Olympic Dam ore genesis—A fluid-mixing model: *Economic Geology*, v. 90, no. 2, p. 281-307.
- Hoover, D.B., and Cordell, L.E., 1992, Geophysical model of Olympic Dam, *in* Hoover, D.B., Heran, W.D., and Hill, P.L., eds., *The geophysical expression of selected mineral deposit models: U.S. Geological Survey Open-File Report 92-557*, p. 112-115.
- Husman, J.R., 1989, Gold, rare earth-element, and other potential by-products of the Pea Ridge iron ore mine: Missouri Department of Natural Resources, Division of Geology and Land Survey, *Contributions to Precambrian Geology No. 21, Open File Report OFR-89-78-MR*, 18 pp.
- Johnson, J.P., and Cross, K.C., 1991, Geochronological and Sm-Nd isotopic constraints on the genesis of the Olympic Dam Cu-U-Au-Ag deposit, South Australia, *in* Pagel, Maurice, and Leroy, J.L., eds., *Source, transport and deposition of metals: Balkema, Rotterdam*, p. 395-400.
- Johnson, J.P., and Hattori, Keiko, 1994, Fe-oxide hosted Cu-U deposits in cratonic (Olympic Dam) and continental arc (Great Bear Magmatic Zone) settings. Products of mantle-derived magmas?: *The Geological Society of America Abstracts with Programs, 1994 Annual Meeting*, v. 26, no. 7, p. A-379.

- Kisvarsanyi, E.B., 1984, The Precambrian tectonic framework of Missouri as interpreted from the magnetic anomaly map: Missouri Department of Natural Resources, Division of Geology and Land Survey Contributions to Precambrian Geology No. 14, 19 p.
- Kisvarsanyi, E.B., and Kisvarsanyi, Geza, 1989a, Alkaline granite ring complexes and metallogeny in the Middle Proterozoic St. Francois terrane, southeastern Missouri, USA: Geological Association of Canada Special Paper 38, 14 p.
- Kisvarsanyi, Geza, and Kisvarsanyi, E.B., 1989b, Precambrian geology and ore deposits of the southeast Missouri iron metallogenic province, *in* Brown, V.M., Kisvarsanyi, E.B., and Hagni, R.D., eds., "Olympic Dam-type" deposits and geology of Middle Proterozoic rocks in the St. Francois Mountains terrane, Missouri: Society of Economic Geologists Guidebook Series, v. 4, p. 1-40.
- Kisvarsanyi, Geza, and Smith, F.J., 1988, Boss-Bixby, a high-temperature iron-copper deposit in the Precambrian of the midcontinent United States: Missouri Department of Natural Resources, Geology and Land Survey Division Contribution to Precambrian Geology No. 18, Open-File Report 88-72-G1, 6 p.
- Knutson, Janice, Donnelly, T.H., Eadington, P.J., and Tonkin, D.G., 1992, Hydrothermal alteration of Middle Proterozoic basalts, Stuart shelf, South Australia—A possible source for Cu mineralization: *Economic Geology*, v. 87, no. 4, p. 1054-1077.
- Nuelle, L.M., Day, W.C., Sidder, G.B., and Seeger, C.M., 1992, Rare earth element- and gold-bearing breccia pipes of the Pea Ridge iron ore mine, Washington County, Missouri: *U.S. Geological Survey Bulletin* 1989-A, p. A1-A11.
- O'Driscoll, E.S.T., 1985, The application of lineament tectonics in the discovery of the Olympic Dam Cu-Au-U deposit at Roxby Downs, South Australia: *Global Tectonics and Metallogeny*, v. 3, no. 1, p. 43-57.
- Oreskes, Naomi, and Einaudi, M.T., 1990, Origin of rare earth element-enriched hematite breccias at the Olympic Dam Cu-U-Au-Ag deposit, Roxby Downs, South Australia: *Economic Geology*, v. 85, no. 1, p. 1-28.
- Oreskes, Naomi, and Einaudi, M.T., 1992, Origin of hydrothermal fluids at Olympic Dam—Preliminary results from fluid inclusions and stable isotopes: *Economic Geology*, v. 87, no. 1, p. 64-90.
- Patchett, J. P., and Ruiz, J., 1989, Nd isotopes and the origin of Grenville-age rocks in Texas—Implications for Proterozoic evolution of the United States Mid-continent region: *Journal of Geology*, v. 97, p. 685-695.
- Reeve, J.S., Cross, K.C., Smith, R.N., and Oreskes, Naomi, 1990, Olympic Dam copper-uranium-gold-silver deposit, *in* Hughes, F.E., ed., *Geology of the mineral deposits of Australia and Papua New Guinea*: Melbourne, Australasian Institute of Mining and Metallurgy, Monograph 14, p. 1009-1035.
- Rutter, H., and Esdale, D.J., 1985, The geophysics of the Olympic Dam discovery: *Proceedings Volume, 4th Annual, Australian Society of Exploration Geophysicists, Exploration Geophysics*, v. 16, 3 p.
- Ryan, R.F., 1981, The Pilot Knob hematite deposit, *in* Kisvarsanyi, E.B., Hebrank, A.W., and Ryan, R.F., eds., *Guidebook to the geology and ore deposits of the St. Francois Mountains*, Missouri: Missouri Department of Natural Resources Report of Investigations No. 67, p. 111-114.
- Sidder, G.B., and Day, W.C., 1993, Fe-Cu-REE deposits in Middle Proterozoic rocks of the Midcontinent region of the United States—Are they Olympic Dam-type deposits?: *The Gangue, Geological Association of Canada-Mineral Deposits Division Newsletter*, Issue 42, p. 1-5.
- Sidder, G.B., Day, W.C., Nuelle, L.M., Seeger, C.M., and Kisvarsanyi, E.B., 1993, Mineralogic and fluid-inclusion studies of the Pea Ridge iron-rare-earth-element deposit, southeast Missouri, *in* Scott, R.W., Jr., Detra, P.S., and Berger, B.R., eds., *Advances related to United States and international mineral resources—Developing frameworks and exploration technologies*: *U.S. Geological Survey Bulletin* 2039, Chapter U, p. 205-216.
- Sims, P.K., 1990, Geologic setting and ages of Proterozoic anorogenic rhyolite-granite terranes in the central United States, *in* Pratt, W.P., and Sims, P.K., eds., *The Midcontinent of the United States—*

- Permissive terrane for an Olympic Dam-type deposit?: U.S. Geological Survey Bulletin 1932, p. 40-47.
- Swan, M.M., and Keith, S.B., 1986, Orogenic model for “anorogenic” granitoids in North America—Product of oblique subduction at 1.4 Ga: Arizona Geological Society Digest , v. 16, p. 489-498.
- Whitten, C.W., and Yancey, R.J., 1990, Characterization of the rare earth mineralogy at the Pea Ridge deposit: U.S. Bureau of Mines, Report of Investigations 9331, 15 p.

Rift-basin Vein Deposits

Massachusetts, Connecticut
New York, New Jersey
Pennsylvania, Maryland, Virginia

by Gilpin R. Robinson, Jr.

General Description

Numerous small veins deposits of Pb, Zn, Cu, Au, Ag, Fe, Ba, and F related to Mesozoic rift basins are widespread in the eastern U.S. (Robinson and Sears, 1988; Robinson, 1988; Gray, 1988; Robinson and Woodruff, 1988). A review of data on metal mines and occurrences associated with early Mesozoic basins (Smith, 1977; Robinson and Sears, 1988) showed that production of Cu, Pb, Zn, Au, and Ag from known deposits was too small include in this assessment. No grade and tonnage models have been developed for Mesozoic veins associated with rift basins.

References

- Gray, N.H., 1988, The origin of copper occurrences in the Hartford basin, *in* Froelich A.J., and Robinson, G.R., Jr., Studies of the early Mesozoic basins of the eastern United States: U.S. Geological Survey Bulletin 1776, p.341-349.
- Robinson, G.R., 1988, Base and precious metals associated with diabase in the Newark, Gettysburg, and Culpeper basins of the eastern United States—A review, *in* Froelich A.J., and Robinson, G.R., Jr., Studies of the early Mesozoic basins of the eastern United States: U.S. Geological Survey Bulletin 1776, p. 303-319.
- Robinson, G.R., Jr., and Sears, C.M., 1988, Inventory of metal mines and occurrences associated with early Mesozoic basins of the eastern United States—Summary Tables, *in* Froelich A.J., and Robinson, G.R., Jr., Studies of the early Mesozoic basins of the eastern United States: U.S. Geological Survey Bulletin 1776, p. 265-302.
- Robinson G.R. and Woodruff, L.G., 1988, Characteristics of base-metal and barite deposits associated with rift basins, with examples from some early Mesozoic basins of eastern North America, *in* Froelich A.J., and Robinson, G.R., Jr., Studies of the early Mesozoic basins of the eastern United States: U.S. Geological Survey Bulletin 1776, p. 377-390.
- Smith, R. C. II, 1977, Zinc and lead occurrences in Pennsylvania: Pennsylvania Geological Survey, 4th Series, Mineral Resource Report, 72, 318 p.

Franklin and Sterling Zn Deposits

New Jersey

Mineral Deposits

by Sandra H.B. Clark

General Description

The largest known deposits of probable sedimentary-exhalative origin in the northeastern U.S. are the [Franklin](#) and [Sterling Hill](#) mines. Zinc production began about 1840 and yielded more than 5 million metric tons of metal before the closing of the Franklin mine in 1957 and the Sterling Hill mine in 1986 (Brown 1968; US. Bureau of Mines Minerals Yearbooks for 1955-86). The mineralogy of these deposits is unique in the world in that the ores consisted of oxides rather than sulfides. The host rocks are strongly deformed Precambrian marble; ore minerals are willemite, franklinite, and zincite that occurred as disseminated grains and in massive lenses (Palache, 1935; Pinger, 1948, 1950). The origin of the deposits is uncertain, but they are herein considered to be metamorphosed carbonate-hosted sedimentary-exhalative deposits because of the stratiform nature of the ore bodies, the presence of magnetite iron formation, and the large amount of manganese. The tonnage of the Franklin and Sterling Hill ore bodies is above the median for sedimentary exhalative deposits. The zinc grade is slightly higher than any deposits included in the model of Menzie and Mosier (1986).

References

- Palache, Charles, 1935, The minerals of Franklin and Sterling Hill, Sussex County, New Jersey: U.S. Geological Survey Professional Paper 180, 135 p.
- Brown, J.S., 1968, Ore deposits of the northeastern United States, *in* Ridge, J.D., ed., Ore deposits of the United States, 1933-1967: New York, American Institute of Mining, Metallurgical, and Petroleum Engineers, v. 1, p. 1-19.
- Menzie, W.D., and Mosier, D.L., 1986, Grade and tonnage model of sedimentary exhalative Zn-Pb, *in* Cox, D.P. and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 212-215.
- Pinger, A.W., 1948, Geology of the Franklin-Sterling area, Sussex County, New Jersey: Geological Society of America, 61st Annual Meeting, Guidebook of Excursions, p 1-14.
- Pinger, A.W., 1950, Geology of the Franklin-Sterling area, Sussex County, New Jersey: 18th International Geological Congress, pt. 7, p 77-87.

Sediment-hosted Cu Deposits

Pennsylvania

by Sandra H.B. Clark

General Description

Numerous copper occurrences are known in the Upper Devonian Catskill Formation (Smith and Rose, 1985). However, estimated sizes of the mineralized zones from data given by Rose and others (1986) shows that the deposits are much smaller than those that make up the sediment-hosted copper (Cox and Singer, 1986) or the red-bed copper model of Lindsey (unpub. model).

Thick Paleozoic red-bed sequences in which copper occurrences are known are permissive for the occurrence of sediment-hosted copper deposits. These red-bed sequences are the following: (1) Upper Devonian Catskill Formation in Pennsylvania; (2) Devonian Hampshire Formation and Mississippian Macrady Shale below the Mauch Chunk and stratigraphically equivalent Bluefield, Hinton, and Bluestone Formations above the Greenbrier Formation; (3) cyclic sequences of red and gray shale and sandstone and coal in the Conemaugh and Monongahela Groups of Pennsylvanian age; and (4) the red shale and sandstone in the Dunkard Group of Permian age in West Virginia (Cannon and others, in press). Within the Catskill Formation the most favorable part of the formation for copper occurrences has been identified as magnafacies Mf-B, which is predominantly thick red shale with thin, fine-grained sandstone (Smith and Rose, 1985).

Because of the wide distribution of thick red-bed sequences and numerous small copper occurrences, the Paleozoic red-bed sequences are considered to be permissive for small red-bed copper deposits. However, because of absence of evidence of deposits large enough to fit the grade and tonnage models for either sediment-hosted or red-bed copper, the permissive tract was not delineated, and no resource estimates were made.

References

- Cannon, W.F., Clark, S.H.B., Lesure, F.G., Hinkle, M.E., Paylor, R.L., King, H.M., Simard, C.M., Ashton, K.C., and Kite, J.S., in press, Mineral resources of West Virginia: U.S. Geological Survey Miscellaneous Investigations Series Map (with pamphlet).
- Rose, A.W., Smith, A.T., Lustwerk, R.L., Ohhmoto, H., and Hoy, L.D., 1986, Geochemical aspects of stratiform and red-bed copper deposits in the Catskill Formation (Pennsylvania, USA) and Redstone area (Canada). Sequence of mineralization in sediment-hosted copper deposits (part 3), *in* Friedrich, G.H., Genkin, A.D., Naldrett, A.J., Ridge, J.D., Sillitoe, R.H., and Vokes, F.M., *Geology and Metallogeny of Copper Deposits*, Proceedings of the Copper Symposium, 27th International Geological Congress, Moscow, 1984, Springer-Verlag, Berlin Heidelberg, p. 412-421.
- Smith, A.T., and Rose, A.W., 1985, Relation of red-bed copper-uranium occurrences to the regional sedimentology of the Catskill Formation in Pennsylvania, *in* Woodrow, D.L., and Sevon, W.D., *The Catskill Delta: Geological Society of America Special Paper 201*, p. 183-197.

Cu-bearing Fe Skarn Deposits

Pennsylvania

Mineral Deposits

by Gilpin R. Robinson, Jr., and Sandra H.B. Clark

General Description

Numerous magnetite skarn deposits occur in areas affected by Mesozoic rifting and are associated with thermal aureoles of Mesozoic dike swarms in the Newark, Gettysburg, and Culpepper basins (Robinson, 1988; Smith, 1988). Although the magnetite ore bodies were been mined chiefly for iron, the [Cornwall](#) mine produced approximately 240,000 metric tons of copper, along with significant amounts of gold, silver, and cobalt (Lapham, 1968). The Cornwall deposit is included in the Fe skarn model (18d) of Cox (1986), but no grade distributions have been developed for copper. The resource potential for Cu, Au, and Ag from undiscovered Fe skarns is thought to be small, so no tracts were delineated or resource estimates made.

References

- Cox, D.P., 1986, Descriptive model of Fe skarn deposits, *in* Cox, D.P., and Singer, D.A., eds. 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 82-89.
- Lapham, D.M., 1968, Triassic magnetite and diabase at Cornwall Pennsylvania, *in* Ridge, J.D., ed., Ore deposits of the United States, 1933-1967: New York, American Institute of Mining, Metallurgical, and Petroleum Engineers, v. 1, p. 72-95.
- Robinson, G.R., Jr, 1988, Base and precious metals associated with diabase in the Newark, Gettysburg, and Culpepper basins of the eastern United States—A review, *in* Froelich A.J., and Robinson, G.R., Jr., Studies of the early Mesozoic basins of the eastern United States: U.S. Geological Survey Bulletin 1776, p. 303-319.
- Smith, R.C., II, 1988, Locations and analyses of selected early Mesozoic copper occurrences in Pennsylvania, *in* Froelich, A.J., and Robinson, G.R., Jr., Studies of the early Mesozoic basins of the eastern United States: U.S. Geological Survey Bulletin 1776, p. 320-332.

National Assessment 1998
Alaska
Known Deposits

Layer	Tract	Map No.	Deposit	District	Quadrangle 250K Scale	Lat	Long	Deposit Type	Alternative Deposit Type
AKEV	AK-AP04	01	Shumagin (Choumagin)	Kodiak - Unga Island	Port Moller	55.224	-160.580	Epithermal vein, quartz-adularia	
AKEV	AK-AP04	02	Apollo (Alaska Apollo)	Kodiak - Unga Island	Port Moller	55.191	-160.562	Epithermal vein, quartz-adularia	
AKPC	AK-AP09	01	Pyramid	Kodiak - Unga Island	Port Moller	55.625	-160.667	Porphyry Cu-Mo	
AKKC	AK-BR06	01	Ruby Creek (Bornite)	Kiana	Ambler River	67.064	-156.947	Kipushi Cu	
AKKU1	AK-BR07	01	Smucker	Kiana	Ambler River	67.300	-157.200	Massive sulfide, kuroko	
AKKU1	AK-BR07	02	Sunshine Creek	Kiana	Ambler River	67.219	-156.632	Massive sulfide, kuroko	
AKKU1	AK-BR07	03	Arctic	Kiana	Ambler River	67.181	-156.386	Massive sulfide, kuroko	
AKKU1	AK-BR07	04	BT	Shungnak	Survey Pass	67.104	-155.908	Massive sulfide, kuroko	
AKKU1	AK-BR07	05	Sun	Shungnak	Survey Pass	67.070	-155.020	Massive sulfide, kuroko	
AKPL2	AK-BR13	01	Chandalar District	Chandalar	Chandalar	67.833	-148.000	Placer Au-PGE	
AKPL2	AK-BR13	02	Wiseman (Koyukuk) District	Koyukuk	Wiseman	67.250	-150.750	Placer Au-PGE	
AKSX2 AKSX3	AK-BR23 AK04	01	Drenchwater	Noatak	Howard Pass	68.570	-158.680	Sedimentary exhalative Zn-Pb	
AKSX2 AKSX3	AK-BR23 AK04	02	Lik - Su	Lisburne	De Long Mtns.	68.167	-163.200	Sedimentary exhalative Zn-Pb	
AKSX2 AKSX3	AK-BR23 AK04	03	Red Dog	Lisburne	De Long Mtns.	68.067	-162.824	Sedimentary exhalative Zn-Pb	
AKGA	AK-EC05	01	Ryan Lode	Fairbanks	Fairbanks	64.868	-147.986	Low sulfide Au-quartz vein	
AKGQ1	AK-EC06	02	True North	Fairbanks	Livengood	65.053	-147.560	Low-sulfide Au-quartz vein	Gold-antimony deposits
AKGQ1	AK-EC07	01	Grant (Ester Dome)	Fairbanks	Fairbanks	64.882	-147.957	Low sulfide Au-quartz vein	
AKPG	AK-EC14	01	Fort Knox	Fairbanks	Fairbanks	64.967	-147.367	Porphyry Au	
AKPG	AK-EC14	02	Pogo	Goodpasture	Big Delta	64.450	-144.883	Porphyry Au(?)	

Layer	Tract	Map No.	Deposit	District	Quadrangle 250K Scale	Lat	Long	Deposit Type	Alternative Deposit Type
AKPL1	AK-EC15 02		Livengood (Tolovana) District	Livengood (Tolovana)	Livengood	65.500	-148.167	Placer Au-PGE	
AKPL1	AK-EC15 03		Rampart District	Rampart	Tanana	65.500	-150.000	Placer Au-PGE	
AKPL1	AK-EC15 04		Hot Springs (Tofty) District	Hot Springs	Tanana	65.167	-151.000	Placer Au-PGE	Placer Sn
AKPL1	AK-EC15 05		Fairbanks District	Fairbanks	Fairbanks	64.917	-147.500	Placer Au-PGE	
AKPL1	AK-EC15 06		Fortymile District	Fortymile	Eagle	64.333	-142.000	Placer Au-PGE	
AKPL1 AKPL3	AK-EC15 01 AK03 01		Circle District	Circle	Circle	65.500	-144.750	Placer Au-PGE	
AKBC	AK-SC01 01		Kennecott	Nizina (Kennecott)	McCarthy	61.528	-142.840	Kennecott-type Cu	Basaltic Cu
AKBS	AK-SC02 01		Shellabarger Pass	Yentna	Talkeetna	62.561	-152.789	Massive sulfide, Besshi	
AKBS	AK-SC03 01		Denali (Pass Creek)	Valdez Creek	Mt. Hayes	63.141	-147.145	Massive sulfide, Besshi	
AKBS	AK-SC04 01		Midas	Prince William Sound	Valdez	61.013	-146.274	Massive sulfide, Besshi	
AKBS	AK-SC04 02		Ellamar (Gladhaugh)	Prince William Sound	Cordova	60.900	-146.700	Massive sulfide, Besshi	
AKBS	AK-SC04 03		Latouche - Beatson	Prince William Sound	Seward	60.033	-147.850	Massive sulfide, Besshi	
AKCY1	AK-SC06 01		Copper Bullion (Rua Cove)	Prince William Sound	Seward	60.348	-147.650	Massive sulfide, Besshi	
AKGQ1	AK-SC10 03		Lucky Hill - Gold Hill - Timberline Creek	Valdez Creek	Talkeetna Mountains	62.188	-147.272	Low sulfide Au-quartz vein	
AKGQ1	AK-SC11 01		Willow Creek - Independence - Lucky Shot - War Baby	Willow Creek	Anchorage	61.750	-149.500	Low sulfide Au-quartz vein	
AKGQ1	AK-SC12 01		Cliff (Port Valdez)	Prince William Sound	Valdez	61.117	-146.550	Low sulfide Au-quartz vein	
AKKU1	AK-SC14 01		Liberty Bell	Fairbanks	Fairbanks	64.617	-148.850	Massive sulfide, kuroko	
AKKU1	AK-SC14 02		Delta	Tok	Mt. Hayes	63.233	-144.160	Massive sulfide, kuroko	
AKKU1	AK-SC14 03		WTF	Bonnifield	Healy	63.933	-147.367	Massive sulfide, kuroko	

Layer	Tract	Map No.	Deposit	District	Quadrangle 250K Scale	Lat	Long	Deposit Type	Alternative Deposit Type
AKKU1	AK-SC15	01	Johnson River	Redoubt	Kenai	60.117	-152.950	Massive sulfide, kuroko	
AKKU1	AK-SC16	03	Sheep Creek	Bonnifield	Healy	63.900	-148.280	Massive sulfide, kuroko	
AKPC1	AK-SC20	01	Taurus	Fortymile	Tanacross	63.521	-141.324	Porphyry Cu-Mo	
AKPC1 AKPV1	AK-SC21 AK-SC28	01	Golden Zone	Valdez Creek	Healy	63.214	-149.649	Unclassified	Breccia pipe
AKPC2	AK-SC22	01	Orange Hill	Chisana	Nabesna	62.206	-142.842	Porphyry Cu-Mo	
AKPC2	AK-SC22	02	Bond Creek	Chisana	Nabesna	62.200	-142.705	Porphyry Cu-Mo	Porphyry Cu, skarn-related
AKPC2	AK-SC22	03	Baultoff	Chisana	Nabesna	62.083	-141.217	Porphyry Cu-Mo	
AKPG	AK-SC24	01	Kantishna District	Kantishna	Mt. McKinley	63.667	-150.830	Plutonic Porphyry Au	
AKPL1	AK-SC25	01	Valdez Creek (Denali) District	Valdez Creek	Mt. Hayes	63.183	-147.142	Placer Au-PGE	
AKPL1	AK-SC25	02	Chistochina District	Chistochina	Mr. Hayes	63.125	-144.150	Placer Au-PGE	
AKPL1	AK-SC25	03	Yentna District	Yentna	Talkeetna	62.333	-151.000	Placer Au-PGE	
AKPL1	AK-SC25	04	Willow Creek District	Willow Creek	Anchorage	61.667	-149.000	Placer Au-PGE	
AKPL1	AK-SC25	05	Nizina District	Nizina	McCarthy	61.333	-142.750	Placer Au-PGE	
AKPL1	AK-SC25	06	Hope District	Hope	Seward	60.875	-149.627	Placer Au-PGE	
AKPV1	AK-SC27	01	Banjo (Eureka, Red Top)	Kantishna	Mt. McKinley	63.567	-150.733	Low sulfide Au-quartz vein	Vein, polymetallic
AKPV1	AK-SC27	02	Quigley Ridge (Little Annie)	Kantishna	Mt. McKinley	63.543	-150.947	Vein, polymetallic	Low sulfide Au-quartz vein
AKPV1	AK-SC28	03	Spruce Creek	Kantishna	Mt. McKinley	63.583	-151.583	Vein, polymetallic	Low sulfide Au-quartz vein
AKSK1	AK-SC31	01	Zackly	Valdez Creek	Mt. Hayes	63.217	-146.700	Skarn, Au	
AKSK2 AKPV1	AK-SC32 AK-SC28	01 02	Nabesna	Chisana	Nabesna	62.377	-143.016	Skarn, Au	
AKGQ	AK-SE03	01	Kensington - Jualin	Juneau	Juneau	58.866	-135.087	Low sulfide Au-quartz vein	

Layer	Tract	Map No.	Deposit	District	Quadrangle 250K Scale	Lat	Long	Deposit Type	Alternative Deposit Type
AKGQ	AK-SE03	02	Alaska-Juneau (A.J., Perseverance)	Juneau	Juneau	58.308	-134.345	Low sulfide Au-quartz vein	
AKGQ	AK-SE03	03	Treadwell mines	Juneau	Juneau	58.267	-134.378	Low-sulfide Au-quartz vein	
AKGQ	AK-SE03	04	Chichagoff - Hirst Chichagoff	Admiralty	Sitka	57.664	-136.097	Low sulfide Au-quartz vein	
AKKU2	AK-SE04	01	Khayyam (Kiam)	Ketchikan	Craig	55.299	-132.388	Massive sulfide, kuroko	
AKKU2	AK-SE04	02	Niblack	Ketchikan	Ketchikan	55.067	-132.147	Massive sulfide, kuroko	
AKKU1	AK-SE05	01	Greens Creek	Admiralty	Juneau	58.077	-134.619	Massive sulfide, kuroko	
AKKU1	AK-SE05	02	Sumdum	Petersburg	Sumdum	57.792	-133.452	Massive sulfide, kuroko	
AKKU1	AK-SE05	03	Zarembo Island	Petersburg - Sumdum	Petersburg	56.284	-132.943	Massive sulfide, kuroko	
AKPC1	AK-SE07	01	Margerie Glacier	Juneau	Yakatat	59.013	-137.087	Porphyry Cu-Au	
AKPL1	AK-SE08	01	Porcupine Creek	Juneau	Skagway	59.333	-136.130	Placer Au-PGE	
AKSK3	AK-SE09	01	Jumbo	Ketchikan	Craig	55.253	-132.619	Skarn, Cu	
AKNC	AK-SE17	01	Brady Glacier	Porcupine	Mt. Fairweather	58.550	-136.933	Synorogenic-synvolcanic Ni-Cu	Gabbroic Ni-Cu
AKNC	AK-SE17	02	Bohemia Basin	Admiralty	Sitka	57.970	-136.420	Synorogenic-synvolcanic Ni-Cu	Gabbroic Ni-Cu
AKNC	AK-SE17	03	Salt Chuck	Ketchikan	Ketchikan	55.633	-132.558	Synorogenic-synvolcanic Ni-Cu	Gabbroic Ni-Cu
AKPC3	AK-SE20	01	Nunatak (Muir Inlet)	Juneau	Mt. Fairweather	58.988	-136.103	Porphyry Mo, low-F	
AKGP	AK-SW05	01	Donlin	Aniak	Iditarod	62.075	-158.217	Porphyry Au	
AKPC	AK-SW12	01	Kijik River	Iliamna	Lake Clark	60.353	-154.315	Porphyry Cu-Mo	
AKPC	AK-SW12	02	Pebble Copper	Iliamna	Iliamna	59.898	-155.296	Porphyry Cu-Au	
AKPG	AK-SW13	01	Vinasale Mountain	McGrath	McGrath	62.703	-155.718	Porphyry Au	
AKPG	AK-SW13	02	Golden Horn	Iditarod	Iditarod	62.464	-157.917	Porphyry Au	Vein, polymetallic
AKPG	AK-SW13	03	Chicken Mountain	Iditarod	Iditarod	62.396	-157.988	Porphyry Au	

Layer	Tract	Map No.	Deposit	District	Quadrangle 250K Scale	Lat	Long	Deposit Type	Alternative Deposit Type
AKPL1	AK-SW14	02	Marshall District	Marshall	Russian Mission	61.917	-161.500	Placer Au-PGE	Placer PGE
AKPL1	AK-SW14	03	Aniak District	Aniak	Bethel	61.000	-158.000	Placer Au-PGE	
AKPL1	AK-SW14	04	Goodnews Bay District	Goodnews Bay	Goodnews Bay	59.000	-161.000	Placer PGE	Placer Au-PGE
AKPL1 AKPL3	AK-SW14 AK03	01 02	Iditarod District	Iditarod	Iditarod	62.500	-158.500	Placer Au-PGE	
AKPV1	AK-SW16	01	Cirque	Innoko	Iditarod	62.845	-156.978	Vein, polymetallic, Ag-Sn	
AKGQ1	AK-WC09	01	Big Hurrah	Council	Solomon	64.653	-164.237	Low-sulfide Au quartz vein	
AKGQ1	AK-WC09	02	Rock Creek	Nome	Solomon	64.610	-165.410	Low sulfide Au-quartz vein	Vein, polymetallic
AKKC AKMV3	AK-WC11 AK02	01	Reef Ridge	McGrath	Medfra	63.483	-154.167	Kipushi Cu	Mississippi Valley
AKPL1	AK-WC17	01	Hughes District	Hughes	Melozitna	65.830	-155.000	Placer Au-PGE	
AKPL1	AK-WC17	02	Fairhaven District	Fairhaven	Candle	65.750	-161.667	Placer Au-PGE	
AKPL1	AK-WC17	03	Kougarok District	Kougarok	Melozitna	65.750	-164.830	Placer Au-PGE	Placer Sn
AKPL1	AK-WC17	04	Koyuk District	Koyuk	Candle	65.000	-161.330	Placer Au-PGE	
AKPL1	AK-WC17	07	Ruby District	Ruby	Ruby	64.417	-154.333	Placer Au-PGE	
AKPL1 AKPL3	AK-WC17 AK03	05 03	Council District	Council	Solomon	64.750	-163.500	Placer Au-PGE	
AKPL1 AKPL3	AK-WC17 AK03	06 04	Nome District	Nome	Nome	64.500	-165.500	Placer Au-PGE	
AKPL1	AK-WC17 AK-SW14	08	Innoko District	Innoko	Ophir	63.500	-156.500	Placer Au-PGE	

Layer	Tract	Map No.	Deposit	District	Quadrangle 250K Scale	Lat	Long	Deposit Type	Alternative Deposit Type
AKPL1	AK-WC17 AK-SW14	09	McGrath District	McGrath	McGrath	62.750	-155.000	Placer Au-PGE	
AKPV1	AK-WC22	01	Illinois Creek	Kaiyuh	Nulato	64.080	-158.000	Vein, polymetallic	Polymetallic replacement
AKPV1	AK-WC22	02	Win-Won (Cloudy Mountain)	Innoko	Medfra	63.220	-156.070	Vein, polymetallic, Ag-Sn	
AKSK	AK-WC24	01	Nixon Fork	Innoko	Medfra	63.236	-154.758	Skarn, Cu	

Layer	Tract	Map No.	Deposit	District	County	State	Lat	Long	Deposit Type	Alternative deposit types
SEDX	AD03 01		Pierrepont	Balmat-Edwards	St. Lawrence	NY	44.544	-75.001	Sedimentary exhalative Zn	
SEDX	AD03 02		Edwards	Balmat-Edwards	St. Lawrence	NY	44.328	-75.263	Sedimentary exhalative Zn	
SEDX	AD03 03		Balmat	Balmat-Edwards	St. Lawrence	NY	44.252	-75.400	Sedimentary exhalative Zn	
SCU2	CP03 01			Lisbon Valley	San Juan	UT	38.125	-109.125	Sediment-hosted Cu, redbed	
PMR1	CR15 01		Gilman	Gilman	Eagle	CO	39.517	-106.367	Polymetallic replacement	
PMR1	CR15 02			Aspen	Pitkin	CO	39.167	-106.833	Polymetallic replacement	Sherman type
PMR2	CR16 01			Tenmile Kokomo Robinson Frisco	Summit	CO	39.417	-106.214	Polymetallic replacement	Vein, polymetallic
PMR2	CR16 02			Alma	Park	CO	39.333	-106.125	Polymetallic replacement	Vein, polymetallic
PMR2	CR16 03			Leadville	Lake	CO	39.250	-106.250	Polymetallic replacement	Vein, polymetallic
PMR3	CR17 01			Rico Dunton	Dolores	CO	37.667	-108.025	Polymetallic replacement	Vein, polymetallic; Climax Mo
PMR1	CR18 01			Magdalena	Socorro	NM	34.083	-107.208	Polymetallic replacement	
PMR1	CR19 01			Shafter	Presidio	TX	29.810	-104.330	Polymetallic replacement	
ALKG	CR20 01			Jamestown	Boulder	CO	40.125	-105.375	Alkaline Au-Te	Vein, polymetallic
ALKG	CR20 02			Ward	Boulder	CO	40.071	-105.500	Alkaline Au-Te	Vein, polymetallic
ALKG	CR20 03			Gold Hill-Sugarloaf	Boulder	CO	40.054	-105.383	Alkaline Au-Te	Vein, polymetallic
ALKG	CR20 04			Magnolia	Boulder	CO	39.990	-105.380	Alkaline Au-Te	Vein, polymetallic
ALKG	CR20 05			La Plata	La Plata	CO	37.417	-108.042	Alkaline Au-Te	Porphyry Cu-Au
ALKG	CR21 01			Cripple Creek	Teller	CO	38.717	-105.133	Alkaline Au-Te	
ALKG	CR22 01			Elizabethtown-Baldy	Colfax	NM	36.625	-105.250	Alkaline Au-Te	Vein, polymetallic
ALKG	CR22 02			Old Placers	Santa Fe	NM	35.339	-106.132	Alkaline Au-Te	
ALKG	CR22 03		Carache Canyon	Old Placers	Santa Fe	NM	35.317	-106.163	Alkaline Au-Te	
ALKG	CR22 04		Lukas Canyon	Old Placers	Santa Fe	NM	35.301	-106.189	Alkaline Au-Te	
ALKG	CR22 05			White Oaks	Lincoln	NM	33.767	-106.750	Alkaline Au-Te	
ALKG	CR22 06			Nogal	Lincoln	NM	33.530	-105.750	Alkaline Au-Te	Porphyry Cu-Au
KVMS	CR24 01		Dawson	Grape Creek	Fremont	CO	38.390	-105.290	Massive sulfide, kuroko	
KVMS	CR24 02			Gunnison Gold Belt	Gunnison	CO	38.367	-107.100	Massive sulfide, kuroko	
KVMS	CR25 01		Pecos	Willow Creek	San Miguel	NM	35.792	-105.667	Massive sulfide, kuroko	
QZAD	CR26 01			Lake City	Hinsdale	CO	38.017	-107.333	Epithermal vein, quartz-adularia	Vein, polymetallic

Layer	Tract	Map No.	Deposit	District	County	State	Lat	Long	Deposit Type	Alternative deposit types
QZAD	CR26 02			Creede	Mineral	CO	37.875	-106.933	Epithermal vein, Creede	Vein, polymetallic
QZAD	CR26 03			Crystal Hill	Saguache	CO	37.870	-106.270	Epithermal vein, quartz-adularia	
QZAD	CR26 04		Platoro		Conejos	CO	37.350	-106.536	Epithermal vein, quartz-adularia	
QZAD	CR27 01			Mogollon	Catron	NM	33.400	-108.800	Epithermal vein, quartz-adularia	
QZAD	CR27 02		St. Cloud	Chloride	Sierra	NM	33.330	-107.710	Epithermal vein, quartz-adularia	
QZAD	CR27 03			Hillsboro	Sierra	NM	32.930	-107.500	Epithermal vein, quartz-adularia	Placer Au
QZAL	CR29 01		Summitville	Summitville	Rio Grande	CO	37.417	-106.550	Epithermal vein, quartz-alunite	
SCU3	CR34 01		Nacimiento	Nacimiento	Sandoval	NM	35.985	-106.900	Sediment-hosted Cu, redbed	
LSGQ	CR36 01		Keystone	Southern Medicine Bow Mountains	Albany	WY	41.167	-106.244	Low-sulfide Au-quartz vein	
MVTD	EC03 01		Elmwood and Gordonsville	Central Tennessee	Smith	TN	36.197	-85.934	Mississippi Valley	Appalachian Zn
MVTD	EC05 01		Friedensville	Friedensville	Lehigh	PA	40.554	-75.405	Mississippi Valley	Appalachian Zn
MVTD	EC05 02			Austinville-Ivanhoe	Wythe	VA	36.847	-80.920	Mississippi Valley	Appalachian Zn
MVTD	EC05 03		Copper Ridge and Mascot-Jefferson	Copper Ridge-Mascot-Jefferson City	Grainger, Jefferson	TN	36.400	-83.350	Mississippi Valley	Appalachian Zn
FFTG	FFTG 01		San Luis	San Luis	Costilla	CO	37.254	-105.342	Flat fault Au	
FFTG	FFTG 02		Briggs		Inyo	CA	35.938	-117.184	Flat fault Au	
FFTG	FFTG 03		Eldorado	Eldorado	Clark	NV	35.710	-114.840	Flat fault Au	
FFTG	FFTG 04		Copperstone	Moon Mountains	La Paz	AZ	33.870	-114.290	Flat Fault Au	
SKC1	GB02 01		Buffalo Valley	Battle Mountain	Lander	NV	40.600	-117.250	Skarn Au	
SKC1	GB02 02		Fortitude - Surprise	Battle Mountain	Lander	NV	40.550	-117.130	Skarn Au	
SKC1	GB02 03		Northeast Extension (Silver King)	Battle Mountain	Lander	NV	40.550	-117.130	Skarn Au	
SKC1	GB02 04		Tomboy-Minnie	Battle Mountain	Lander	NV	40.530	-117.120	Skarn Au	
SKC1	GB02 05			Yerington	Lyon	NV	38.947	-119.280	Skarn Cu	
SKZ1	GB04 01			Ophir	Tooele	UT	40.380	-112.270	Skarn Zn-Pb	
SKZ1	GB04 02		Crypto	Fish Springs	Juab	UT	39.860	-113.450	Skarn Zn-Pb	
SKNG	GB05 01		Ward	Ward	White Pine	NV	39.080	-114.880	Skarn Zn-Pb	

Layer	Tract	Map No.	Deposit	District	County	State	Lat	Long	Deposit Type	Alternative deposit types
PCU1	GB08	01	Ely	Robinson	White Pine	NV	39.260	-115.000	Porphyry Cu, skarn-related	
PCU1	GB08	02	Sullivan - Cuervo	Fairplay	Nye	NV	38.780	-117.950	Porphyry Cu	
PCU2	GB09	01	Copper Canyon	Battle Mountain	Lander	NV	40.540	-117.120	Porphyry Cu, skarn-related	
PCU3	GB10	01	Macarthur	Yerington	Lyon	NV	39.050	-119.240	Porphyry Cu	
PCU3	GB10	02	Bear Prospect	Yerington	Lyon	NV	39.030	-119.180	Porphyry Cu	
PCU3	GB10	03	Yerington	Yerington	Lyon	NV	38.980	-119.200	Porphyry Cu	
PCU3	GB10	04	Ann Mason	Yerington	Lyon	NV	38.960	-119.270	Porphyry Cu	
PCU2	GB11	01	Bingham Canyon	Bingham Canyon	Salt Lake	UT	40.540	-112.140	Porphyry Cu	Polymetallic replacement; skarn Cu
PMR1	GB14	01		Cerro Gordo	Inyo	CA	36.540	-117.791	Polymetallic replacement	
PMR1	GB14	02		Darwin	Inyo	CA	36.280	-117.600	Polymetallic replacement	
PMR1	GB14	03		Argus	Inyo	CA	35.925	-117.516	Polymetallic replacement	
PMR1	GB15	01		Eureka	Eureka	NV	39.500	-115.980	Polymetallic replacement	
PMR1	GB15	02		Bristol - Jackrabbit	Lincoln	NV	38.100	-114.600	Polymetallic replacement	
PMR1	GB15	03		Pioche	Lincoln	NV	37.920	-114.460	Polymetallic replacement	
PMR1	GB16	01		Tecoma	Box Elder	UT	41.267	-114.000	Polymetallic replacement	Distal disseminated Ag-Au
PMR1	GB16	02		Little and Big Cottonwood	Salt Lake	UT	40.620	-111.670	Polymetallic replacement	
PMR1	GB16	03		Park City	Summit	UT	40.620	-111.510	Polymetallic replacement	
PMR1	GB16	04		Tintic	Utah-Juab	UT	39.910	-112.100	Polymetallic replacement	
PMR1	GB16	05	Detroit	Detroit	Juab	UT	39.550	-112.990	Polymetallic replacement	Distal disseminated Ag-Au
PMR1	GB16	06		San Francisco and adjacent districts (Milford area)	Beaver	UT	38.480	-113.300	Polymetallic replacement	
DSDG	GB18	01	Lone Tree	Battle Mountain	Humboldt	NV	40.830	-117.210	Distal disseminated Ag-Au	
DSDG	GB18	02	Stonehouse	Battle Mountain	Humboldt	NV	40.830	-117.210	Distal disseminated Ag-Au	
DSDG	GB18	03	Eight South	Battle Mountain	Humboldt	NV	40.742	-117.160	Distal disseminated Ag-Au	
DSDG	GB18	04	Marigold	Battle Mountain	Humboldt	NV	40.730	-117.180	Distal disseminated Ag-Au	
DSDG	GB18	05	East Hill - UNR - Top	Battle Mountain	Humboldt	NV	40.729	-117.175	Distal disseminated Ag-Au	

Layer	Tract	Map No.	Deposit	District	County	State	Lat	Long	Deposit Type	Alternative deposit types
DSDG	GB18 06		Trenton - Valmy	Battle Mountain	Humboldt	NV	40.645	-117.178	Distal disseminated Ag-Au	
DSDG	GB18 07		Reona	Battle Mountain	Lander	NV	40.540	-117.140	Distal Disseminated Ag-Au	Skarn Au
DSDG	GB18 08		Hilltop	Hilltop	Lander	NV	40.420	-116.810	Distal disseminated Ag-Au	
DSDG	GB18 09		Cove - McCoy	McCoy	Lander	NV	40.340	-117.210	Distal disseminated Ag-Au	Skarn Au
DSDG	GB18 10		Tenabo	Bullion	Lander	NV	40.310	-116.640	Distal disseminated Ag-Au	
DSDG	GB18 11		White Pine	White Pine	White Pine	NV	39.980	-115.480	Distal disseminated Ag-Au	
DSDG	GB18 12		Windfall	Eureka	Eureka	NV	39.450	-115.980	Distal disseminated Ag-Au	
DSDG	GB18 13		Star Pointer	Robinson	White Pine	NV	39.250	-114.980	Distal disseminated Ag-Au	
DSDG	GB18 14		Mt. Hamilton	White Pine	White Pine	NV	39.250	-115.570	Distal disseminated Ag-Au	
DSDG	GB18 15		Treasure Hill	White Pine	White Pine	NV	39.220	-115.480	Distal disseminated Ag-Au	
DSDG	GB18 16		Taylor	Taylor	White Pine	NV	39.080	-114.680	Distal disseminated Ag-Au	
DSDG	GB18 17		Candelaria	Candelaria	Mineral	NV	38.150	-118.080	Distal disseminated Ag-Au	
BVMS	GB20 01		Rio Tinto	Mountain City	Elko	NV	41.810	-115.980	Massive sulfide, Besshi	
QZAD	GB22 01		Zaca	Monitor-Mogul	Alpine	CA	38.666	-119.704	Epithermal vein, Comstock	
QZAD	GB22 02			Patterson	Mono	CA	38.412	-119.232	Epithermal vein, Comstock	
QZAD	GB22 03			Bodie	Mono	CA	38.223	-118.982	Epithermal vein, Comstock	
QZAD	GB22 04		Long Valley		Mono	CA	37.700	-118.867	Epithermal vein, Comstock	Hot-spring Au-Ag
QZAD	GB23 01			Jarbidge	Elko	NV	41.840	-115.410	Epithermal vein, Comstock	
QZAD	GB23 02			National	Humboldt	NV	41.840	-117.590	Epithermal vein, Comstock	
QZAD	GB23 03			Tuscarora	Elko	NV	41.320	-116.220	Epithermal vein, Comstock	
QZAD	GB23 04			Gold Circle	Elko	NV	41.250	-116.790	Epithermal vein, Comstock	

Layer	Tract	Map No.	Deposit	District	County	State	Lat	Long	Deposit Type	Alternative deposit types
QZAD	GB23	05	Rosebud	Rosebud	Pershing	NV	40.800	-118.650	Epithermal vein, Comstock	
QZAD	GB23	06		Seven Troughs	Pershing	NV	40.450	-118.790	Epithermal vein, Comstock	
QZAD	GB23	07		Trinity	Pershing	NV	40.410	-118.590	Epithermal vein, Comstock	
QZAD	GB23	08	Gooseberry	Ramsey	Storey	NV	39.480	-119.460	Epithermal vein, Comstock	
QZAD	GB23	09	Talapoosa	Talapoosa	Lyon	NV	39.450	-119.270	Epithermal vein, Comstock	
QZAD	GB23	10		Wonder	Churchill	NV	39.450	-118.050	Epithermal vein, Comstock	
QZAD	GB23	11		Comstock Lode	Storey	NV	39.320	-119.590	Epithermal vein, Comstock	
QZAD	GB23	12		Fairview	Churchill	NV	39.180	-118.130	Epithermal vein, Comstock	
QZAD	GB23	13		Bruner	Nye	NV	39.080	-117.800	Epithermal vein, quartz-adularia	Epithermal vein, Sado
QZAD	GB23	14		Rawhide - Regent	Mineral	NV	39.030	-118.420	Epithermal vein, Comstock	
QZAD	GB23	15		Bovard - Rand	Mineral	NV	38.790	-118.400	Epithermal vein, Comstock	
QZAD	GB23	16		Manhattan	Nye	NV	38.530	-117.060	Epithermal vein, Comstock	
QZAD	GB23	17		Longstreet	Nye	NV	38.380	-116.710	Epithermal vein, Comstock	
QZAD	GB23	18		Silver Star	Mineral	NV	38.340	-118.200	Epithermal vein, Comstock	
QZAD	GB23	19		Aurora	Mineral	NV	38.290	-118.890	Epithermal vein, Comstock	
QZAD	GB23	20		Tonopah	Nye	NV	38.070	-117.230	Epithermal vein, Comstock	
QZAD	GB23	21		Divide	Esmeralda	NV	37.990	-117.240	Epithermal vein, Comstock	
QZAD	GB23	22	Sixteen To One - Nivloc	Silver Peak	Esmeralda	NV	37.720	-117.780	Epithermal vein, Comstock	
QZAD	GB23	23		Delamar	Lincoln	NV	37.460	-114.770	Epithermal vein, Comstock	
QZAD	GB23	24	Bullfrog	Bullfrog	Nye	NV	36.900	-116.880	Epithermal vein, Comstock	

Layer	Tract	Map No.	Deposit	District	County	State	Lat	Long	Deposit Type	Alternative deposit types
QZAD	GB24 01			Marysvale	Piute	UT	38.430	-112.330	Epithermal vein, quartz-adularia	
QZAD	GB24 02			Escalante	Washington	UT	37.650	-113.810	Epithermal vein, quartz-adularia	
QZAD	GB24 03			Goldstrike	Washington	UT	37.400	-113.930	Epithermal vein, quartz-adularia	
QZAL	GB26 01		Freedom Flat	Lucky Boy	Mineral	NV	38.380	-118.770	Epithermal vein, quartz-alunite	
QZAL	GB26 02			Goldfield	Esmeralda	NV	37.710	-117.210	Epithermal vein, quartz-alunite	
HTSG	GB28 01		Buckskin National	National	Humboldt	NV	41.790	-117.540	Hot spring Au-Ag	
HTSG	GB28 02		Sleeper	Awakening	Humboldt	NV	41.330	-118.050	Hot spring AuAg	
HTSG	GB28 03		Western Hog Ranch	Leadville	Washoe	NV	41.160	-119.450	Hot spring Au-Ag	
HTSG	GB28 04		Ivanhoe	Ivanhoe	Elko	NV	41.110	-116.560	Hot spring Au-Ag	
HTSG	GB28 05		Crofoot - Lewis	Sulphur	Humboldt	NV	40.860	-118.690	Hot spring Au-Ag	
HTSG	GB28 06		Mule Canyon	Beowave	Lander	NV	40.600	-116.683	Hot spring Au-Ag	
HTSG	GB28 07		Florida Canyon	Imlay	Pershing	NV	40.580	-118.240	Hot spring Au-Ag	
HTSG	GB28 08		Wind Mountain	San Emidio	Washoe	NV	40.430	-119.390	Hot spring Au-Ag	
HTSG	GB28 09		Buckhorn	Buckhorn	Eureka	NV	40.180	-116.490	Hot spring Au-Ag	
HTSG	GB28 10		Dixie Comstock	Dixie Valley	Churchill	NV	39.870	-118.020	Hot spring Au-Ag	
HTSG	GB28 11		Paradise Peak	Fairplay	Nye	NV	38.750	-117.970	Hot spring Au-Ag	
HTSG	GB28 12		Ketchup Flat	Fairplay	Nye	NV	38.733	-117.958	Hot spring Au-Ag	
HTSG	GB28 13		Round Mountain	Round Mountain	Nye	NV	38.700	-117.080	Hot spring Au-Ag	
HTSG	GB28 14		Santa Fe Gold	Santa Fe	Mineral	NV	38.550	-118.170	Hot spring Au-Ag	
HTSG	GB28 15		Atlanta	Atlanta	Lincoln	NV	38.470	-114.320	Hot spring AuAg	
HTSG	GB28 16		Borealis	Lucky Boy	Mineral	NV	38.380	-118.760	Hot spring Au-Ag	
HTSG	GB28 17		Tonopah Hasbrouck	Divide	Esmeralda	NV	37.990	-117.270	Hot spring Au-Ag	
SEDG	GB30 01		Big Springs	Birch Creek	Elko	NV	41.550	-115.980	Sediment-hosted Au	
SEDG	GB30 02		Winters Creek	Burns Basin	Elko	NV	41.450	-115.950	Sediment-hosted Au	
SEDG	GB30 03		Wright Window	Burns Basin	Elko	NV	41.400	-116.069	Sediment-hosted Au	
SEDG	GB30 04		Burns Basin-Jerritt Canyon	Burns Basin	Elko	NV	41.340	-116.010	Sediment-hosted Au	
SEDG	GB30 05		Twin Creeks (Chimney Creek and Rabbit Creek)	Potosi	Humboldt	NV	41.280	-117.170	Sediment-hosted Au	

Layer	Tract	Map No.	Deposit	District	County	State	Lat	Long	Deposit Type	Alternative deposit types
SEDG	GB30	06	Getchell	Potosi	Humboldt	NV	41.210	-117.260	Sediment-hosted Au	
SEDG	GB30	07	Pinson	Potosi	Humboldt	NV	41.130	-117.270	Sediment-hosted Au	
SEDG	GB30	08	Dee	Bootstrap	Elko	NV	41.030	-116.430	Sediment-hosted Au	
SEDG	GB30	09	Bootstrap/Capstone	Bootstrap	Elko	NV	41.020	-116.420	Sediment-hosted Au	
SEDG	GB30	10	Meikle	Bootstrap	Elko	NV	41.010	-116.360	Sediment-hosted Au	
SEDG	GB30	11	Preble	Potosi	Humboldt	NV	41.000	-117.390	Sediment-hosted Au	
SEDG	GB30	12	Goldstrike-Post	Bluestar-Goldstrike	Eureka	NV	40.977	-116.358	Sediment-hosted Au	
SEDG	GB30	13	North Star	Bluestar-Goldstrike	Eureka	NV	40.962	-116.362	Sediment-hosted Au	
SEDG	GB30	14	Deepstar	Bluestar-Goldstrike	Eureka	NV	40.962	-116.353	Sediment-hosted Au	
SEDG	GB30	15	Bobcat	Bluestar-Goldstrike	Eureka	NV	40.960	-116.353	Sediment-hosted Au	
SEDG	GB30	16	Genesis - Blue Star	Bluestar-Goldstrike	Eureka	NV	40.952	-116.352	Sediment-hosted Au	
SEDG	GB30	17	Lantern	Lynn	Eureka	NV	40.923	-116.333	Sediment-hosted Au	
SEDG	GB30	18	Universal Gas (Bullion Monarch)	Lynn	Eureka	NV	40.920	-116.330	Sediment-hosted Au	
SEDG	GB30	19	Carlin	Lynn	Eureka	NV	40.912	-116.320	Sediment-hosted Au	
SEDG	GB30	20	Pete	Lynn	Eureka	NV	40.910	-116.313	Sediment-hosted Au	
SEDG	GB30	21	Tusc	Maggie Creek	Eureka	NV	40.833	-116.233	Sediment-hosted Au	
SEDG	GB30	22	Mac	Maggie Creek	Eureka	NV	40.828	-116.232	Sediment-hosted Au	
SEDG	GB30	23	Gold Quarry	Maggie Creek	Eureka	NV	40.825	-116.225	Sediment-hosted Au	
SEDG	GB30	24	Maggie Creek	Maggie Creek	Eureka	NV	40.825	-116.225	Sediment-hosted Au	
SEDG	GB30	25	Emigrant	Rain	Elko	NV	40.620	-115.970	Sediment-hosted Au	
SEDG	GB30	26	Rain - SMZ	Rain	Elko	NV	40.610	-116.010	Sediment-hosted Au	
SEDG	GB30	27	Gnome	Rain	Elko	NV	40.600	-116.110	Sediment-hosted Au	
SEDG	GB30	28	Piñon Range - Cord Ranch		Elko	NV	40.458	-115.844	Sediment-hosted Au	
SEDG	GB30	29	Dark Star		Elko	NV	40.458	-115.844	Sediment-hosted Au	
SEDG	GB30	30	Horse Canyon	Cortez	Lander	NV	40.410	-116.920	Sediment-hosted Au	
SEDG	GB30	31	Robertson		Lander	NV	40.310	-116.694	Sediment-hosted Au	
SEDG	GB30	32	Elder Creek		Lander	NV	40.308	-116.850	Sediment-hosted Au	
SEDG	GB30	33	Cortez	Cortez Bullion	Lander	NV	40.260	-116.740	Sediment-hosted Au	
SEDG	GB30	34	Pipeline		Lander	NV	40.255	-116.740	Sediment-hosted Au	
SEDG	GB30	35	South Pipeline		Lander	NV	40.248	-116.740	Sediment-hosted Au	
SEDG	GB30	36	Relief Canyon	Antelope Springs	Pershing	NV	40.210	-118.170	Sediment-hosted Au	

Layer	Tract	Map No.	Deposit	District	County	State	Lat	Long	Deposit Type	Alternative deposit types
SEDG	GB30	37	Cortez	Cortez	Eureka	NV	40.150	-116.580	Sediment-hosted Au	
SEDG	GB30	38	Saddle (Toiyabe project)		Lander	NV	40.030	-116.710	Sediment-hosted Au	
SEDG	GB30	39	Bald Mountain	Bald Mountain	White Pine	NV	39.960	-115.590	Sediment-hosted Au	
SEDG	GB30	40	Little Bald Mountain	Bald Mountain	White Pine	NV	39.920	-115.550	Sediment-hosted Au	
SEDG	GB30	41	Tonkin Springs	Tonkin Springs	Eureka	NV	39.900	-116.430	Sediment-hosted Au	
SEDG	GB30	42	Golden Butte	Cherry Creek	White Pine	NV	39.830	-115.050	Sediment-hosted Au	
SEDG	GB30	43	Gold Pick	Antelope	Eureka	NV	39.800	-116.330	Sediment-hosted Au	
SEDG	GB30	44	Fondaway Canyon		Churchill	NV	39.800	-118.200	Sediment-hosted Au	
SEDG	GB30	45	Alligator Ridge	Alligator Ridge	White Pine	NV	39.760	-115.520	Sediment-hosted Au	
SEDG	GB30	46	Gold Canyon	Roberts	Eureka	NV	39.760	-116.170	Sediment-hosted Au	
SEDG	GB30	47	Gold Bar	Roberts	Eureka	NV	39.750	-116.200	Sediment-hosted Au	
SEDG	GB30	48	Yankee	Alligator Ridge	White Pine	NV	39.690	-115.530	Sediment-hosted Au	
SEDG	GB30	49	Easy Junior - Nighthawk Ridge		White Pine	NV	39.450	-115.880	Sediment-hosted Au	
SEDG	GB30	50	Pan		White Pine	NV	39.411	-115.676	Sediment-hosted Au	
SEDG	GB30	51	Ratto Canyon	Eureka	Eureka	NV	39.400	-115.990	Sediment-hosted Au	
SEDG	GB30	52	Austin Gold Venture		Lander	NV	39.380	-117.090	Sediment-hosted Au	
SEDG	GB30	53	Green Springs	White Pine	White Pine	NV	39.140	-115.550	Sediment-hosted Au	
SEDG	GB30	54	Northumberland	Northumberland	Nye	NV	38.960	-116.860	Sediment-hosted Au	
SEDG	GB30	55	Mother Lode	Bare Mountain	Nye	NV	36.910	-116.650	Sediment-hosted Au	
SEDG	GB31	01	Black Pine (Tallman)	Black Pine	Cassia	ID	42.078	-113.042	Sediment-hosted Au	
SEDG	GB31	02	Barney's Canyon	Barney's Canyon	Salt Lake	UT	40.610	-112.160	Sediment-hosted Au	
SEDG	GB31	03	Melco	Melco	Salt Lake	UT	40.600	-112.170	Sediment-hosted Au	
SEDG	GB31	04	Mercur	Mercur	Tooele	UT	40.320	-112.240	Sediment-hosted Au	
SCU3	GB32	01	Silver Reef (Harrisonburg)		Washington	UT	37.250	-113.370	Sediment-hosted Cu, redbed	
SCU1	GP04	01	Mangum		Greer	OK	34.830	-99.530	Sediment-hosted Cu, reduced facies	
SCU1	GP04	02	Creta		Jackson	OK	34.500	-99.500	Sediment-hosted Cu, reduced facies	
MVTD	GP05	01		Upper Mississippi Valley	Lafayette, Grant, Green, Jo Daviess, Dubuque	IL, WI, IA	42.450	-90.420	Mississippi Valley	Southeast Missouri Pb-Zn

Layer	Tract	Map No.	Deposit	District	County	State	Lat	Long	Deposit Type	Alternative deposit types
MVTD	GP05 02		Indian Creek	Southeast Missouri	Washington	MO	38.500	-90.900	Mississippi Valley	Southeast Missouri Pb-Zn
MVTD	GP05 03			Central Missouri	Morgan, Miller, Camden, Moniteau, Cooper, Cole	MO	38.250	-92.817	Mississippi Valley	
MVTD	GP05 04		Lead Belt	Southeast Missouri	St. Francois	MO	37.842	-90.534	Mississippi Valley	Southeast Missouri Pb-Zn
MVTD	GP05 05		Viburnum Trend	Southeast Missouri	Crawford, Washington, Iron, Reynolds	MO	37.583	-91.167	Mississippi Valley	Southeast Missouri Pb-Zn
MVTD	GP05 06		Mine LaMotte-Fredericktown	Southeast Missouri	Madison	MO	37.533	-90.273	Mississippi Valley	Southeast Missouri Pb-Zn
MVTD	GP05 07			Illinois-Kentucky	Pope, Hardin, Livingston, Crittenden	IL, KY	37.527	-88.423	Mississippi Valley	Southeast Missouri Pb-Zn
MVTD	GP05 08		Annapolis	Southeast Missouri	Iron	MO	37.367	-90.700	Mississippi Valley	Southeast Missouri Pb-Zn
MVTD	GP05 09		Southwest Missouri (Joplin)	Tri-state	Jasper, Newton, Lawrence	MO	37.133	-94.483	Mississippi Valley	Southeast Missouri Pb-Zn
MVTD	GP05 10		Galena	Tri-state	Cherokee	KS	37.083	-94.650	Mississippi Valley	Southeast Missouri Pb-Zn
MVTD	GP05 11		Picher Field	Tri-state	Ottawa	OK	36.983	-94.833	Mississippi Valley	Southeast Missouri Pb-Zn
DMCU	LS01 01			Duluth	Lake	MN	48.050	-90.933	Duluth Cu-Ni	
KVMS	LS04 01		Lynne		Oneida	WI	45.695	-89.970	Massive sulfide, kuroko	
KVMS	LS04 02		Catwillow		Forest	WI	45.629	-88.549	Massive sulfide, kuroko	
KVMS	LS04 03		Pelican		Oneida	WI	45.578	-89.417	Massive sulfide, kuroko	
KVMS	LS04 04		Thornapple		Rusk	WI	45.514	-91.140	Massive sulfide, kuroko	
KVMS	LS04 05		Crandon		Forest	WI	45.483	-88.926	Massive sulfide, kuroko	
KVMS	LS04 06		Flambeau		Rusk	WI	45.441	-91.119	Massive sulfide, kuroko	
KVMS	LS04 07		Bend		Taylor	WI	45.298	-90.607	Massive sulfide, kuroko	
SCU2	LS07 01		White Pine	White Pine	Ontonagon	MI	46.744	-89.534	Sediment-hosted Cu, reduced facies	
SCU2	LS07 02		Presque Isle	White Pine	Gogebic	MI	46.700	-89.950	Sediment-hosted Cu, reduced facies	
NTCU	LS08 01		Kearsarge	Keweenaw	Houghton	MI	47.307	-88.363	Native Cu	
NTCU	LS08 02		Isle Royale	Keweenaw	Houghton	MI	47.236	-88.461	Native Cu	
NTCU	LS08 03		Osceola	Keweenaw	Houghton	MI	47.186	-88.516	Native Cu	

Layer	Tract	Map No.	Deposit	District	County	State	Lat	Long	Deposit Type	Alternative deposit types
NTCU	LS08 04		Calumet and Hecla	Keweenaw	Houghton	MI	47.140	-88.579	Native Cu	
NTCU	LS08 05		Pewabic	Keweenaw	Houghton	MI	47.140	-88.600	Native Cu	
NTCU	LS08 06		Atlantic	Keweenaw	Houghton	MI	47.100	-88.650	Native Cu	
NTCU	LS08 07		Baltic	Keweenaw	Houghton	MI	47.079	-88.579	Native Cu	
LSGQ	LS10 01		Reef		Marathon	WI	44.960	-89.362	Low-sulfide Au-quartz vein	
HMAS	LS12 01		Ropes	Marquette	Marquette	MI	46.530	-87.425	Low-sulfide Au-quartz vein, Archean	
LSGP	LSGP 01			Osceola	White Pine	NV	39.080	-114.400	Vein, Au-quartz, peraluminous granite	
LSGP	LSGP 02		Weepah	Lone Mountain	Esmeralda	NV	37.930	-117.560	Vein, Au-quartz, peraluminous granite	
LSGP	LSGP 03		Mary-Drinkwater	Silver Peak (Mineral Ridge)	Esmeralda	NV	37.800	-117.700	Vein, Au-quartz, peraluminous granite	
LSGP	LSGP 04		Skidoo	Skidoo-Wild Rose	Inyo	CA	36.463	-117.216	Vein, Au-quartz, peraluminous granite	
MO	MOCX 01		Cave Peak		Culberson	TX	31.440	-104.887	Porphyry Mo, Climax	
MO	MOLF 01		Mt Tolman	Sanpoil,Keller	Ferry	WA	48.057	-118.692	Porphyry Mo, Low-F	
MO	MOLF 02		Cumo	Grimes Pass	Boise	ID	44.038	-115.783	Porphyry Mo, Low-F	
MO	MOLF 03		Buckingham	Battle Mountain	Lander	NV	40.617	-117.075	Porphyry Mo, Low-F	
MO	MOLF 04		Cyprus Tonopah (Hall)		Nye	NV	38.300	-117.300	Porphyry Mo, Low-F	
MO	MOLF 05		Rialto	Nogal	Lincoln	NM	33.510	-105.780	Porphyry Mo, Low-F	
PCU1	NA02 01		Catheart		Somerset	ME	45.320	-70.100	Porphyry Cu	
BVMS	NA05 01		Black Hawk		Hancock	ME	44.392	-68.625	Massive sulfide, Besshi	
BVMS	NA08 01		Elizabeth	Orange County Copper	Orange	VT	43.817	-72.333	Massive sulfide, Besshi	
KVMS	NA11 01		Bald Mountain		Aroostook	ME	46.733	-68.743	Massive sulfide, kuroko	
KVMS	NA11 02		Mount Chase		Penobscot	ME	46.133	-68.469	Massive sulfide, kuroko	
KVMS	NA13 01		Harborside (Penobscot)		Hancock	ME	44.337	-68.820	Massive sulfide, kuroko	
KVMS	NA14 01		Ledge Ridge		Oxford	ME	45.233	-71.050	Massive sulfide, kuroko	
KVMS	NA14 02		Milan		Coos	NH	44.346	-71.133	Massive sulfide, kuroko	
NONE	NONE 01		Sheep Hill		Coconino	AZ	unk	unk	Unclassified	
NONE	NONE 02		Sumich		unk	CO	unk	unk	Unclassified	
NONE	NONE 03		Madison		unk	MT	unk	unk	Unclassified	

Layer	Tract	Map No.	Deposit	District	County	State	Lat	Long	Deposit Type	Alternative deposit types
NONE	NONE	04	Oliver Hills		Storey/Lyon	NV	unk	unk	Unclassified	
NONE	NONE	05	Red Mountain	Chiwawa	Chelan	WA	48.756	-120.849	Breccia pipe	
NONE	NONE	06	Lamefoot	Republic	Ferry	WA	48.734	-118.646	Unclassified	Veinlets in argillite; replacements in dolomite
NONE	NONE	07	Key East - Key West	Republic	Ferry	WA	48.710	-118.551	Unclassified	Veinlets in argillite; replacements in dolomite
NONE	NONE	08	Overlook zone	Republic	Ferry	WA	48.699	-118.569	Unclassified	Veinlets in argillite; replacements in dolomite
NONE	NONE	09	543-S		Keweenaw	MI	47.360	-88.180	Chalcocite in basalt	
NONE	NONE	10	St. Louis		Houghton	MI	47.240	-88.390	Chalcocite in basalt	
NONE	NONE	11	York	York	Lewis and Clark	MT	46.721	-111.750	Disseminated Au	
NONE	NONE	12	Miller Mountain	Confederate Gulch	Broadwater	MT	46.620	-111.414	Disseminated Au	
NONE	NONE	13	Kona		Marquette	MI	46.500	-87.367	Unclassified	
NONE	NONE	14	Montana Tunnels	Wickes (Colorado)	Jefferson	MT	46.371	-112.126	Unclassified	Diatreme, polymetallic, Au-bearing
NONE	NONE	15		Renova	Madison	MT	45.794	-112.000	Vein, epithermal?	
NONE	NONE	16	Blackbird	Blackbird	Lemhi	ID	45.121	-114.339	Cu-Co, Blackbird type	Sedimentary exhalative Zn-Pb (Cu-Co rich)
NONE	NONE	17	Iron Creek	Blackbird	Lemhi	ID	44.962	-114.115	Cu-Co, Blackbird type	Sed-hosted Cu, reduced facies
NONE	NONE	18	Hercules	Heath	Washington	ID	44.770	-116.860	unclassified	Epithermal submarine veins and disseminations
NONE	NONE	19	Lower Whitewood Creek		Lawrence	SD	44.400	-103.700	Tailings	Placer Au
NONE	NONE	20	Cobb Creek		Elko	NV	41.775	-116.025	Unclassified	
NONE	NONE	21	Tag-Wildcat Prospect	Trinity	Pershing	NV	40.370	-118.530	Unclassified	
NONE	NONE	22	Coeur Rochester	Rochester	Pershing	NV	40.280	-118.150	Disseminated Ag-Au	Low-sulfide Au-quartz vein
NONE	NONE	23	Cornwall	Cornwall	Lebanon	PA	40.269	-76.403	Skarn Fe	Skarn Au
NONE	NONE	24	Zeke	Buckhorn	Eureka	NV	40.156	-116.483	Unclassified	
NONE	NONE	25	Kinsley Consolidated	Kinsley	Elko	NV	40.130	-114.340	Unclassified	
NONE	NONE	26	Bellview		White Pine	NV	40.086	-115.639	Unclassified	
NONE	NONE	27	Archimedes	Ruby Hill	Eureka	NV	39.523	-115.988	Unclassified	
NONE	NONE	28	Fire Angel	Eldorado	Lyon	NV	39.230	-119.456	Unclassified	
NONE	NONE	29	Kings Canyon		unk	UT	39.078	-113.656	Unclassified	Sediment-hosted Au
NONE	NONE	30	Mindora		Mineral	NV	38.477	-118.294	Unclassified	

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NONE	NONE	31	Baxter Springs	Manhattan	Nye	NV	38.440	-117.120	Unclassified	
NONE	NONE	32	Apex		Washington	UT	37.067	-113.802	Kipushi Cu-Pb-Zn	
NONE	NONE	33	Daisy Gold		Nye	NV	36.890	-116.680	Unclassified	
NONE	NONE	34	Sterling	Fluorine	Nye	NV	36.830	-116.640	Unclassified	
NONE	NONE	35	Colosseum	Clark	San Bernardino	CA	35.622	-115.569	Breccia pipe, Au	
NONE	NONE	36	Morning Star	Ivanpah	San Bernardino	CA	35.360	-115.490	Unclassified	Flat fault Au
NONE	NONE	37	Zenda	Loraine	Kern	CA	35.291	-118.465	Unclassified	
NONE	NONE	38	San Lazarus	Old Placers	Santa Fe	NM	35.239	-106.176	Unclassified	
NONE	NONE	39	America		San Bernardino	CA	34.400	-115.580	Unclassified	Vein, polyetallic
NONE	NONE	40	Waters Sunset		Yavapai	AZ	34.358	-113.215	Unclassified	
NONE	NONE	41	Clementine		unk	AZ	33.813	-112.313	Unclassified	
NONE	NONE	42	Big Horn	Alamo Spring	La Paz	AZ	33.430	-113.860	Unclassified	
NONE	NONE	43	Oro Cruz	Tumco	Imperial	CA	32.867	-114.800	Unclassified	
NONE	NONE	44	American Girl	Cargo Muchacho	Imperial	CA	32.790	-114.765	Unclassified	Flat fault Au
NONE	NONE	45		Van Horn-Allamoore	Culberson	TX	31.170	-104.900	Unclassified	Vein, polymetallic
SKNG	NR05	01	Buckhorn Mountain (Crown Jewel)	Meyers Creek	Okanogan	WA	48.956	-118.983	Skarn Au	
SKNG	NR07	01	Diamond Hill	Indian Creek (Hassel)	Broadwater	MT	46.313	-111.675	Skarn Au	
SKNG	NR07	02	Elkhorn	Elkhorn	Jefferson	MT	46.278	-111.941	Skarn Au	
SKNG	NR07	03	Cable	Georgetown (Cable)	Deer Lodge	MT	46.200	-113.216	Skarn Au	
SKNG	NR07	04	Butte Highlands	Highland	Silver Bow	MT	45.797	-112.516	Skarn Au	
SKNG	NR07	05	Bannack district	Bannack	Beaverhead	MT	45.155	-112.985	Skarn Au	
SKNG	NR07	06	New World	New World	Park	MT	45.060	-109.960	Skarn Au	
PCU2	NR08	01	Kelsey	unnamed	Okanogan	WA	48.995	-119.478	Porphyry Cu	
PCU2	NR10	01	Heddeleston	Heddeleston	Lewis and Clark	MT	47.026	-112.360	Porphyry Cu-Mo	
PCU2	NR10	02	Continental Berkeley	Butte	Silver Bow	MT	46.020	-112.526	Porphyry Cu-Mo	
PMR1	NR12	01	Clayton Silver	Bayhorse	Custer	ID	44.283	-114.410	Polymetallic replacement	
PMR1	NR13	01		Garnet (First Chance)	Granite	MT	46.827	-113.343	Polymetallic replacement	Vein, polymetallic
PMR1	NR13	02		Castle Mountain	Meagher	MT	46.470	-110.680	Polymetallic replacement	
PMR1	NR13	03	Hope	Philipsburg	Granite	MT	46.344	-113.274	Polymetallic replacement	
PMR1	NR13	04	Scratch Awl - True Fissure	Philipsburg	Granite	MT	46.332	-113.266	Polymetallic replacement	Vein, polymetallic
PMR1	NR13	05	Trout	Philipsburg	Granite	MT	46.329	-113.267	Polymetallic replacement	Vein, polymetallic

Layer	Tract	Map No.	Deposit	District	County	State	Lat	Long	Deposit Type	Alternative deposit types
PMR1	NR13 06		Elkhorn (Holter)	Elkhorn	Jefferson	MT	46.282	-111.953	Polymetallic replacement	
PMR1	NR13 07			Silver Star - Iron Rod	Madison	MT	45.696	-112.314	Polymetallic replacement	
PMR1	NR13 08			Hecla (Bryant)	Beaverhead	MT	45.605	-112.913	Polymetallic replacement	
PMR1	NR13 09			Argenta (Montana)	Beaverhead	MT	45.335	-112.904	Polymetallic replacement	Vein, polymetallic
ALKG	NR15 01		Zortman - Landusky	Little Rocky Mountains	Phillips	MT	47.929	-108.586	Alkaline Au-Te	
ALKG	NR15 02		Canyon Resources (Kendall)	Kendall	Fergus	MT	47.294	-109.459	Alkaline Au-Te	
ALKG	NR15 03		Spotted Horse	Warm Springs (Maiden)	Fergus	MT	47.176	-109.210	Alkaline Au-Te	
ALKG	NR15 04		Maginnis	Warm Springs (Maiden)	Fergus	MT	47.176	-109.219	Alkaline Au-Te	
ALKG	NR15 05		Gilt Edge	Warm Springs (Gilt Edge)	Fergus	MT	47.144	-109.226	Alkaline Au-Te	
ALKG	NR15 06		Golden Sunlight	Whitehall	Jefferson	MT	45.906	-112.014	Alkaline Au-Te	
ALKG	NR16 01		Richmond Hill	Carbonate	Lawrence	SD	44.383	-103.856	Alkaline Au-Te	
ALKG	NR16 02		Johnson Gulch	Ragged Top	Lawrence	SD	44.350	-103.900	Alkaline Au-Te	
ALKG	NR16 03		Wharf	Bald Mountain	Lawrence	SD	44.344	-103.842	Alkaline Au-Te	
ALKG	NR16 04		Golden Reward	Bald Mountain	Lawrence	SD	44.331	-103.806	Alkaline AuTe	
ALKG	NR16 05		Gilt Edge	Gilt Edge	Lawrence	SD	44.328	-103.764	Alkaline Au-Te	
QZAD	NR21 01		Orient	Orient	Stevens	WA	48.884	-118.159	Epithermal vein, Comstock	Hot spring Au-Ag
QZAD	NR21 02		Kettle River	Republic	Ferry	WA	48.879	-118.626	Epithermal vein, Comstock	Hot spring Au-Ag
QZAD	NR21 03		Golden Eagle	Republic	Ferry	WA	48.680	-118.759	Epithermal vein, Comstock	Hot spring Au-Ag
QZAD	NR21 04		Knob Hill-Golden Promise	Republic	Ferry	WA	48.673	-118.758	Epithermal vein, Comstock	Hot spring Au-Ag
QZAD	NR21 05		Last Chance	Republic	Ferry	WA	48.668	-118.755	Epithermal vein, Comstock	Hot spring Au-Ag
QZAD	NR21 06		Republic	Republic	Ferry	WA	48.638	-118.745	Epithermal vein, Comstock	Hot spring Au-Ag
QZAD	NR24 01		Seven-Up Pete	Seven-Up Pete	Lewis and Clark	MT	46.972	-112.530	Epithermal vein, quartz-adularia	
QZAD	NR24 02		Basin Creek (Paupers Dream)	Rimini (Vaughn)	Lewis and Clark	MT	46.420	-112.290	Epithermal vein, quartz-adularia	Hot-Spring Au-Ag
HTSG	NR28 01		Thunder Mountain	Thunder Mountain	Valley	ID	44.958	-115.142	Hot spring Au-Ag	

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HTSG	NR28 02		Sunbeam-Grouse Creek	Yankee Fork	Custer	ID	44.439	-114.736	Hot spring Au-Ag	Epithermal vein, Comstock
HTSG	NR28 03		Champagne	Lava Creek	Butte	ID	43.594	-113.571	Hot spring Au-Ag	Epithermal vein, Comstock
HTSG	NR30 01			Hog Heaven (Flathead)	Flathead	MT	47.923	-114.582	Hot spring Au-Ag (Pb)	
HTSG	NR30 02		McDonald Meadows	Seven-Up Pete	Lewis and Clark	MT	47.000	-112.525	Hot spring Au-Ag	Epithermal vein, quartz-adularia
SCU1	NR37 01		Troy (Spar Lake)	Cabinet Mountains area	Lincoln	MT	48.230	-115.860	Sediment-hosted Cu, Revett	
SCU1	NR37 02		Rock Lake (Montanore)	Cabinet Mountains area	Sanders	MT	48.080	-115.640	Sediment-hosted Cu, Revett	
SCU1	NR37 03		Rock Creek	Cabinet Mountains area	Sanders	MT	48.070	-115.660	Sediment-hosted Cu, Revett	
SCU1	NR37 04		Snowstorm	Coeur d'Alene	Shoshone	ID	47.467	-115.733	Sediment-hosted Cu, Revett	
SEDX	NR39 01		Sheep Creek		Meagher	MT	46.750	-110.680	Sedimentary exhalative Zn-Pb (Cu-Co rich)	Massive sulfide, Besshi
SEDX	NR40 01		Triumph	Warm Springs	Blaine	ID	43.665	-114.284	Sedimentary exhalative Zn-Pb	Polymetallic replacement and veins
MVTD	NR43 01		Yellowhead	Metalline	Pend Oreille	WA	48.883	-117.371	Mississippi Valley	Irish Sedex Pb-Zn
MVTD	NR43 02		Pend Oreille	Metalline	Pend Oreille	WA	48.882	-117.360	Mississippi Valley	Irish Sedex Pb-Zn
MVTD	NR43 03		Van Stone	Bossburg	Stevens	WA	48.761	-117.757	Mississippi Valley	Irish Sedex Pb-Zn
HMAS	NR47 01			South Pass-Atlantic City and Lewiston	Fremont	WY	42.500	-108.700	Low-sulfide Au-quartz vein, Archean	
HMAS	NR48 01		Mineral Hill	Sheepeater (Jardine)	Park	MT	45.080	-110.620	Homestake stratiform Au	
HMAS	NR49 01		Homestake	Homestake	Lawrence	SD	44.360	-103.770	Homestake stratiform Au	
HMAS	NR49 02		Cloverleaf	Roubaix	Lawrence	SD	44.283	-103.650	Homestake stratiform Au?	
PCU2	PC04 01		Mazama	Mazama	Okanogan	WA	48.615	-120.382	Porphyry Cu	
PCU2	PC04 02		Gold Mountain		Snohomish	WA	48.216	-121.334	Porphyry Cu	
PCU2	PC04 03		Glacier Peak	Sampson	Snohomish	WA	48.198	-120.979	Porphyry Cu	
PCU2	PC04 04		Sunrise	Sultan Basin	Snohomish	WA	48.009	-121.504	Porphyry Cu, breccia pipe	
PCU2	PC04 05		North Fork	Snoqualmie	King	WA	47.669	-121.636	Porphyry Cu, breccia pipe	
PCU2	PC04 06		Clipper - Three Brothers	Middle Fork Snoqualmie	King	WA	47.518	-121.344	Porphyry Cu	

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PCU2	PC04 07		Condor-Hemlock	Middle Fork Snoqualmie	King	WA	47.497	-121.360	Porphyry Cu	
PCU2	PC05 01		Margaret	St. Helens	Skamania	WA	46.356	-122.081	Porphyry Cu	
PCU2	PC05 02		Bornite		Marion	OR	44.850	-122.310	Porphyry Cu-Au, breccia pipe	
PCU1	PC08 01		Lights Creek	Lights Creek	Plumas	CA	40.300	-120.750	Porphyry Cu	
CVMS	PC10 01		Turner-Albright	Waldo	Josephine	OR	42.007	-123.757	Massive sulfide, Cyprus	
KVMS	PC12 01		Holden	Railroad Creek	Chelan	WA	48.197	-120.780	Massive sulfide, kuroko	
KVMS	PC13 01		Red Ledge	Seven Devils	Adams	ID	45.226	-116.664	Massive sulfide, kuroko	Submassive sulfide; stockwork;
KVMS	PC13 02		Iron Dyke	Seven Devils	Baker	OR	45.026	-116.849	Massive sulfide, kuroko	dissemination Massive sulfide fragments in laharc breccia
KVMS	PC14 01		Gray Eagle	Happy Camp	Siskiyou	CA	41.863	-123.371	Massive sulfide, kuroko	
KVMS	PC15 01		Mammoth	West Shasta	Shasta	CA	40.763	-122.454	Massive sulfide, kuroko	
KVMS	PC15 02		Balacklala	West Shasta	Shasta	CA	40.725	-122.498	Massive sulfide, kuroko	
KVMS	PC15 03		Iron Mountain	West Shasta	Shasta	CA	40.673	-122.524	Massive sulfide, kuroko	
KVMS	PC17 01		Western World		Yuba	CA	39.175	-121.292	Massive sulfide, kuroko	
KVMS	PC17 02		Penn	Campo Seco	Calaveras	CA	38.294	-120.824	Massive sulfide, kuroko	
KVMS	PC17 03		Blue Moon-Amer. Eagle	Hornitos	Mariposa	CA	37.542	-120.217	Massive sulfide, kuroko	
QZAD	PC19 01		Cannon	Wenatchee	Chelan	WA	47.396	-120.325	Epithermal vein, Comstock	
QZAD	PC19 02		Lovitt	Wenatchee	Chelan	WA	47.382	-120.315	Epithermal vein, Comstock	
QZAD	PC24 01		War Eagle Project	French Carson	Owyhee	ID	43.007	-116.711	Epithermal vein, Comstock	Vein, polymetallic, Au-Ag
HTSG	PC28 01		Quartz Mountain		Lake	OR	42.300	-120.800	Hot spring Au-Ag	
HTSG	PC28 02		Hayden Hill		Lassen	CA	41.080	-120.576	Hot spring Au-Ag	Epithermal vein, Comstock
HTSG	PC30 01		Grassy Mountain		Malheur	OR	43.669	-117.360	Hot spring Au-Ag	
HTSG	PC31 01		Idaho Almaden	Weiser	Washington	ID	44.240	-116.714	Hot spring Ag	Hot spring Au-Ag
HTSG	PC32 01		Stone Cabin	Florida Mountain	Owyhee	ID	43.025	-116.756	Hot spring Au-Ag	Epithermal vein, Comstock
HTSG	PC32 02		DeLamar	De Lamar	Owyhee	ID	43.020	-116.831	Hot spring Au-Ag	Epithermal vein, Comstock

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HTSG	PC34	01	Cherry Hill	Sulphur Creek	Colusa	CA	39.042	-122.433	Hot spring Au-Ag	
HTSG	PC34	02	McLaughlin	Knoxville	Napa	CA	38.780	-122.313	Hot spring Au-Ag	
HTSG	PC34	03		Calistoga	Napa	CA	38.649	-122.611	Hot spring Au-Ag	
LSGQ	PC38	01	Sanger	Eagle	Baker	OR	44.994	-117.408	Low-sulfide Au-quartz vein	
LSGQ	PC38	02	Virtue	Virtue	Baker	OR	44.793	-117.697	Low-sulfide Au-quartz vein	
LSGQ	PC38	03	Connor Creek	Connor Cr.	Baker	OR	44.566	-117.201	Low-sulfide Au-quartz vein	
LSGQ	PC38	04	Mormon Basin	Mormon Basin	Baker/Malheur	OR	44.425	-117.555	Low-sulfide Au-quartz vein	
LSGQ	PC40	01	Greenback	Greenback	Josephine	OR	42.654	-123.306	Low-sulfide Au-quartz vein	
LSGQ	PC40	02		Ashland	Jackson	OR	42.182	-122.791	Low-sulfide Au-quartz vein	
LSGQ	PC40	03	Black Bear	Liberty	Siskiyou	CA	41.252	-123.161	Low-sulfide Au-quartz vein	
LSGQ	PC40	04	Globe	Dedrick-Canyon Creek	Trinity	CA	40.880	-123.367	Low-sulfide Au-quartz vein	
LSGQ	PC40	05	Gladstone	French Gulch	Shasta	CA	40.724	-122.584	Low-sulfide Au-quartz vein	
LSGQ	PC40	06	Brown Bear	Deadwood	Trinity	CA	40.720	-122.730	Low-sulfide Au-quartz vein	
LSGQ	PC40	07	Milkmaid-Franklin	French Gulch	Shasta	CA	40.719	-122.669	Low-sulfide Au-quartz vein	
LSGQ	PC40	08	Reid	Old Diggings	Shasta	CA	40.666	-122.429	Low-sulfide Au-quartz vein	
LSGQ	PC40	09	Midas	Harrison Gulch	Shasta	CA	40.390	-122.985	Low-sulfide Au-quartz vein	
LSGQ	PC40	10		Crescent Mills	Plumas	CA	40.121	-120.937	Low-sulfide Au-quartz vein	
LSGQ	PC40	11	Rich Gulch	Virgilia	Plumas	CA	40.062	-121.088	Low-sulfide Au-quartz vein	
LSGQ	PC40	12	Plumas-Eureka	Johnsville	Plumas	CA	39.758	-120.708	Low-sulfide Au-quartz vein	
LSGQ	PC40	13		Sierra City	Sierra	CA	39.619	-120.610	Low-sulfide Au-quartz vein	
LSGQ	PC40	14		Forbestown	Butte	CA	39.535	-121.268	Low-sulfide Au-quartz vein	

Layer	Tract	Map No.	Deposit	District	County	State	Lat	Long	Deposit Type	Alternative deposit types
LSGQ	PC40 15		Brush Creek	Alleghany	Sierra	CA	39.512	-120.889	Low-sulfide Au-quartz vein	
LSGQ	PC40 16		Sixteen-to-one	Alleghany	Sierra	CA	39.464	-120.847	Low-sulfide Au-quartz vein	
LSGQ	PC40 17		Oriental	Alleghany	Sierra	CA	39.460	-120.858	Low-sulfide Au-quartz vein	
LSGQ	PC40 18		Rainbow	Alleghany	Sierra	CA	39.457	-120.835	Low-sulfide Au-quartz vein	
LSGQ	PC40 19		Plumbago	Alleghany	Sierra	CA	39.453	-120.812	Low-sulfide Au-quartz vein	
LSGQ	PC40 20			Brown's Valley	Yuba	CA	39.378	-121.235	Low-sulfide Au-quartz vein	
LSGQ	PC40 21		Dinero		Nevada	CA	39.346	-120.717	Low-sulfide Au-quartz vein	
LSGQ	PC40 22		Idaho-Maryland	Grass Valley	Nevada	CA	39.224	-121.038	Low-sulfide Au-quartz vein	
LSGQ	PC40 23			Grass Valley-remainder	Nevada	CA	39.218	-121.036	Low-sulfide Au-quartz vein	
LSGQ	PC40 24		Golden Center	Grass Valley	Nevada	CA	39.215	-121.069	Low-sulfide Au-quartz vein	
LSGQ	PC40 25		Empire-Star	Grass Valley	Nevada	CA	39.206	-121.045	Low-sulfide Au-quartz vein	
LSGQ	PC40 26		Herman		Placer	CA	39.127	-120.564	Low-sulfide Au-quartz vein	
LSGQ	PC40 27		Rising Sun	Colfax	Placer	CA	39.107	-120.968	Low-sulfide Au-quartz vein	
LSGQ	PC40 28		Sliger		El Dorado	CA	38.941	-120.932	Low-sulfide Au-quartz vein	
LSGQ	PC40 29			Georgia Slide	El Dorado	CA	38.937	-120.745	Low-sulfide Au-quartz vein	
LSGQ	PC40 30			Ophir	Placer	CA	38.912	-121.082	Low-sulfide Au-quartz vein	
LSGQ	PC40 31			Penryn	Placer	CA	38.844	-121.157	Low-sulfide Au-quartz vein	
LSGQ	PC40 32		Angels	Angels Camp-Carson Hill	Calaveras	CA	38.756	-120.547	Low-sulfide Au-quartz vein	
LSGQ	PC40 33		Pacific Quartz	Placerville	El Dorado	CA	38.726	-120.806	Low-sulfide Au-quartz vein	
LSGQ	PC40 34		Union	El Dorado	El Dorado	CA	38.647	-120.827	Low-sulfide Au-quartz vein	

Layer	Tract	Map No.	Deposit	District	County	State	Lat	Long	Deposit Type	Alternative deposit types
LSGQ	PC40 35			Nashville	El Dorado	CA	38.579	-120.841	Low-sulfide Au-quartz vein	
LSGQ	PC40 36		Plymouth Consolidated		Amador	CA	38.475	-120.950	Low-sulfide Au-quartz vein	
LSGQ	PC40 37		Fremont-Gover	Amador City	Amador	CA	38.439	-120.831	Low-sulfide Au-quartz vein	
LSGQ	PC40 38		Bunker Hill	Amador City	Amador	CA	38.425	-120.862	Low-sulfide Au-quartz vein	
LSGQ	PC40 39		Original Amador	Amador City	Amador	CA	38.423	-120.824	Low-sulfide Au-quartz vein	
LSGQ	PC40 40		Keystone	Amador City	Amador	CA	38.418	-120.822	Low-sulfide Au-quartz vein	
LSGQ	PC40 41		Wildman-Mahoney		Amador	CA	38.395	-120.800	Low-sulfide Au-quartz vein	
LSGQ	PC40 42		Old Eureka		Amador	CA	38.388	-120.799	Low-sulfide Au-quartz vein	
LSGQ	PC40 43		Central Eureka		Amador	CA	38.383	-120.797	Low-sulfide Au-quartz vein	
LSGQ	PC40 44		South Eureka		Amador	CA	38.380	-120.795	Low-sulfide Au-quartz vein	
LSGQ	PC40 45		Kennedy		Amador	CA	38.367	-120.779	Low-sulfide Au-quartz vein	
LSGQ	PC40 46		Argonaut		Amador	CA	38.363	-120.785	Low-sulfide Au-quartz vein	
LSGQ	PC40 47			Zeila	Amador	CA	38.345	-120.763	Low-sulfide Au-quartz vein	
LSGQ	PC40 48			Paloma-Gwinn	Calaveras	CA	38.259	-120.759	Low-sulfide Au-quartz vein	
LSGQ	PC40 49			Sheep Ranch	Calaveras	CA	38.208	-120.483	Low-sulfide Au-quartz vein	
LSGQ	PC40 50		Lightner	Angels Camp-Carson Hill	Calaveras	CA	38.074	-120.542	Low-sulfide Au-quartz vein	
LSGQ	PC40 51		Utica	Angels Camp-Carson Hill	Calaveras	CA	38.070	-120.538	Low-sulfide Au-quartz vein	
LSGQ	PC40 52		Gold Cliff	Angels Camp-Carson Hill	Calaveras	CA	38.066	-120.544	Low-sulfide Au-quartz vein	
LSGQ	PC40 53			Confidence-Lamphere	Tuolumne	CA	38.044	-120.208	Low-sulfide Au-quartz vein	
LSGQ	PC40 54		Carson Hill	Angels Camp-Carson Hill	Calaveras	CA	38.022	-120.502	Low-sulfide Au-quartz vein	

Layer	Tract	Map No.	Deposit	District	County	State	Lat	Long	Deposit Type	Alternative deposit types
LSGQ	PC40 55			Homer	Mono	CA	38.013	-119.226	Low-sulfide Au-quartz vein	
LSGQ	PC40 56			Royal Mountain King	Calaveras	CA	38.006	-120.692	Low-sulfide Au-quartz vein	
LSGQ	PC40 57			Soulbysville	Tuolumne	CA	37.988	-120.262	Low-sulfide Au-quartz vein	
LSGQ	PC40 58			Pocket Belt	Tuolumne	CA	37.962	-120.345	Low-sulfide Au-quartz vein	
LSGQ	PC40 59			Jamestown	Tuolumne	CA	37.950	-120.417	Low-sulfide Au-quartz vein	
LSGQ	PC40 60			Chinese Camp	Tuolumne	CA	37.868	-120.440	Low-sulfide Au-quartz vein	
LSGQ	PC40 61		Red Cloud		Mariposa	CA	37.739	-120.085	Low-sulfide Au-quartz vein	
LSGQ	PC40 62			Coulterville	Mariposa	CA	37.697	-120.200	Low-sulfide Au-quartz vein	
LSGQ	PC40 63			Kinsley	Mariposa	CA	37.693	-120.042	Low-sulfide Au-quartz vein	
LSGQ	PC40 64			Bagby	Mariposa	CA	37.688	-120.063	Low-sulfide Au quartz vein	
LSGQ	PC40 65			El Portal	Mariposa	CA	37.673	-119.864	Low-sulfide Au-quartz vein	
LSGQ	PC40 66		Pine Tree-Josephine	Mount Bullion	Mariposa	CA	37.588	-120.119	Low-sulfide Au-quartz vein	
LSGQ	PC40 67		Mount Gaines	Hornitos	Mariposa	CA	37.541	-120.172	Low-sulfide Au-quartz vein	
LSGQ	PC40 68		Washington	Hornitos	Mariposa	CA	37.526	-120.224	Low-sulfide Au-quartz vein	
LSGQ	PC40 69		Princeton	Mount Bullion	Mariposa	CA	37.501	-120.031	Low-sulfide Au-quartz vein	
LSGQ	PC40 70		Mariposa	Mariposa	Mariposa	CA	37.489	-119.958	Low-sulfide Au-quartz vein	
LSGQ	PC40 71			Cove	Kern	CA	35.711	-118.407	Low-sulfide Au-quartz vein	
LSGQ	PC40 72			Mammoth	Kern	CA	35.623	-118.501	Low-sulfide Au-quartz vein	
LSGQ	PC40 73			San Gabriel	Los Angeles	CA	34.225	-117.716	Low-sulfide Au-quartz vein	Placer Au
LSGQ	PC40 74			Julian-Banner	San Diego	CA	33.078	-116.492	Low-sulfide Au-quartz vein	

Layer	Tract	Map No.	Deposit	District	County	State	Lat	Long	Deposit Type	Alternative deposit types
LSGQ	PC40	75	Stonewall		San Diego	CA	32.983	-116.569	Low-sulfide Au-quartz vein	
PLAC	PLAC 01			Murray (Coeur d'Alene)	Shoshone	ID	47.617	-115.917	Placer Au	
PLAC	PLAC 02			Cedar Creek-Trout Creek	Mineral	MT	47.144	-114.967	Placer Au	
PLAC	PLAC 03			Ninemile Creek	Missoula	MT	47.133	-114.550	Placer Au	
PLAC	PLAC 04			Lincoln	Lewis and Clark	MT	46.942	-112.751	Placer Au	
PLAC	PLAC 05			Elk Creek-Coloma	Missoula	MT	46.894	-113.385	Placer Au	
PLAC	PLAC 06			Stemple-Virginia Creek	Lewis and Clark	MT	46.886	-112.342	Placer Au	
PLAC	PLAC 07			McClellan	Lewis and Clark	MT	46.882	-112.631	Placer Au	
PLAC	PLAC 08			First Chance (Garnet)	Granite	MT	46.825	-113.337	Placer Au	
PLAC	PLAC 09			Finn	Powell	MT	46.797	-112.667	Placer Au	
PLAC	PLAC 10			Marysville-Silver Creek	Lewis and Clark	MT	46.750	-112.333	Placer Au	
PLAC	PLAC 11			Missouri River-York	Lewis and Clark	MT	46.717	-111.750	Placer Au	
PLAC	PLAC 12			Ophir	Powell	MT	46.632	-112.542	Placer Au	
PLAC	PLAC 13			White Creek	Broadwater	MT	46.610	-111.503	Placer Au	
PLAC	PLAC 14			Confederate Gulch	Broadwater	MT	46.599	-111.416	Placer Au	
PLAC	PLAC 15			Helena-Last Chance Placer	Lewis and Clark	MT	46.591	-111.979	Placer Au	
PLAC	PLAC 16			Pioneer	Powell	MT	46.519	-112.946	Placer Au	
PLAC	PLAC 17			Henderson placers	Granite	MT	46.502	-113.262	Placer Au	
PLAC	PLAC 18			Pierce City (Orofino Creek)	Clearwater	ID	46.501	-115.875	Placer Au	
PLAC	PLAC 19			Prickly Pear-Clancy	Jefferson	MT	46.422	-112.089	Placer Au	
PLAC	PLAC 20			Butte	Silver Bow	MT	46.025	-112.529	Placer Au	
PLAC	PLAC 21			French Creek	Deer Lodge	MT	45.952	-113.022	Placer Au	
PLAC	PLAC 22			Tenmile	Idaho	ID	45.833	-115.667	Placer Au	
PLAC	PLAC 23			Elk City	Idaho	ID	45.820	-115.455	Placer Au	
PLAC	PLAC 24			Gibbonsville	Lemhi	ID	45.555	-113.925	Placer Au	
PLAC	PLAC 25			Virginia City-Alder Creek	Madison	MT	45.324	-112.002	Placer Au	
PLAC	PLAC 26			Warren-Marshall	Idaho	ID	45.306	-115.745	Placer Au	
PLAC	PLAC 27			Mackinaw	Lemhi	ID	45.236	-114.157	Placer Au	

Layer	Tract	Map No.	Deposit	District	County	State	Lat	Long	Deposit Type	Alternative deposit types
PLAC	PLAC 28			Bannack	Beaverhead	MT	45.159	-112.983	Placer Au	
PLAC	PLAC 29			Granite	Grant	OR	44.823	-118.391	Placer Au	
PLAC	PLAC 30			Sumpter Placer	Baker	OR	44.744	-118.206	Placer Au	
PLAC	PLAC 31			Greenhorn	Baker	OR	44.700	-118.417	Placer Au	
PLAC	PLAC 32			Florence	Idaho	ID	44.517	-116.033	Placer Au	
PLAC	PLAC 33			Canyon Placer	Grant	OR	44.433	-118.958	Placer Au	
PLAC	PLAC 34			Deadwood Gulch	Lawrence	SD	44.377	-103.732	Placer Au	
PLAC	PLAC 35			Boise Basin	Boise	ID	43.857	-115.900	Placer Au	
PLAC	PLAC 36			Galice	Josephine	OR	42.644	-123.506	Placer Au	
PLAC	PLAC 37			Upper Applegate	Jackson	OR	42.230	-122.939	Placer Au	
PLAC	PLAC 38			Waldo	Josephine	OR	42.115	-123.563	Placer Au	
PLAC	PLAC 39			Cottonwood-Ft. Jones	Siskiyou	CA	41.789	-122.568	Placer Au	
PLAC	PLAC 40			Greenhorn Creek	Siskiyou	CA	41.700	-122.648	Placer Au	
PLAC	PLAC 41			Scott River	Siskiyou	CA	41.462	-122.634	Placer Au	
PLAC	PLAC 42			Klamath River Placer	Humboldt	CA	41.381	-123.541	Placer Au	
PLAC	PLAC 43			Salmon River	Siskiyou	CA	41.379	-123.180	Placer Au	
PLAC	PLAC 44			Trinity River Basin	Trinity	CA	40.956	-123.014	Placer Au	
PLAC	PLAC 45			Sierra	Pershing	NV	40.739	-117.928	Placer Au	
PLAC	PLAC 46			Igo	Shasta	CA	40.549	-122.538	Placer Au	
PLAC	PLAC 47			Bingham Canyon	Salt Lake	UT	40.542	-112.147	Placer Au	
PLAC	PLAC 48			Battle Mountain placers	Lander	NV	40.517	-117.133	Placer Au	
PLAC	PLAC 49		Crescent Valley		Lander	NV	40.400	-116.650	Placer Au	
PLAC	PLAC 50			Rochester-Spring Valley	Pershing	NV	40.337	-118.110	Placer Au	
PLAC	PLAC 51			Magalia	Butte	CA	39.824	-121.387	Placer Au	
PLAC	PLAC 52			Blackhawk	Clear Creek, Gilpin	CO	39.772	-105.263	Placer Au	
PLAC	PLAC 53			La Porte	Plumas	CA	39.713	-120.945	Placer Au	
PLAC	PLAC 54			Poker Flat	Sierra	CA	39.675	-120.792	Placer Au	
PLAC	PLAC 55			Olinghouse-Frank Free Canyons Alluvial Fans	Washoe	NV	39.649	-119.416	Placer Au	
PLAC	PLAC 56			Cherokee Creek	Butte	CA	39.640	-121.547	Placer Au	

Layer	Tract	Map No.	Deposit	District	County	State	Lat	Long	Deposit Type	Alternative deposit types
PLAC	PLAC 57			Alleghany	Sierra	CA	39.509	-120.838	Placer Au	
PLAC	PLAC 58			Oroville	Butte	CA	39.479	-121.573	Placer Au	
PLAC	PLAC 59			Breckenridge and others	Summit	CO	39.470	-105.980	Placer Au	
PLAC	PLAC 60			Moore's Flat	Nevada	CA	39.419	-120.850	Placer Au	
PLAC	PLAC 61			North Bloomfield	Nevada	CA	39.370	-120.916	Placer Au	
PLAC	PLAC 62			Alpha-Omega	Nevada	CA	39.335	-120.750	Placer Au	
PLAC	PLAC 63			San Juan Ridge	Nevada	CA	39.333	-120.750	Placer Au	
PLAC	PLAC 64			Lowell Hill	Nevada	CA	39.266	-120.795	Placer Au	
PLAC	PLAC 65			Dutch Flat-Gold Run	Placer	CA	39.261	-120.765	Placer Au	
PLAC	PLAC 66			Hammonton	Yuba	CA	39.245	-121.384	Placer Au	
PLAC	PLAC 67			Leadville, Tennessee Pass, Buckeye Gulch and others	Lake	CO	39.240	-106.320	Placer Au	
PLAC	PLAC 68			Silver City placers	Lyon	NV	39.227	-119.617	Placer Au	
PLAC	PLAC 69			Fairplay, Alma, Tarryall and others	Park	CO	39.221	-105.090	Placer Au	
PLAC	PLAC 70			You Bet	Nevada	CA	39.213	-120.891	Placer Au	
PLAC	PLAC 71			Michigan Bluff	Placer	CA	39.209	-120.674	Placer Au	
PLAC	PLAC 72			Iowa Hill	Placer	CA	39.162	-120.827	Placer Au	
PLAC	PLAC 73			Forest Hill	Placer	CA	39.114	-120.707	Placer Au	
PLAC	PLAC 74			Osceola	White Pine	NV	39.041	-114.414	Placer Au	
PLAC	PLAC 75			Lincoln	Placer	CA	38.867	-121.294	Placer Au	
PLAC	PLAC 76			Placerville	El Dorado	CA	38.730	-120.750	Placer Au	
PLAC	PLAC 77			Round Mountain	Nye	NV	38.706	-117.083	Placer Au	
PLAC	PLAC 78			Folsom	Sacramento	CA	38.684	-121.175	Placer Au	
PLAC	PLAC 79			Manhattan Gulch	Nye	NV	38.525	-117.084	Placer Au	
PLAC	PLAC 80			Volcano	Amador	CA	38.459	-120.508	Placer Au	
PLAC	PLAC 81			Sloughhouse	Sacramento	CA	38.437	-121.176	Placer Au	
PLAC	PLAC 82			Camanche	Calaveras	CA	38.231	-120.924	Placer Au	
PLAC	PLAC 83			Jenny Lind	Calaveras	CA	38.117	-120.860	Placer Au	
PLAC	PLAC 84			Angels Camp	El Dorado	CA	38.102	-120.550	Placer Au	
PLAC	PLAC 85			Columbia Basin	Tuolumne	CA	38.061	-120.319	Placer Au	
PLAC	PLAC 86			Big Oak Flat	Tuolumne	CA	37.828	-120.262	Placer Au	

Layer	Tract	Map No.	Deposit	District	County	State	Lat	Long	Deposit Type	Alternative deposit types
PLAC	PLAC 87			La Grange-Waterford	Stanislaus	CA	37.642	-120.507	Placer Au	
PLAC	PLAC 88			Snelling	Merced	CA	37.517	-120.418	Placer Au	
PLAC	PLAC 89			Mormon Bar	Mariposa	CA	37.433	-119.933	Placer Au	
PLAC	PLAC 90			Friant	Fresno	CA	36.924	-119.653	Placer Au	
PLAC	PLAC 91			Elizabethtown - Baldy	Colfax	NM	36.629	-105.213	Placer Au	
PLAC	PLAC 92			Old Placers	Santa Fe	NM	35.749	-106.148	Placer Au	
PLAC	PLAC 93			New Placers	Santa Fe	NM	35.253	-106.211	Placer Au	
PLAC	PLAC 94			Lynx Creek	Yavapai	AZ	34.499	-112.330	Placer Au	
PLAC	PLAC 95			Holcomb	San Bernardino	CA	34.283	-116.888	Placer Au	
PLAC	PLAC 96			San Gabriel	Los Angeles	CA	34.225	-117.716	Placer Au	
PLAC	PLAC 97			Weaver (Rich Hill) Dist.	Yavapai	AZ	34.142	-112.689	Placer Au	
PLAC	PLAC 98			La Paz	Yuma	AZ	33.605	-114.386	Placer Au	
PLAC	PLAC 99			Hillsboro	Sierra	NM	32.921	-107.566	Placer Au	
PMV	PMVC 01			Ticonderoga	Yavapai	AZ	34.479	-112.290	Vein, Congress-type	Vein, polymetallic
PMV	PMVC 02		Niagra Vein	Martinez	Yavapai	AZ	34.200	-112.850	Vein, Congress-type	
PMV	PMVC 03		Congress	Martinez	Yavapai	AZ	34.200	-112.850	Vein, Congress-type	Vein, polymetallic
PMV	PMVC 04		Pilgrim	Tiger	Yavapai	AZ	34.180	-112.420	Vein, Congress-type	Vein, polymetallic
PMV	PMVD 01		Jack Waite	Eagle	Shoshone	ID	47.668	-115.744	Vein, polymetallic, Coeur d' Alene	Lower Prichard Fm
PMV	PMVD 02		Interstate-Callahan	Coeur d'Alene	Shoshone	ID	47.544	-115.887	Vein, polymetallic, Coeur d' Alene	Middle Prichard Fm
PMV	PMVD 03		Hercules	Coeur d'Alene	Shoshone	ID	47.543	-115.808	Vein, polymetallic, Coeur d' Alene	Prichard-Burke Fms
PMV	PMVD 04		Tamarack-Custer	Coeur d'Alene	Shoshone	ID	47.536	-115.848	Vein, polymetallic, Coeur d' Alene	Prichard-Burke Fms
PMV	PMVD 05		Bunker Hill	Coeur d'Alene	Shoshone	ID	47.536	-116.138	Vein, polymetallic, Coeur d' Alene	Revett-St Regis Fms
PMV	PMVD 06		Page Group	Coeur d'Alene	Shoshone	ID	47.528	-116.201	Vein, polymetallic, Coeur d' Alene	Revett-St Regis Fms
PMV	PMVD 07		Sherman	Coeur d'Alene	Shoshone	ID	47.525	-115.820	Vein, polymetallic, Coeur d' Alene	Prichard-Burke Fms
PMV	PMVD 08		Senator Stewart	Coeur d'Alene	Shoshone	ID	47.525	-116.171	Vein, polymetallic, Coeur d' Alene	Revett-St Regis Fms
PMV	PMVD 09		Caledonia	Coeur d'Alene	Shoshone	ID	47.524	-116.168	Vein, polymetallic, Coeur d' Alene	Revett-St Regis Fms

Layer	Tract	Map No.	Deposit	District	County	State	Lat	Long	Deposit Type	Alternative deposit types
PMV	PMVD 10		Tiger-Poorman	Coeur d'Alene	Shoshone	ID	47.523	-115.813	Vein, polymetallic, Coeur d' Alene	Prichard-Burke Fms
PMV	PMVD 11		Hecla	Coeur d'Alene	Shoshone	ID	47.520	-115.814	Vein, polymetallic, Coeur d' Alene	Prichard-Burke Fms
PMV	PMVD 12		Standard Mammoth	Coeur d'Alene	Shoshone	ID	47.519	-115.836	Vein, polymetallic, Coeur d' Alene	Prichard-Burke Fms
PMV	PMVD 13		Last Chance	Coeur d'Alene	Shoshone	ID	47.517	-116.149	Vein, polymetallic, Coeur d' Alene	Revett-St Regis Fms
PMV	PMVD 14		Dayrock	Coeur d'Alene	Shoshone	ID	47.512	-115.900	Vein, polymetallic, Coeur d' Alene	
PMV	PMVD 15		Helena-Frisco	Coeur d'Alene	Shoshone	ID	47.510	-115.850	Vein, polymetallic, Coeur d' Alene	Prichard-Burke Fms
PMV	PMVD 16		Silver Summit	Coeur d'Alene	Shoshone	ID	47.506	-116.025	Vein, polymetallic, Coeur d' Alene	Revett-St Regis Fms
PMV	PMVD 17		Crescent	Coeur d'Alene	Shoshone	ID	47.506	-116.073	Vein, polymetallic, Coeur d' Alene	Revett-St Regis Fms
PMV	PMVD 18		Polaris	Coeur d'Alene	Shoshone	ID	47.502	-116.052	Vein, polymetallic, Coeur d' Alene	Revett-St Regis Fms
PMV	PMVD 19		Sunshine Unit	Coeur d'Alene	Shoshone	ID	47.501	-116.068	Vein, polymetallic, Coeur d' Alene	Revett-St Regis Fms
PMV	PMVD 20		Mineral Point	Coeur d'Alene	Shoshone	ID	47.489	-116.006	Vein, polymetallic, Coeur d' Alene	Revett-St Regis Fms
PMV	PMVD 21		Coeur	Coeur d'Alene	Shoshone	ID	47.489	-115.992	Vein, polymetallic, Coeur d' Alene	Revett-St Regis Fms
PMV	PMVD 22		Sidney	Coeur d'Alene	Shoshone	ID	47.488	-115.192	Vein, polymetallic, Coeur d' Alene	Middle Prichard Fm
PMV	PMVD 23		Galena	Coeur d'Alene	Shoshone	ID	47.477	-115.965	Vein, polymetallic, Coeur d' Alene	Revett-St Regis Fms
PMV	PMVD 24		Gold Hunter	Coeur d'Alene	Shoshone	ID	47.472	-115.785	Vein, polymetallic, Coeur d' Alene	Wallace Fm
PMV	PMVD 25		Lucky Friday	Coeur d'Alene	Shoshone	ID	47.471	-115.780	Vein, polymetallic, Coeur d' Alene	Revett-St Regis Fms
PMV	PMVD 26		Star-Morning	Coeur d'Alene	Shoshone	ID	47.468	-115.812	Vein, polymetallic, Coeur d' Alene	Revett-St Regis Fms
PMV	PMVD 27		Hercules	Heath	Washington	ID	44.770	-116.860	Unclassified	Vein, polymetallic, Coeur d' Alene, with Au and W
PMV	PMVG 01		Cruse-Belmont-Empire	Marysville	Lewis and Clark	MT	46.749	-112.321	Vein, polymetallic, Au-Ag	Polymetallic replacement
PMV	PMVG 02		Drumlummon	Marysville	Lewis and Clark	MT	46.743	-112.296	Vein, polymetallic, Au-Ag	
PMV	PMVG 03		Beal Mountain	Siberia (German Gulch)	Silver Bow	MT	45.954	-112.881	Vein, polymetallic, Au-Ag	Skarn Au

Layer	Tract	Map No.	Deposit	District	County	State	Lat	Long	Deposit Type	Alternative deposit types
PMV	PMVG 04			Elk City	Idaho	ID	45.825	-115.471	Vein, polymetallic, Au-Ag	Idaho Batholith type; disseminated
PMV	PMVG 05			Warren	Idaho	ID	45.258	-115.700	Vein, polymetallic, Au-Ag	Idaho Batholith type
PMV	PMVG 06		Beartrack	Mackinaw	Lemhi	ID	45.233	-114.113	Vein, polymetallic, Au-Ag	Stockwork; disseminated Au-Ag
PMV	PMVG 07			Virginia City	Madison	MT	45.232	-111.960	Vein, polymetallic, Au-Ag	Epithermal
PMV	PMVG 08			Cornucopia	Baker	OR	45.010	-117.217	Vein, polymetallic, Cu-Au-Ag	Blue Mtns model
PMV	PMVG 09		Yellow Jacket	Yellow Jacket	Lemhi	ID	44.982	-114.527	Vein, polymetallic, Cu-Pb-Au	
PMV	PMVG 10		Homestake	Stibnite	Valley	ID	44.950	-115.320	Vein, polymetallic, AuAg	Stockwork; disseminated Au-Ag
PMV	PMVG 11		West End	Stibnite	Valley	ID	44.947	-115.308	Vein, polymetallic, AuAg	Stockwork; disseminated Au-Ag
PMV	PMVG 12		Yellow Pine	Stibnite	Valley	ID	44.927	-115.332	Vein, polymetallic, Au-Ag-Sb-W	Stockwork; disseminated Au-Ag
PMV	PMVG 13			Rock Creek	Baker	OR	44.853	-118.070	Vein, polymetallic, Au-Ag	Blue Mtns model
PMV	PMVG 14			Granite	Grant	OR	44.847	-118.413	Vein, polymetallic, Au-Ag	Blue Mtns model
PMV	PMVG 15			Cracker Cr.	Baker	OR	44.842	-118.195	Vein, polymetallic, Au-Ag	Blue Mtns model
PMV	PMVG 16			Greenhorn	Baker/Grant	OR	44.710	-118.408	Vein, polymetallic, Au-Ag	Blue Mtns model
PMV	PMVG 17			Boise Basin	Boise	ID	43.917	-116.083	Vein, polymetallic, AuAg	Epithermal vein, Comstock
PMV	PMVG 18		Atlanta	Atlanta	Elmore	ID	43.771	-115.118	Vein, polymetallic, AuAg	Idaho Batholith type; veinlets; disseminated
PMV	PMVG 19			Rocky Bar	Elmore	ID	43.694	-115.299	Vein, polymetallic, AuAg	Idaho Batholith type
PMV	PMVG 20			Neal	Elmore	ID	43.583	-115.833	Vein, polymetallic, Au-Ag	Idaho Batholith type
PMV	PMVG 21		Hailey gold belt	Camas	Blaine	ID	43.417	-114.450	Vein, polymetallic, AuAg	Idaho Batholith type
PMV	PMVG 22			Dale	San Bernardino	CA	34.068	-115.764	Vein, polymetallic, Au	Epithermal vein, quartz-adularia
PMV	PMVN 01			Slate Creek	Whatcom	WA	48.768	-120.742	Vein, polymetallic	
PMV	PMVN 02			Silverton	Snohomish	WA	48.130	-121.546	Vein, polymetallic	Placer Au
PMV	PMVN 03		Pride of the Mountains	Monte Cristo	Snohomish	WA	47.981	-121.369	Vein, polymetallic	
PMV	PMVN 04		Mystery	Monte Cristo	Snohomish	WA	47.981	-121.369	Vein, polymetallic	
PMV	PMVN 05		New Discovery	Monte Cristo	Snohomish	WA	47.980	-121.358	Vein, polymetallic	
PMV	PMVN 06		Justice	Monte Cristo	Snohomish	WA	47.980	-121.379	Vein, polymetallic	Revett-St Regis Fms
PMV	PMVN 07		New York-Seattle	Silver Creek	Snohomish	WA	47.949	-121.430	Vein, polymetallic	

Layer	Tract	Map No.	Deposit	District	County	State	Lat	Long	Deposit Type	Alternative deposit types
PMV	PMVN 08		Block P	Barker	Judith Basin	MT	47.084	-110.632	Vein, polymetallic	
PMV	PMVN 09		Silver Dyke	Neihart (Montana)	Cascade	MT	46.984	-110.694	Vein, polymetallic	
PMV	PMVN 10		Big Seven	Neihart (Montana)	Cascade	MT	46.949	-110.705	Vein, polymetallic	
PMV	PMVN 11		Broadwater	Neihart (Montana)	Cascade	MT	46.934	-110.724	Vein, polymetallic	
PMV	PMVN 12		Jay Gould	Stemple-Gould	Lewis and Clark	MT	46.882	-112.459	Vein, polymetallic	Polymetallic replacement
PMV	PMVN 13		Piegan-Gloster	Marysville	Lewis and Clark	MT	46.762	-112.341	Vein, polymetallic	
PMV	PMVN 14		Penobscot	Marysville	Lewis and Clark	MT	46.731	-112.356	Vein, polymetallic	
PMV	PMVN 15		Bald Butte	Marysville	Lewis and Clark	MT	46.723	-112.346	Vein, polymetallic	
PMV	PMVN 16		Whitlatch-Union	Helena	Lewis and Clark	MT	46.548	-112.093	Vein, polymetallic	
PMV	PMVN 17		Rimini district 1865-1928	Rimini (Vaughn)	Lewis and Clark	MT	46.486	-112.247	Vein, polymetallic	Disseminated
PMV	PMVN 18			Black Pine (Combination)	Granite	MT	46.448	-113.366	Vein, polymetallic	
PMV	PMVN 19		Alta	Wickes (Colorado)	Jefferson	MT	46.372	-112.093	Vein, polymetallic	
PMV	PMVN 20		Granite-Bimetallic	Philipsburg	Granite	MT	46.316	-113.242	Vein, polymetallic	
PMV	PMVN 21		Comet	Boulder	Jefferson	MT	46.310	-112.167	Vein, polymetallic	
PMV	PMVN 22		Southern Cross	Georgetown (Southern Cross)	Deer Lodge	MT	46.210	-113.235	Vein, polymetallic	Polymetallic replacement
PMV	PMVN 23		Keating	Radersburg	Broadwater	MT	46.188	-111.661	Vein, polymetallic	Polymetallic replacement, Skarn Au, Porphyry Cu
PMV	PMVN 24		Ohio-Keating	Radersburg	Broadwater	MT	46.185	-111.668	Vein, polymetallic	
PMV	PMVN 25			Pony (Mineral Hill and South Boulder)	Madison	MT	45.664	-111.956	Vein, polymetallic	
PMV	PMVN 26			Rochester (Rabbit)	Madison	MT	45.620	-112.505	Vein, polymetallic	
PMV	PMVN 27			Norris (Upper and Lower Hot Springs)	Madison	MT	45.534	-111.771	Vein, polymetallic	
PMV	PMVN 28			Sheridan-Twin Bridges	Madison	MT	45.481	-112.130	Vein, polymetallic	
PMV	PMVN 29			Grand Island-Caribou	Boulder	CO	39.983	-105.583	Vein, polymetallic	Alkaline Au-Te
PMV	PMVN 30			Central City	Clear Creek	CO	39.783	-105.517	Vein, polymetallic	Alkaline Au-Te
PMV	PMVN 31			Empire	Clear Creek	CO	39.779	-105.683	Vein, polymetallic	Alkaline Au-Te
PMV	PMVN 32			Idaho Springs	Clear Creek	CO	39.742	-105.550	Vein, polymetallic	
PMV	PMVN 33			Freeland-Lamartine	Clear Creek	CO	39.733	-105.600	Vein, polymetallic	
PMV	PMVN 34			Georgetown-SilverPlume	Clear Creek	CO	39.700	-105.725	Vein, polymetallic	

Layer	Tract	Map No.	Deposit	District	County	State	Lat	Long	Deposit Type	Alternative deposit types
PMV	PMVN 35			Breckenridge	Summit	CO	39.483	-106.042	Vein, polymetallic	Polymetallic replacement
PMV	PMVN 36			Twin Lakes	Lake	CO	39.083	-106.417	Vein, polymetallic	
PMV	PMVN 37			Chalk Creek	Chaffee	CO	38.667	-106.333	Vein, polymetallic	
PMV	PMVN 38			Gold Brick-Quartz Creek	Gunnison	CO	38.625	-106.583	Vein, polymetallic	
PMV	PMVN 39			Silver Cliff/Rosita Hills	Custer	CO	38.167	-105.458	Vein, polymetallic	Epithermal quartz-adularia, alkaline Au-Te
PMV	PMVN 40			Uncompahgre	Ouray	CO	38.042	-107.667	Vein, polymetallic	Polymetallic replacement; Porphyry Cu
PMV	PMVN 41			Sneffels - Red Mountain	Ouray	CO	37.958	-107.750	Vein, polymetallic	Polymetallic replacement
PMV	PMVN 42		Treasure Hill	Pioche	Lincoln	NV	37.920	-114.460	Vein, polymetallic	
PMV	PMVN 43			Telluride	San Miguel	CO	37.917	-107.800	Vein, polymetallic	Polymetallic replacement
PMV	PMVN 44			Eureka	San Juan	CO	37.875	-107.542	Vein, polymetallic	
PMV	PMVN 45		Ophir	Ophir	San Miguel	CO	37.833	-107.808	Vein, polymetallic	
PMV	PMVN 46			Animas	San Juan	CO	37.792	-107.583	Vein, polymetallic	
PMV	PMVN 47			Beveridge	Inyo	CA	36.717	-117.900	Vein, polymetallic	
PMV	PMVN 48			Tiger	Yavapai	AZ	34.230	-112.330	Vein, polymetallic	
PMV	PMVN 49			Pinacate	Riverside	CA	33.734	-117.339	Vein, polymetallic	
PMV	PMVN 50		Pinos Altos	Pinos Altos	Grant	NM	32.867	-108.233	Vein, polymetallic	Skarn Cu-Zn
PMV	PMVN 51		North Star	North Star	Pinal	AZ	32.830	-111.340	Vein, polymetallic	
PMV	PMVN 52			Mammoth	Pinal	AZ	32.710	-110.680	Vein, polymetallic	
PMV	PMVN 53			Lordsburg	Hidalgo	NM	32.292	-108.767	Vein, polymetallic	
PMV	PMVN 54		Gold Prince-Dos Cabezas	Apache Pass	Cochise	AZ	32.210	-109.630	Vein, polymetallic	
PMV	PMVN 55		Commonwealth	Pearce	Cochise	AZ	31.900	-109.810	Vein, polymetallic	
PMV	PMVP 01			Butte	Silver Bow	MT	46.020	-112.530	Vein, polymetallic, porphyry Cu-related	Porphyry Cu-Mo
PMV	PMVS 01		Chartam	Winston	Broadwater	MT	46.450	-111.683	Stockwork, Au-bearing	Vein, polymetallic, Au-Ag
PMV	PMVS 02		Atlanta	Atlanta	Elmore	ID	43.771	-115.118	Stockwork, disseminated AuAg	vein, polymetallic, AuAg, Idaho batholith
BVMS	SA01 01			Gossan Lead	Carroll	VA	36.817	-80.750	Massive sulfide, Besshi	
BVMS	SA01 02		Ore Knob		Ashe	NC	36.383	-81.333	Massive sulfide, Besshi	
BVMS	SA03 01		Fontana		Swain	NC	35.478	-83.803	Massive sulfide, Besshi	

Layer	Tract	Map No.	Deposit	District	County	State	Lat	Long	Deposit Type	Alternative deposit types
BVMS	SA03 02			Ducktown (Copperhill)	Polk	TN	35.032	-84.366	Massive sulfide, Besshi	
KVMS	SA04 01			Mineral	Louisa	VA	38.045	-77.892	Massive sulfide, kuroko	
KVMS	SA04 02			Andersonville	Buckingham	VA	37.663	-78.464	Massive sulfide, kuroko	
KVMS	SA04 03		London and Virginia		Buckingham	VA	37.633	-78.464	Massive sulfide, kuroko	
KVMS	SA07 01		Barite Hill	Lincolnton McCormick	McCormick	SC	33.874	-82.294	Massive sulfide, kuroko	
QZAL	SA10 01		Brewer		Chesterfield	SC	34.650	-80.417	Epithermal vein, quartz-alunite	
HTSG	SA15 01		Portis		Franklin	NC	36.200	-78.017	Hot spring Au-Ag	
HTSG	SA15 02		Russell-Coggins		Montgomery	NC	35.503	-80.023	Hot spring Au-Ag	
HTSG	SA15 03		Haile		Lancaster	SC	34.578	-80.543	Hot spring Au-Ag	
HTSG	SA15 04		Ridgeway		Fairfield	SC	34.266	-80.875	Hot spring Au-Ag	
HTSG	SA17 01		Kings Mountain		Cleveland	NC	35.212	-81.339	Hot spring Au-Ag	
LSGQ	SA21 01		Vaucluse		Orange	VA	38.354	-77.729	Low-sulfide Au-quartz vein	
LSGQ	SA21 02		Franklin		Fauquier	VA	38.353	-77.661	Low-sulfide Au-quartz vein	
LSGQ	SA21 03		Whitehall		Spotsylvania	VA	38.239	-77.739	Low-sulfide Au-quartz vein	
LSGQ	SA22 01		Iola group		Montgomery	NC	35.309	-79.774	Low-sulfide Au-quartz vein	
LSGQ	SA22 02		Rudisil		Mecklenburg	NC	35.203	-80.869	Low-sulfide Au-quartz vein	
LSGQ	SA23 01		Gold Hill group	Gold Hill	Rowan	NC	35.513	-80.346	Low-sulfide Au-quartz vein	
LSGQ	SA23 02		Whitney group		Cabarrus	NC	35.500	-80.366	Low-sulfide Au-quartz vein	
LSGQ	SA23 03		Reed		Cabarrus	NC	35.285	-80.464	Low-sulfide Au-quartz vein	
LSGQ	SA23 04		Howie		Union	NC	34.956	-80.715	Low-sulfide Au-quartz vein	
LSGQ	SA26 01		Creighton		Cherokee	GA	34.295	-84.267	Low-sulfide Au-quartz vein	
LSGQ	SA27 01		Hog Mountain		Tallapoosa	AL	33.076	-85.851	Low-sulfide Au-quartz vein	
SKC1	SB03 01		Oracle Ridge	Marble Peak	Pima-Pinal	AZ	32.470	-110.750	Skarn Cu	
SKC1	SB03 02		Republic-Burro	Cochise (Johnson Camp)	Cochise	AZ	32.090	-110.030	Skarn Cu	

Layer	Tract	Map No.	Deposit	District	County	State	Lat	Long	Deposit Type	Alternative deposit types
SKC1	SB03 03		Elgin	Helvetia	Pima	AZ	31.860	-110.790	Skarn Cu	Porphyry Cu, skarn-related
SKC1	SB04 01		Fierro-Hanover	Fierro-Hanover	Grant	NM	32.833	-108.083	Polymetallic replacement	Skarn Cu, porphyry Cu, skarn Fe, skarn Zn-Pb
PCU1	SB09 01		Mineral Park	Wallapai	Mohave	AZ	35.350	-114.100	Porphyry Cu-Mo	
PCU1	SB10 01		Cyprus Bagdad	Eureka	Yavapai	AZ	34.580	-113.170	Porphyry Cu-Mo	
PCU1	SB10 02		Copper Basin	Copper Basin	Yavapai	AZ	34.510	-112.580	Porphyry Cu	
PCU1	SB10 03		Sheep Mountain	Castle Creek	Yavapai	AZ	34.080	-112.460	Porphyry Cu	
PCU1	SB13 01		Mineral Butte	Mineral	Pinal	AZ	33.110	-111.580	Porphyry Cu	
PCU1	SB13 02		Florence	Poston Butte	Pinal	AZ	33.050	-111.410	Porphyry Cu, skarn related	
PCU1	SB13 03		Sacaton East	Casa Grande	Pinal	AZ	32.960	-111.800	Porphyry Cu	
PCU1	SB13 04		Casa Grande West - Santa Cruz	Francisco Grande	Pinal	AZ	32.890	-111.860	Porphyry Cu	
PCU1	SB13 05		Vekol Hills	Vekol	Pinal	AZ	32.580	-112.090	Porphyry Cu	
PCU1	SB13 06		Cyprus Tohono	Lakeshore	Pinal	AZ	32.520	-111.880	Porphyry Cu, skarn-related	
PCU1	SB13 07		North Silver Bell	Martinez Canyon	Pima	AZ	32.400	-111.500	Porphyry Cu	
PCU1	SB13 08		Silver Bell	Martinez Canyon	Pima	AZ	32.400	-111.500	Porphyry Cu, skarn-related	
PCU1	SB13 09		Mission-Pima-San Xavier	Pima	Pima	AZ	31.970	-111.070	Porphyry Cu, skarn-related	
PCU1	SB13 10		Twin Buttes	Pima	Pima	AZ	31.880	-111.030	Porphyry Cu, skarn-related	
PCU1	SB13 11		Sierrita-Esperanza	Pima	Pima	AZ	31.870	-111.120	Porphyry Cu-Mo	
PCU1	SB14 01		Copper Cities	Miami-Inspiration	Gila	AZ	33.430	-110.870	Porphyry Cu	
PCU1	SB14 02		Miami East	Globe Hills	Gila	AZ	33.420	-110.740	Porphyry Cu	
PCU1	SB14 03		Cyprus Miami (Inspiration)	Miami-Inspiration	Gila	AZ	33.400	-110.870	Porphyry Cu	
PCU1	SB14 04		Carlota-Cactus	Miami-Inspiration	Gila	AZ	33.400	-110.930	Porphyry Cu	
PCU1	SB14 05		Van Dyke	Miami-Inspiration	Gila	AZ	33.400	-110.890	Porphyry Cu	
PCU1	SB14 06		Pinto Valley - Castle Dome	Miami-Inspiration	Gila	AZ	33.400	-110.950	Porphyry Cu-Mo	
PCU1	SB14 07		Ray	Mineral Creek	Pinal	AZ	33.160	-110.970	Porphyry Cu-Mo	
PCU1	SB14 08		Morenci-Metcalf	Copper Mountain	Greenlee	AZ	33.090	-109.340	Porphyry Cu-Mo	
PCU1	SB14 09		Chilito	Banner	Gila	AZ	33.070	-110.780	Porphyry Cu	

Layer	Tract	Map No.	Deposit	District	County	State	Lat	Long	Deposit Type	Alternative deposit types
PCU1	SB14 10		Christmas	Banner (Christmas)	Gila	AZ	33.070	-110.690	Porphyry Cu, skarn-related	
PCU1	SB14 11		San Juan	Lone Star (Safford)	Graham	AZ	32.940	-109.650	Porphyry Cu	
PCU1	SB14 12		Lone Star	Lone Star (Safford)	Graham	AZ	32.930	-109.600	Porphyry Cu	
PCU1	SB14 13		Copper Creek	Bunker Hill	Pinal-Graham	AZ	32.750	-110.480	Porphyry Cu	
PCU1	SB14 14		Kalamazoo	San Manuel	Pinal	AZ	32.670	-110.670	Porphyry Cu	
PCU1	SB14 15		San Manuel	San Manuel	Pinal	AZ	32.670	-110.670	Porphyry Cu	
PCU1	SB14 16		Korn Kob	Redington	Pima	AZ	32.400	-110.580	Porphyry Cu, skarn-related	
PCU1	SB14 17		I-10	Cochise	Cochise	AZ	32.090	-110.030	Porphyry Cu	
PCU1	SB14 18		Helvetia	Helvetia-Rosemont	Pima	AZ	31.870	-110.780	Porphyry Cu	
PCU1	SB14 19		Rosemont	Helvetia-Rosemont	Pima	AZ	31.830	-110.760	Porphyry Cu	
PCU1	SB14 20		Red Mountain	Harshaw	Santa Cruz	AZ	31.490	-110.720	Porphyry Cu	
PCU1	SB14 21		Lavender Pit (Bisbee) - Copper Queen	Warren	Cochise	AZ	31.430	-109.910	Porphyry Cu	Polymetallic replacement
PCU1	SB15 01		Copper Flat	Hillsboro	Sierra	NM	32.958	-107.583	Porphyry Cu	
PCU1	SB15 02		Santa Rita (Chino)	Central	Grant	NM	32.792	-108.067	Porphyry Cu	
PCU1	SB15 03		Tyrone	Burro Mts.	Grant	NM	32.633	-108.367	Porphyry Cu	
PCUG	SB17 01		Dos Pobres	Lone Star (Safford)	Graham	AZ	32.970	-109.650	Porphyry Cu-Au	
PCUG	SB17 02		Sanchez	Lone Star (Safford)	Graham	AZ	32.890	-109.530	Porphyry Cu-Au	
PCUG	SB17 03		New Cornelia	Ajo	Pima	AZ	32.360	-112.850	Porphyry Cu-Au	
PMR1	SB18 01			Shoshone	Inyo	CA	35.839	-116.101	Polymetallic replacement	Mississippi Valley
PMR1	SB19 01			Goodsprings	Clark	NV	35.850	-115.500	Polymetallic replacement	
PMR1	SB20 01			Pioneer	Pinal	AZ	33.300	-111.090	Polymetallic replacement	
PMR1	SB20 02		Star Hill	Turquoise	Cochise	AZ	31.760	-109.800	Polymetallic replacement	
PMR1	SB20 03		Copper Queen	Warren	Cochise	AZ	31.430	-109.910	Polymetallic Replacement	
PMR1	SB20 04			Harshaw	Santa Cruz	AZ	31.420	-110.700	Skarn Zn-Pb	Polymetallic replacement
PMR1	SB20 05			Washington Camp	Santa Cruz	AZ	31.370	-110.700	Skarn Zn-Pb	
PMR1	SB21 01			Kingston	Hidalgo	NM	32.958	-107.708	Polymetallic replacement	
PMR1	SB21 02			Georgetown	Grant	NM	32.850	-108.025	Polymetallic replacement	
PMR1	SB21 03			Bayard	Grant	NM	32.792	-108.125	Polymetallic replacement	Skarn Cu, skarn Zn-Pb
PMR1	SB21 04			Chloride Flat	Grant	NM	32.767	-108.292	Polymetallic replacement	
PMR1	SB21 05			Lake Valley	Sierra	NM	32.720	-107.570	Polymetallic replacement	

Layer	Tract	Map No.	Deposit	District	County	State	Lat	Long	Deposit Type	Alternative deposit types
DSDG	SB24 01		Tombstone	Tombstone	Cochise	AZ	31.700	-110.050	Distal disseminated Ag-Au	
DSDG	SB24 02		Hardshell	Harshaw	Santa Cruz	AZ	31.460	-110.720	Distal disseminated Ag-Au	
KVMS	SB25 01		Copper World	Hualapai	Mohave	AZ	34.910	-113.920	Massive sulfide, kuroko?	
KVMS	SB25 02		Antler	Hualapai	Mohave	AZ	34.880	-113.970	Massive sulfide, kuroko?	
KVMS	SB25 03		Jerome Verde	Verde	Yavapai	AZ	34.750	-112.120	Massive sulfide, kuroko	
KVMS	SB25 04		Old Dick - Bruce	Old Dick	Yavapai	AZ	34.540	-113.230	Massive sulfide, kuroko	
KVMS	SB25 05		Iron King	Big Bug	Yavapai	AZ	34.490	-112.260	Massive sulfide, kuroko	
KVMS	SB25 06			Big Bug	Yavapai	AZ	34.450	-112.190	Massive sulfide, kuroko	
KVMS	SB25 07		Blue Bell-De Soto	Mayer	Yavapai	AZ	34.340	-112.240	Massive sulfide, kuroko	
QZAD	SB27 01			Calico	San Bernardino	CA	34.967	-116.867	Epithermal vein, Comstock	
QZAD	SB29 01		Katherine - Frisco - Secret Pass	Union Pass	Mohave	AZ	35.230	-114.550	Epithermal vein, Comstock	
QZAD	SB29 02		Frisco	McConnico	Mohave	AZ	35.117	-114.092	Epithermal vein, Comstock	
QZAD	SB29 03		Gold Road	Oatman	Mohave	AZ	35.040	-114.380	Epithermal vein, Comstock	
QZAD	SB29 04		Tom Reed	Oatman	Mohave	AZ	34.970	-114.380	Epithermal vein, Comstock	
QZAD	SB29 05		Newsboy	Vulture	Maricopa	AZ	33.875	-112.817	Epithermal vein, Comstock	
QZAD	SB29 06			Pikes Peak	Maricopa	AZ	33.807	-112.330	Epithermal vein, Comstock	
QZAD	SB29 07			Little Harquahala	La Paz	AZ	33.670	-113.580	Epithermal vein, Comstock	
QZAD	SB29 08			Kofa	Yuma	AZ	33.280	-113.970	Epithermal vein, Comstock	
QZAD	SB29 09		Reymert	Mineral	Pinal	AZ	33.240	-111.200	Epithermal vein, Comstock Au-Ag	
QZAD	SB29 10			Silver Eureka	La Paz	AZ	33.100	-114.630	Epithermal vein, Comstock	
QZAD	SB29 11		Ash Peak	Ash Peak	Greenlee	AZ	32.760	-109.250	Epithermal vein, Comstock	
QZAD	SB29 12		Mexican Hat	Turquoise	Cochise	AZ	31.800	-109.810	Epithermal vein, Comstock	
QZAD	SB29 13			Oro Blanco	Santa Cruz	AZ	31.420	-111.250	Epithermal vein, Comstock	

Layer	Tract	Map No.	Deposit	District	County	State	Lat	Long	Deposit Type	Alternative deposit types
QZAD	SB30 01		Steeple Rock	Steeple Rock	Grant	NM	32.833	-108.950	Epithermal vein, quartz-adularia	Epithermal vein, quartz-alunite
SADO	SB31 01		Butte	Randsburg	Kern	CA	35.366	-117.645	Epithermal vein, Sado	
SADO	SB31 02		Kelly	Randsburg	Kern	CA	35.360	-117.650	Epithermal vein, Sado	
SADO	SB31 03		Yellow Aster	Randsburg	Kern	CA	35.357	-117.661	Epithermal vein, Sado	
SADO	SB31 04		Baltic	Randsburg	Kern	CA	35.349	-117.639	Epithermal vein, Sado	
SADO	SB31 05		Soledad	Mohave	Kern	CA	34.980	-118.169	Epithermal vein, Sado	
QZAL	SB32 01		Middle Butte	Mohave	Kern	CA	34.958	-118.268	Epithermal vein, quartz-alunite	
QZAL	SB32 02			Stedman	San Bernardino	CA	34.621	-116.151	Epithermal vein, quartz-alunite	
HTSG	SB36 01		Castle Mountain	Hart	San Bernardino	CA	35.330	-115.250	Hot spring Au-Ag	Epithermal vein, Comstock
HTSG	SB36 02		Shumake-Cactus Queen	Mohave	Kern	CA	34.958	-118.286	Hot spring Au-Ag	
HTSG	SB37 01		Mesquite	Mesquite	Imperial	CA	33.042	-114.862	Hot spring Au-Ag	Flat fault Au
HTSG	SB37 02		Indian Rose		Imperial	CA	32.983	-114.783	Hot spring Au-Ag	
HTSG	SB37 03		Picacho	Picacho	Imperial	CA	32.966	-114.658	Hot spring Au-Ag	Flat fault Au
SEDZ	SEDZ 01		Franklin	Franklin-Sterling Hill	Sussex	NJ	41.120	-74.590	Stratabound Zn	Sedimentary exhalative
SEDZ	SEDZ 02		Sterling Hill	Franklin-Sterling Hill	Sussex	NJ	41.080	-74.600	Stratabound Zn	Sedimentary exhalative



Mark3 Index	Model Name	Model Number	Reference to Descriptive Model		Reference to Grade and Tonnage Model		Description	Selected References	Comments
1	Homestake Au	36b	B.R. Berger	Bull 1693	D.L. Mosier	Bull 1693	Gold in massive persistent quartz veins mainly in shear zones in regionally metamorphosed Archean and Proterozoic volcanic rocks and volcanic sediments.		Replaced by Mark 3 indices 100 and 101
2	Porphyry Cu–Mo	21a	D.P. Cox	Bull 1693	D.A. Singer, D.P. Cox, and D.L. Mosier	Bull 1693	Stockwork veinlets of quartz, chalcopyrite, and molybdenite in or near a porphyritic intrusion. Ratio of Au (in ppm) to Mo (in percent) less than 3.	Titley (1982), Cox and Singer (1992)	
4	Porphyry Cu	17	D.P. Cox	Bull 1693	D.A. Singer, D.L. Mosier, and D.P. Cox	Bull 1693	Generalized model includes various subtypes, all of which contain chalcopyrite in stockwork veinlets in hydrothermally altered porphyry and adjacent country rock.	Titley (1982)	
8	Skarn Cu	18b	D.P. Cox and T.G. Theodore	Bull 1693	G.M. Jones and W.D. Menzie	Bull 1693	Chalcopyrite in calc-silicate metasomatic rocks near contacts with weakly mineralized igneous intrusives.	Einaudi and Burt (1982), Einaudi and others (1981), Einaudi (1982a, b)	
9	Porphyry Cu, skarn–related	18a	D.P. Cox	Bull 1693	D.A. Singer	Bull 1693	Chalcopyrite in stockwork veinlets in hydrothermally altered and mineralized porphyry, and in calc-silicate contact metasomatic rocks with extensive retrograde alteration.	Einaudi and Burt (1982)	
11	Massive sulfide, Cyprus	24a	D.A. Singer	Bull 1693	D.A. Singer and D.L. Mosier	Bull 1693	Stratabound lenses of massive pyrite, chalcopyrite, and sphalerite in pillow basalts of ophiolite assemblages.	Franklin and others (1981)	
13	Sedimentary exhalative Zn–Pb	31a	J.A. Briskey	Bull 1693	W.D. Menzie and D.L. Mosier	Bull 1693	Stratiform basinal accumulations of sulfides and barite interbedded with euxinic marine sediments form sheet- or lens-like ore bodies tens of meters thick, distributed through a stratigraphic interval of more than 1,000 m.	Large (1981)	
15	Carbonate–hosted Au–Ag	26a	B.R. Berger	Bull 1693	W.C. Bagby, W.D. Menzie, D.L. Mosier, and D.L. Singer	Bull 1693	Very fine grained gold, pyrite and As-Sb sulfides disseminated in carbonaceous calcareous and siliceous sedimentary rocks and associated jasperoids.		Superceded by Mark3 index 17
16	Epithermal vein, Comstock	25c	D.L. Mosier, D.A. Singer, and B.R. Berger	Bull 1693	D.L. Mosier, Takeo Sato, and D.A. Singer	Bull 1693	Gold, electrum, silver sulfosalts, and argentite in vuggy quartz-adularia veins hosted by felsic to intermediate volcanic rocks that overlie predominantly clastic sedimentary rocks, and their metamorphic equivalents.	Buchanan (1980), Boyle (1979), Mosier and others (1986).	
17	Sediment–hosted Au	26a.1	B.R. Berger	Bull 2004	D.L. Mosier, D.A. Singer, W.C. Bagby, and W.D. Menzie	Bull 2004	Very fine grained gold, pyrite, and As-Sb sulfides disseminated in carbonaceous calcareous and siliceous sedimentary rocks and associated jasperoids.	Berger and Bagby (1991)	Replaces Mark3 index 15

Mark3 Index	Model Name	Model Number	Reference to Descriptive Model		Reference to Grade and Tonnage Model		Description	Selected References	Comments
18	Distal disseminated Ag–Au	19c	D.P. Cox	Bull 2004	D.P. Cox and D.A. Singer	Bull 2004	Disseminated Ag and Au mainly in sedimentary rocks distal to porphyry Cu, skarns, and polymetallic veins.	Graybeal and others (1986)	
19	Synorogenic–synvolcanic Ni–Cu	7a	N. J Page	Bull 1693	D.A. Singer, N. J Page, and W.D. Menzie	Bull 1693	Massive lenses, matrix and disseminated sulfide in small to medium-sized gabbroic intrusions in greenstone belts.	Ross and Travis (1981), Marston and others (1981).	
22	Skarn Zn–Pb	18c	D.P. Cox	Bull 1693	D.L. Mosier	Bull 1693	Sphalerite and galena in calc-silicate rocks near igneous intrusive contacts.	Einaudi and Burt (1982), Einaudi and others (1981)	
25	Epithermal vein, quartz–adularia	25c + 25d		Unpublished	Steve Ludington	Unpublished	Gold, electrum, silver sulfosalts, and argentite in vuggy quartz-adularia veins hosted by felsic to intermediate volcanic rocks that overlie unspecified basement.	Heald and others (1987)	Combination of grades and tonnages of Comstock (Mark3 index 16) and Sado (Mark3 index 28) types.
26	Low–sulfide Au–quartz vein, Chugach type	36a.1	J.D.Bliss	Bull 2004	J.D. Bliss	Bull 2004	Subtype of low-sulfide Au-quartz vein; typical deposit has about half the tonnage and half the Au grade; characterized by absence of association with batholithic-scale intrusive bodies.	Goldfarb and others 1986	Updated by author 1/15/91
27	Low–sulfide Au–quartz vein	36a	B.R. Berger	Bull 1693	J.D. Bliss	Bull 1693	Gold in massive persistent quartz veins mainly in shear zones in regionally metamorphosed volcanic rocks and volcanic sediments.		Updated by author 1/15/91
28	Epithermal vein, Sado	25d	D.L. Mosier, B.R. Berger, D.A. Singer	Bull 1693	D.L. Mosier and Takeo Sato	Bull 1693	Gold, chalcopyrite, sulfosalts, and argentite in vuggy veins hosted by felsic to intermediate volcanic rocks that overlie older volcanic sequences or igneous intrusions.	Boyle (1979), Mosier and others (1986)	
30	Massive sulfide, Besshi	24b	D.P. Cox	Bull 1693	D.A. Singer	Bull 1693	Thin, sheetlike bodies of massive to well-laminated pyrite, pyrrhotite, and chalcopyrite within thinly laminated clastic sediments associated with basalt flows and tuffs.	Klau and Large (1980), Fox (1984)	Grade and tonnage model includes only Japanese deposits
34	Porphyry Cu–Au	20c	D.P. Cox	Bull 1693	D.A. Singer and D.P. Cox	Bull 1693	Stockwork veinlets of chalcopyrite, bornite, and magnetite in porphyritic intrusions and coeval volcanic rocks. Ratio of Au (ppm) to Mo (percent) is greater than 30.	Sillitoe (1979), Cox and Singer (1992)	
38	Epithermal vein, quartz–alunite	25e	B.R. Berger	Bull 1693	D.L. Mosier and W.D. Menzie	Bull 1693	Gold, pyrite, and enargite in vuggy veins and breccias in zones of high-alumina alteration related to felsic volcanism.	Ashley (1982)	
42	Mississippi Valley, Appalachian Zn	32b	J.A. Briskey	Bull 1693	D.L. Mosier and J.A. Briskey	Bull 1693	Stratabound deposits of sphalerite and minor galena in primary and secondary voids in favorable beds or horizons in thick platform dolostone and limestone.	Sangster (1983)	Grade and tonnage model for combination of model numbers 32a and 32b; now superceded by Mark3 index 108.

Mark3 Index	Model Name	Model Number	Reference to Descriptive Model		Reference to Grade and Tonnage Model		Description	Selected References	Comments
42	Mississippi Valley, S.E. Missouri Pb–Zn	32a	J.A. Briskey	Bull 1693	D.L. Mosier and J.A. Briskey	Bull 1693	Stratabound, carbonate-hosted deposits of galena, sphalerite, and chalcopyrite in rocks having primary and secondary porosity, commonly related to reefs on paleotopographic highs.	Sangster (1983)	Grade and tonnage model for combination of model numbers 32a and 32b; now superceded by Mark3 index 108.
43	Plutonic porphyry Au	43	V.F. Hollister	Nonrenewable Resources, v. 1, no. 4	none	none	Felsic porphyritic plutons with disseminated gold in veins, veinlets and stockworks.	Newberry and others (1995)	
44	Massive sulfide, Sierran kuroko	28a.1		Unpublished	D.A. Singer	Bull 2004	Copper and zinc in massive sulfide deposits in intermediate to felsic marine volcanic rocks. Triassic and Jurassic deposits have significantly lower tonnages.	Ishihara (1974), Franklin and others (1981), Hutchinson and others (1982), Ohmoto and Skinner (1983)	
45	Hot Spring Au–Ag	25a	B.R. Berger	Bull 1693	B.R. Berger and D.A. Singer	Bull 2004	Fine-grained silica and quartz in silicified breccia with gold, pyrite, and Sb and As sulfides.	Berger (1985)	Revised grade and tonnage model in Bulletin 2004 (1992)
46	Polymetallic vein	22c	D.P. Cox	Bull 1693	J.D. Bliss and D.P. Cox	Bull 1693	Quartz-carbonate veins with Au and Ag associated with base metal sulfides related to hypabyssal intrusions in sedimentary and metamorphic terranes.	Sangster (1984)	
47	Polymetallic replacement	19a	H.T. Morris	Bull 1693	D.L. Mosier, H.T. Morris, and D.A. Singer	Bull 1693	Hydrothermal, epigenetic, Ag, Pb, Zn, Cu minerals in massive lenses, pipes, and veins in limestone, dolomite, or other soluble rock near igneous intrusive contacts.	Graybeal, and others (1986), Megaw and others (1988)	
54	Placer Au	39a	W.E. Yeend	Bull 1693	G.J. Orris and J.D. Bliss	Bull 1693	Elemental gold and platinum-group alloys in grains and (rarely) nuggets in gravel, sand, silt, and clay, and their consolidated equivalents, in alluvial, beach, eolian, and (rarely) glacial deposits	Boyle (1979), Wells (1973)	Direct estimate of gold contained in undiscovered gold placer deposits in Alaska statewide
58	Epithermal vein, Creede	25b	D.L. Mosier, T. Sato, N. J Page, D.A. Singer, and B.R. Berger	Bull 1693	D.L. Mosier, T. Sato, and D.A. Singer	Bull 1693	Galena, sphalerite, chalcopyrite, sulfosalts, ± tellurides ± gold in quartz-carbonate veins hosted by felsic to intermediate volcanics.	Buchanan (1980), Boyle (1979)	
63	Sediment–hosted Cu	30b	D.P. Cox	Bull 1693	D.L. Mosier, D.A. Singer, and D.P. Cox	Bull 1693	Stratabound, disseminated copper sulfides in reduced beds of red-bed sequences.	Kirkham (1989)	Obsolete; replaced by Mark3 indices 64, 96, and 97
64	Sediment–hosted Cu, Revett		G.T. Spanski	Nonrenewable Resources, v. 1, no. 2	G.T. Spanski	Nonrenewable Resources, v. 1, no. 2	Stratabound, disseminated copper sulfide deposits in white to light gray quartzite. This model is restricted to the Precambrian Belt Basin of Montana.	Hayes and Einaudi (1986)	Created for Kootenai National Forest assessment
76	Sandstone–hosted Pb–Zn	30a	J.A. Briskey	Bull 1693	D.L. Mosier	Bull 1693	Stratabound to stratiform galena and sphalerite in multiple, thin, sheetlike ore bodies in arenaceous sedimentary rocks.	Bjorlykke and Sangster (1981)	

Mark3 Index	Model Name	Model Number	Reference to Descriptive Model		Reference to Grade and Tonnage Model		Description	Selected References	Comments
80	Alkaline Au–Te	22b	D.P. Cox and W.C. Bagby	OFR 92-208	J.D. Bliss, D.M. Sutphin, D.L. Mosier, and M.S. Allen	OFR 92-208	Veins or breccias associated with alkalic igneous rocks and containing gold ± gold tellurides ± vanadian micas.	Kelly and Goddard (1969), Mutschler and Mooney (1995)	Was Au-Ag-Te veins
81	Porphyry Cu (North America)	17	J.M. Hammarstrom	OFR 93-207	J.M. Hammarstrom	OFR 93-207	Generalized model includes various subtypes, all of which contain chalcopyrite in stockwork veinlets in hydrothermally altered porphyry and adjacent country rock.	Titley (1982)	North American subset of Mark3 index 4
82	Skarn Au		T.G. Theodore, J.M. Hammarstrom, G.J. Orris, and J.D. Bliss	Bull 1930	T.G. Theodore, J.M. Hammarstrom, G.J. Orris, and J.D. Bliss	Bull 1930	Gold in skarns near intrusive igneous contacts. Includes Cu, Zn-Pb, and Fe skarns with gold as a major commodity.	Meinert (1989)	See Mark3 index 105
89	Porphyry Cu (BC–AK)	17.1	W.D. Menzie	OF 93-275	W.D. Menzie	OF 93-275	Generalized model includes various subtypes all of which contain chalcopyrite in stockwork veinlets in hydrothermally altered porphyry and adjacent country rock.		Data from deposits in British Columbia, Yukon, and Alaska only
92	Polymetallic replacement + skarn Zn–Pb	19a + 18c		Unpublished	D.A. Singer	Unpublished	Hydrothermal, epigenetic, Ag, Pb, Zn, Cu minerals in massive lenses in limestone, dolomite, or other soluble rock, with or without calc-silicate minerals, near igneous intrusive contacts.	Graybeal and others (1986), Megaw and others (1988)	Combination of grades and tonnages of polymetallic replacement (19a, Mark3 index 47) and Zn-Pb skarn (18c, Mark3 index 22)
93	Massive sulfide, kuroko	28a	D.A Singer	Bull 1693	D.A Singer and D.L. Mosier	Bull 1693	Copper- and zinc-bearing massive sulfide deposits in marine volcanic rocks of intermediate to felsic composition. Deposits of all ages are included in the model.	Ishihara (1974), Franklin and others (1981), Hutchinson and others (1982), Ohmoto and Skinner (1983)	
94	Mississippi Valley, minor	32a + 32b		Unpublished	S.E. Box	B.R. Berger	Stratabound deposits of sphalerite and minor galena in primary and secondary voids in favorable beds or horizons in thick platform dolostone and limestone.	Sangster (1983)	Subset of Mark3 index 42 for northeast Washington; deposits below the median tonnage.
96	Sediment–hosted Cu, reduced–facies		D.P. Cox	Unpublished	D.L. Mosier and D.P. Cox	Unpublished	Stratabound, disseminated copper sulfide deposits in reduced-facies sedimentary rocks associated with red-bed or subaerial basalt sequences.	Kirkham (1989)	Subset of Mark3 index 63
97	Sediment–hosted Cu, red–bed		D.A. Lindsey	Unpublished	D.A. Lindsey, D.L. Mosier, and D.P. Cox	Unpublished	Red-bed copper deposits are stratabound mineralized bodies of disseminated copper and copper sulfides, with or without silver, uranium, and vanadium, occurring in reduced zones of red-bed sequences.	Kirkham (1989), Eugster (1989)	Subset of Mark3 index 63
98	Massive sulfide, Besshi	24b.1	J.F. Slack	GAC Special Paper 40	J.F. Slack	GAC Special Paper 40	Thin, sheetlike bodies of massive to well-laminated pyrite, pyrrhotite, and chalcopyrite within thinly laminated clastic sediments associated with basalt flows and tuffs.	Klau and Large (1980), Fox (1984), Slack (1993)	Model includes worldwide deposits
99	Native Cu		W.F. Cannon	Unpublished	W.F. Cannon	Unpublished	Native copper filling vesicles, breccias, and fractures in subaerial basalt.	White (1968)	Unpublished data from Upper Peninsula, Michigan

Mark3 Index	Model Name	Model Number	Reference to Descriptive Model		Reference to Grade and Tonnage Model		Description	Selected References	Comments
100	Homestake stratiform Au			OF 94-250	T.L. Klein and W.C. Day	OF 94-250	Gold in stratiform carbonate-, silicate-, and sulfide-facies iron formation in regionally metamorphosed volcanic rocks and volcanic sediments.	Slaughter (1968), Rye and Shelton (1983)	
101	Low-sulfide Au-quartz, Archean		T.L. Klein and W.C. Day	OF 94-250	T.L. Klein and W.C. Day	OF 94-250	Gold in massive persistent quartz veins mainly in shear zones in regionally metamorphosed Archean volcanic rocks and volcanic sediments.	Colvine and others (1988)	
102	Sediment-hosted Cu, reduced-facies (modified)			Unpublished	W.F. Cannon	Unpublished	Stratabound, disseminated copper sulfide deposits in reduced-facies sedimentary rocks associated with red-bed or subaerial basalt sequences.	Kirkham (1989)	Mark3 index 96 with African Copper Belt deposits excluded
103	Massive sulfide, kuroko (Precambrian)	28a	D.A Singer	Bull 1693	K.J. Schulz	Unpublished	Copper- and zinc-bearing massive sulfide deposits in marine volcanic rocks of intermediate to felsic composition. Precambrian deposits only.	Ishihara (1974), Franklin and others (1981), Hutchinson and others (1982), Ohmoto and Skinner (1983)	Precambrian deposits only from Mark3 index 93
104	Massive sulfide, kuroko (Phanerozoic)	28a	D.A Singer	Bull 1693	T.L. Klein	Unpublished	Copper- and zinc-bearing massive sulfide deposits in marine volcanic rocks of intermediate to felsic composition. Phanerozoic deposits only.	Ishihara (1974), Franklin and others (1981), Hutchinson and others (1982), Ohmoto and Skinner (1983)	Phanerozoic deposits only from Mark3 index 93
105	Skarn Au, truncated		T.G. Theodore, J.M. Hammarstrom, G.J. Orris, and J.D. Bliss	Bull 1930	D.B. Stoeser and Steve Ludington	Unpublished	Gold in skarns near intrusive igneous contacts. Includes Cu, Zn-Pb, and Fe skarns with gold as a major commodity.	Meinert (1989)	Deposits from Mark3 index 82 that are larger than 15,000 metric tons
106	Sedimentary exhalative Zn			Unpublished	S.H.B. Clark	Unpublished	Stratiform basinal accumulations of sulfides and barite interbedded with euxinic marine sediments. Adirondack deposits have low Pb and Ag grades.	Large (1981), Lea and Dill (1968)	Mark3 index 13 with lead and silver data removed
108	Mississippi Valley, updated	32a		Unpublished	D.L. Mosier	Unpublished	Stratabound, carbonate-hosted deposits of galena, sphalerite, and chalcopyrite in rocks having primary and secondary porosity, commonly related to reefs on paleotopographic highs.	Sangster (1983)	Replaces Mark3 index 42; silver grade for S.E. Missouri changed
109	Mississippi Valley, without Missouri	32a		Unpublished	S.H.B. Clark	Unpublished	Stratabound, carbonate-hosted deposits of galena, sphalerite, and chalcopyrite in rocks having primary and secondary porosity, commonly related to reefs on paleotopographic highs.	Sangster (1983)	Subset of Mark3 index 108 with Central and Southeast Missouri districts removed
114	Au-Sb vein	36c	V.I. Berger	U.S. Geological Survey Open-File Report 93-194	V.I. Berger	U.S. Geological Survey Open-File Report 93-194	Stibnite, berthierite, gold, aurostibnite in metamorphosed quartz-carbonate veins in compressive shear zones in low-grade greenschist facies of regionally metamorphosed rocks	V.I. Berger (1993)	

Mark3 Index	Model Name	Model Number	Reference to Descriptive Model		Reference to Grade and Tonnage Model		Description	Selected References	Comments
118	Basaltic Cu	23	D.P. Cox	Bull 1693	R.B. McCammon	Unpublished	A diverse group including disseminated native copper and copper sulfides in the upper parts of thick sequences of subaerial basalt, and copper sulfides in overlying sedimentary beds.	Kirkham (1984)	Based on assumed mean grade and tonnage similar to the basaltic Cu deposits of the Upper Peninsula of Michigan, which have a median size of 15.7 million metric tons and a median grade of 1.1 percent Cu.
119	Epithermal vein, generic	25a-d	F.A. Wilson	Bull 1693	F.A. Wilson	Unpublished	Combined model based on Creede epithermal vein, Comstock epithermal vein, Sado epithermal vein, and epithermal quartz-alunite gold deposit models	Wilson and others (1988)	Based on same size as known deposits, Apollo and Shumagin, in Alaska Peninsula and Aleutian Is.
120	Alaskan PGE	9	N. J Page and F. Gray	Bull 1693	D.A. Brew	Unpublished	Crosscutting ultramafic to felsic intrusive rocks with approximately concentric zoning of rock types containing chromite, platinum and Ti-V-magnetite	Cabri and Naldrett (1984)	Based on known deposits, Union Bay, Kasaan-Salt Chuck, Duke Island, Snettisham, and Klukwan, in Alaska
none	Kennecott Cu	none		none		none	Massive copper sulfides in the lower part of the Chitistone Limestone. The Cu was derived from the underlying Nikolai Greenstone.	Armstrong and MacKevett (1982)	
none	Kipushi Cu–Pb–Zn	32c	D.P. Cox and L.R. Bernstein	Bull. 1693		none	Stockwork sulfides in tabular, pipe, or karst zones in dolomite breccia.	Runnels (1969)	
none	Cu–Ag quartz veins	none	Nokleberg and others (1993)	OFR 93-339		none	Cu sulfides and accessory Ag in quartz veins and disseminations in weakly regionally metamorphosed mafic igneous rocks.		
none	Zn–Pb–Ag veins	none		none		none	Sphalerite, argentiferous galena, and quartz as banded veins and breccias, with inclusions of wall rock fragments which are overgrown and infilled by sulfides + quartz. Alteration consists of minor silicification and de-carbonation of wall rocks.		Deposits are unrelated spatially or genetically to volcanic or plutonic rocks, and probably formed by dewatering of a large sedimentary basin.
none	Peraluminous granite porphyry	none	T.K. Bundtzen and M.L. Miller	Economic Geology Monograph No. 9.		none	Gold associated with Late Cretaceous to Early Tertiary peraluminous granite porphyry and rhyolite dikes that intrude Cretaceous turbidite and volcanic rocks.		
none	Podiform chromite	8a	J.P. Albers	Bull 1693	D.A. Singer and N.J. Page	OFR 86-1693	Podlike masses of chromitite in ultramafic parts of ophiolite complexes.		

References cited in file MODLLIST

- Ashley, R.P., 1982, Occurrence model for enargite-gold deposits, *in* Erickson, R.L., ed., Characteristics of mineral deposit occurrences: U.S. Geological Survey Open-File Report 82-795, p. 126-129.
- Berger, B.R., 1985, Geologic-geochemical features of hot-spring precious metal deposits, *in* Tooker, E.W., ed., Geologic characteristics of sediment- and volcanic-hosted disseminated gold deposits: U.S. Geological Survey Bulletin 1646, p. 47-48.
- Berger, B.R., and Bagby, W.C., 1991, The geology and origin of Carlin type deposits, *in* Foster, R.P., ed., Gold exploration and metallogeny: London, Blackie and Sons, p. 210-248.
- Bjørlykke, A., and Sangster, D.F., 1981, An overview and sandstone lead deposits and their relationship to red-bed copper and carbonate-hosted lead-zinc deposits, *in* Skinner, B.J., ed., Economic Geology 75th Anniversary Volume, 1905-1980: Economic Geology, p. 179-213.
- Boyle, R.W., 1979, The geochemistry of gold and its deposits: Geological Survey of Canada Bulletin 280, 584 p.
- Buchanan, L.J., 1980, Ore controls of vertically stacked deposits, Guanajuato, Mexico: American Institute of Mining Engineers, Preprint 80-82, 26 p.
- Colvine, A.C., Fyon, J.A., Heather, K.B., Marmont, Soussan, Smith, P.M., and Troop, D.G., 1988, Archean lode gold deposits in Ontario: Ontario Geological Survey Miscellaneous Paper 139, 136 p.
- Cox, D.P., and Singer, D.A., 1992, Descriptive and grade and tonnage model of distal-disseminated Ag-Au, *in* Bliss, J.D., ed., Developments in deposit modeling: U.S. Geological Survey Bulletin 2004, p. 20-22.
- Cox, D.P., and Singer, D.A., 1992, Distribution of gold in porphyry copper deposits, *in* DeYoung, J.H., Jr., and Hammarstrom, J.M., eds., Contributions to commodity geology research: U.S. Geological Survey Bulletin 1877, p. C1-C14.
- Einaudi, M.T., 1982a, Description of skarns associated with porphyry copper plutons, *in* Titley, S.R., ed., Advances in geology of the porphyry copper deposits—Southwestern North America: Tucson, University of Arizona Press, p. 139–184.
- Einaudi, M.T., 1982b, General features and origin of skarns associated with porphyry copper plutons, *in* Titley, S.R., ed., Advances in geology of the porphyry copper deposits—Southwestern North America: Tucson, University of Arizona Press, p. 185–210.
- Einaudi, M.T., and Burt, D.M., 1982, Introduction—Terminology, classification, and composition of skarn deposits: Economic Geology, v. 77, no. 4, p. 745-754.
- Einaudi, M.T., Meinert, L.D., and Newberry, R.J., 1981, Skarn deposits, *in* Skinner, B.J., ed., Economic Geology 75th Anniversary Volume, 1905-1980: Economic Geology, p. 317–391.
- Eugster, H.P., 1989, Geochemical environments of sediment-hosted Cu-Pb-Zn deposits, *in* Boyle, R.W., Brown, A.C., Jefferson, C.W., Jowett, E.C., and Kirkham, R.V., eds., Sediment-hosted stratiform copper deposits: Geological Association of Canada Special Paper 36, p. 111-126.
- Fox, J.S., 1984, Besshi-type volcanogenic sulfide deposits--A review: Canadian Institute Mining and Metallurgy Bulletin, v. 77, no. 864, p. 57-68.
- Franklin, J.M., Sangster, D.M., and Lydon, J.W., 1981, Volcanic-associated massive sulfide deposits, *in* Skinner, B.J., ed., Economic Geology 75th Anniversary Volume, 1905-1980: Economic Geology, p. 485-627.
- Graybeal, F.T., Smith, D.M., Jr., and Vickre, P.G., 1986, The geology of silver deposits, *in* Wolf, K.H., ed., Handbook of strata-bound and stratiform ore deposits: Amsterdam, Elsevier, v. 14, p. 1-184.
- Hayes, T.S., and Einaudi, M.T., 1986, Genesis of the Spar Lake strata-bound copper-silver deposit, Montana. Part I—Controls inherited from sedimentation and pre-ore diagenesis: Economic Geology, v. 81, no. 8, p. 1899-1931.

- Heald, Pamela, Foley, N.K., and Hayba, D.O., 1987, Comparative anatomy of volcanic-hosted epithermal deposits—Acid-sulfate and adularia-sericite types: *Economic Geology*, v. 82, no. 1, p. 1-26.
- Hoagland, A.D., 1976, Appalachian zinc-lead deposits, *in* Wolf, K.H., ed., *Handbook of strata-bound and stratiform ore deposits*: Amsterdam, Elsevier, v. 6, p. 495-534.
- Hollister, V.F., 1992, On a proposed plutonic porphyry gold deposit model: *Nonrenewable Resources*, v. 1, no. 4, p. 293-302.
- Hutchinson, R.W., Spence, C.D., and Franklin, J.M., eds., 1982, Precambrian sulfide deposits, H.S. Robinson Memorial Volume: Geological Association of Canada Special Paper 25, 791 p.
- Ishihara, S., ed., 1974, Geology of the Kuroko deposits: Society of Mining Geologists of Japan, Special Issue 6, 473 p.
- Kelly, W.C., and Goddard, E.N., 1969, Telluride ores of Boulder County, Colorado: Geological Society of America Memoir 109, 237 p.
- Kirkham, R.V., 1989, Distribution, settings, and genesis of sediment-hosted stratiform copper deposits, *in* Boyle, R.W., Brown, A.C., Jefferson, C.W., Jowett, E.C., and Kirkham, R.V., eds., *Sediment-hosted stratiform copper deposits*: Geological Association of Canada Special Paper 36, p. 3-38.
- Klau, W., and Large, D.E., 1980, Submarine exhalative Cu-Pb-Zn deposits—A discussion of their classification and metallogensis: *Geologisches Jahrbuch*, sec. D, no. 40, p. 13-58.
- Klein, T.L., and Day, W.C., 1994, Descriptive and grade-tonnage models of Archean low-sulfide Au-quartz and a revised grade-tonnage model of Homestake Au: U.S. Geological Survey Open-File Report 94-250.
- Large, D.E., 1981, Sediment-hosted submarine exhalative lead-zinc deposits—A review of their geological characteristics and genesis, *in* Wolf, K.H., ed., *Handbook of strata-bound and stratiform ore deposits*: Amsterdam, Elsevier, v. 9, p. 469-508.
- Megaw, P.K.M., Ruiz, Joaquin, and Titley, S.R., 1988, High-temperature, carbonate-hosted Ag-Pb-Zn (Cu) deposits of northern Mexico: *Economic Geology*, v. 83, no. 8, p. 1856-1885.
- Meinert, L.D., Gold skarn deposits—Geology and exploration criteria, *in* Keays, R.R., Ramsay, W.R.H., and Groves, eds., *Geology of gold deposits*: Economic Geology Monograph 6, p. 537-552.
- Menzie, W.D., and Singer, D.A., 1993, Grade and tonnage model of porphyry Cu deposits in British Columbia, Canada, and Alaska, USA: U.S. Geological Survey Open-File Report 93-275, 8 p.
- Mosier, D.L., Singer, D.A., Sato, T., and Page, N.J., 1986, Relationship of grade, tonnage, and basement lithology in volcanic-hosted epithermal precious- and base-metal quartz-adularia-type districts: *Mining Geology*, v. 36, no. 4, p. 245-264.
- Mutschler, F.E., and Mooney, T.C., 1993, Precious metal deposits related to alkaline igneous rocks—Provisional classification, grade-tonnage data, and exploration frontiers, *in* Kirkham, R.V., Sinclair, W.D., Thorpe, R.I., and Duke, J.M., eds., *Mineral deposit modeling*: Geological Association of Canada Special Paper 40, p. 479-520.
- Ohmoto, H., and Skinner, B.J., eds., 1983, The Kuroko and related volcanogenic massive sulfide deposits: *Economic Geology Monograph* 5, 604 p.
- Rye, D.M., and Shelton, K.L., 1983, A stable isotope study of the Homestake gold mine—An example of a lower Proterozoic submarine hydrothermal vent system: Geological Association of Canada and Mineralogical Association of Canada, Program with Abstracts, v. 8, p. A60.
- Rytuba, J.J., and Cox, D.P., 1991, Porphyry gold—A supplement to U.S. Geological Survey Bulletin 1693: U.S. Geological Survey Open-File Report 91-0116, 5 p.
- Sangster, D.F., 1983, Mississippi Valley-type lead-zinc deposits—A geological melange, *in* Kisvarsanyi, Geza, Grant, S.K., Pratt, W.P., and Koenig, J.W., eds., *International conference on Mississippi Valley type lead-zinc deposits*: University of Missouri-Rolla, Proceedings, p. 7-9.

- Sangster, D.F., 1984, Felsic intrusion-associated silver-lead-zinc veins, *in* Eckstrand, R.O., ed., Canadian mineral deposit types, a geological synopsis: Geological Survey of Canada Report No. 36, p. 66.
- Sillitoe, R.H., 1983, Enargite-bearing massive sulfide deposits high in porphyry copper systems: *Economic Geology*, v. 78, no. 2, p. 348-352.
- Slack, J.F., 1993, Descriptive and grade-tonnage models for Besshi-type massive sulphide deposits, *in* Kirkham, R.V., Sinclair, W.D., Thorpe, R.I., and Duke, J.M., eds., Mineral deposit modeling: Geological Association of Canada Special Paper 40, p. 343-371.
- Slaughter, A.L., 1968, The Homestake mine, *in* Ridge, J.D., ed., Ore deposits of the United States, 1933-1967 (Graton-Sales Volume): New York, American Institute of Mining, Metallurgical, and Petroleum Engineers, v. 2, p. 1436-1459.
- Spanski, G.T., 1992, Quantitative assessment of future development of copper/silver resources in the Kootenai National Forest, Idaho/Montana—Part I, estimation of the copper and silver endowments: *Nonrenewable Resources*, v. 1, no. 2, p. 163-183.
- Thacker, J.L., and Anderson, K.H., 1977, The geologic setting of the Southeast Missouri lead district—Regional geologic history, structure and stratigraphy: *Economic Geology*, v. 72, no. 3, p. 339-348.
- Titely, S.R., 1982, The style and progress of mineralization and alteration and alteration in porphyry copper systems, *in* Titely, S.R., ed., Advances in geology of the porphyry copper deposits—Southwestern North America: Tucson, University of Arizona Press, p. 93-116.
- Vila, Tomás and Sillitoe, R.H., 1991, Gold-rich porphyry systems in the Maricunga belt, northern Chile: *Economic Geology*, v. 86, no. 6, p. 1238-1260.
- Weiblen, P.W., and Morey, G.B., 1980, A summary of the stratigraphy, petrology and structure of the Duluth Complex: *American Journal of Science*, v. 280-A, p. 88-133.
- White, W.S., 1968, The native-copper deposits of northern Michigan, *in* Ridge, J.D., ed., Ore deposits of the United States, 1933-1967 (Graton-Sales Volume): New York, American Institute of Mining, Metallurgical, and Petroleum Engineers, v. 1, p. 303-325.

Layer	Tract ID	Deposit Type	Deposit Model	Mark3 Index	Age	Region	State	90	50	10	5	1	p(0)	Estimators	Area (km2)
AKBS	AK-AP01	Besshi massive sulfide	24b		Tertiary	AK Peninsula & Aleutian Is.	AK	No estimate made					--	na	1,467
AKCY	AK-AP02	Cyprus massive sulfide	24a		Mesozoic	AK Peninsula & Aleutian Is.	AK	No estimate made					--	na	2,138
AKCY	AK-AP03	Cyprus massive sulfide	24a	11	Tertiary	AK Peninsula & Aleutian Is.	AK	0	0	1	1	1	--	Wilson, Church, Saltus, Drew, Menzie	1,467
AKEV	AK-AP04	Epithermal vein, generic	25	119	Cenozoic	AK Peninsula & Aleutian Is.	AK	5	10	27	27	27	--	Wilson, Church, Saltus, Drew, Menzie	27,515
AKEV	AK-AP05	Epithermal vein, generic	25	119	Cenozoic	AK Peninsula & Aleutian Is.	AK	5	10	30	30	30	--	Wilson, Church, Saltus, Drew, Menzie	20,011
AKGQ2	AK-AP06	Low-sulfide Au-quartz veins, Chugach type	36a.1		Mesozoic--Tertiary	AK Peninsula & Aleutian Is.	AK	No estimate made					--	na	2,138
AKGQ2	AK-AP07	Low-sulfide Au-quartz veins, Chugach type	36a.1	26	Tertiary	AK Peninsula & Aleutian Is.	AK	4	10	30	30	30	--	Wilson, Church, Saltus, Drew, Menzie	8,932
AKGQ2	AK-AP08	Low-sulfide Au-quartz veins, chugach type	36a		Tertiary	AK Peninsula & Aleutian Is.	AK	No estimate made					--	na	1,467
AKPC	AK-AP09	Porphyry Cu, BC-Ak type	17.1	89	Tertiary	AK Peninsula & Aleutian Is.	AK	5	13	25	25	25	--	Wilson, Church, Saltus, Drew, Menzie	27,515
AKPC	AK-AP10	Porphyry Cu, BC-Ak type	17.1	89	Cenozoic	AK Peninsula & Aleutian Is.	AK	0	1	4	4	4	--	Wilson, Church, Saltus, Drew, Menzie	20,010
AKPL	AK-AP11	Placer Au	39a		Quaternary	AK Peninsula & Aleutian Is.	AK	No estimate made					--	na	51,342
AKPL	AK-AP12	Placer Au	39a		Quaternary	AK Peninsula & Aleutian Is.	AK	No estimate made					--	na	12,635
AKPV	AK-AP13	Polymetallic vein	22c	46	Cenozoic	AK Peninsula & Aleutian Is.	AK	10	40	90	90	90	--	Wilson, Church, Saltus, Drew, Menzie	27,515
AKPV	AK-AP14	Polymetallic vein	22c	46	Cenozoic	AK Peninsula & Aleutian Is.	AK	5	10	45	45	45	--	Wilson, Church, Saltus, Drew, Menzie	20,011
AKBS	AK-BR01	Besshi massive sulfide	24b		Jurassic (?)	Brooks Range, AK	AK	No estimate made					--	na	12,609
AKCY	AK-BR02	Cyprus massive sulfide	24a		Jurassic (?)	Brooks Range, AK	AK	No estimate made					--	na	4,203
AKCY2	AK-BR03	Cyprus massive sulfide	24a		Jurassic (?)	Brooks Range, AK	AK	No estimate made					--	na	12,189
AKGQ	AK-BR04	Low-sulfide Au-quartz veins	36a	27	Cretaceous(?)	Brooks Range, AK	AK	1	2	5	10	15	--	Schmidt, Kelley, Cady, Berger, Kilburn, Spanski	35,958
AKKC	AK-BR05	Kipushi Cu-Pb-Zn	32c		Miss--Penn	Brooks Range, AK	AK	No estimate made					--	na	49,825

Layer	Tract ID	Deposit Type	Deposit Model	Mark3 Index	Age	Region	State	90	50	10	5	1	p(0)	Estimators	Area (km2)
AKKC	AK-BR06	Kipushi Cu-Pb-Zn	32c		Early Paleozoic	Brooks Range, AK	AK	No estimate made					--	na	32,935
AKKU	AK-BR07	Kuroko massive sulfide	28a	93	Cretaceous (?)	Brooks Range, AK	AK	3	5	7	10	15	--	Schmidt, Kelley, Cady, Berger, Kilburn, Spanski	2,423
AKMV	AK-BR08	Mississippi Valley Type	32a & 32b		Miss--Penn	Brooks Range, AK	AK	No estimate made					--	na	49,825
AKMV2	AK-BR09	Mississippi Valley Type	32a & 32b		Early Paleozoic	Brooks Range, AK	AK	No estimate made					--	na	32,935
AKPC	AK-BR11	Porphyry Cu, BC-Ak type	17.1		Cretaceous	Brooks Range, AK	AK	No estimate made					--	na	9,782
AKPG	AK-BR12	Plutonic Porphyry Au	43		Cretaceous	Brooks Range, AK	AK	No estimate made					--	na	9,782
AKPL2	AK-BR13	Placer Au	39a		Quaternary	Brooks Range, AK	AK	No estimate made					--	na	108,594
AKPL	AK-BR14	Placer Au	39a		Quaternary	Brooks Range, AK	AK	No estimate made					--	na	94,199
AKPR	AK-BR15	Polymetallic replacement	19a		Cretaceous	Brooks Range, AK	AK	No estimate made					--	na	9,782
AKPV	AK-BR16	Polymetallic vein	22c		Cretaceous	Brooks Range, AK	AK	No estimate made					--	na	9,782
AKPZ	AK-BR17	Zn-Pb-Ag veins	none		Dev--Miss	Brooks Range, AK	AK	No estimate made					--	na	59,440
AKSK	AK-BR18	Cu (Au) skarn	18b		Cretaceous	Brooks Range, AK	AK	No estimate made					--	na	9,782
AKSK4	AK-BR19	Zn-Pb skarn	18c		Cretaceous	Brooks Range, AK	AK	No estimate made					--	na	9,782
AKSS	AK-BR20	Sandstone hosted Pb-Zn	30a		Dev--Miss	Brooks Range, AK	AK	No estimate made					--	na	59,440
AKSS	AK-BR21	Sediment-hosted Cu	30b		Pz--Mz (?)	Brooks Range, AK	AK	No estimate made					--	na	183,781
AKSX	AK-BR22	Sedex Zn-Pb	31a		Miss--Penn	Brooks Range, AK	AK	No estimate made					--	na	49,825
AKSX2	AK-BR23	Sedex Zn-Pb	31a	13	Miss-Penn	Brooks Range, AK	AK	2	5	7	10	15	--	Schmidt, Kelley, Cady, Berger, Kilburn, Spanski	29,735
AKBS	AK-EC01	Besshi Massive Sulfide	24b		Pz-Mz	East Central, AK	AK	No estimate made					--	na	44,937
AKCY	AK-EC02	Cyprus massive sulfide	24a		Jurassic (?)	East Central, AK	AK	No estimate made					--	na	17,538
AKEV	AK-EC04	Epithermal vein, generic	25		Cret.-Tertiary	East Central, AK	AK	No estimate made					--	na	1,061
AKGA	AK-EC05	Au-Sb veins	36c	114	Cret.-Tertiary	East Central, AK	AK	1	3	5	8	12	--	Grybeck, Cox, Light, Lee, Phillips	1,721
AKGQ	AK-EC06	Low-sulfide Au-quartz veins	36a		Cret.-Tertiary (?)	East Central, AK	AK	No estimate made					--	na	25,659

Layer	Tract ID	Deposit Type	Deposit Model	Mark3 Index	Age	Region	State	90	50	10	5	1	p(0)	Estimators	Area (km2)
AKGQ	AK-EC07	Low-sulfide Au-quartz veins	36a	27	Cret.-Tertiary	East Central, AK	AK	2	8	15	20	30	--	Grybeck, Cox, Light, Lee, Phillips	74,586
AKGQ2	AK-EC08	Low-sulfide Au-quartz veins	36a	27	Cret.-Tertiary	East Central, AK	AK	5	12	20	30	50	--	Grybeck, Cox, Light, Lee, Phillips	1,721
AKKC	AK-EC09	Kipushi Cu-Pb-Zn	32c		Paleozoic	East Central, AK	AK	No estimate made					--	na	23,291
AKKC	AK-EC10	Kipushi cu-Pb-Zn	32c		Paleozoic	East Central, AK	AK	No estimate made					--	na	5,974
AKMV	AK-EC11	Mississippi Valley Type	32a & 32b		Paleozoic	East Central, AK	AK	No estimate made					--	na	23,298
AKMV	AK-EC12	Mississippi Valley Type	32a & 32b		Paleozoic	East Central, AK	AK	No estimate made					--	na	5,974
AKPC	AK-EC13	Porphyry Cu, BC-Ak type	17.1	89	Cret.-Tertiary	East Central, AK	AK	1	2	4	8	10	--	Grybeck, Cox, Light, Lee, Phillips	105,247
AKPG	AK-EC14	Plutonic Porphyry Au	43	43	Cret.-Tertiary	East Central, AK	AK	1	3	5	9	13	--	Grybeck, Cox, Light, Lee, Phillips	84,106
AKPL	AK-EC15	Placer Au	39a		Cenozoic	East Central, AK	AK	No estimate made					--	na	93,722
AKPR	AK-EC16	Polymetallic replacement	19a		Cret.-Tertiary	East Central, AK	AK	No estimate made					--		27,331
AKPR	AK-EC17	Polymetallic replacement	19a		Mz-Tertiary	East Central, AK	AK	No estimate made					--	na	5,974
AKPV	AK-EC18	Polymetallic vein	22c		Mz-Tertiary	East Central, AK	AK	No estimate made					--	na	124,544
AKSK	AK-EC19	Cu (Au) Skarn	18b		Cret.-Tertiary (?)	East Central, AK	AK	No estimate made					--	na	29,265
AKSK4	AK-EC20	Zn-Pb Skarn	18c		Mz-Tertiary	East Central, AK	AK	No estimate made					--	na	29,265
AKSX	AK-EC21	Sedex Zn-Pb	31a		Paleozoic	East Central, AK	AK	No estimate made					--	na	23,298
AKSX	AK-EC22	Sedex Zn-Pb	31a		Paleozoic	East Central, AK	AK	No estimate made					--	na	4,721
AKBC	AK-SC01	Basaltic Cu/Kennecott Cu	23		Cretaceous	South Central, AK	AK	No estimate made					--	na	25,441
AKBS	AK-SC02	Besshi massive sulfide	24b		Trias.-Jurassic	South Central, AK	AK	No estimate made					--	na	1,660
AKBS	AK-SC03	Besshi massive sulfide	24b	30	Late Triassic	South Central, AK	AK	1	2	4	4	4	--	Nokleberg, Goldfarb, Cox, Campbell, Koch, Yeend	9,684
AKBS	AK-SC04	Besshi massive sulfide	24b	30	Late Cret.--early Tertiary	South Central, AK	AK	5	10	30	30	30	--	Nokleberg, Goldfarb, Cox, Campbell, Koch, Yeend	21,717
AKCS	AK-SC05	Cu-Ag quartz veins	none		Cretaceous	South Central, AK	AK	No estimate made					--	na	25,441
AKCY	AK-SC06	Cyprus massive sulfide	24a	11	early Tertiary	South Central, AK	AK	1	2	8	8	8	--	Nokleberg, Goldfarb, Cox, Campbell, Koch, Yeend	19,811
AKGA	AK-SC07	Au-Sb veins	36c	114	Cret.-Tertiary	South Central, AK	AK	2	4	10	10	10	--	Nokleberg, Goldfarb, Cox, Campbell, Koch, Yeend	46,929

Layer	Tract ID	Deposit Type	Deposit Model	Mark3 Index	Age	Region	State	90	50	10	5	1	p(0)	Estimators	Area (km2)
AKGQ	AK-SC08	Low-Sulfide Au-quartz veins	36a	27	Cret-Tertiary	South Central, AK	AK	5	10	50	50	50	--	Nokleberg, Goldfarb, Cox, Campbell, Koch, Yeend	48,045
AKGQ	AK-SC09	Low-Sulfide Au-quartz veins	36a		Cretaceous	South Central, AK	AK	No estimate made					--	na	25,441
AKGQ	AK-SC10	Low-Sulfide Au-quartz veins	36a	27	Tertiary	South Central, AK	AK	1	3	4	4	4	--	Nokleberg, Goldfarb, Cox, Campbell, Koch, Yeend	594
AKGQ	AK-SC11	Low-Sulfide Au-quartz veins, Chugach type	36a.1	26	Tertiary	South Central, AK	AK	1	5	7	7	7	--	Nokleberg, Goldfarb, Cox, Campbell, Koch, Yeend	11,786
AKGQ	AK-SC12	Low-Sulfide Au-quartz veins, Chugach type	36a.1	26	Eocene-Oligocene	South Central, AK	AK	80	600	800	800	800	--	Nokleberg, Goldfarb, Cox, Campbell, Koch, Yeend	40,281
AKKC	AK-SC13	Kipushi cu-Pb-Zn	32c		Paleozoic	South Central, AK	AK	No estimate made					--	na	4,445
AKKU	AK-SC14	Kuroko massive sulfide	28a	93	Dev.-Miss	South Central, AK	AK	3	5	25	25	25	--	Nokleberg, Goldfarb, Cox, Campbell, Koch, Yeend	31,989
AKKU	AK-SC15	Sierran Kuroko mass. sulf.	28a.1	44	Jurassic	South Central, AK	AK	0	1	2	4	10	--	Nokleberg, Goldfarb, Cox, Campbell, Koch, Yeend	7,593
AKKU	AK-SC16	Kuroko massive sulfide	28a	93	Late Paleozoic	South Central, AK	AK	0	0	1	1	1	--	Nokleberg, Goldfarb, Cox, Campbell, Koch, Yeend	17,220
AKMV	AK-SC17	Mississippi Valley Type	32a & 32b		Paleozoic	South Central, AK	AK	No estimate made					--	na	4,445
AKNC	AK-SC18	Synorogenic-synvolcanic Ni-Cu	7a		Late Triassic	South Central, AK	AK	No estimate made					--	na	25,441
AKNC	AK-SC19	Synorogenic-synvolcanic Ni-Cu	7a		Triassic-Jurassic	South Central, AK	AK	No estimate made					--	na	3,994
AKPC	AK-SC20	Porphyry Cu, BC-Ak type	17.1	89	Cret.-Tertiary	South Central, AK	AK	1	5	7	7	7	--	Nokleberg, Goldfarb, Cox, Campbell, Koch, Yeend	45,408
AKPC	AK-SC21	Porphyry Cu, BC-Ak type	17.1	89	Cret-Tertiary	South Central, AK	AK	1	2	6	6	6	--	Nokleberg, Goldfarb, Cox, Campbell, Koch, Yeend	79,025
AKPC2	AK-SC22	Porphyry Cu, BC-Ak type	17.1	89	Jurassic-Cret.	South Central, AK	AK	4	15	30	30	30	--	Nokleberg, Goldfarb, Cox, Campbell, Koch, Yeend	37,930
AKPC3	AK-SC23	Porphyry Cu, BC-Ak type	17.1	89	Paleozoic	South Central, AK	AK	0	0	1	2	3	--	Nokleberg, Goldfarb, Cox, Campbell, Koch, Yeend	17,242
AKPG	AK-SC24	Plutonic Porphyry Au	43	43	Cret-Tertiary	South Central, AK	AK	1	5	7	7	7	--	Nokleberg, Goldfarb, Cox, Campbell, Koch, Yeend	46,929
AKPL	AK-SC25	Placer Au	39a		Cenozoic	South Central, AK	AK	No estimate made					--	na	266,047
AKPR	AK-SC26	Polymetallic replacement	19a		Mz-Tertiary	South Central, AK	AK	No estimate made					--	na	4,445
AKPV	AK-SC27	Polymetallic vein	22c		Mz-Tertiary	South Central, AK	AK	No estimate made					--	na	50,568
AKPV	AK-SC28	Polymetallic vein	22c	46	Cret-Tertiary	South Central, AK	AK	1	5	7	7	7	--	Nokleberg, Goldfarb, Cox, Campbell, Koch, Yeend	79,025
AKPV2	AK-SC29	Polymetallic vein	22c		Cenozoic	South Central, AK	AK	No estimate made					--	na	16,669

Layer	Tract ID	Deposit Type	Deposit Model	Mark3 Index	Age	Region	State	90	50	10	5	1	p(0)	Estimators	Area (km2)
AKSK	AK-SC30	Cu (Au) skarn	18b		Mz-Tertiary	South Central, AK	AK	No estimate made					--	na	4,445
AKSK	AK-SC31	Cu (Au) skarn	18b	8	Cret-Tertiary	South Central, AK	AK	1	2	6	6	6	--	Nokleberg, Goldfarb, Cox, Campbell, Koch, Yeend	79,025
AKSK2	AK-SC32	Cu (Au) skarn	18b	8	Jurassic-Cret.	South Central, AK	AK	1	2	6	6	6	--	Nokleberg, Goldfarb, Cox, Campbell, Koch, Yeend	37,930
AKSK3	AK-SC33	Cu (Au) skarn	18b	8	Paleozoic	South Central, AK	AK	0	0	1	2	3	--	Nokleberg, Goldfarb, Cox, Campbell, Koch, Yeend	17,242
AKSK4	AK-SC34	Zn-Pb Skarn	18c		Mz-Tertiary	South Central, AK	AK	No estimate made					--	na	4,565
AKSK4	AK-SC35	Zn-Pb skarn	18c		Mz-Tertiary	South Central, AK	AK	No estimate made					--	na	15,193
AKSX	AK-SC36	Sedex Zn-Pb	31a		Paleozoic	South Central, AK	AK	No estimate made					--	na	4,874
AKSX	AK-SC37	Sedex Zn-Pb	31a		Cenozoic	South Central, AK	AK	no estimate made					--	na	9,064
AKBS	AK-SE01	Besshi massive sulfide	24b	30	Paleozoic	Southeastern AK	AK	0	0	0	0	1	--	Brew, Taylor, Jachens, Koch, Grybeck, Drinkwater, Barnes, Drew	754
AKEV	AK-SE02	Creede epithermal veins	25b	58	Tertiary	Southeastern AK	AK	0	0	0	1	2	--	Brew, Taylor, Jachens, Koch, Grybeck, Drinkwater, Barnes, Drew	688
AKGQ	AK-SE03	Low-sulfide Au-quartz veins	36a	27	Cret.-Tertiary	Southeastern AK	AK	1	5	13	14	17	--	Brew, Taylor, Jachens, Koch, Grybeck, Drinkwater, Barnes, Drew	14,559
AKKU	AK-SE04	Kuroko massive sulfide	28a	93	pC-Paleoz.	Southeastern AK	AK	0	0	2	2	4	--	Brew, Taylor, Jachens, Koch, Grybeck, Drinkwater, Barnes, Drew	5,573
AKKU	AK-SE05	Sierran Kuroko mass. sulf.	28a.1	44	Late Triassic	Southeastern AK	AK	1	3	7	9	13	--	Brew, Taylor, Jachens, Koch, Grybeck, Drinkwater, Barnes, Drew	797
AKMV	AK-SE06	Mississippi Valley Type (SE Missouri Pb-Zn)	32a	108	Paleozoic--Mesozoic	Southeastern AK	AK	0	0	0	0	1	--	Brew, Taylor, Jachens, Koch, Grybeck, Drinkwater, Barnes, Drew	150
AKPC	AK-SE07	Porphyry Cu	17	81	Tertiary	Southeastern AK	AK	0	0	2	4	7	--	Brew, Taylor, Jachens, Koch, Grybeck, Drinkwater, Barnes, Drew	9,382
AKPL	AK-SE08	Placer Au	39a	54	Quaternary	Southeastern AK	AK	0	0	0	0	1	--	Brew, Taylor, Jachens, Koch, Grybeck, Drinkwater, Barnes, Drew	973
AKSK3	AK-SE09	Cu Skarn	18b	8	Cret.-Tert.	Southeastern AK	AK	1	4	6	7	8	--	Brew, Taylor, Jachens, Koch, Grybeck, Drinkwater, Barnes, Drew	8,009
AKBC	AK-SE10	Basaltic Cu	23	118	Triassic	Southeastern AK	AK	0	0	0	2	3	--	Brew, Taylor, Jachens, Koch, Grybeck, Drinkwater, Barnes, Drew	1,809
AKCY	AK-SE11	Cyprus massive sulfide	24a	11	Triassic	Southeastern AK	AK	0	0	0	0	2	--	Brew, Taylor, Jachens, Koch, Grybeck, Drinkwater, Barnes, Drew	1,374
AKPR	AK-SE12	Polymetallic replacement	19a	47	Cret.-Tertiary	Southeastern AK	AK	0	0	0	1	3	--	Brew, Taylor, Jachens, Koch, Grybeck, Drinkwater, Barnes, Drew	594

Layer	Tract ID	Deposit Type	Deposit Model	Mark3 Index	Age	Region	State	90	50	10	5	1	p(0)	Estimators	Area (km2)
AKPV	AK-SE13	Polymetallic vein	22c	46	Cret-Tertiary	Southeastern AK	AK	5	9	15	17	21	--	Brew, Taylor, Jachens, Koch, Grybeck, Drinkwater, Barnes, Drew	21,295
AKSK4	AK-SE14	Zn-Pb skarn	18c	22	Cret.-Tertiary	Southeastern AK	AK	0	1	4	5	7	--	Brew, Taylor, Jachens, Koch, Grybeck, Drinkwater, Barnes, Drew	3,476
AKNC	AK-SE17	Synorogenic-synvolcanic Ni-Cu	7a	19	Jurassic (?)	Southeastern, AK	AK	0	1	3	8	13	--	Brew, Taylor, Jachens, Koch, Grybeck, Drinkwater, Barnes, Drew	1,324
AKPt	AK-SE18	Alaskan PGE	9	120	Paleoz.-Cret.	Southeastern, AK	AK	0	0	0	1	2	--	Brew, Taylor, Jachens, Koch, Grybeck, Drinkwater, Barnes, Drew	448
AKPC	AK-SE19	Porphyry Cu, skarn related	18a	9	Tertiary	Southeastern AK	AK	0	0	0	1	3	--	Brew, Taylor, Jachens, Koch, Grybeck, Drinkwater, Barnes, Drew	9,382
AKPC	AK-SE20	Porphyry Cu-Mo	21a	2	Tertiary	Southeastern AK	AK	0	0	1	4	5	--	Brew, Taylor, Jachens, Koch, Grybeck, Drinkwater, Barnes, Drew	9,382
AKBC	AK-SW01	Basaltic Cu/Kennecott Cu	23		Triassic	Southwestern, AK	AK	No estimate made					--	na	1,347
AKBS	AK-SW02	Besshi massive sulfide	24b		Pz-Mz	Southwestern, AK	AK	No estimate made					--	na	28,702
AKCY	AK-SW03	Cyprus massive sulfide	24a	11	Pz-Mz	Southwestern, AK	AK	0	0	1	2	4	--	Miller, Bundtzen, Cox, Gray, Phillips	6,310
AKEV	AK-SW04	Epithermal vein, generic	25		Cenozoic	Southwestern, AK	AK	No estimate made					--	na	24,282
AKGP	AK-SW05	Peraluminous granite porphyry gold	none		Cret.-Tertiary	Southwestern, AK	AK	No estimate made					--	na	36,097
AKGQ	AK-SW06	Low-sulfide Au-quartz veins	36a	27	pC-Mz	Southwestern, AK	AK	1	2	3	4	6	--	Miller, Bundtzen, Cox, Gray, Phillips	11,948
AKKC	AK-SW07	Kipushi cu-Pb-Zn	32c		Paleozoic	Southwestern, AK	AK	No estimate made					--	na	6,926
AKKU	AK-SW08	Kuroko massive sulfide	28a	93	pC-Mz	Southwestern, AK	AK	0	0	0	1	3	--	Miller, Bundtzen, Cox, Gray, Phillips	6,536
AKKU	AK-SW09	Kuroko massive sulfide	28a		Jurassic	Southwestern, AK	AK	No estimate made					--	na	1,433
AKMV	AK-SW10	Mississippi Valley Type	32a & 32b	108	Paleozoic	Southwestern, AK	AK	0	0	1	1	2	--	Miller, Bundtzen, Cox, Gray, Phillips	6,926
AKPC	AK-SW11	Porphyry Cu, BC-Ak type	17.1		Cret.-Tertiary	Southwestern, AK	AK	No estimate made					--	na	28,279
AKPC	AK-SW12	Porphyry Cu, BC-Ak type	17.1	89	Mz-Tertiary	Southwestern, AK	AK	1	2	6	8	10	--	Miller, Bundtzen, Cox, Gray, Phillips	46,986
AKPG	AK-SW13	Plutonic porphyry Au	43	121	Mz-Tertiary	Southwestern, AK	AK	3	6	10	15	20	--	Miller, Bundtzen, Cox, Gray, Phillips	67,723
AKPL	AK-SW14	Placer Au	39a		Cenozoic	Southwestern, AK	AK	No estimate made					--	na	187,525
AKPR	AK-SW15	Polymetallic replacement	19a		Mz-Tertiary	Southwestern, AK	AK	No estimate made					--	na	6,926

Layer	Tract ID	Deposit Type	Deposit Model	Mark3 Index	Age	Region	State	90	50	10	5	1	p(0)	Estimators	Area (km2)
AKPV	AK-SW16	Polymetallic vein	22c		Mz-Tertiary	Southwestern, AK	AK	No estimate made					--	na	229,939
AKSK	AK-SW17	Cu (Au) skarn	18b	8	Mz-Tertiary	Southwestern, AK	AK	2	3	8	12	24	--	Miller, Bundtzen, Cox, Gray, Phillips	33,372
AKSK4	AK-SW18	Zn-Pb skarn	18c	22	Mz-Tertiary	Southwestern, AK	AK	1	2	4	6	12	--	Miller, Bundtzen, Cox, Gray, Phillips	33,372
AKSX	AK-SW19	Sedex Zn-Pb	31a	13	Paleozoic	Southwestern, AK	AK	0	1	2	3	5	--	Miller, Bundtzen, Cox, Gray, Phillips	14,717
AKEV	AK-SW20	Epithermal vein, hot spring Au	25a	45	Cret.-Tertiary	Southwestern, AK	AK	0	1	2	3	6	--	Miller, Bundtzen, Cox, Gray, Phillips	17,898
AKPT	AK-SW21	Alaskan PGE	9	120	Pz-Mz	Southwestern, AK	AK	No estimate made					--	na	6,302
AKBS	AK-WC01	Besshi massive sulfide	24b		Pz (?)	West Central, AK	AK	No estimate made					--	na	37,919
AKBS	AK-WC02	Besshi massive sulfide	24b		Mz (?)	West Central, AK	AK	No estimate made					--	na	57,404
AKBS	AK-WC03	Besshi Massive Sulfide	24b		Pz-Mz	West Central, AK	AK	No estimate made					--	na	13,309
AKBS	AK-WC04	Besshi massive sulfide	24b		Pz-Mz	West Central, AK	AK	No estimate made					--	na	1,054
AKCY	AK-WC05	Cyprus massive sulfide	24a		Mz (?)	West Central, AK	AK	No estimate made					--	na	57,404
AKCY	AK-WC06	Cyprus massive sulfide	24a		Pz (?)	West Central, AK	AK	No estimate made					--	na	1,789
AKEV	AK-WC07	Epithermal vein, hot spring Au	25a		Cret.-Tertiary (?)	West Central, AK	AK	No estimate made					--	na	4,402
AKEV	AK-WC08	Epithermal vein, generic	25		Cret.-Tertiary	West Central, AK	AK	No estimate made					--	na	57,393
AKGQ	AK-WC09	Low-sulfide Au-quartz veins	36a	27	Cret.-Tertiary (?)	West Central, AK	AK	1	2	3	5	10	--	Gamble, Church, Cady, Eppinger, Berger, Spanski	37,880
AKGQ	AK-WC10	Low-sulfide Au-quartz veins	36a		Cret.-Tertiary (?)	West Central, AK	AK	No estimate made					--	na	11,935
AKKC	AK-WC11	Kipushi cu-Pb-Zn	32c		Paleozoic	West Central, AK	AK	No estimate made					--	na	7,891
AKKU	AK-WC12	Kuroko massive sulfide	28a		pC-Mz	West Central, AK	AK	No estimate made					--	na	1054
AKMV	AK-WC13	Mississippi Valley Type	32a & 32b		Paleozoic	West Central, AK	AK	No estimate made					--	na	7,891
AKPC	AK-WC14	Porphyry Cu, BC-Ak type	17.1		Cret.-Tertiary (?)	West Central, AK	AK	No estimate made					--	na	57,404
AKPC	AK-WC15	Porphyry Cu, BC-Ak type	17.1		Cret.-Tertiary	West Central, AK	AK	No estimate made					--	na	15,970
AKPG	AK-WC16	Plutonic porphyry Au	43		Mz-Tertiary	West Central, AK	AK	No estimate made					--	na	9,976
AKPL	AK-WC17	Placer Au	39a		Cenozoic	West Central, AK	AK	No estimate made					--	na	163,544

Layer	Tract ID	Deposit Type	Deposit Model	Mark3 Index	Age	Region	State	90	50	10	5	1	p(0)	Estimators	Area (km2)
AKPR	AK-WC18	Polymetallic replacement	19a		Cret.-Tertiary (?)	West Central, AK	AK	No estimate made					--	na	11,026
AKPR	AK-WC19	Polymetallic replacement	19a		Mz-Tertiary	West Central, AK	AK	No estimate made					--	na	7,891
AKPV	AK-WC20	Polymetallic vein	22c		Cret.-Tertiary (?)	West Central, AK	AK	No estimate made					--	na	11,026
AKPV	AK-WC21	Polymetallic vein	22c		Cret.-Tertiary (?)	West Central, AK	AK	No estimate made					--	na	57,404
AKPV	AK-WC22	Polymetallic vein	22c		Mz-Tertiary	West Central, AK	AK	No estimate made					--	na	66,650
AKSK	AK-WC23	Cu (Au) skarn	18b		Cret.-Tertiary	West Central, AK	AK	No estimate made					--	na	11,026
AKSK	AK-WC24	Cu (Au) skarn	18b		Mz-Tertiary	West Central, AK	AK	No estimate made					--	na	7,891
AKSK4	AK-WC25	Zn-Pb skarn	18c		Cret.-Tertiary (?)	West Central, AK	AK	No estimate made					--	na	11,026
AKSK4	AK-WC26	Zn-Pb Skarn	18c		Mz-Tertiary	West Central, AK	AK	No estimate made					--	na	7,891
AKSX	AK-WC27	Sedex Zn-Pb	31a		Paleozoic (?)	West Central, AK	AK	No estimate made					--	na	37,919
AKSX	AK-WC28	Sedex Zn-Pb	31a		Paleozoic	West Central, AK	AK	No estimate made					--	na	3,918
AKCY3	AK01	Cyprus massive sulfide	24a	11	Pz-Tertiary	AK statewide	AK	1	3	5	10	12	--	Berger, Drew, Gamble, Grybeck, Light, Miller, Schmidt, Wilson	2,225,630
AKMV3	AK02	Mississippi Valley Type	32a & 32b	108	Paleozoic	AK statewide	AK	1	2	4	6	6	--	Berger, Drew, Gamble, Grybeck, Light, Miller, Schmidt,	1,112,815
AKPL3	AK03	Placer Au	39a	115	Cenozoic	AK statewide	AK	10*	15*	20*	25*	30*	--	Berger, Drew, Gamble, Grybeck, Light, Miller, Schmidt,	942,218
AKSX2	AK04	Sedex Zn-Pb	31a	13	Paleozoic--Cenozoic	AK statewide	AK	3	8	12	17	30	--	Berger, Drew, Gamble, Grybeck, Light, Miller, Schmidt,	166,679

Layer	Tract ID	Deposit Type	Deposit Model	Mark3 Index	Age	Region	State	90	50	10	5	1	p(0)	Estimators	Area (km2)
SSPB	AD01	Sandstone-hosted Pb-Zn	30a		Paleozoic	Adirondack Mountains	NY	No estimate made						na	4,620
SEDX	AD02	Sedimentary exhalative Zn	31a	106	Middle Proterozoic	Adirondack Mountains	NY	0	0	1	1	1	0.9	Brown, Foose, Clark	253
SEDX	AD03	Sedimentary exhalative Zn	31a	106	Middle Proterozoic	Adirondack Mountains	NY	0	0	1	1	1	0.9	Brown, Foose, Clark	986
SEDX	AD04	Sedimentary exhalative Zn	31a		Middle Proterozoic	Adirondack Mountains	NY	No estimate made						na	51
SEDX	AD05	Sedimentary exhalative Zn	31a		Middle Proterozoic	Adirondack Mountains	NY	No estimate made						na	251
MVTD	AD06	Mississippi Valley, Appalachian Zn	32b		Late Paleozoic	Adirondack Mountains	NY	No estimate made						na	14,300
SCU3	CP01	Sediment-hosted Cu, redbed	30b.2	97	Upper Triassic	Colorado Plateau	UT NM AZ CO	0	0	1	2	4	0.9	DCox, Lindsey, Zientek	36,300
SCU1	CP02	Sediment-hosted Cu, redbed	30b.2	97	Pennsylvanian Permian	Colorado Plateau	AZ UT NM	0	0	0	1	3		DCox, Lindsey, Zientek	17,800
SCU2	CP03	Sediment-hosted Cu, redbed	30b.2	97	Mesozoic	Colorado Plateau	AZ UT CO	1	3	4	4	5		DCox, Lindsey, Zientek	937
SKC1	CR01	Skarn Cu	18b	8	Laramide	Central and Southern Rocky Mountains	CO	0	0	0	0	1	0.99	Ludington, Wallace, Nash, Berger, Spanski	4,450
SKC2	CR02	Skarn Cu	18b	8	Middle Tertiary	Central and Southern Rocky Mountains	CO	0	0	0	0	1	0.99	Ludington, Wallace, Nash, Berger, Spanski	7,490
SKC2	CR03	Skarn Cu	18b	8	Middle Tertiary	Central and Southern Rocky Mountains	NM	0	0	0	0	2	0.98	Ludington, Wallace, Nash, Berger, Spanski	81,100
SKC1	CR04	Skarn Cu	18b	8	Tertiary	Central and Southern Rocky Mountains	TX	0	0	0	0	1	0.99	Spanski, Ludington, Wallace, Nash, Berger	36,900
SKZ1	CR05	Skarn Zn-Pb	18c	22	Laramide	Central and Southern Rocky Mountains	CO	0	0	0	0	1	0.99	Ludington, Wallace, Nash, Berger, Spanski	4,450

Layer	Tract ID	Deposit Type	Deposit Model	Mark3 Index	Age	Region	State	90	50	10	5	1	p(0)	Estimators	Area (km2)
SKZ2	CR06	Skarn Zn-Pb	18c	22	Middle Tertiary	Central and Southern Rocky Mountains	CO	0	0	0	0	1	0.99	Ludington, Wallace, Nash, Berger, Spanski	7,490
SKZ1	CR07	Skarn Zn-Pb	18c	22	Tertiary	Central and Southern Rocky Mountains	TX	0	0	0	0	1	0.99	Spanski, Ludington, Wallace, Nash, Berger	36,900
PCU1	CR08	Porphyry Cu	17	4	Laramide	Central and Southern Rocky Mountains	CO	0	0	0	0	1	0.99	Ludington, Wallace, Nash, Berger, Spanski	47,600
PCU2	CR09	Porphyry Cu	17	4	Middle Tertiary	Central and Southern Rocky Mountains	CO	0	0	1	2	8	0.9	Ludington, Wallace, Nash, Berger, Spanski	84,400
PCU2	CR10	Porphyry Cu	17	4	Middle Tertiary	Central and Southern Rocky Mountains	NM	0	0	0	0	1	0.99	Bartsch-Winkler, McLemore, Ludington, Wallace, Nash, Berger, Spanski	44,600
PCUG	CR11	Porphyry Cu-Au	20c	34	Laramide	Central and Southern Rocky Mountains	CO	0	0	1	1	2	0.9	Ludington, Wallace, Nash, Berger, Spanski	9,690
PCUG	CR12	Porphyry Cu-Au	20c	34	Middle Tertiary	Central and Southern Rocky Mountains	CO	0	0	0	0	1	0.99	Ludington, Wallace, Nash, Berger, Spanski	12,900
PCUG	CR13	Porphyry Cu-Au	20c	34	Middle Tertiary	Central and Southern Rocky Mountains	NM	3	5	9	15	20		Bartsch-Winkler, McLemore, Ludington, Wallace, Nash, Berger, Spanski	45,600
PCUG	CR14	Porphyry Cu-Au	20c	34	Middle Tertiary	Central and Southern Rocky Mountains	TX	0	0	0	1	2		Spanski, Ludington, Wallace, Nash, Berger	25,400
PMR1	CR15	Polymetallic replacement	19a	47	Laramide	Central and Southern Rocky Mountains	CO	0	0	0	0	1	0.99	Ludington, Wallace, Nash, Berger, Spanski	4,450
PMR2	CR16	Polymetallic replacement	19a	47	Middle Tertiary	Central and Southern Rocky Mountains	CO	0	1	2	3	4		Ludington, Wallace, Nash, Berger, Spanski	7,490
PMR3	CR17	Polymetallic replacement	19a	47	Late Tertiary	Central and Southern Rocky Mountains	CO	0	0	1	2	4	0.9	Ludington, Wallace, Nash, Berger, Spanski	6,640

Layer	Tract ID	Deposit Type	Deposit Model	Mark3 Index	Age	Region	State	90	50	10	5	1	p(0)	Estimators	Area (km2)
PMR1	CR18	Polymetallic replacement	19a	47	Middle Tertiary	Central and Southern Rocky Mountains	NM	2	4	6	8	11		Bartsch-Winkler, McLemore, Ludington, Wallace, Nash, Berger, Spanski	81,100
PMR1	CR19	Polymetallic replacement	19a	47	Tertiary	Central and Southern Rocky Mountains	TX	0	1	2	2	2		Spanski, Ludington, Wallace, Nash, Berger	36,900
ALKG	CR20	Alkaline Au-Te	22b	80	Laramide	Central and Southern Rocky Mountains	CO	0	0	0	0	1	0.99	Ludington, Wallace, Nash, Berger, Spanski	9,690
ALKG	CR21	Alkaline Au-Te	22b	80	Middle Tertiary	Central and Southern Rocky Mountains	CO	0	0	0	1	2		Ludington, Wallace, Nash, Berger, Spanski	12,900
ALKG	CR22	Alkaline Au-Te	22b	80	Middle Tertiary	Central and Southern Rocky Mountains	NM TX	2	5	8	12	20		Bartsch-Winkler, McLemore, Ludington, Wallace, Nash, Berger, Spanski	70,900
BVMS	CR23	Massive sulfide, Besshi	24b	30	Proterozoic	Central and Southern Rocky Mountains	WY CO	0	0	0	0	1	0.99	Day, Ludington, Nash, Wallace, Hausel	2,220
KVMS	CR24	Massive sulfide, kuroko	28a	93	Proterozoic	Central and Southern Rocky Mountains	WY CO	0	0	0	4	5		Day, Sidder, Ludington, Wallace, Spanski	11,700
KVMS	CR25	Massive sulfide, kuroko	28a	93	Proterozoic	Central and Southern Rocky Mountains	NM TX	0	1	2	4	6		Day, Sidder, Ludington, Wallace, Spanski	10,800
QZAD	CR26	Epithermal vein, quartz-adularia	25c + 25d	25	Tertiary	Central and Southern Rocky Mountains	CO	1	3	5	7	10		Ludington, Wallace, Nash, Berger, Spanski	20,400
QZAD	CR27	Epithermal vein, quartz-adularia	25c + 25d	25	Tertiary	Central and Southern Rocky Mountains	NM	0	2	5	6	7		Bartsch-Winkler, McLemore, Ludington, Wallace, Nash, Berger, Spanski	43,600
QZAD	CR28	Epithermal vein, quartz-adularia	25c + 25d	25	Tertiary	Central and Southern Rocky Mountains	TX	0	0	0	0	1	0.99	Spanski, Ludington	9,730
QZAL	CR29	Epithermal vein, quartz-alunite	25e	38	Tertiary	Central and Southern Rocky Mountains	CO	0	0	1	3	5	0.9	Ludington, Wallace, Nash, Berger, Spanski	20,400

Layer	Tract ID	Deposit Type	Deposit Model	Mark3 Index	Age	Region	State	90	50	10	5	1	p(0)	Estimators	Area (km2)
QZAL	CR30	Epithermal vein, quartz-alunite	25e	38	Tertiary	Central and Southern Rocky Mountains	NM	0	0	0	2	4		Bartsch-Winkler, McLemore, Ludington, Wallace, Nash, Berger, Spanski	43,600
HTSG	CR31	Hot-spring Au-Ag	25a	45	Tertiary	Central and Southern Rocky Mountains	CO	0	0	0	1	2		Wallace, Ludington	65,900
HTSG	CR32	Hot-spring Au-Ag	25a	45	Tertiary	Central and Southern Rocky Mountains	NM	0	0	0	1	2		Wallace, Ludington	93,200
SCU1	CR33	Sediment-hosted Cu, redbed	30b.2	97	Pennsylvanian Permian	Central and Southern Rocky Mountains	CO NM TX	0	1	2	4	5		DCox, Lindsey, Zientek	26,800
SCU3	CR34	Sediment-hosted Cu, redbed	30b.2	97	Upper Triassic	Central and Southern Rocky Mountains	NM CO	1	3	5	6	6		DCox, Lindsey, Zientek	4,440
SEDX	CR35	Sedimentary exhalative Zn-Pb	31a	13	Proterozoic	Central and Southern Rocky Mountains	CO WY	0	0	0	0	1	0.99	Day, Sidder, Ludington, Wallace, Spanski	11,300
LSGQ	CR36	Low-sulfide Au-quartz vein	36a	27	Proterozoic	Central and Southern Rocky Mountains	WY CO	1	2	3	4	5		Day, Ludington, Nash, Wallace, Hausel	11,400
SSPB	EC01	Sandstone-hosted Pb-Zn	30a		Paleozoic	East-central United States	NY PA NJ MD VA WV NC TN GA AL	No estimate made						na	71,000
SEDX	EC02	Sedimentary exhalative Zn-Pb	31a		Devonian Mississippian	East-central United States	NY PA MD OH WV VA KY TN	No estimate made						na	220,100
MVTD	EC03	Mississippi Valley, Appalachian Zn	32b	109	Late Paleozoic	East-central United States	NY OH MI IN IL KY TN MS AL	1	2	3	4	5		Briskey, Clark, DCox	233,200
MVTD	EC04	Mississippi Valley, Appalachian Zn	32b		Late Paleozoic	East-central United States	NY PA NJ MD VA WV OH KY TN GA AL	No estimate made						na	145,400

Layer	Tract ID	Deposit Type	Deposit Model	Mark3 Index	Age	Region	State	90	50	10	5	1	p(0)	Estimators	Area (km2)
MVTD	EC05	Mississippi Valley, Appalachian Zn	32b	109	Late Paleozoic	East-central United States	NY PA NJ MD VA WV NC TN GA AL	0	1	3	3	4		Briskey, Clark, DCox	42,300
MVTD	EC06	Mississippi Valley, Appalachian Zn	32b	109	Late Paleozoic	East-central United States	PA NJ MD VA WV TN GA AL	3	6	8	11	14		Briskey, Clark, DCox	44,500
SKC1	GB01	Skarn Cu	18b	8	Mesozoic Tertiary	Great Basin	CA	0	1	1	2	2		DCox, Ludington	17,700
SKC1	GB02	Skarn Cu	18b	8	Mesozoic Tertiary	Great Basin	NV OR ID	6	10	14	16	18		DCox, Singer, Berger, Ludington, Tingley	111,900
SKC2	GB03	Skarn Cu	18b	8	Tertiary	Great Basin	UT ID	0	1	2	4	6		Stoeser, Nutt, Ludington	43,400
SKZ1	GB04	Skarn Zn-Pb	18c	22	Tertiary	Great Basin	UT ID	0	2	3	4	7		Stoeser, Nutt, Albino, Ludington, Wallace, Nash, Berger, Spanski	43,400
SKNG	GB05	Skarn Au, truncated	Bull. 1930	105	Mesozoic Tertiary	Great Basin	NV OR ID	1	3	6	8	12		DCox, Ludington	112,100
SKNG	GB06	Skarn Au, truncated	Bull. 1930	105	Tertiary	Great Basin	UT ID	0	0	1	2	4	0.9	Stoeser, Nutt	43,400
PCU1	GB07	Porphyry Cu	17	4	Mesozoic Tertiary	Great Basin	CA	0	0	0	1	2		DCox, Albino, Church, Ashley, Diggles, Kleinkopf	24,500
PCU1	GB08	Porphyry Cu	17	4	Cretaceous	Great Basin	NV OR ID	1	2	2	3	5		DCox, Singer, Berger, Ludington, Tingley	111,300
PCU2	GB09	Porphyry Cu	17	4	Tertiary	Great Basin	NV OR ID	1	3	4	6	8		DCox, Singer, Berger, Ludington, Tingley	111,300
PCU3	GB10	Porphyry Cu	17	4	Jurassic	Great Basin	NV OR ID	1	3	6	9	12		DCox, Singer, Berger, Ludington, Tingley	111,300
PCU2	GB11	Porphyry Cu (North America)	17	81	Middle Tertiary	Great Basin	UT ID	1	3	6	8	11		Stoeser, Nutt, Albino, Ludington, Wallace, Nash, Berger, Spanski	19,300
PCU2	GB12	Porphyry Cu (North America)	17	81	Middle Tertiary	Great Basin	UT	0	0	2	3	4	0.80	Stoeser, Nutt, Albino, Ludington, Wallace, Nash, Berger, Spanski	24,600

Layer	Tract ID	Deposit Type	Deposit Model	Mark3 Index	Age	Region	State	90	50	10	5	1	p(0)	Estimators	Area (km2)
PCU3	GB13	Porphyry Cu, skarn-related	18a	9	Tertiary	Great Basin	UT ID	0	2	5	6	8		Stoeser, Nutt	43,400
PMR1	GB14	Polymetallic replacement + skarn Zn-Pb	19a + 18c	92	Mesozoic Tertiary	Great Basin	CA	0	3	5	8	8		DCox, Albino, Church, Ashley, Diggles, Kleinkopf	17,700
PMR1	GB15	Polymetallic replacement + skarn Zn-Pb	19a + 18c	92	Mesozoic Tertiary	Great Basin	NV OR ID	9	14	18	20	22		DCox, Singer, Berger, Ludington, Tingley	111,800
PMR1	GB16	Polymetallic replacement	19a	47	Tertiary	Great Basin	UT ID	3	7	11	13	20		Stoeser, Nutt, Albino, Ludington, Wallace, Nash, Berger, Spanski	43,400
DSDG	GB17	Distal disseminated Ag-Au	Bull. 2004		Mesozoic Tertiary	Great Basin	UT ID	No estimate made						na	43,400
DSDG	GB18	Distal disseminated Ag-Au	Bull. 2004	18	Mesozoic Tertiary	Great Basin	NV	6	10	14	15	17		DCox, Singer, Berger, Ludington, Tingley	111,800
CVMS	GB19	Massive sulfide, Cyprus	24a	11	Paleozoic	Great Basin	NV	1	2	5	7	8		DCox, Singer, Berger, Ludington, Tingley	37,500
BVMS	GB20	Massive sulfide, Besshi	24b	30	Paleozoic	Great Basin	NV	0	1	2	2	3		DCox, Singer, Ludington	28,800
KVMS	GB21	Massive sulfide, Sierran kuroko	28a.1	44	Mesozoic	Great Basin	NV OR CA	1	3	6	7	8		DCox, Singer, Berger, Ludington, Tingley	13,500
QZAD	GB22	Epithermal vein, Comstock	25c	16	Tertiary	Great Basin	CA	0	1	2	2	2		Rytuba, Albino, Diggles, DCox, Sawlan, Ashley, Kleinkopf, Church	13,400
QZAD	GB23	Epithermal vein, Comstock	25c	16	Tertiary	Great Basin	NV OR ID	14	18	24	26	29		DCox, Singer, Berger, Ludington, Tingley	161,500
QZAD	GB24	Epithermal vein, quartz-adularia	25c + 25d	25	Tertiary	Great Basin	UT ID	1	2	4	6	9		Stoeser, Nutt, Albino, Ludington, Wallace, Nash, Berger, Spanski	41,600
QZAL	GB25	Epithermal vein, quartz-alunite	25e	38	Tertiary	Great Basin	CA	0	1	2	2	2		DCox, Albino, Church, Ashley, Diggles, Kleinkopf, Sawlan	13,400
QZAL	GB26	Epithermal vein, quartz-alunite	25e	38	Tertiary	Great Basin	NV	2	5	9	12	15		DCox, Singer, Berger, Ludington, Tingley	161,600
QZAL	GB27	Epithermal vein, quartz-alunite	25e	38	Tertiary	Great Basin	UT ID	0	0	0	1	2		Stoeser, Nutt, Albino, Ludington, Wallace, Nash, Berger, Spanski	41,600

Layer	Tract ID	Deposit Type	Deposit Model	Mark3 Index	Age	Region	State	90	50	10	5	1	p(0)	Estimators	Area (km2)
HTSG	GB28	Hot-spring Au-Ag	25a	45	Tertiary	Great Basin	NV OR ID	13	18	21	25	29		DCox, Singer, Berger, Ludington, Tingley	161,500
HTSG	GB29	Hot-spring Au-Ag	25a	45	Tertiary	Great Basin	UT ID	0	0	0	1	2		Stoeser, Nutt, Albino, Ludington, Wallace, Nash, Berger, Spanski	41,600
SEDG	GB30	Sediment-hosted Au	26a	17	Phanerozoic	Great Basin	NV CA ID	15	21	27	30	33		DCox, Singer, Berger, Ludington, Tingley	195,100
SEDG	GB31	Sediment-hosted Au	26a	17	Phanerozoic	Great Basin	UT ID	1	2	6	9	16		Stoeser, Nutt, Albino, Ludington, Wallace, Nash, Berger, Spanski	87,400
SCU3	GB32	Sediment-hosted Cu, redbed	30b.2	97	Upper Triassic	Great Basin	UT AZ	0	0	1	1	1	0.9	DCox, Lindsey, Zientek	2,310
SEDX	GB33	Sedimentary exhalative Zn-Pb	31a	13	Paleozoic	Great Basin	NV	0	0	1	3	5	0.9	DCox, Singer, Ludington	27,500
SCU2	GP01	Sediment-hosted Cu, redbed	30b.2	97	Mesozoic	Great Plains	NM OK CO	0	0	1	1	1	0.9	DCox, Lindsey, Zientek	476
SCU3	GP02	Sediment-hosted Cu, redbed	30b.2	97	Upper Triassic	Great Plains	NM TX OK CO	0	1	1	2	5		DCox, Lindsey, Zientek	33,100
SCU1	GP03	Sediment-hosted Cu, redbed	30b.2	97	Pennsylvanian Permian	Great Plains	OK TX KS	1	10	20	20	20		DCox, Lindsey, Zientek	114,200
SCU1	GP04	Sediment-hosted Cu, reduced-facies	30b.1	96	Permian	Great Plains	KS OK TX NM	1	3	10	10	10		DCox, Lindsey, Zientek	215,200
MVTD	GP05	Mississippi Valley, S.E. Missouri Pb-Zn	32a	108	Late Paleozoic	Great Plains	MO IL WI IN MI OH KY TN IA NE KS OK AR TX	2	3	3	6	8		Pratt, Goldhaber, Leach, Vietz, Spanski	702,400
DMCU	LS01	Duluth Cu-Ni-PGE	5a		Middle Proterozoic	Lake Superior	MN WI IA	No estimate made						na	17,500
KVMS	LS02	Massive sulfide, kuroko	28a		Archean	Lake Superior	MN ND SD	No estimate made						na	153,800
KVMS	LS03	Massive sulfide, kuroko	28a	103	Archean	Lake Superior	MN	1	2	3	3	3		Cannon, LeBarge, Schulz, Sims	3,000

Layer	Tract ID	Deposit Type	Deposit Model	Mark3 Index	Age	Region	State	90	50	10	5	1	p(0)	Estimators	Area (km2)
KVMS	LS04	Massive sulfide, kuroko	28a	103	Early Proterozoic	Lake Superior	WI MI	30	65	85	85	85		Cannon, LeBarge, Schulz, Sims	22,900
KVMS	LS05	Massive sulfide, kuroko	28a		Archean	Lake Superior	WI	No estimate made						na	51,300
SCU1	LS06	Sediment-hosted Cu, redbed	30b.2		Pennsylvanian Permian	Lake Superior	KS NE	No estimate made						na	24,300
SCU2	LS07	Sediment-hosted Cu, reduced-facies (modified)	30b.1	102	Middle Proterozoic	Lake Superior	MI WI MN IA NE KS	2	5	10	10	10		Cannon, Nicholson, Woodruff	123,100
NTCU	LS08	Native Cu	NA	99	Middle Proterozoic	Lake Superior	MI MN WI IA NE KS	10	20	40	40	40		Cannon, Nicholson, Woodruff	45,300
MVTD	LS09	Mississippi Valley, S.E. Missouri Pb-Zn	32a	108	Late Paleozoic	Lake Superior	IA MN WI MI SD ND NE KS MO	0	0	0	1	2		Pratt, Goldhaber, Leach, Vietz, Spanski	381,200
LSGQ	LS10	Low-sulfide Au-quartz vein	36a	27	Early Proterozoic	Lake Superior	WI MI	1	3	6	6	6		Cannon, LaBerge, Schulz, Sims	39,600
HMAS	LS11	Low-sulfide Au-quartz vein, Archean	36b	101	Archean	Lake Superior	MN ND SD	2	4	6	6	6		Cannon, LaBerge, Schulz, Sims	171,900
HMAS	LS12	Low-sulfide Au-quartz vein, Archean	36b	101	Archean	Lake Superior	MN MI	2	3	6	6	6		Cannon, LaBerge, Schulz, Sims	4,860
DMCU	NA01	Magmatic Cu	NA		Devonian	Northern Appalachian Mountains	ME NH MA CT	No estimate made						na	2,690
PCU1	NA02	Porphyry Cu	17	4	Ordovician Devonian	Northern Appalachian Mountains	ME NH VT	1	1	2	2	2		Ayuso, Lipin, Robinson, Slack	26,500
PCU2	NA03	Porphyry Cu	17		Mesozoic	Northern Appalachian Mountains	ME NH VT	No estimate made						na	17,000
CVMS	NA04	Massive sulfide, Cyprus	24a		Cambrian	Northern Appalachian Mountains	ME	No estimate made						na	52

Layer	Tract ID	Deposit Type	Deposit Model	Mark3 Index	Age	Region	State	90	50	10	5	1	p(0)	Estimators	Area (km2)
BVMS	NA05	Massive sulfide, Besshi	24b		Cambrian Ordovician	Northern Appalachian Mountains	ME	No estimate made						na	1,000
BVMS	NA06	Massive sulfide, Besshi	24b	98	Cambrian Ordovician	Northern Appalachian Mountains	VT	1	2	2	2	2		Ayuso, Hemley, Lipin, Robinson, Slack	1,600
BVMS	NA07	Massive sulfide, Besshi	24b	98	Silurian Devonian	Northern Appalachian Mountains	VT MA	1	2	2	2	2		Ayuso, Hemley, Lipin, Robinson, Slack	785
BVMS	NA08	Massive sulfide, Besshi	24b	98	Silurian Devonian	Northern Appalachian Mountains	VT	1	2	3	3	3		Ayuso, Lipin, Robinson, Slack	491
BVMS	NA09	Massive sulfide, Besshi	24b	98	Cambrian Ordovician	Northern Appalachian Mountains	VT MA	0	1	2	2	2		Ayuso, Hemley, Lipin, Robinson, Slack	475
BVMS	NA10	Massive sulfide, Besshi	24b	98	Late Proterozoic Ordovician	Northern Appalachian Mountains	MA CT	0	0	1	1	1	0.9	Ayuso, Lipin	954
KVMS	NA11	Massive sulfide, kuroko	28a	104	Ordovician	Northern Appalachian Mountains	ME	1	3	5	5	5		Ayuso, Hemley, Lipin, Robinson, Slack	1,520
KVMS	NA12	Massive sulfide, kuroko	28a	104	Cambrian Ordovician	Northern Appalachian Mountains	ME	1	2	2	2	2		Ayuso, Hemley, Lipin, Slack	2,350
KVMS	NA13	Massive sulfide, kuroko	28a	104	Ordovician Devonian	Northern Appalachian Mountains	ME	1	3	5	5	5		Ayuso, Hemley, Lipin, Slack	76
KVMS	NA14	Massive sulfide, kuroko	28a	104	Ordovician	Northern Appalachian Mountains	ME NH VT MA	4	8	15	15	15		Ayuso, Lipin, Robinson, Slack,	9,860
KVMS	NA15	Massive sulfide, kuroko	28a		Cambrian Ordovician	Northern Appalachian Mountains	ME VT	No estimate made						na	29
KVMS	NA16	Massive sulfide, kuroko	28a	104	Ordovician Silurian	Northern Appalachian Mountains	VT MA	1	2	3	3	3		Ayuso, Lipin, Slack	601

Layer	Tract ID	Deposit Type	Deposit Model	Mark3 Index	Age	Region	State	90	50	10	5	1	p(0)	Estimators	Area (km2)
SEDG	NA17	Sediment-hosted Au	26a		Ordovician	Northern Appalachian Mountains	VT NY	No estimate made						na	3,600
SSPB	NA18	Sandstone-hosted Pb-Zn	30a		Cambrian Ordovician	Northern Appalachian Mountains	VT NY CT MA	No estimate made						na	8,510
SCU1	NA19	Sediment-hosted Cu	30b	63	Early Mesozoic	Northern Appalachian Mountains	MA CT	0	0	1	1	1	0.9	Clark, Robinson	3,600
SEDX	NA20	Sedimentary exhalative Zn-Pb	31a	13	Cambrian Ordovician	Northern Appalachian Mountains	VT NY MA CT	0	1	5	5	5		Clark, Slack	8,240
SEDX	NA21	Sedimentary exhalative Zn-Pb	31a	13	Cambrian Ordovician	Northern Appalachian Mountains	VT NY	0	1	3	3	3		Clark, Slack	5,380
MVTD	NA22	Mississippi Valley, Appalachian Zn	32b		Cambrian Ordovician	Northern Appalachian Mountains	VT NY CT MA	No estimate made						na	10,800
LSGQ	NA23	Low-sulfide Au-quartz vein	36a	27	Ordovician	Northern Appalachian Mountains	VT	2	3	5	5	5		Ayuso, Hemley, Lipin, Robinson, Slack	1,710
LSGQ	NA24	Low-sulfide Au-quartz vein	36a	27	Ordovician	Northern Appalachian Mountains	NH VT	1	1	2	2	2		Ayuso, Hemley, Lipin, Robinson, Slack	2,130
SKC2	NR01	Skarn Cu	18b	8	Mesozoic Tertiary	Northern Rocky Mountains	WA	0	0	0	0	1	0.99	Box, Bookstrom	1,740
SKC2	NR02	Skarn Cu	18b	8	Mesozoic Tertiary	Northern Rocky Mountains	ID WA	0	0	0	0	1	0.99	Box, Bookstrom	21,300
SKZ1	NR03	Skarn Zn-Pb	18c	22	Mesozoic Tertiary	Northern Rocky Mountains	ID WA	0	0	0	0	1	0.99	Box, Bookstrom	21,300
SKZ1	NR04	Skarn Zn-Pb	18c	22	Mesozoic Tertiary	Northern Rocky Mountains	MT WY	0	0	2	4	6	0.80	Elliott, Frishman, Ludington, Wallace, Nash, Berger, Spanski	16,000
SKNG	NR05	Skarn Au, truncated	Bull. 1930	105	Mesozoic	Northern Rocky Mountains	WA	0	1	3	5	7		Box, DCox, Bookstrom	1,740

Layer	Tract ID	Deposit Type	Deposit Model	Mark3 Index	Age	Region	State	90	50	10	5	1	p(0)	Estimators	Area (km2)
SKNG	NR06	Skarn Au, truncated	Bull. 1930	105	Mesozoic	Northern Rocky Mountains	ID WA	0	0	0	0	1	0.99	Box, Bookstrom	21,300
SKNG	NR07	Skarn Au	Bull. 1930	82	Mesozoic Tertiary	Northern Rocky Mountains	MT WY	5	12	20	28	36		Elliott, Frishman, Ludington, Wallace, Nash, Berger, Spanski	16,200
PCU2	NR08	Porphyry Cu (BC-AK)	17	89	Mesozoic	Northern Rocky Mountains	WA	0	0	2	3	4	0.80	Box, Bookstrom	5,580
PCU2	NR09	Porphyry Cu (North America)	17	81	Mesozoic	Northern Rocky Mountains	ID WA	0	0	0	0	1	0.99	Box, Bookstrom	91,700
PCU2	NR10	Porphyry Cu (North America)	17	81	Cretaceous Eocene	Northern Rocky Mountains	MT	0	1	3	6	7		Elliott, Frishman, Ludington, Wallace, Nash, Berger, Spanski	42,100
PCU2	NR11	Porphyry Cu (North America)	17	81	Eocene	Northern Rocky Mountains	MT WY	1	4	6	7	9		Elliott, Frishman, Ludington, Wallace, Nash, Berger, Spanski	14,800
PMR1	NR12	Polymetallic replacement	19a	47	Mesozoic Tertiary	Northern Rocky Mountains	ID WA	0	0	0	0	1	0.99	Box, Bookstrom	21,300
PMR1	NR13	Polymetallic replacement	19a	47	Mesozoic Tertiary	Northern Rocky Mountains	MT WY	1	4	6	8	12		Elliott, Frishman, Ludington, Wallace, Nash, Berger, Spanski	16,000
ALKG	NR14	Alkaline Au-Te	22b	80	Cretaceous	Northern Rocky Mountains	WA	0	0	1	2	4	0.9	Box, Bookstrom	6,420
ALKG	NR15	Alkaline Au-Te	22b	80	Eocene	Northern Rocky Mountains	MT	1	6	11	12	20		Elliott, Frishman, Ludington, Wallace, Nash, Berger, Spanski	5,990
ALKG	NR16	Alkaline Au-Te	22b	80	Early Tertiary	Northern Rocky Mountains	SD WY	1	2	3	4	5		Wallace, Ludington	1,250
BVMS	NR17	Massive sulfide, Besshi	24b	30	Mesozoic	Northern Rocky Mountains	WA	0	0	0	0	1	0.99	Box, Bookstrom	1,660
KVMS	NR18	Massive sulfide, kuroko	28a	93	Permian Triassic	Northern Rocky Mountains	WA	0	0	0	0	1	0.99	Box, Bookstrom	1,740

Layer	Tract ID	Deposit Type	Deposit Model	Mark3 Index	Age	Region	State	90	50	10	5	1	p(0)	Estimators	Area (km2)
KVMS	NR19	Massive sulfide, kuroko	28a	93	Proterozoic	Northern Rocky Mountains	MT	0	0	0	0	1	0.99	Elliott, Frishman, Ludington, Wallace, Nash, Berger, Spanski	1,570
KVMS	NR20	Massive sulfide, kuroko	28a	93	Proterozoic	Northern Rocky Mountains	WY	0	0	1	3	4	0.9	Day, Ludington, Hausel	2,540
QZAD	NR21	Epithermal vein, Comstock	25c	16	Tertiary	Northern Rocky Mountains	WA	1	2	4	5	8		Box, DCox, Bookstrom	3,180
QZAD	NR22	Epithermal vein, Comstock	25c		Tertiary	Northern Rocky Mountains	ID	No estimate made						na	17,600
QZAD	NR23	Epithermal vein, Comstock	25c		Tertiary	Northern Rocky Mountains	ID	No estimate made						na	14,400
QZAD	NR24	Epithermal vein, quartz-adularia	25c + 25d	25	Tertiary	Northern Rocky Mountains	MT	1	3	5	6	9		Elliott, Frishman, Ludington, Wallace, Nash, Berger, Spanski	2,160
QZAD	NR25	Epithermal vein, Comstock	25c	16	Tertiary	Northern Rocky Mountains	WY	0	0	1	4	5	0.9	Elliott, Frishman, Ludington, Wallace, Nash, Berger, Spanski	5,380
QZAL	NR26	Epithermal vein, quartz-alunite	25e	38	Tertiary	Northern Rocky Mountains	MT	0	0	0	0	1	0.99	Elliott, Frishman, Ludington, Wallace, Nash, Berger, Spanski	2,160
HTSG	NR27	Hot-spring Au-Ag	25a		Tertiary	Northern Rocky Mountains	WA	No estimate made						na	3,180
HTSG	NR28	Hot-spring Au-Ag	25a	45	Tertiary	Northern Rocky Mountains	ID	0	2	5	7	8		Box, DCox, Bookstrom	17,600
HTSG	NR29	Hot-spring Au-Ag	25a	45	Tertiary	Northern Rocky Mountains	ID	0	0	2	3	4	0.80	Box, Bookstrom	14,400
HTSG	NR30	Hot-spring Au-Ag	25a	45	Tertiary	Northern Rocky Mountains	MT	1	3	5	6	9		Elliott, Frishman, Ludington, Wallace, Nash, Berger, Spanski	2,170
HTSG	NR31	Hot-spring Au-Ag	25a	45	Tertiary	Northern Rocky Mountains	WY	0	2	3	4	5		Elliott, Frishman, Ludington, Wallace, Nash, Berger, Spanski	5,380

Layer	Tract ID	Deposit Type	Deposit Model	Mark3 Index	Age	Region	State	90	50	10	5	1	p(0)	Estimators	Area (km2)
SEDG	NR32	Sediment-hosted Au	26a	17	Phanerozoic	Northern Rocky Mountains	WA	0	0	0	0	1	0.99	Box, DCox, Bookstrom	2,420
SCU3	NR34	Sediment-hosted Cu, redbed	30b.2		Proterozoic	Northern Rocky Mountains	MT ID WA	No estimate made						na	81,900
SCU3	NR35	Sediment-hosted Cu, redbed	30b.2		Mesozoic	Northern Rocky Mountains	ID WY UT	No estimate made						na	6,310
SCU2	NR36	Sediment-hosted Cu, reduced-facies	30b.1	96	Proterozoic	Northern Rocky Mountains	MT ID WA	0	0	1	3	5	0.90	DCox, Whipple, Spanski, Zientek	81,900
SCU1	NR37	Sediment-hosted Cu, Revett	30b.3	64	Proterozoic	Northern Rocky Mountains	MT ID WA	9	10	15	20	30		DCox, Whipple, Spanski, Zientek	81,900
SEDX	NR38	Sedimentary exhalative Zn-Pb	31a	13	Paleozoic	Northern Rocky Mountains	WA	0	0	1	2	4	0.9	Box, DCox, Bookstrom	4,680
SEDX	NR39	Sedimentary exhalative Zn-Pb	31a	13	Late Proterozoic	Northern Rocky Mountains	MT ID WA	0	2	4	6	8		Whipple, DCox, and others at Spokane	100,100
SEDX	NR40	Sedimentary exhalative Zn-Pb	31a	13	Paleozoic	Northern Rocky Mountains	ID MT	0	0	1	2	3	0.9	Box, DCox, Bookstrom	4,470
SEDX	NR41	Sedimentary exhalative Zn-Pb	31a		Proterozoic	Northern Rocky Mountains	SD	No estimate made						na	352
SEDX	NR42	Sedimentary exhalative Zn-Pb	31a	13	Proterozoic	Northern Rocky Mountains	WY	0	0	0	0	1	0.99	Day, Ludington, Hausel	147
MVTD	NR43	Mississippi Valley, minor	32a + 32b	94	Paleozoic	Northern Rocky Mountains	WA	0	1	1	2	2		Box, DCox, Bookstrom	2,410
LSGQ	NR44	Low-sulfide Au-quartz vein	36a	27	Mesozoic	Northern Rocky Mountains	WA	0	0	0	0	1	0.99	Box, Bookstrom	3,480
LSGQ	NR45	Low-sulfide Au-quartz vein	36a	27	Proterozoic	Northern Rocky Mountains	SD WY	0	1	2	3	8		Wallace, Ludington	3,780
LSGQ	NR46	Low-sulfide Au-quartz vein	36a	27	Proterozoic	Northern Rocky Mountains	WY	0	0	0	1	2		Day, Ludington, Hausel	244
HMAS	NR47	Low-sulfide Au-quartz vein, Archean	36b	101	Archean	Northern Rocky Mountains	WY	0	0	1	4	5	0.9	Day, Ludington, Hausel	2,390

Layer	Tract ID	Deposit Type	Deposit Model	Mark3 Index	Age	Region	State	90	50	10	5	1	p(0)	Estimators	Area (km2)
HMAS	NR48	Homestake stratiform Au	OFR 94-250	100	Archean	Northern Rocky Mountains	MT WY ID	0	2	4	5	6		Elliott, Frishman, Ludington, Wallace, Nash, Berger, Spanski	6,180
HMAS	NR49	Homestake stratiform Au	OFR 94-250	100	Archean	Northern Rocky Mountains	SD	0	1	2	3	4		Wallace, Ludington	246
HMAS	NR50	Homestake stratiform Au	OFR 94-250	100	Archean	Northern Rocky Mountains	WY	0	0	0	0	2	0.98	Day, Ludington, Hausel	152
SKC2	PC01	Skarn Cu	18b	8	Mesozoic Tertiary	Pacific Coast	ID OR WA	0	3	5	9	12		Box, Bookstrom	15,900
SKNG	PC02	Skarn Au, truncated	Bull. 1930	105	Mesozoic	Pacific Coast	ID OR WA	0	0	0	0	1	0.99	Box, Bookstrom	15,900
SKC1	PC03	Skarn Cu	18b	8	Mesozoic	Pacific Coast	CA OR	0	0	0	0	1	0.99	DCox, Ludington	68,900
PCU2	PC04	Porphyry Cu (BC-AK)	17	89	Mesozoic Tertiary	Pacific Coast	WA	3	6	15	15	15		Diggles, DCox, Albino, Church, Ashley, Kleinkopf	30,000
PCU2	PC05	Porphyry Cu (BC-AK)	17	89	Tertiary	Pacific Coast	OR WA	1	3	10	10	10		Diggles, DCox, Albino, Church, Ashley, Kleinkopf	45,100
PCU2	PC06	Porphyry Cu (BC-AK)	17	89	Mesozoic Tertiary	Pacific Coast	OR ID WA	0	0	1	2	5	0.9	Box, DCox, Bookstrom	28,500
PCU2	PC07	Porphyry Cu (North America)	17	81	Mesozoic	Pacific Coast	ID	0	0	0	0	1	0.99	Box, Bookstrom	2,810
PCU1	PC08	Porphyry Cu	17	4	Mesozoic	Pacific Coast	CA OR	0	0	0	1	1		DCox, Ludington	143,100
CVMS	PC09	Massive sulfide, Cyprus	24a	11	Paleozoic Mesozoic	Pacific Coast	OR ID	0	0	0	0	1	0.99	Box, Bookstrom	5,210
CVMS	PC10	Massive sulfide, Cyprus	24a	11	Jurassic	Pacific Coast	CA OR	0	3	4	5	6		Diggles, DCox, Albino, Church, Ashley, Kleinkopf	16,000
BVMS	PC11	Massive sulfide, Besshi	24b	30	Mesozoic	Pacific Coast	CA OR WA	0	0	0	0	1	0.99	Diggles, DCox, Albino, Church, Ashley, Kleinkopf	38,700
KVMS	PC12	Massive sulfide, Sierran kuroko	28a.1	44	Mesozoic	Pacific Coast	WA	0	0	1	2	2	0.9	Diggles, DCox, Albino, Church, Ashley, Kleinkopf	5,720

Layer	Tract ID	Deposit Type	Deposit Model	Mark3 Index	Age	Region	State	90	50	10	5	1	p(0)	Estimators	Area (km2)
KVMS	PC13	Massive sulfide, kuroko	28a	93	Permian	Pacific Coast	OR ID WA	1	3	6	6	6		Box, DCox, Bookstrom	15,900
KVMS	PC14	Massive sulfide, Sierran kuroko	28a.1	44	Jurassic	Pacific Coast	CA OR	0	3	7	15	20		Diggles, DCox, Albino, Church, Ashley, Kleinkopf	15,500
KVMS	PC15	Massive sulfide, kuroko	28a	93	Devonian	Pacific Coast	CA	0	1	2	2	2		Diggles, DCox, Albino, Church, Ashley, Kleinkopf	1,020
KVMS	PC16	Massive sulfide, kuroko	28a	93	Permian	Pacific Coast	CA	0	0	0	0	1	0.99	DCox, Ludington	197
KVMS	PC17	Massive sulfide, Sierran kuroko	28a.1	44	Jurassic	Pacific Coast	CA	2	13	25	25	25		Diggles, DCox, Albino, Church, Ashley, Kleinkopf	6,210
KVMS	PC18	Massive sulfide, Sierran kuroko	28a.1	44	Mesozoic	Pacific Coast	CA	0	0	0	0	1	0.99	Diggles, DCox, Ludington	1,030
QZAD	PC19	Epithermal vein, Comstock	25c	16	Tertiary	Pacific Coast	WA	1	3	4	4	4		Ashley, Evarts	4,600
QZAD	PC20	Epithermal vein, Comstock	25c	16	Tertiary	Pacific Coast	OR	0	1	3	5	5		Ashley, Evarts	82,800
QZAD	PC21	Epithermal vein, Comstock	25c	16	Tertiary	Pacific Coast	OR	2	4	7	11	16		Rytuba, Peters, Raines, Evans, Spanski	31,300
QZAD	PC22	Epithermal vein, Comstock	25c	16	Tertiary	Pacific Coast	OR	2	3	4	6	8		Rytuba, Peters, Raines, Evans, Spanski	10,000
QZAD	PC23	Epithermal vein, Comstock	25c		Tertiary	Pacific Coast	ID	No estimate made						na	3,040
QZAD	PC24	Epithermal vein, Comstock	25c		Tertiary	Pacific Coast	ID	No estimate made						na	1,730
QZAD	PC25	Epithermal vein, Comstock	25c		Tertiary	Pacific Coast	ID	No estimate made						na	17,200
QZAD	PC26	Epithermal vein, quartz-adularia	25c + 25d	25	Tertiary	Pacific Coast	CA NV	0	1	2	2	2		Rytuba, Albino, Diggles, DCox, Sawlan, Ashley, Kleinkopf, Church	41,900
SADO	PC27	Epithermal vein, Sado	25d	28	Tertiary	Pacific Coast	OR WA	0	2	5	8	8		DCox, Albino, Church, Ashley, Diggles, Rytuba, Kleinkopf, Sawlan, Peterson	56,200

Layer	Tract ID	Deposit Type	Deposit Model	Mark3 Index	Age	Region	State	90	50	10	5	1	p(0)	Estimators	Area (km2)
HTSG	PC28	Hot-spring Au-Ag	25a	45	Tertiary	Pacific Coast	WA OR CA	0	1	3	5	7		Ashley, Evarts	185,500
HTSG	PC29	Hot-spring Au-Ag	25a	45	Tertiary	Pacific Coast	OR	2	6	10	16	30		Rytuba, Albino, Diggles, DCox, Sawlan, Ashley, Kleinkopf, Church	31,200
HTSG	PC30	Hot-spring Au-Ag	25a	45	Tertiary	Pacific Coast	OR	6	12	18	24	30		Rytuba, Albino, Diggles, DCox, Sawlan, Ashley, Kleinkopf, Church	10,000
HTSG	PC31	Hot-spring Au-Ag	25a		Tertiary	Pacific Coast	ID	No estimate made						na	3,040
HTSG	PC32	Hot-spring Au-Ag	25a	45	Tertiary	Pacific Coast	ID	0	1	3	5	5		Box, DCox, Bookstrom	1,730
HTSG	PC33	Hot-spring Au-Ag	25a		Tertiary	Pacific Coast	ID	No estimate made						na	17,200
HTSG	PC34	Hot-spring Au-Ag	25a	45	Tertiary	Pacific Coast	CA	1	1	2	2	2		Rytuba, Diggles, Kleinkopf, DCox, Ashley, Sawlan, Church	37,000
HTSG	PC35	Hot-spring Au-Ag	25a	45	Tertiary	Pacific Coast	CA	1	1	3	5	5		Rytuba, Diggles, Kleinkopf, DCox, Ashley, Sawlan, Church	7,820
LSGQ	PC36	Low-sulfide Au-quartz vein	36a		Mesozoic	Pacific Coast	WA	No estimate made						na	21,800
LSGQ	PC37	Low-sulfide Au-quartz vein	36a	27	Mesozoic	Pacific Coast	ID OR WA	0	0	2	4	7	0.80	Box, Bookstrom	8,810
LSGQ	PC38	Low-sulfide Au-quartz vein	36a	27	Mesozoic	Pacific Coast	OR	0	0	1	3	8	0.90	Box, Bookstrom	7,100
LSGQ	PC39	Low-sulfide Au-quartz vein	36a	27	Mesozoic	Pacific Coast	CA OR	0	0	0	0	1	0.99	DCox, Albino, Church, Ashley, Diggles, Peterson	54,300
LSGQ	PC40	Low-sulfide Au-quartz vein	36a	27	Mesozoic	Pacific Coast	CA OR	2	6	9	12	15		DCox, Albino, Church, Ashley, Diggles, Peterson	103,300
BVMS	SA01	Massive sulfide, Besshi	24b	98	Late Proterozoic	Southern Appalachian Mountains	VA NC GA	1	3	5	5	5		Gair, Klein, Koeppen, Lipin, Offield	12,100
BVMS	SA02	Massive sulfide, Besshi	24b		Proterozoic Cambrian	Southern Appalachian Mountains	TN NC	No estimate made						na	1,830

Layer	Tract ID	Deposit Type	Deposit Model	Mark3 Index	Age	Region	State	90	50	10	5	1	p(0)	Estimators	Area (km2)
BVMS	SA03	Massive sulfide, Besshi	24b	98	Late Proterozoic	Southern Appalachian Mountains	TN NC GA	1	3	5	5	5		Gair, Klein, Koeppen	8,570
KVMS	SA04	Massive sulfide, kuroko (Phanerozoic)	28a	104	Cambrian	Southern Appalachian Mountains	MD VA DC	4	8	12	12	12		Gair, Klein, Koeppen, Lipin, Offield	3,490
KVMS	SA05	Massive sulfide, kuroko	28a		Proterozoic Cambrian	Southern Appalachian Mountains	VA NC SC GA	No estimate made						na	62,500
KVMS	SA06	Massive sulfide, kuroko	28a		Proterozoic Cambrian	Southern Appalachian Mountains	NC SC GA AL	No estimate made						na	29,600
KVMS	SA07	Massive sulfide, kuroko (Phanerozoic)	28a	104	Proterozoic Cambrian	Southern Appalachian Mountains	NC SC GA	3	7	12	12	12		Gair, Klein, Koeppen, Offield	4,420
KVMS	SA08	Massive sulfide, kuroko (Phanerozoic)	28a	104	Proterozoic Cambrian	Southern Appalachian Mountains	GA AL	2	5	10	10	10		Gair, Klein, Koeppen, Offield	2,780
KVMS	SA09	Massive sulfide, kuroko (Phanerozoic)	28a	104	Ordovician Devonian	Southern Appalachian Mountains	AL	0	1	3	3	3		Gair, Klein, Koeppen, Offield	187
QZAL	SA10	Epithermal vein, quartz-alunite	25e	38	Proterozoic Cambrian	Southern Appalachian Mountains	VA NC SC GA	2	5	10	10	10		Klein, Koeppen, Offield	25,100
QZAL	SA11	Epithermal vein, quartz-alunite	25e		Proterozoic Cambrian	Southern Appalachian Mountains	VA NC SC GA	No estimate made						na	43,200
QZAL	SA12	Epithermal vein, quartz-alunite	25e		Proterozoic Cambrian	Southern Appalachian Mountains	NC SC GA	No estimate made						na	18,400
HTSG	SA13	Hot-spring Au-Ag	25a		Proterozoic Cambrian	Southern Appalachian Mountains	VA NC	No estimate made						na	7,700
HTSG	SA14	Hot-spring Au-Ag	25a		Proterozoic Cambrian	Southern Appalachian Mountains	VA NC SC GA	No estimate made						na	43,200

Layer	Tract ID	Deposit Type	Deposit Model	Mark3 Index	Age	Region	State	90	50	10	5	1	p(0)	Estimators	Area (km2)
HTSG	SA15	Hot-spring Au-Ag	25a	45	Proterozoic Cambrian	Southern Appalachian Mountains	NC SC GA	3	5	12	12	12		Klein, Koeppen, Offield	18,700
HTSG	SA16	Hot-spring Au-Ag	25a	45	Proterozoic Cambrian	Southern Appalachian Mountains	NC	2	5	8	8	8		Klein, Koeppen, Offield	2,920
HTSG	SA17	Hot-spring Au-Ag	25a		Proterozoic Cambrian	Southern Appalachian Mountains	NC SC GA	No estimate made						na	18,000
SCU1	SA18	Sediment-hosted Cu	30b	63	Early Mesozoic	Southern Appalachian Mountains	PA MD VA NJ NY	1	2	3	3	3		Clark, Robinson	11,600
MVTD	SA19	Mississippi Valley, Appalachian Zn	32b		Late Paleozoic	Southern Appalachian Mountains	NC	No estimate made						na	279
LSGQ	SA20	Low-sulfide Au-quartz vein	36a		Paleozoic	Southern Appalachian Mountains	PA NJ DE MD VA NC TN SC GA AL	No estimate made						na	191,000
LSGQ	SA21	Low-sulfide Au-quartz vein	36a	27	Paleozoic	Southern Appalachian Mountains	MD VA	2	5	8	8	8		Gair, Klein, Koeppen, Offield, Peper	5,400
LSGQ	SA22	Low-sulfide Au-quartz vein	36a	27	Paleozoic	Southern Appalachian Mountains	VA NC SC GA	4	7	11	13	13		Klein, Koeppen, Offield, Peper	92,400
LSGQ	SA23	Low-sulfide Au-quartz vein	36a	27	Paleozoic	Southern Appalachian Mountains	NC SC	2	3	8	8	8		Klein, Koeppen, Lesure, Lipin, Offield, Peper	1,860
LSGQ	SA24	Low-sulfide Au-quartz vein	36a	27	Paleozoic	Southern Appalachian Mountains	NC SC	2	3	7	7	7		Klein, Koeppen, Offield, Peper	744
LSGQ	SA25	Low-sulfide Au-quartz vein	36a	27	Paleozoic	Southern Appalachian Mountains	NC	0	1	2	2	2		Klein, Koeppen, Lipin, Offield, Peper	629
LSGQ	SA26	Low-sulfide Au-quartz vein	36a	27	Paleozoic	Southern Appalachian Mountains	GA	1	2	4	4	4		Klein, Koeppen, Lesure, Lipin, Offield, Peper	1,110

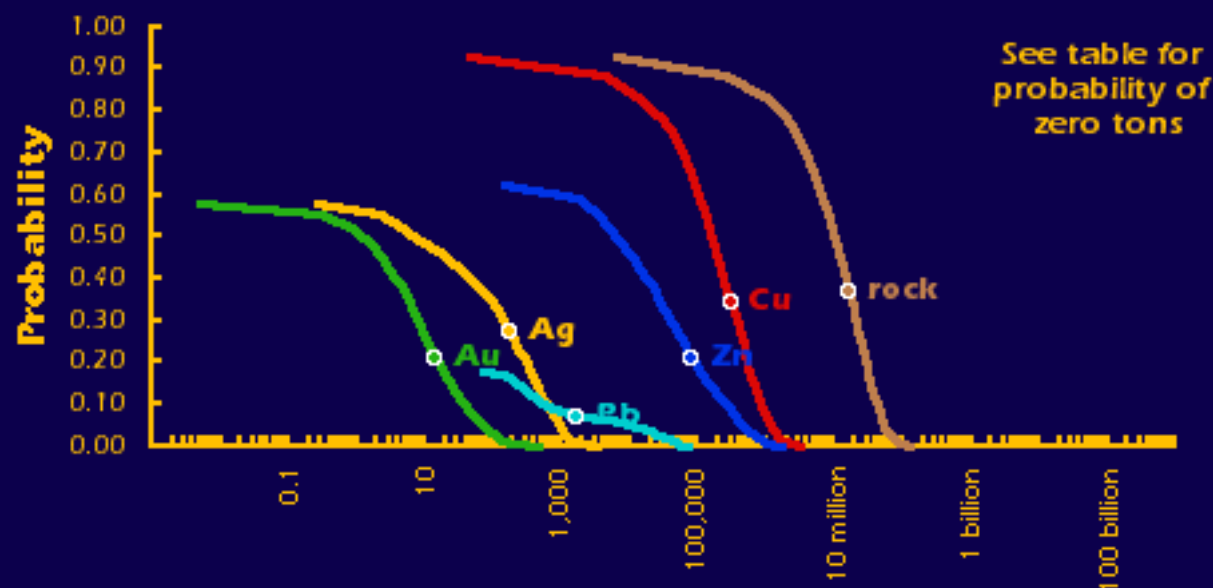
Layer	Tract ID	Deposit Type	Deposit Model	Mark3 Index	Age	Region	State	90	50	10	5	1	p(0)	Estimators	Area (km2)
LSGQ	SA27	Low-sulfide Au-quartz vein	36a	27	Paleozoic	Southern Appalachian Mountains	AL	1	3	4	4	4		Klein, Koeppen, Offield, Peper	756
SKC1	SB01	Skarn Cu	18b	8	Mesozoic Tertiary	Southern Basin and Range	CA	1	2	4	4	4		DCox, Ludington	11,500
SKC1	SB02	Skarn Cu	18b	8	Mesozoic Tertiary	Southern Basin and Range	NV	0	0	0	1	1		DCox, Ludington	1,610
SKC1	SB03	Skarn Cu	18b	8	Mesozoic Tertiary	Southern Basin and Range	AZ	3	30	50	60	60		Church, DCox, LCox, Diggles, Force, Titley	61,700
SKC1	SB04	Skarn Cu	18b	8	Laramide	Southern Basin and Range	NM	0	0	1	2	3	0.9	Wallace, Ludington	20,900
SKZ1	SB05	Skarn Zn-Pb	18c	22	Laramide	Southern Basin and Range	NM	0	0	1	2	3	0.9	Bartsch-Winkler, McLemore, Ludington, Wallace, Nash, Berger, Spanski	20,900
PCU1	SB06	Porphyry Cu	17	4	Mesozoic Tertiary	Southern Basin and Range	CA	0	0	0	2	3		DCox, Ludington	70,200
PCU1	SB07	Porphyry Cu	17	4	Mesozoic	Southern Basin and Range	NV	0	0	1	1	2	0.9	DCox, Ludington	4,680
PCU2	SB08	Porphyry Cu	17	4	Tertiary	Southern Basin and Range	NV	0	0	0	1	2		DCox, Ludington	4,680
PCU1	SB09	Porphyry Cu	17	4	Laramide	Southern Basin and Range	AZ	0	1	2	2	3		Church, DCox, LCox, Diggles, Peters	12,400
PCU1	SB10	Porphyry Cu	17	4	Laramide	Southern Basin and Range	AZ	1	2	5	10	10		Church, DCox, LCox, Diggles, Peters	9,620
PCU1	SB11	Porphyry Cu	17	4	Laramide	Southern Basin and Range	AZ	0	0	1	2	5	0.9	Church, DCox, LCox, Diggles, Peters	29,900

Layer	Tract ID	Deposit Type	Deposit Model	Mark3 Index	Age	Region	State	90	50	10	5	1	p(0)	Estimators	Area (km2)
PCU1	SB12	Porphyry Cu	17		Laramide	Southern Basin and Range	AZ	No estimate made						na	2,400
PCU1	SB13	Porphyry Cu	17	4	Laramide	Southern Basin and Range	AZ	3	15	40	40	40		Church, DCox, LCox, Diggles, Peters	24,800
PCU1	SB14	Porphyry Cu	17	4	Laramide	Southern Basin and Range	AZ	2	5	15	15	15		Church, DCox, LCox, Diggles, Peters	38,500
PCU1	SB15	Porphyry Cu	17	4	Laramide	Southern Basin and Range	NM	2	3	4	6	9		Bartsch-Winkler, McLemore, Ludington, Wallace, Nash, Berger, Spanski	23,100
PCU2	SB16	Porphyry Cu	17	4	Middle Tertiary	Southern Basin and Range	NM	0	0	0	1	2		Bartsch-Winkler, McLemore, Ludington, Wallace, Nash, Berger, Spanski	23,100
PCUG	SB17	Porphyry Cu-Au	20c	34	Laramide	Southern Basin and Range	AZ	0	1	2	3	4	0.15	Carlson, Church, DCox, LCox, Diggles, Force, Guthrie, Kamilli. Kleinkopf, Richard, Titley, Wilt,	117,600
PMR1	SB18	Polymetallic replacement + skarn Zn-Pb	19a + 18c	92	Mesozoic Tertiary	Southern Basin and Range	CA	0	1	2	5	7		DCox, Albino, Church, Ashley, Diggles, Kleinkopf	11,500
PMR1	SB19	Polymetallic replacement + skarn Zn-Pb	19a + 18c	92	Mesozoic Tertiary	Southern Basin and Range	NV	0	1	2	2	2		DCox, Ludington	1,610
PMR1	SB20	Polymetallic replacement + skarn Zn-Pb	19a + 18c	92	Mesozoic Tertiary	Southern Basin and Range	AZ	1	3	5	7	10		Church, DCox, LCox, Diggles, Force, Titley	61,700
PMR1	SB21	Polymetallic replacement	19a	47	Laramide	Southern Basin and Range	NM	4	5	6	8	10		Bartsch-Winkler, McLemore, Ludington, Wallace, Nash, Berger, Spanski	20,900
PMR2	SB22	Polymetallic replacement	19a	47	Middle Tertiary	Southern Basin and Range	NM	3	7	12	14	18		Bartsch-Winkler, McLemore, Ludington, Wallace, Nash, Berger, Spanski	20,900
DSDG	SB23	Distal disseminated Ag-Au	Bull. 2004	18	Mesozoic Tertiary	Southern Basin and Range	NV	0	0	1	1	2	0.9	DCox, Ludington	1,610

Layer	Tract ID	Deposit Type	Deposit Model	Mark3 Index	Age	Region	State	90	50	10	5	1	p(0)	Estimators	Area (km2)
DSDG	SB24	Distal disseminated Ag-Au	Bull. 2004	18	Mesozoic Tertiary	Southern Basin and Range	AZ	1	2	5	7	10		Church, DCox, LCox, Diggles, Force, Titley	61,700
KVMS	SB25	Massive sulfide, kuroko	28a	93	Proterozoic	Southern Basin and Range	AZ	0	1	3	7	7		Church, DCox, LCox, Diggles, Kleinkopf, Peters	3,560
KVMS	SB26	Massive sulfide, kuroko	28a	93	Proterozoic	Southern Basin and Range	NM	0	0	0	0	1	0.99	Bartsch-Winkler, McLemore, Ludington, Wallace, Nash, Berger, Spanski	1,740
QZAD	SB27	Epithermal vein, Comstock	25c	16	Tertiary	Southern Basin and Range	CA	0	1	2	2	2		Tosdal, Rytuba, Theodore, Ludington, Bagby, Jachens, Singer	39,700
QZAD	SB28	Epithermal vein, Comstock	25c	16	Tertiary	Southern Basin and Range	NV	0	1	1	2	2		DCox, Ludington	4,170
QZAD	SB29	Epithermal vein, Comstock	25c	16	Tertiary	Southern Basin and Range	AZ	1	5	7	10	15		Carlson, Church, DCox, LCox, Diggles, Kamilli, Kleinkopf, Richard, Titley	59,600
QZAD	SB30	Epithermal vein, quartz-adularia	25c + 25d	25	Tertiary	Southern Basin and Range	NM	2	3	6	7	8		Bartsch-Winkler, McLemore, Ludington, Wallace, Nash, Berger, Spanski	13,500
SADO	SB31	Epithermal vein, Sado	25d	28	Tertiary	Southern Basin and Range	CA	0	0	1	1	2	0.9	Tosdal, Rytuba, Theodore, Ludington, Bagby, Jachens, Singer	39,700
QZAL	SB32	Epithermal vein, quartz-alunite	25e	38	Tertiary	Southern Basin and Range	CA	0	0	2	3	4	0.80	Tosdal, Rytuba, Theodore, Ludington, Bagby, Jachens, Singer	39,700
QZAL	SB33	Epithermal vein, quartz-alunite	25e	38	Tertiary	Southern Basin and Range	NV	0	1	2	4	5		DCox, Ludington	4,170
QZAL	SB34	Epithermal vein, quartz-alunite	25e		Tertiary	Southern Basin and Range	AZ	No estimate made						na	59,600
QZAL	SB35	Epithermal vein, quartz-alunite	25e	38	Tertiary	Southern Basin and Range	NM	0	0	1	2	4	0.9	Bartsch-Winkler, McLemore, Ludington, Wallace, Nash, Berger, Spanski	13,500

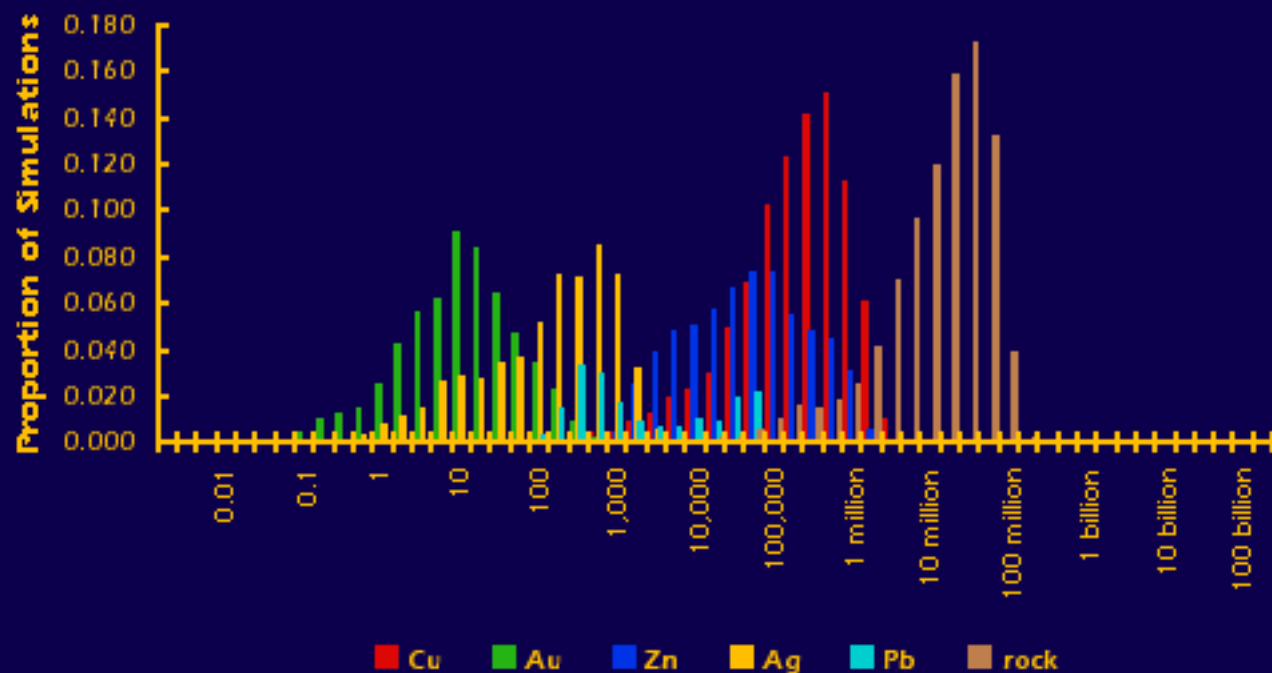
Layer	Tract ID	Deposit Type	Deposit Model	Mark3 Index	Age	Region	State	90	50	10	5	1	p(0)	Estimators	Area (km2)
HTSG	SB36	Hot-spring Au-Ag	25a	45	Tertiary	Southern Basin and Range	CA	0	2	4	6	8		Tosdal, Rytuba, Theodore, Ludington, Bagby, Jachens, Singer	39,700
HTSG	SB37	Hot-spring Au-Ag	25a	45	Tertiary	Southern Basin and Range	CA	1	3	5	5	5		Rytuba, Diggles, Kleinkopf, DCox, Ashley, Sawlan, Church	7,110
HTSG	SB38	Hot-spring Au-Ag	25a	45	Tertiary	Southern Basin and Range	NV	0	1	1	1	2		DCox, Ludington	4,170
HTSG	SB39	Hot-spring Au-Ag	25a		Tertiary	Southern Basin and Range	AZ	No estimate made						na	74,300
SEDG	SB40	Sediment-hosted Au	26a	17	Phanerozoic	Southern Basin and Range	NV CA	0	0	0	0	1	0.99	DCox, Ludington	18,700

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK01

The Mark3 Index is 11: **Massive sulfide, Cyprus**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 10 or more deposits.

There is a 1% or greater chance of 12 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	2,400	0	0	0	0	130,000
0.50	160,000	1	6,100	8	0	10,000,000
0.10	840,000	36	244,000	610	560	41,000,000
0.05	1,200,000	73	460,000	900	11,000	53,000,000
mean	310,000	14	79,000	180	1,700	16,000,000
Probability of mean	0.34	0.21	0.21	0.27	0.07	0.37
Probability of zero	0.07	0.42	0.38	0.42	0.82	0.07

The tract ID is AK01The Mark3 Index is 11: **Massive sulfide, Cyprus**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 10 or more deposits.

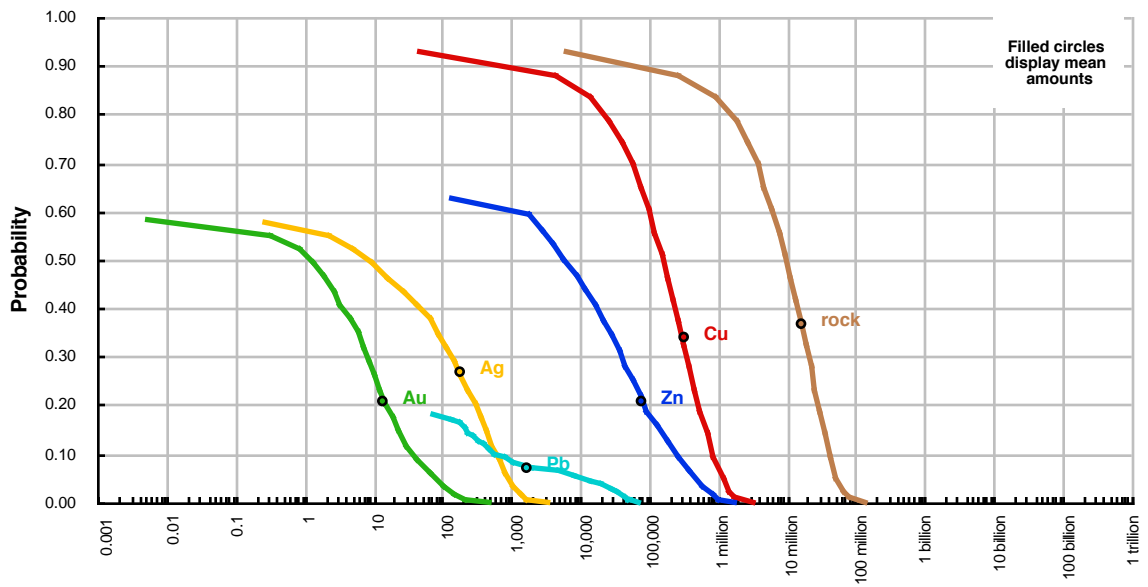
There is a 1% or greater chance of 12 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

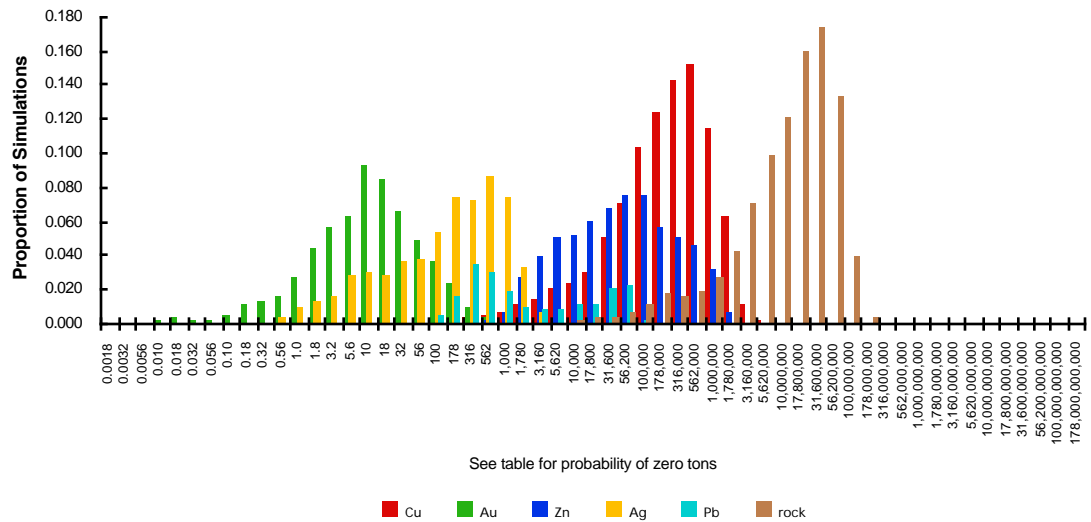
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	2,400	0	0	0	0	130,000
0.50	160,000	1	6,100	8	0	10,000,000
0.10	840,000	36	244,000	610	560	41,000,000
0.05	1,200,000	73	460,000	900	11,000	53,000,000
mean	310,000	14	79,000	180	1,700	16,000,000
Probability of mean	0.34	0.21	0.21	0.27	0.07	0.37
Probability of zero	0.07	0.42	0.38	0.42	0.82	0.07

The tract ID is AK01

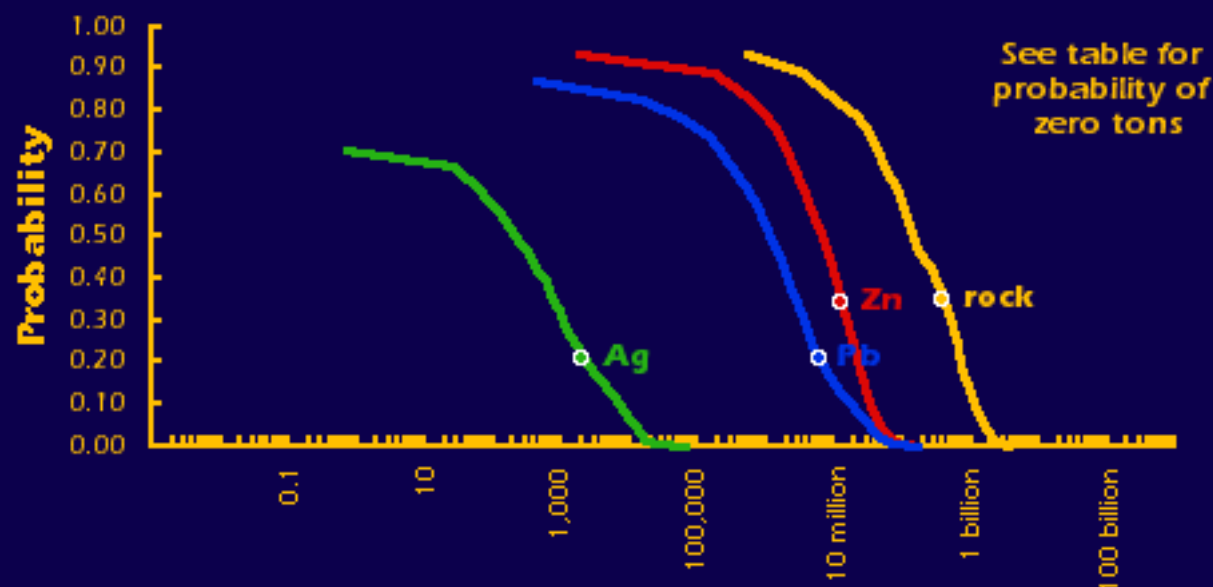
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

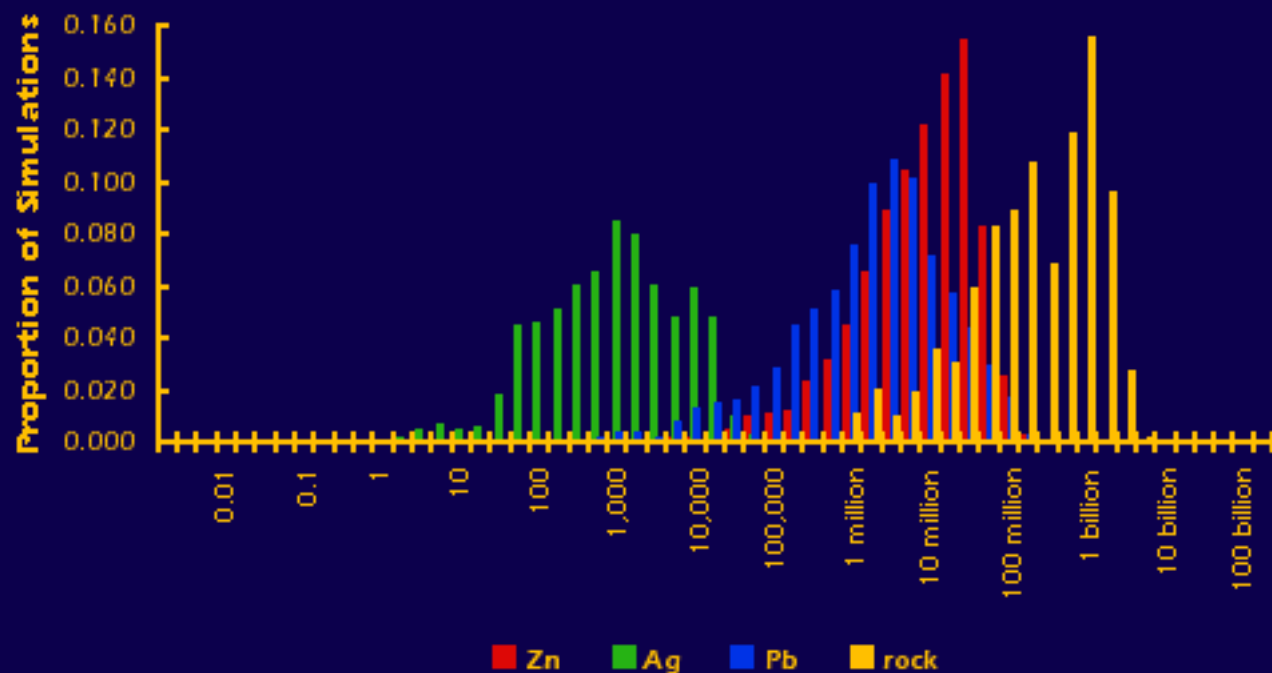


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK02

The Mark3 Index is 108: **Mississippi Valley**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

There is a 1% or greater chance of 6 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Zn	Ag	Pb	rock
0.95	0	0	0	0
0.90	93,000	0	0	2,000,000
0.50	6,500,000	210	1,200,000	150,000,000
0.10	33,000,000	6,900	16,300,000	1,100,000,000
0.05	46,000,000	11,000	31,000,000	1,600,000,000
mean	13,000,000	2,100	6,100,000	400,000,000
Probability of mean	0.34	0.21	0.21	0.35
Probability of zero	0.07	0.30	0.13	0.07

The tract ID is AK02The Mark3 Index is 108: **Mississippi Valley**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

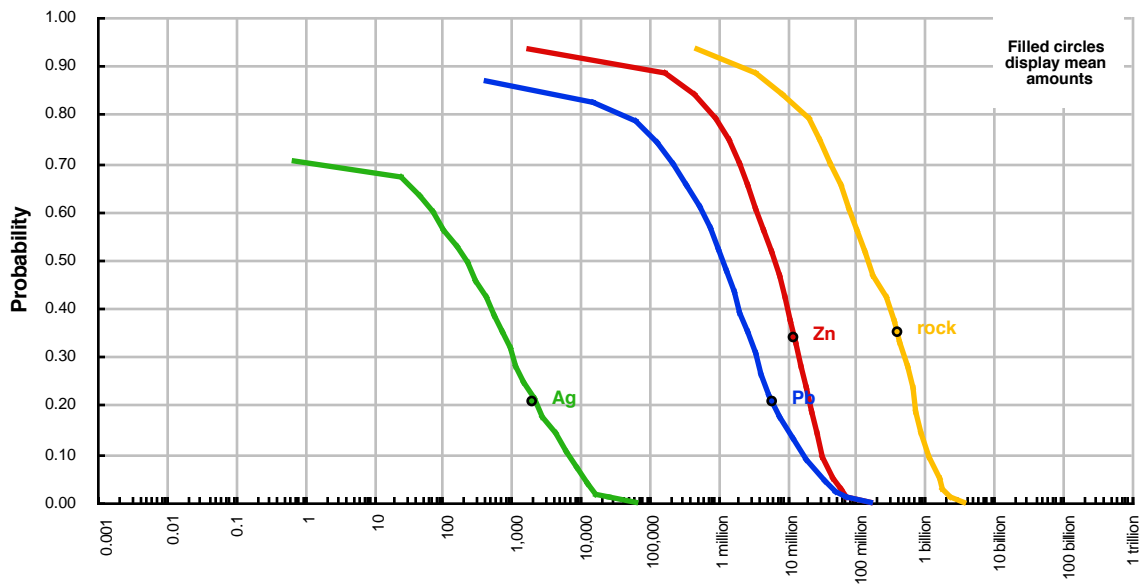
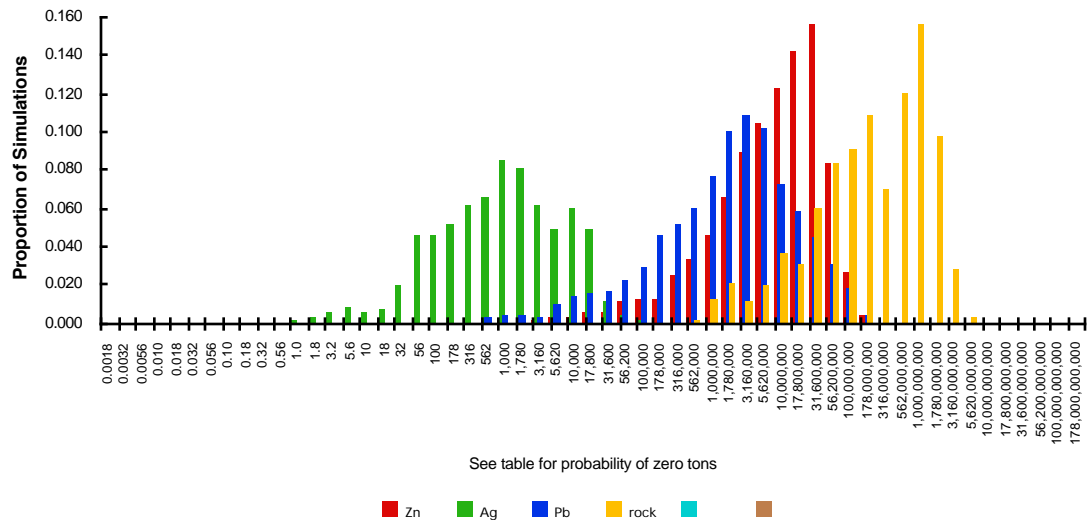
There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

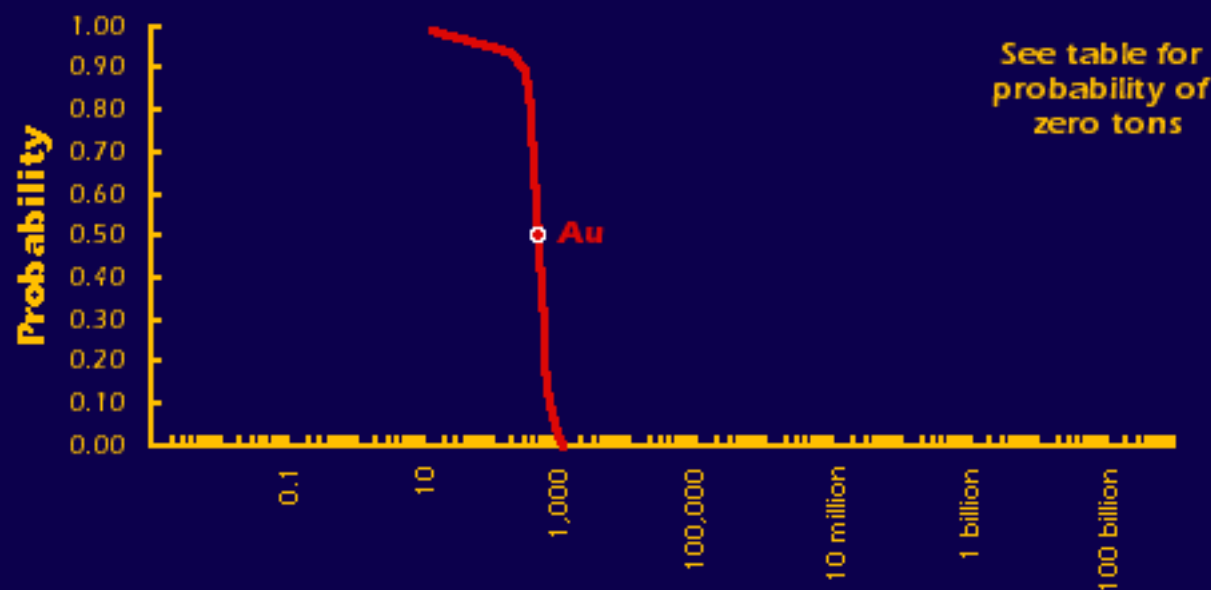
There is a 1% or greater chance of 6 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Zn	Ag	Pb	rock	0	0
0.95	0	0	0	0	0	0
0.90	93,000	0	0	2,000,000	0	0
0.50	6,500,000	210	1,200,000	150,000,000	0	0
0.10	33,000,000	6,900	16,300,000	1,100,000,000	0	0
0.05	46,000,000	11,000	31,000,000	1,600,000,000	0	0
mean	13,000,000	2,100	6,100,000	400,000,000	0	0
Probability of mean	0.34	0.21	0.21	0.35	0.00	0.00
Probability of zero	0.07	0.30	0.13	0.07	0.00	0.00

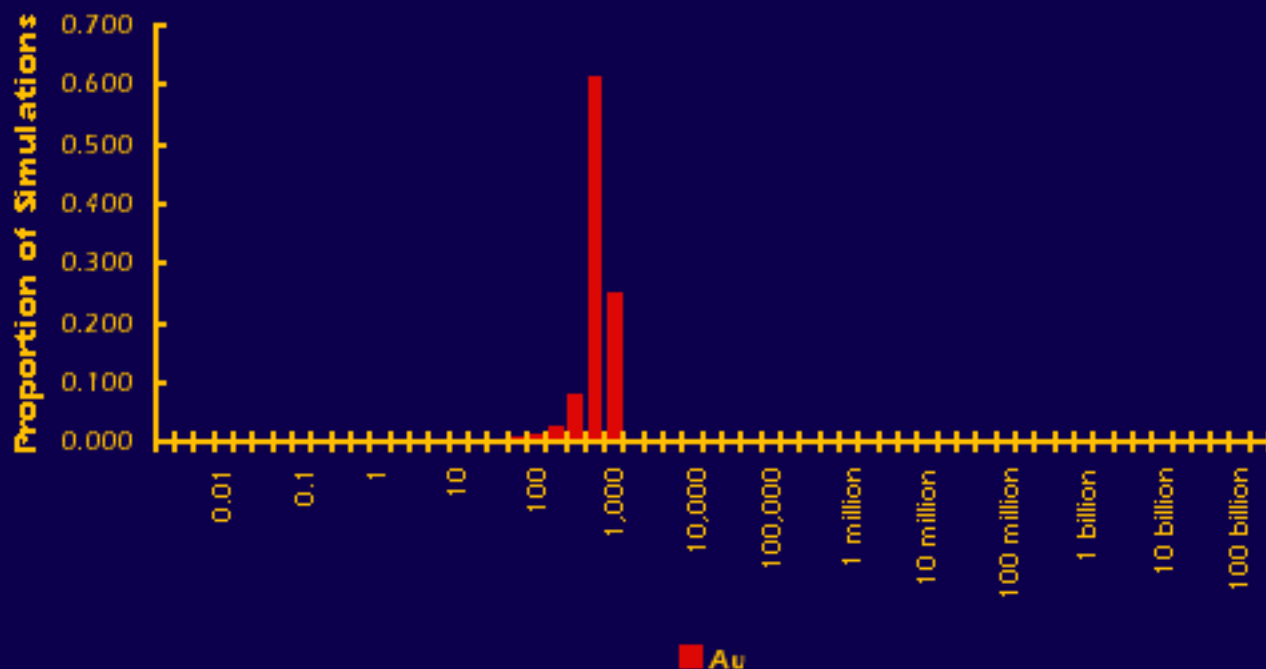
The tract ID is AK02**Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK03

The Mark3 Index is 115: **Pure Au, direct estimate**

There is a 90% or greater chance of 10 or more million ozs.
There is a 50% or greater chance of 15 or more million ozs.
There is a 10% or greater chance of 20 or more million ozs.
There is a 5% or greater chance of 25 or more million ozs.
There is a 1% or greater chance of 30 or more million ozs.

Estimated amounts of gold (metric tons)

quantile	Au
0.95	150
0.90	290
0.50	470
0.10	660
0.05	790
mean	470
Probability of mean	0.50
Probability of zero	0.01

The tract ID is AK03The Mark3 Index is 115: **Pure Au, direct estimate**

There is a 90% or greater chance of 10 or more deposits.

There is a 50% or greater chance of 15 or more deposits.

There is a 10% or greater chance of 20 or more deposits.

There is a 5% or greater chance of 25 or more deposits.

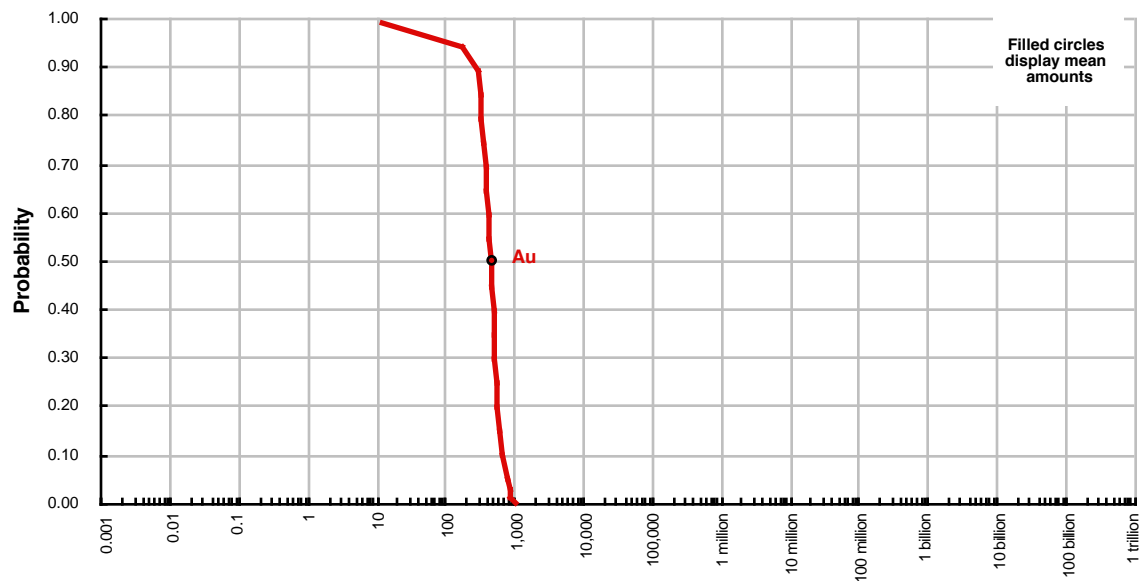
There is a 1% or greater chance of 30 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

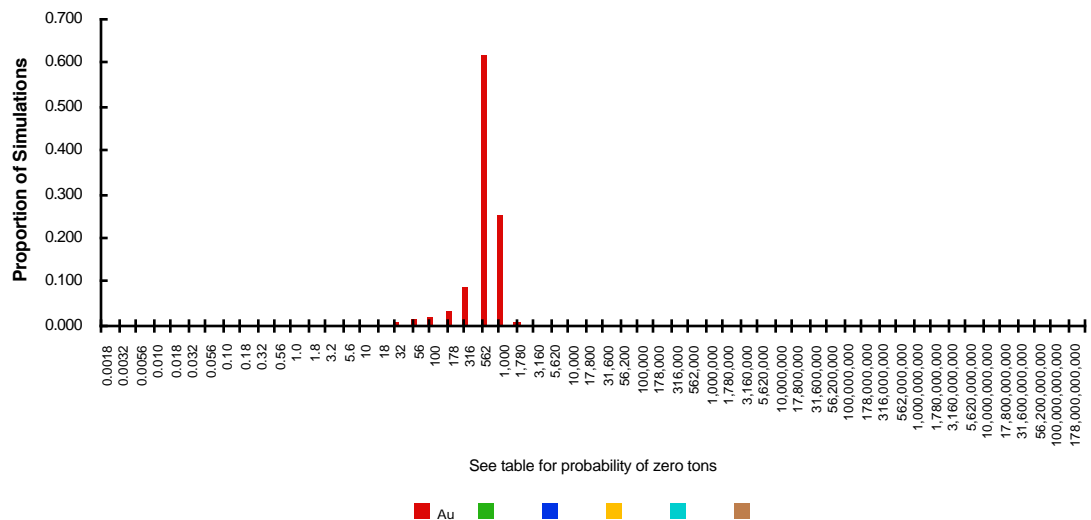
quantile	Au	0	0	0	0	0
0.95	150	0	0	0	0	0
0.90	290	0	0	0	0	0
0.50	470	0	0	0	0	0
0.10	660	0	0	0	0	0
0.05	790	0	0	0	0	0
mean	470	0	0	0	0	0
Probability of mean	0.50	0.00	0.00	0.00	0.00	0.00
Probability of zero	0.01	0.00	0.00	0.00	0.00	0.00

The tract ID is AK03

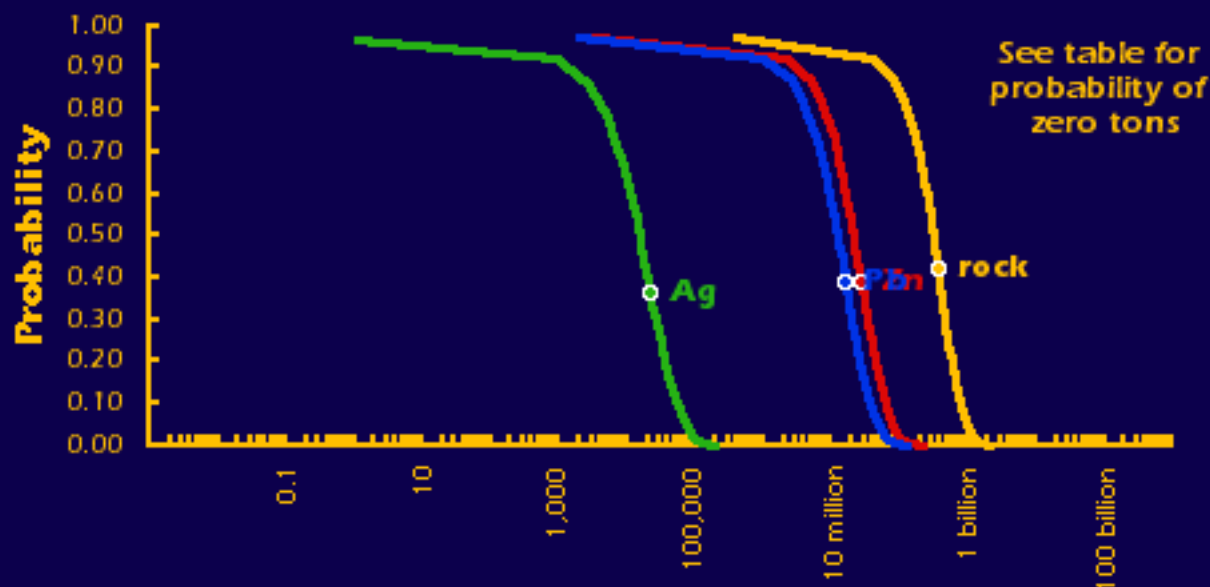
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

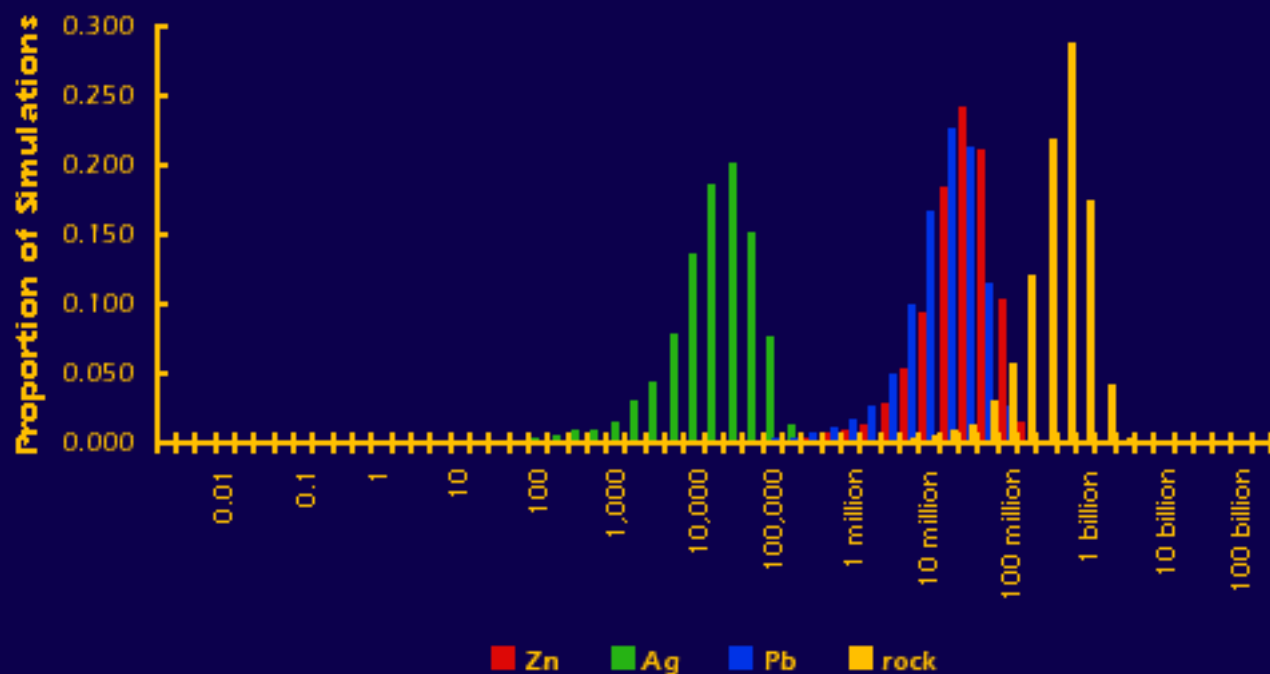


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK04

The Mark3 Index is 13: **Sedimentary exhalative Zn-Pb**

There is a 90% or greater chance of 3 or more deposits.

There is a 50% or greater chance of 8 or more deposits.

There is a 10% or greater chance of 12 or more deposits.

There is a 5% or greater chance of 17 or more deposits.

There is a 1% or greater chance of 30 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Zn	Ag	Pb	rock
0.95	660,000	220	330,000	13,000,000
0.90	3,400,000	1,500	1,700,000	58,000,000
0.50	21,000,000	15,000	13,000,000	320,000,000
0.10	60,000,000	53,000	37,000,000	760,000,000
0.05	77,000,000	71,000	47,000,000	970,000,000
mean	28,000,000	22,000	17,000,000	380,000,000
Probability of mean	0.39	0.36	0.39	0.42
Probability of zero	0.03	0.03	0.03	0.03

The tract ID is AK04The Mark3 Index is 13: **Sedimentary exhalative Zn-Pb**

There is a 90% or greater chance of 3 or more deposits.

There is a 50% or greater chance of 8 or more deposits.

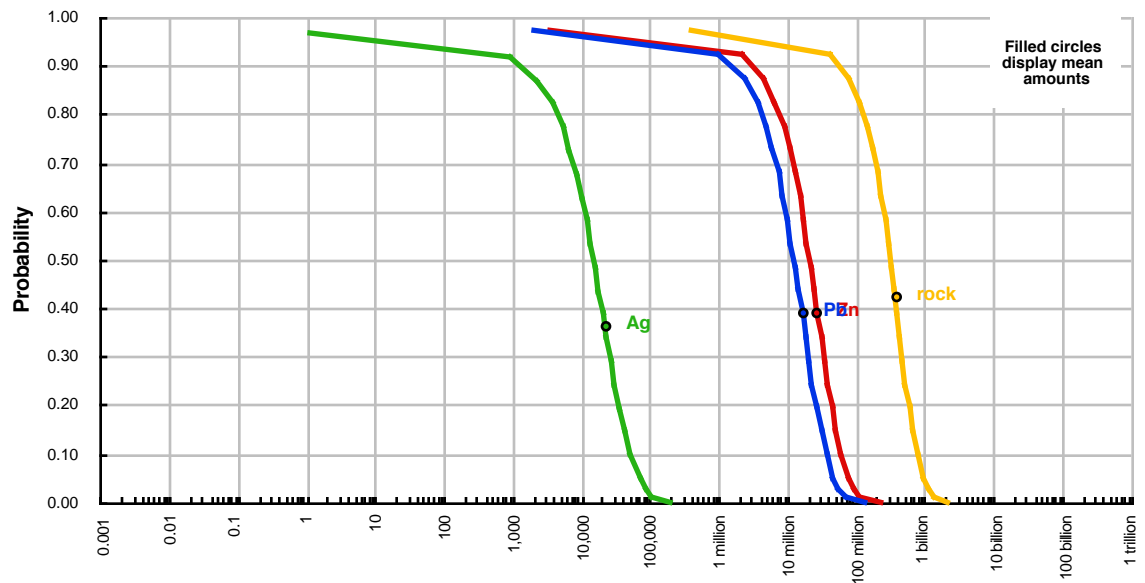
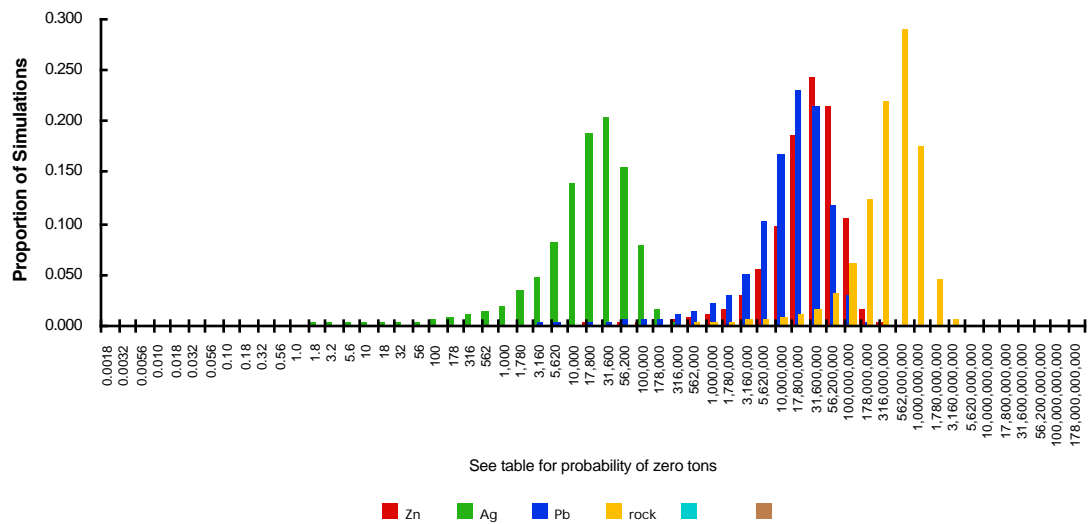
There is a 10% or greater chance of 12 or more deposits.

There is a 5% or greater chance of 17 or more deposits.

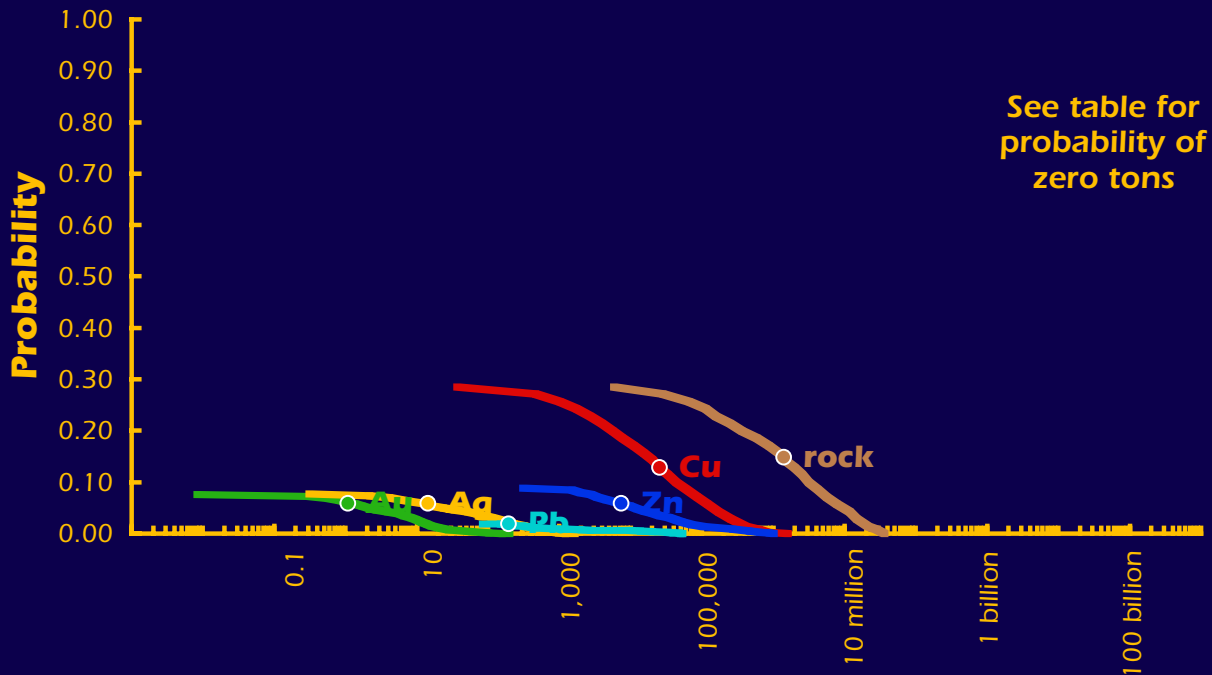
There is a 1% or greater chance of 30 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Zn	Ag	Pb	rock	0	0
0.95	660,000	220	330,000	13,000,000	0	0
0.90	3,400,000	1,500	1,700,000	58,000,000	0	0
0.50	21,000,000	15,000	13,000,000	320,000,000	0	0
0.10	60,000,000	53,000	37,000,000	760,000,000	0	0
0.05	77,000,000	71,000	47,000,000	970,000,000	0	0
mean	28,000,000	22,000	17,000,000	380,000,000	0	0
Probability of mean	0.39	0.36	0.39	0.42	0.00	0.00
Probability of zero	0.03	0.03	0.03	0.03	0.00	0.00

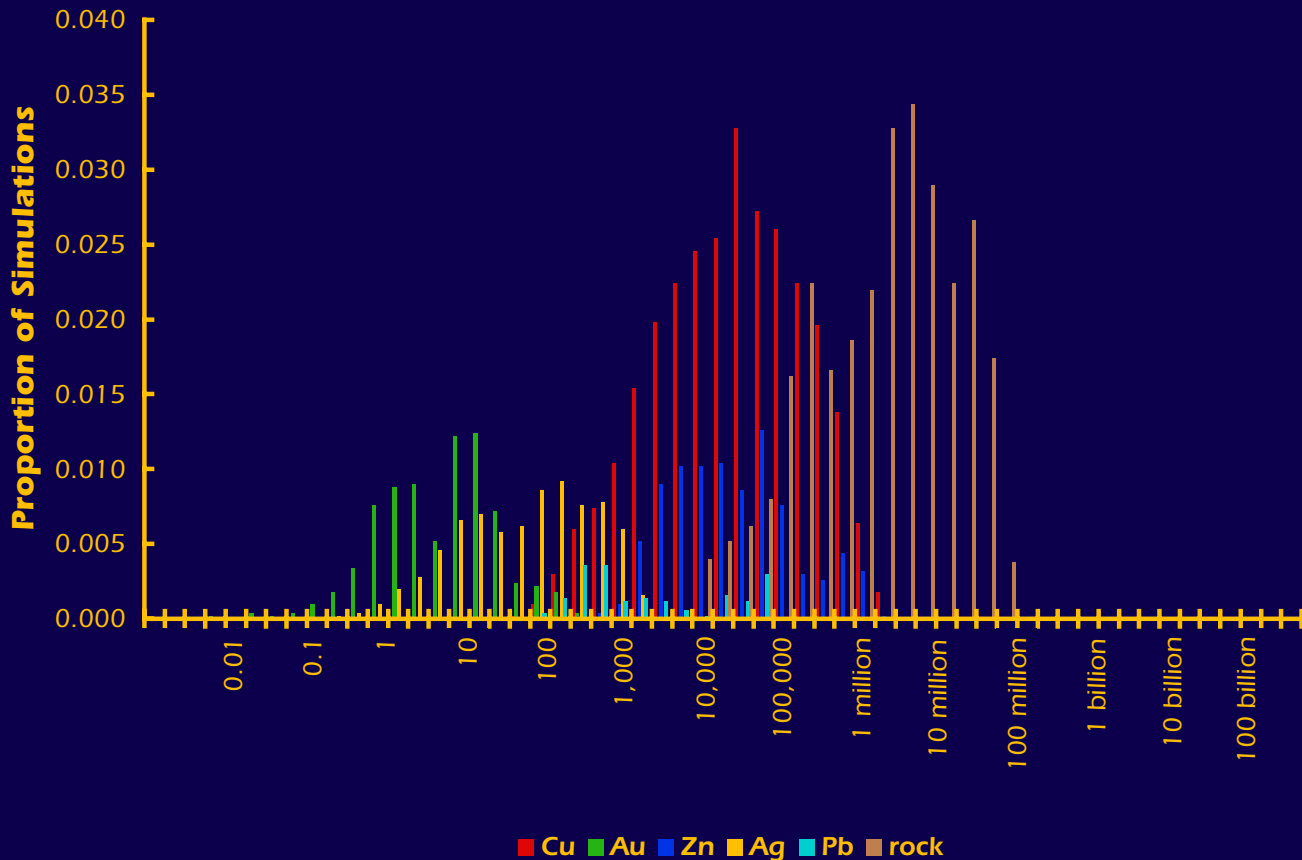
The tract ID is AK04**Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-AP03

The Mark3 Index is 11:

Massive sulfide, Cyprus

There is a 90% or greater chance of 0 or more deposits.
There is a 50% or greater chance of 0 or more deposits.
There is a 10% or greater chance of 1 or more deposits.
There is a 5% or greater chance of 1 or more deposits.
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	44,000	0	0	0	0	3,100,000
0.05	140,000	2	12,000	24	0	9,400,000
mean	25,000	1	7,200	14	190	1,400,000
Probability of mean	0.13	0.06	0.06	0.06	0.02	0.15
Probability of zero	0.71	0.92	0.91	0.92	0.98	0.71

The tract ID is AK-AP03The Mark3 Index is 11: **Massive sulfide, Cyprus**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

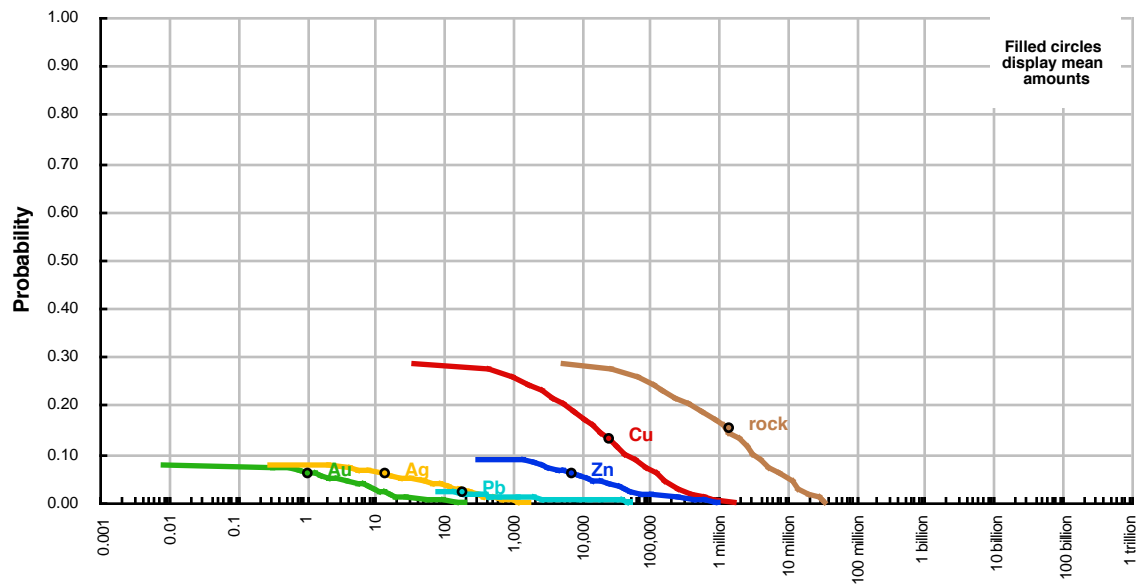
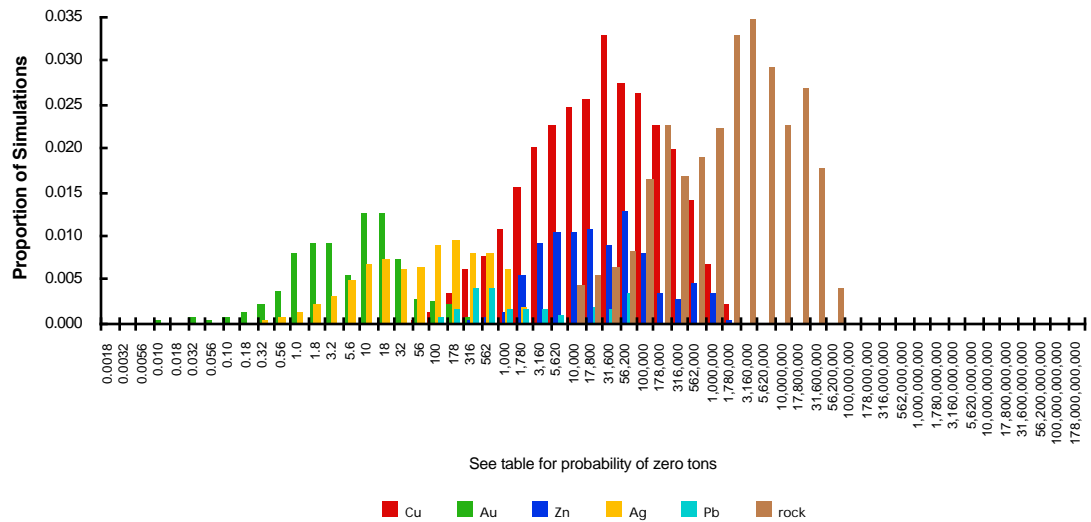
There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

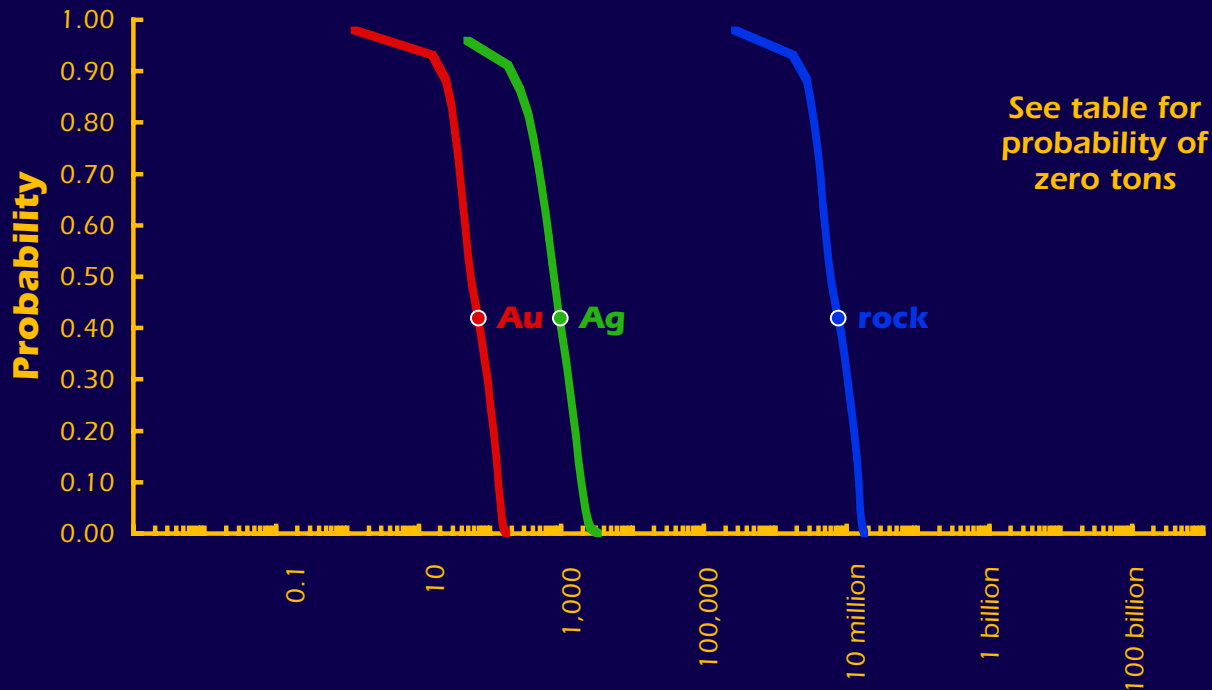
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	44,000	0	0	0	0	3,100,000
0.05	140,000	2	12,000	24	0	9,400,000
mean	25,000	1	7,200	14	190	1,400,000
Probability of mean	0.13	0.06	0.06	0.06	0.02	0.15
Probability of zero	0.71	0.92	0.91	0.92	0.98	0.71

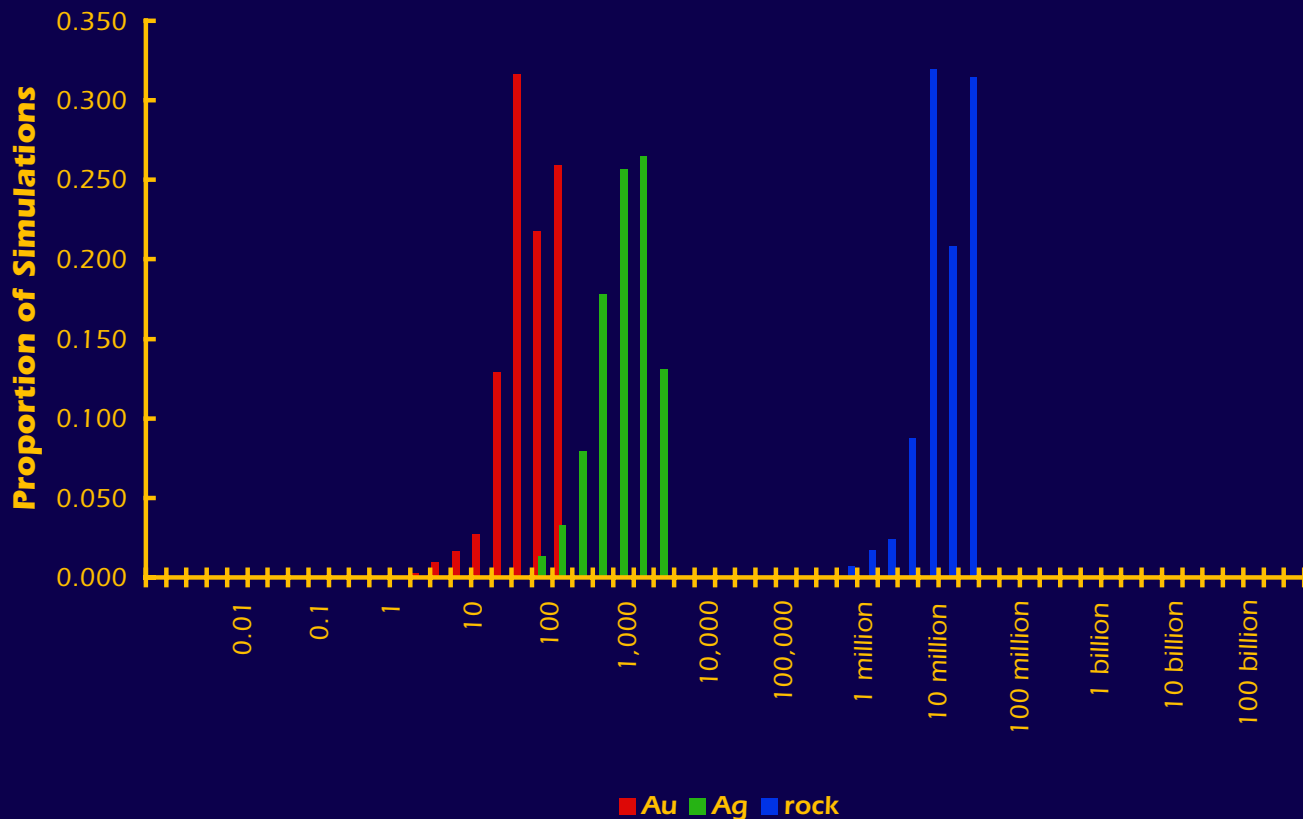
The tract ID is AK-AP03**Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-AP04

The Mark3 Index is 119:

Epithermal vein, generic

There is a 90% or greater chance of 5 or more deposits.

There is a 50% or greater chance of 10 or more deposits.

There is a 10% or greater chance of 27 or more deposits.

There is a 5% or greater chance of 27 or more deposits.

There is a 1% or greater chance of 27 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	10	90	1,200,000
0.90	22	210	2,600,000
0.50	53	790	5,900,000
0.10	130	1,900	14,800,000
0.05	140	2,200	16,000,000
mean	67	940	7,500,000
Probability of mean	0.42	0.42	0.42
Probability of zero	0.02	0.04	0.02

The tract ID is AK-AP04The Mark3 Index is 119: **Epithermal vein, generic**

There is a 90% or greater chance of 5 or more deposits.

There is a 50% or greater chance of 10 or more deposits.

There is a 10% or greater chance of 27 or more deposits.

There is a 5% or greater chance of 27 or more deposits.

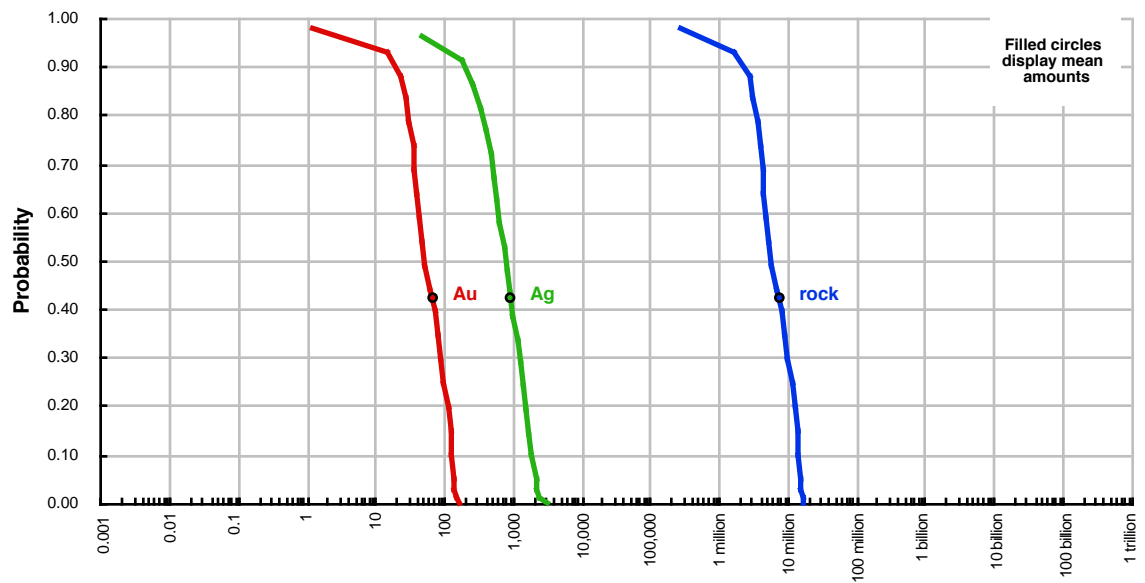
There is a 1% or greater chance of 27 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

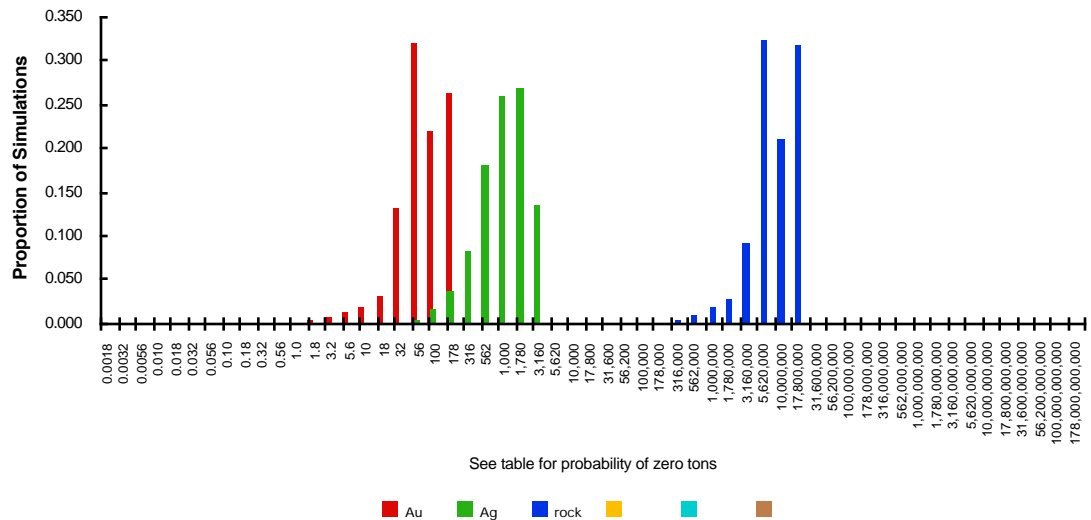
quantile	Au	Ag	rock	0	0	0
0.95	10	90	1,200,000	0	0	0
0.90	22	210	2,600,000	0	0	0
0.50	53	790	5,900,000	0	0	0
0.10	130	1,900	14,800,000	0	0	0
0.05	140	2,200	16,000,000	0	0	0
mean	67	940	7,500,000	0	0	0
Probability of mean	0.42	0.42	0.42	0.00	0.00	0.00
Probability of zero	0.02	0.04	0.02	0.00	0.00	0.00

The tract ID is AK-AP04

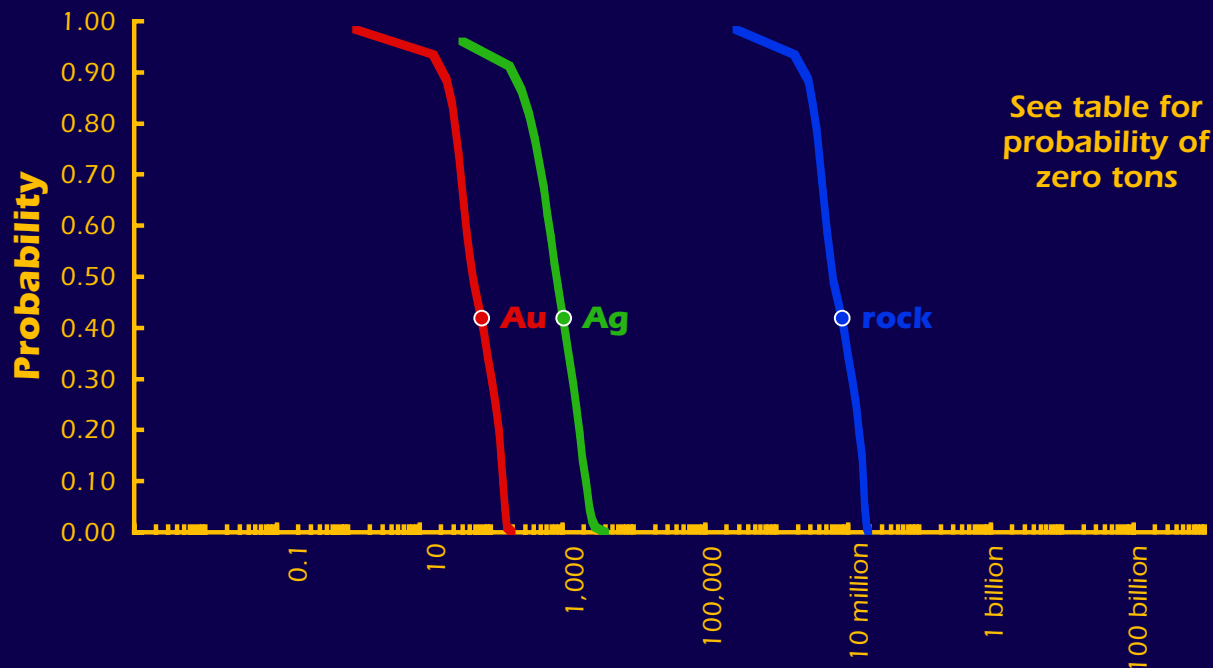
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

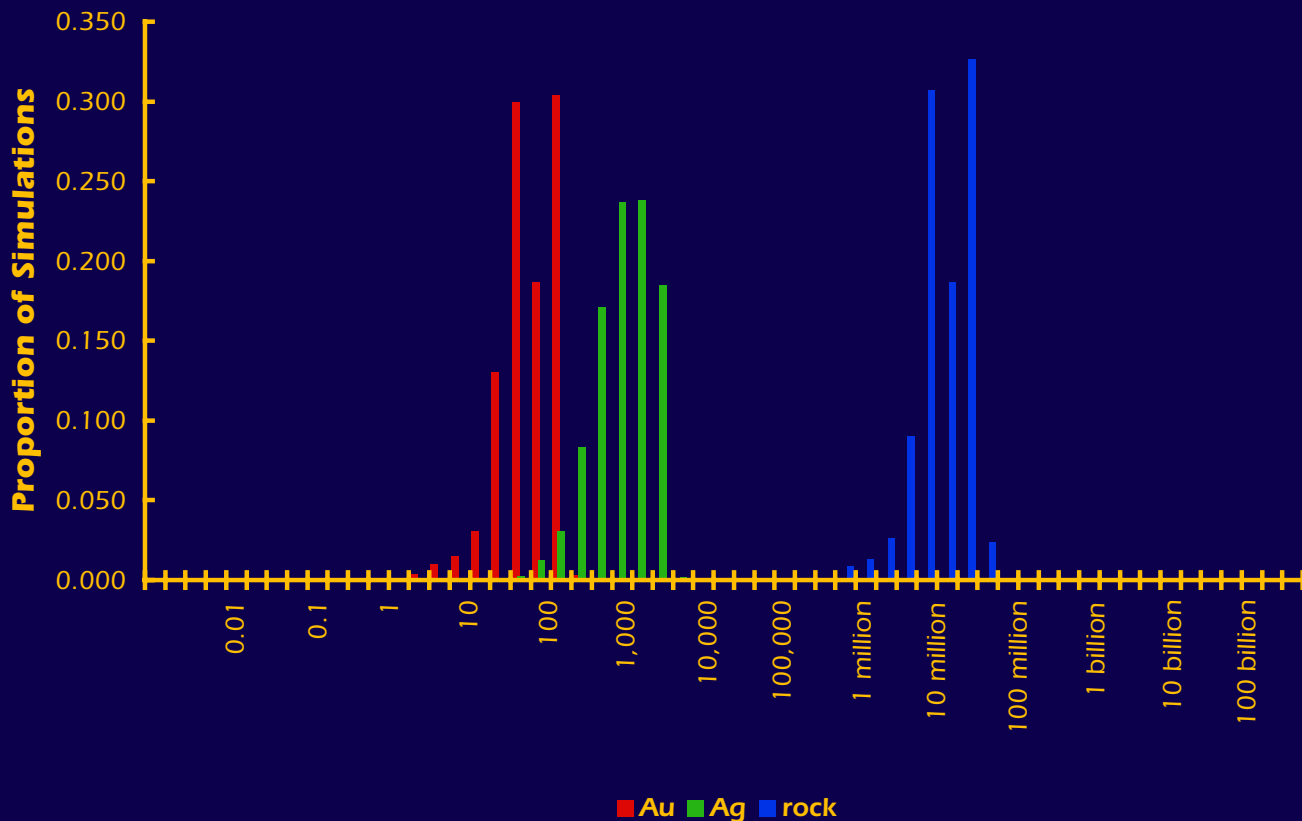


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-AP05

The Mark3 Index is 119:

Epithermal vein, generic

There is a 90% or greater chance of 5 or more deposits.

There is a 50% or greater chance of 10 or more deposits.

There is a 10% or greater chance of 30 or more deposits.

There is a 5% or greater chance of 30 or more deposits.

There is a 1% or greater chance of 30 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	12	93	1,300,000
0.90	22	210	2,600,000
0.50	55	820	6,100,000
0.10	150	2,100	16,500,000
0.05	160	2,400	17,000,000
mean	73	1,000	8,200,000
Probability of mean	0.42	0.42	0.42
Probability of zero	0.02	0.04	0.02

The tract ID is AK-AP05The Mark3 Index is 119: **Epithermal vein, generic**

There is a 90% or greater chance of 5 or more deposits.

There is a 50% or greater chance of 10 or more deposits.

There is a 10% or greater chance of 30 or more deposits.

There is a 5% or greater chance of 30 or more deposits.

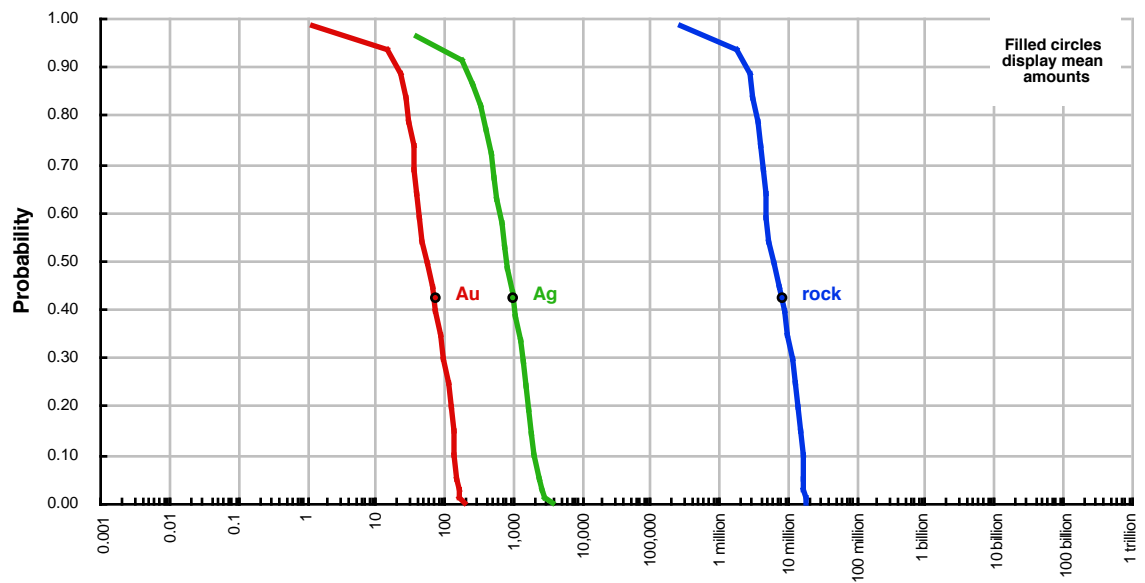
There is a 1% or greater chance of 30 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

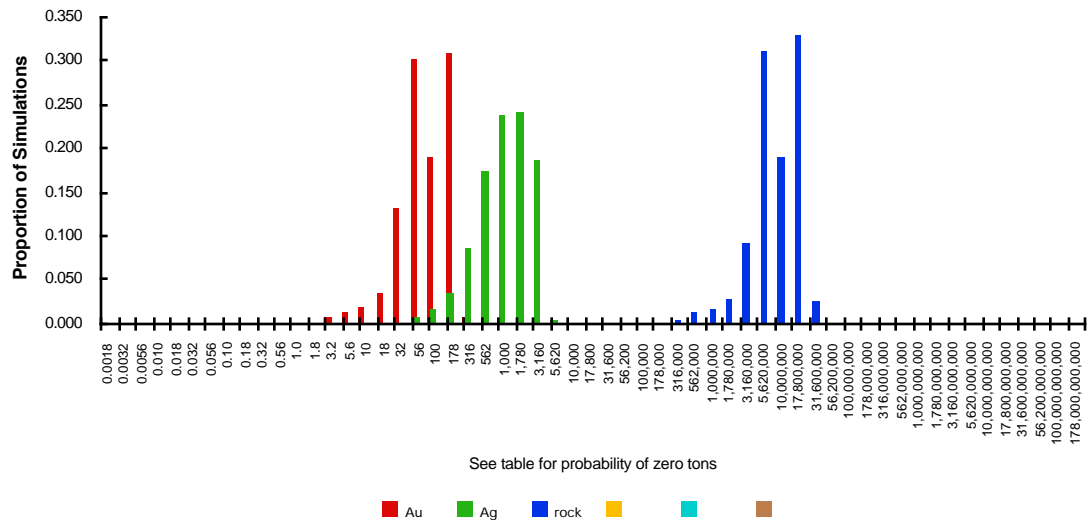
quantile	Au	Ag	rock	0	0	0
0.95	12	93	1,300,000	0	0	0
0.90	22	210	2,600,000	0	0	0
0.50	55	820	6,100,000	0	0	0
0.10	150	2,100	16,500,000	0	0	0
0.05	160	2,400	17,000,000	0	0	0
mean	73	1,000	8,200,000	0	0	0
Probability of mean	0.42	0.42	0.42	0.00	0.00	0.00
Probability of zero	0.02	0.04	0.02	0.00	0.00	0.00

The tract ID is AK-AP05

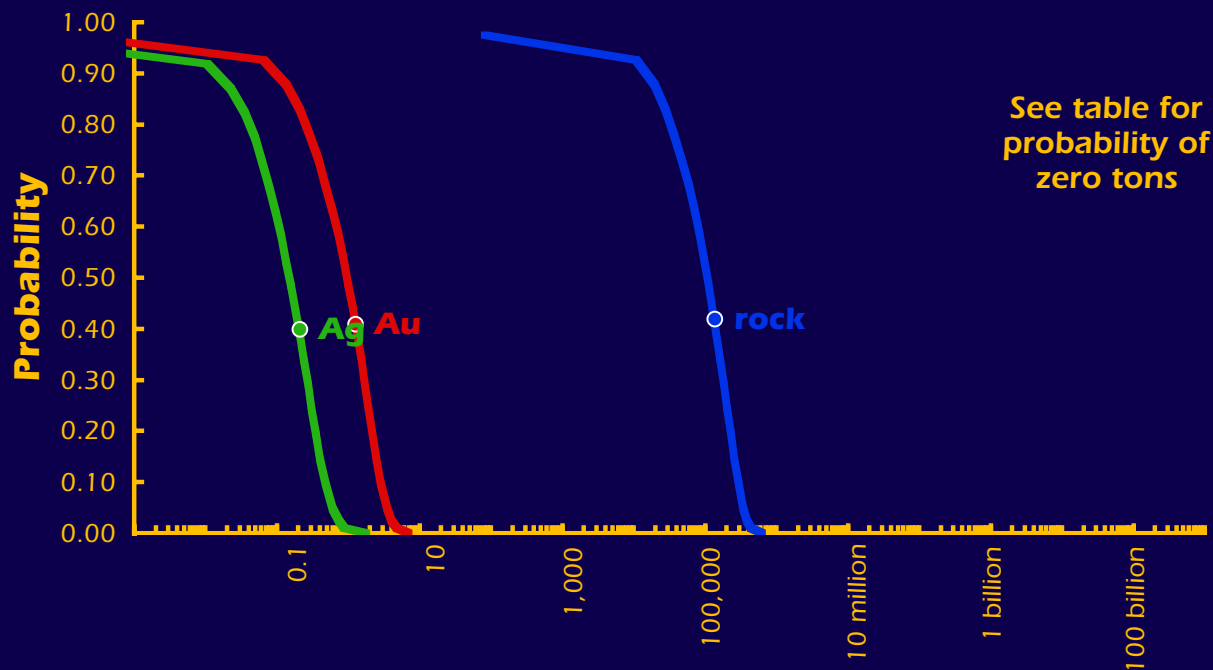
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

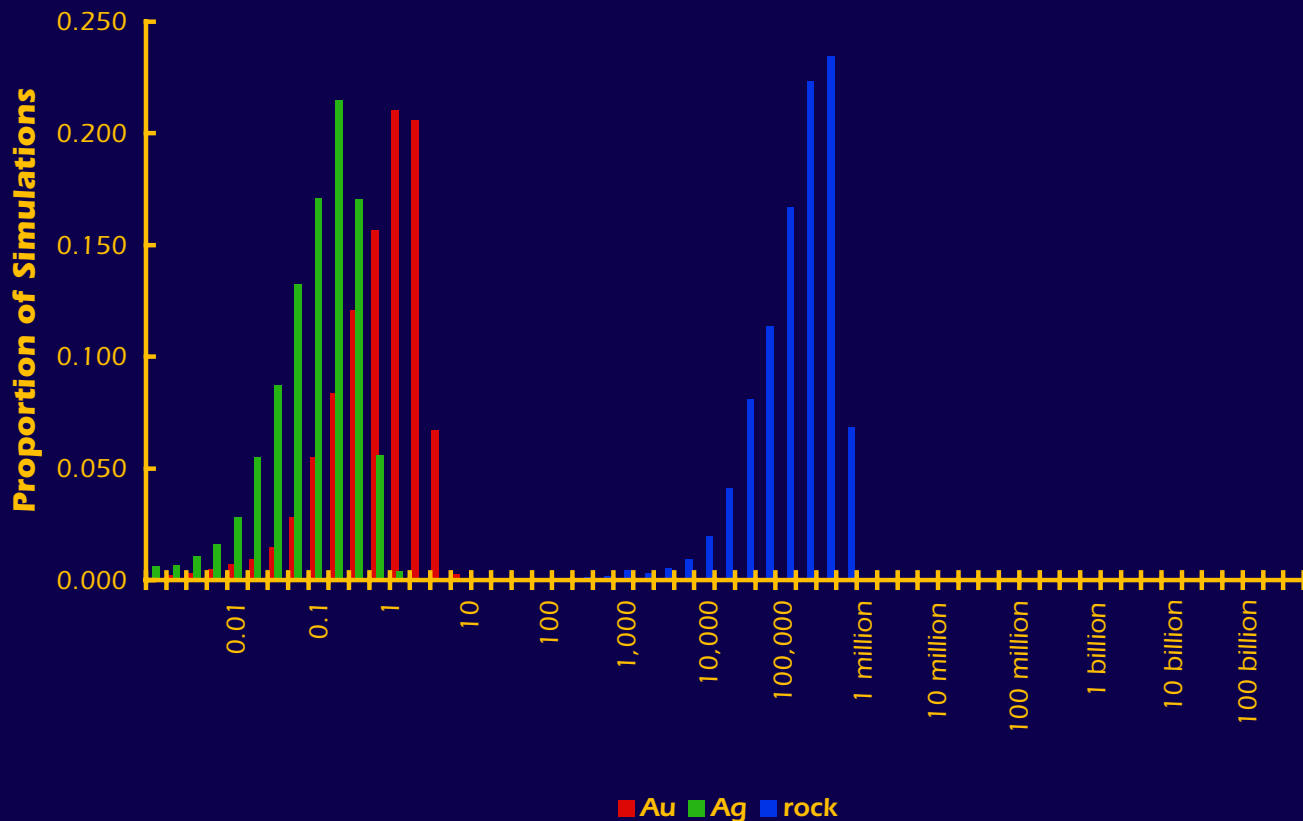


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-AP07

The Mark3 Index is 26:

Low-sulfide Au-quartz vein, Chugach

There is a 90% or greater chance of 4 or more deposits.

There is a 50% or greater chance of 10 or more deposits.

There is a 10% or greater chance of 30 or more deposits.

There is a 5% or greater chance of 30 or more deposits.

There is a 1% or greater chance of 30 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	5,500
0.90	0	0	16,000
0.50	1	0	110,000
0.10	3	1	289,000
0.05	3	1	340,000
mean	1	0	130,000
Probability of mean	0.41	0.40	0.42
Probability of zero	0.02	0.03	0.02

The tract ID is AK-AP07The Mark3 Index is 26: **Low-sulfide Au-quartz vein, Chugach**

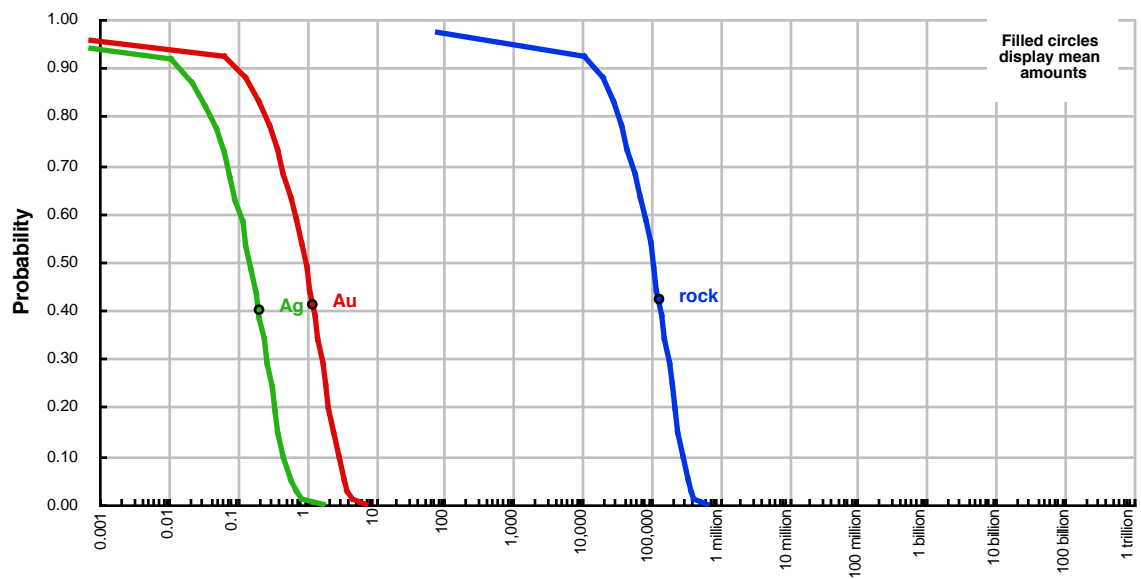
There is a 90% or greater chance of 4 or more deposits.
 There is a 50% or greater chance of 10 or more deposits.
 There is a 10% or greater chance of 30 or more deposits.
 There is a 5% or greater chance of 30 or more deposits.
 There is a 1% or greater chance of 30 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

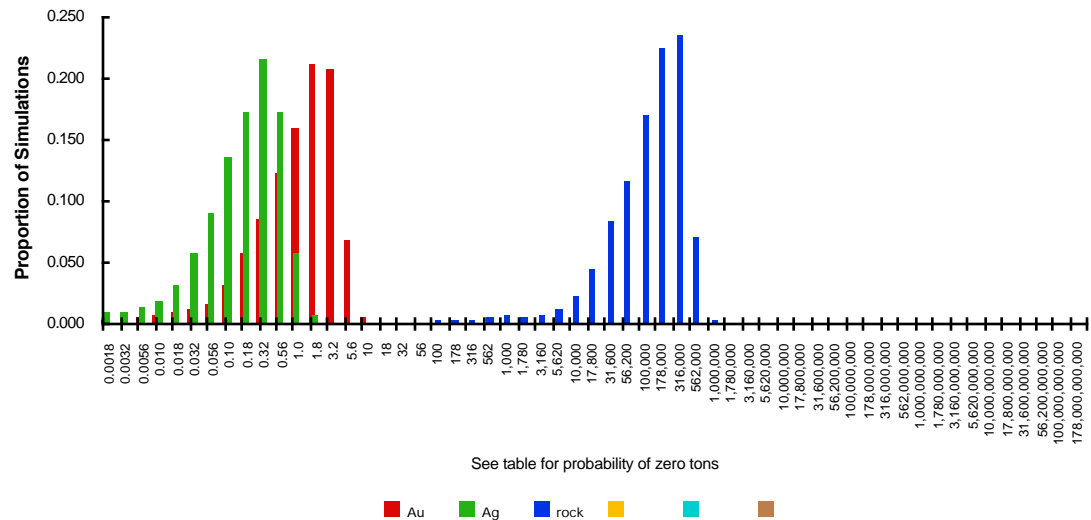
quantile	Au	Ag	rock	0	0	0
0.95	0	0	5,500	0	0	0
0.90	0	0	16,000	0	0	0
0.50	1	0	110,000	0	0	0
0.10	3	1	289,000	0	0	0
0.05	3	1	340,000	0	0	0
mean	1	0	130,000	0	0	0
Probability of mean	0.41	0.40	0.42	0.00	0.00	0.00
Probability of zero	0.02	0.03	0.02	0.00	0.00	0.00

The tract ID is AK-AP07

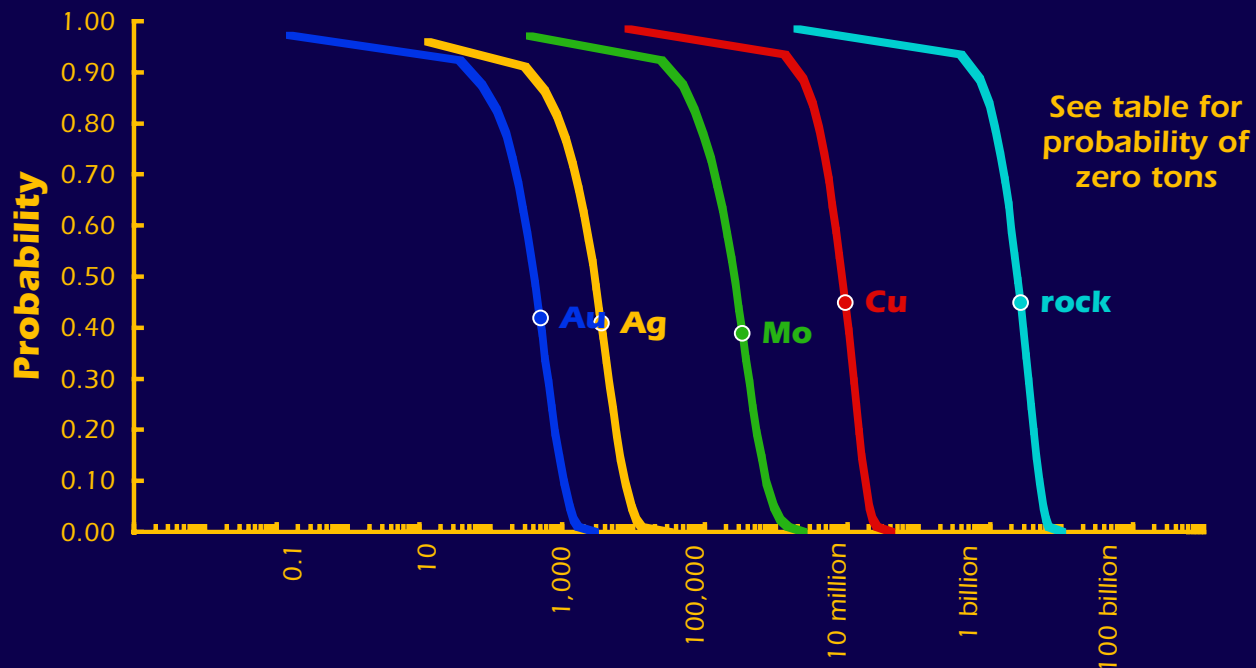
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

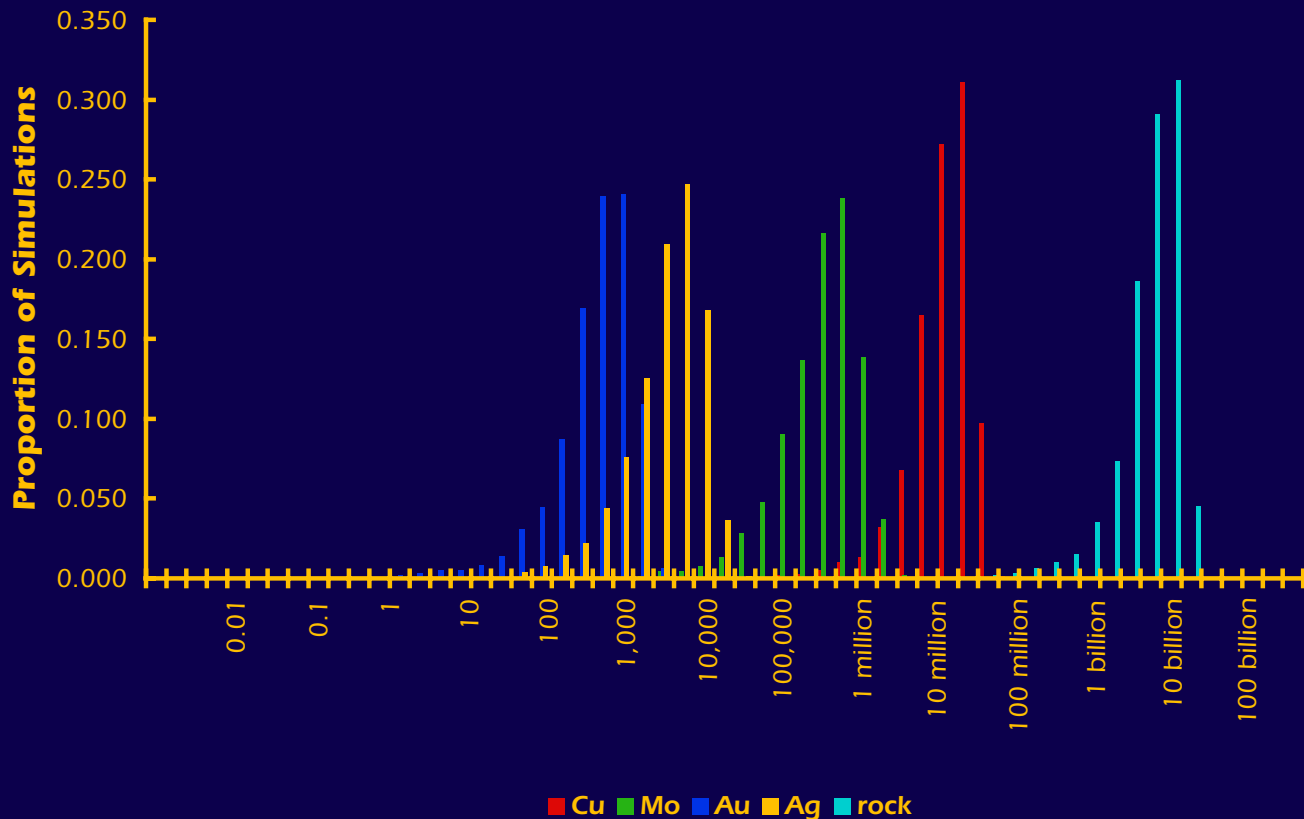


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-AP09

The Mark3 Index is 89:

Porphyry Cu (BC-AK)

There is a 90% or greater chance of 5 or more deposits.
There is a 50% or greater chance of 13 or more deposits.
There is a 10% or greater chance of 25 or more deposits.
There is a 5% or greater chance of 25 or more deposits.
There is a 1% or greater chance of 25 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	970,000	11,000	12	84	280,000,000
0.90	2,200,000	36,000	54	370	640,000,000
0.50	8,500,000	260,000	410	2,900	2,400,000,000
0.10	18,000,000	730,000	1,050	7,600	4,900,000,000
0.05	20,000,000	930,000	1,300	9,400	5,600,000,000
mean	9,300,000	340,000	490	3,500	2,600,000,000
Probability of mean	0.45	0.39	0.42	0.41	0.45
Probability of zero	0.02	0.03	0.03	0.04	0.02

The tract ID is AK-AP09The Mark3 Index is 89: **Porphyry Cu (BC-AK)**

There is a 90% or greater chance of 5 or more deposits.

There is a 50% or greater chance of 13 or more deposits.

There is a 10% or greater chance of 25 or more deposits.

There is a 5% or greater chance of 25 or more deposits.

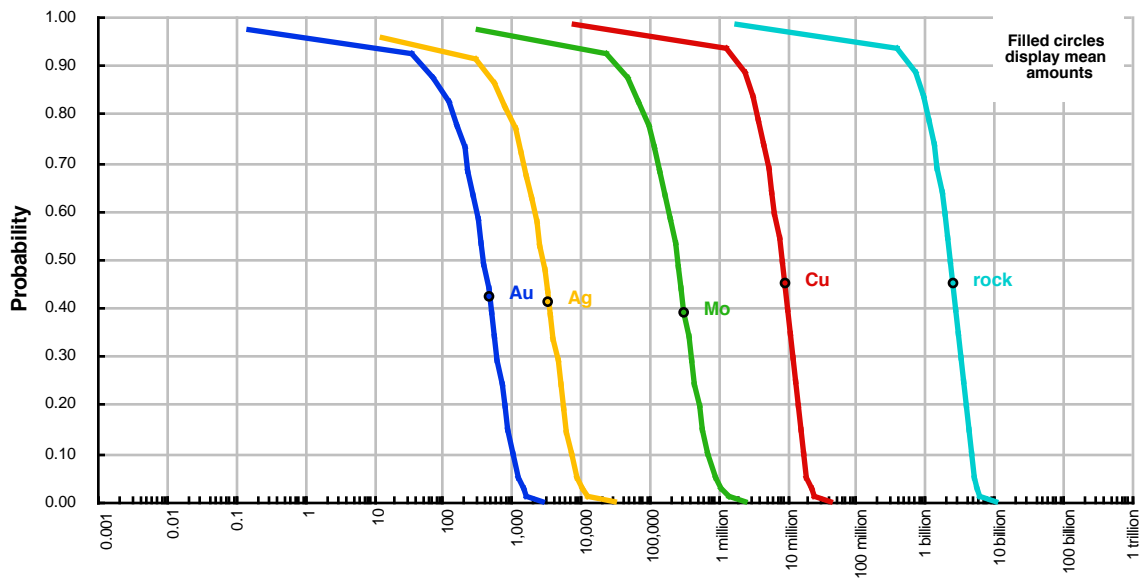
There is a 1% or greater chance of 25 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

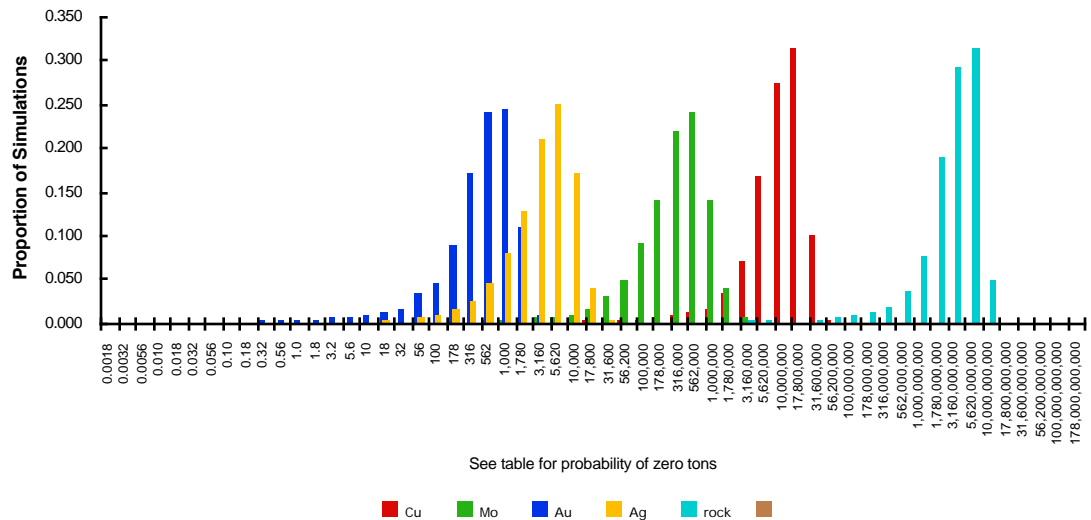
quantile	Cu	Mo	Au	Ag	rock	0
0.95	970,000	11,000	12	84	280,000,000	0
0.90	2,200,000	36,000	54	370	640,000,000	0
0.50	8,500,000	260,000	410	2,900	2,400,000,000	0
0.10	18,000,000	730,000	1,050	7,600	4,900,000,000	0
0.05	20,000,000	930,000	1,300	9,400	5,600,000,000	0
mean	9,300,000	340,000	490	3,500	2,600,000,000	0
Probability of mean	0.45	0.39	0.42	0.41	0.45	0.00
Probability of zero	0.02	0.03	0.03	0.04	0.02	0.00

The tract ID is AK-AP09

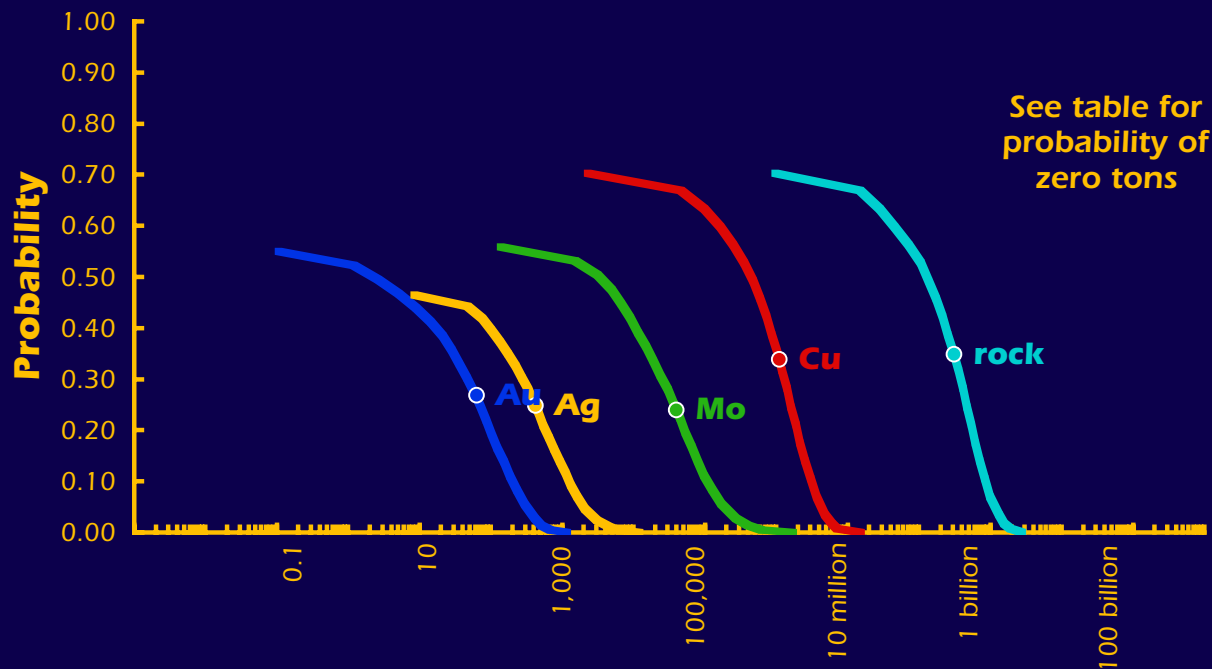
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

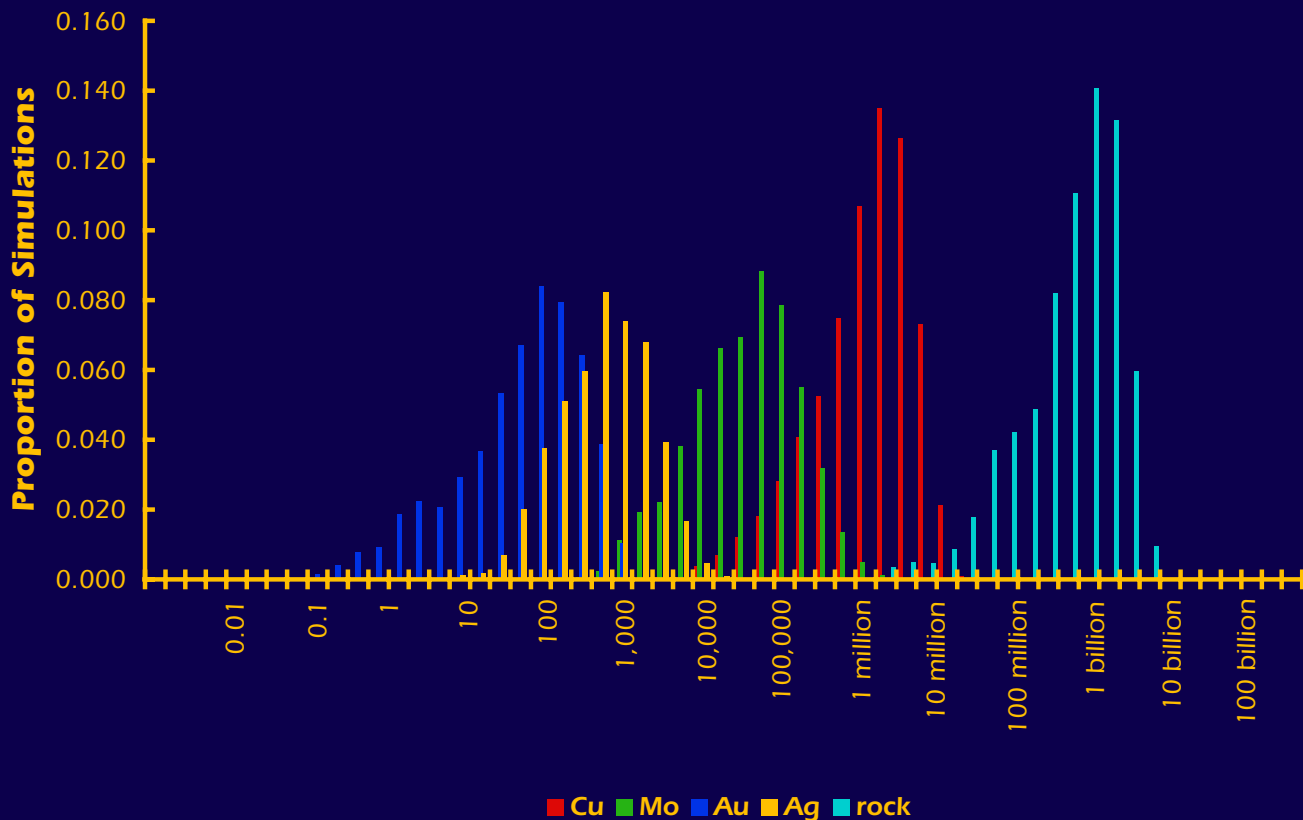


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-AP10

The Mark3 Index is 89:

Porphyry Cu (BC-AK)

There is a 90% or greater chance of 0 or more deposits.
There is a 50% or greater chance of 1 or more deposits.
There is a 10% or greater chance of 4 or more deposits.
There is a 5% or greater chance of 4 or more deposits.
There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	450,000	3,300	2	0	130,000,000
0.10	3,100,000	110,000	197	1,300	860,000,000
0.05	4,200,000	190,000	320	2,000	1,200,000,000
mean	1,100,000	39,000	61	410	300,000,000
Probability of mean	0.34	0.24	0.27	0.25	0.35
Probability of zero	0.30	0.44	0.45	0.53	0.30

The tract ID is AK-AP10The Mark3 Index is 89: **Porphyry Cu (BC-AK)**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

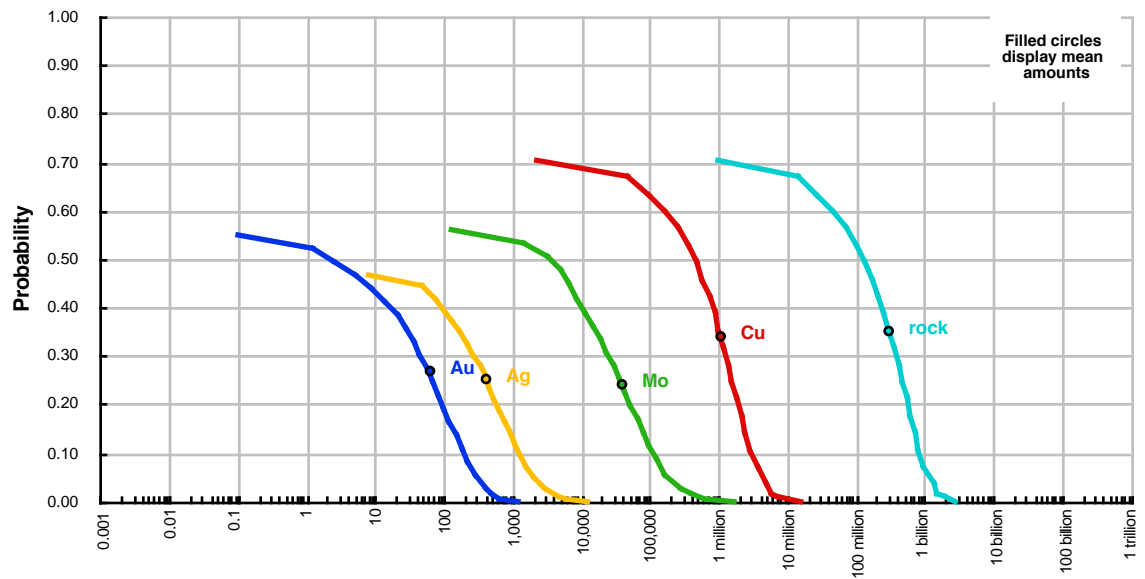
There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

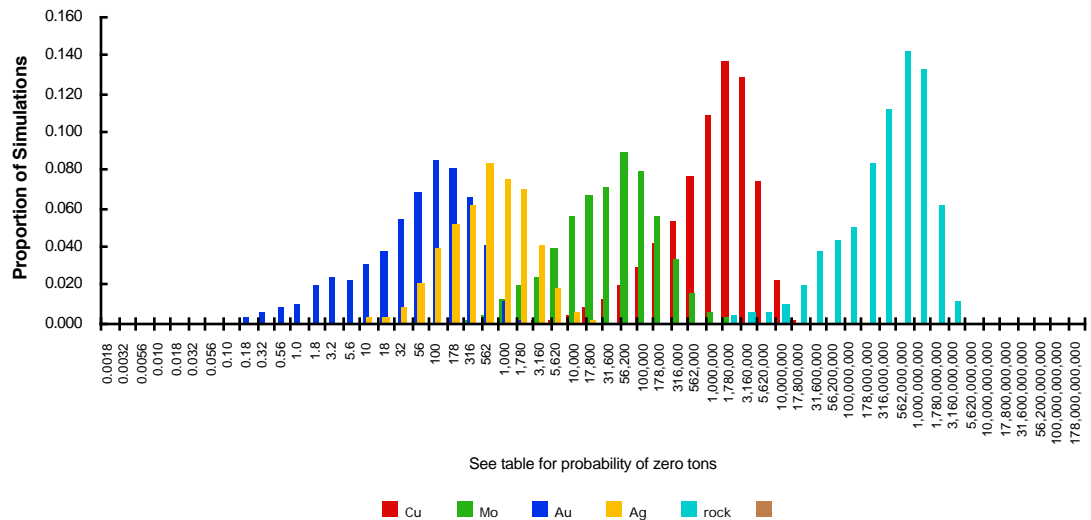
quantile	Cu	Mo	Au	Ag	rock	0
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	450,000	3,300	2	0	130,000,000	0
0.10	3,100,000	110,000	197	1,300	860,000,000	0
0.05	4,200,000	190,000	320	2,000	1,200,000,000	0
mean	1,100,000	39,000	61	410	300,000,000	0
Probability of mean	0.34	0.24	0.27	0.25	0.35	0.00
Probability of zero	0.30	0.44	0.45	0.53	0.30	0.00

The tract ID is AK-AP10

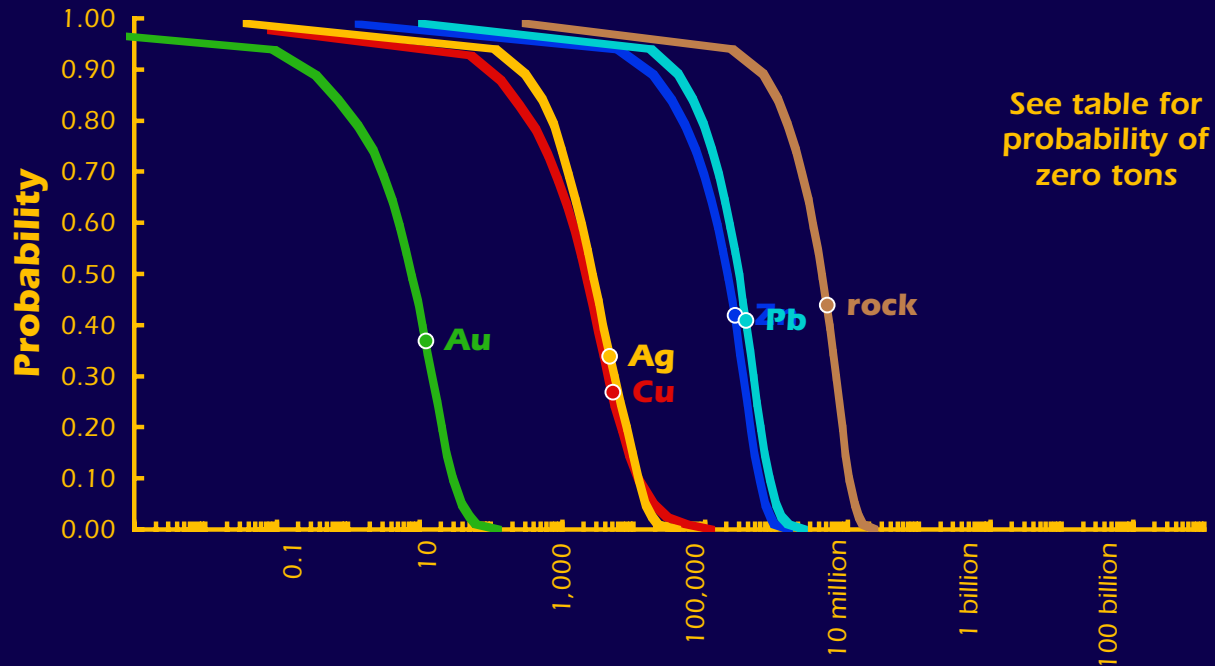
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)



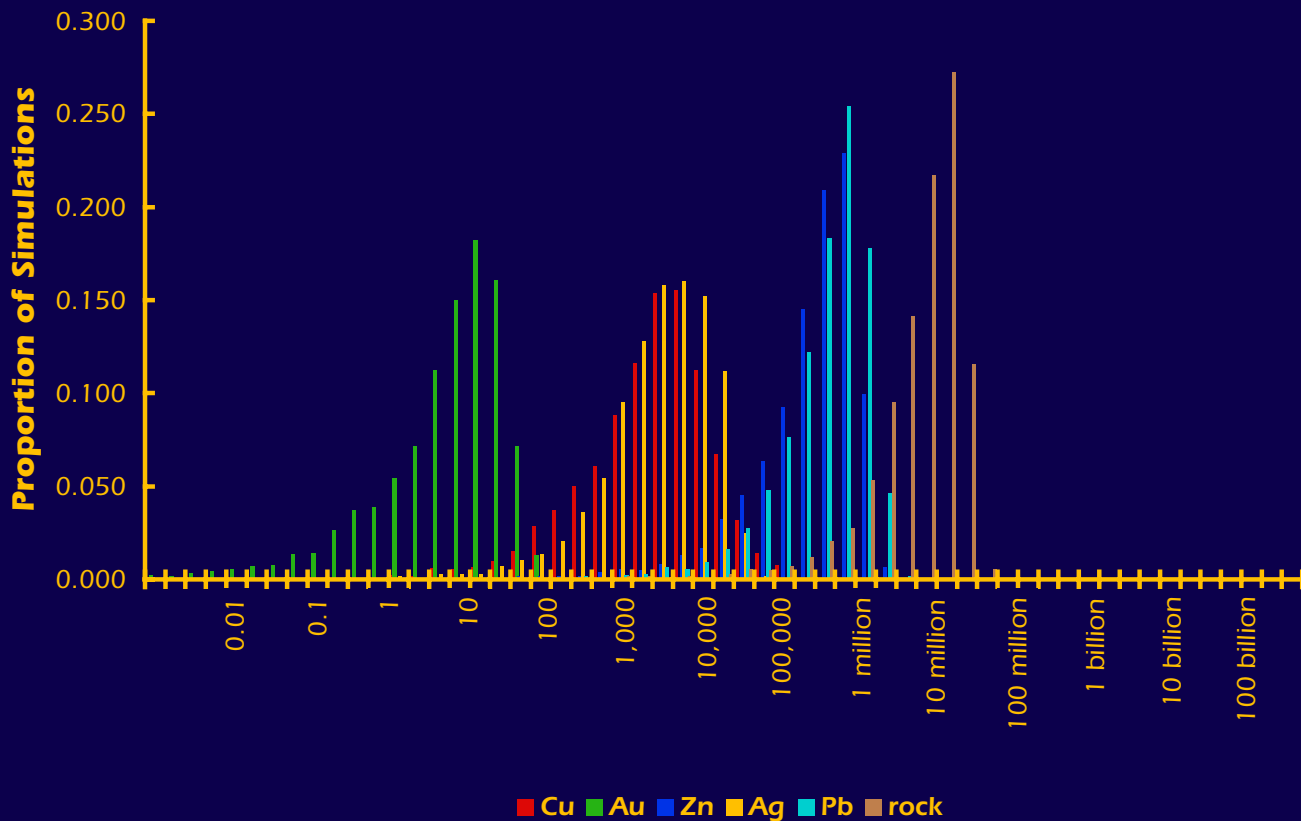
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



See table for
probability of
zero tons

Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-AP13

The Mark3 Index is 46:

Polymetallic vein

There is a 90% or greater chance of 10 or more deposits.

There is a 50% or greater chance of 40 or more deposits.

There is a 10% or greater chance of 90 or more deposits.

There is a 5% or greater chance of 90 or more deposits.

There is a 1% or greater chance of 90 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	19	0	4,100	82	13,000	170,000
0.90	97	0	16,000	270	38,000	570,000
0.50	2,100	8	210,000	2,700	300,000	4,400,000
0.10	12,000	29	576,000	12,000	810,000	11,000,000
0.05	19,000	39	700,000	15,000	990,000	13,000,000
mean	5,000	12	260,000	4,600	370,000	5,100,000
Probability of mean	0.27	0.37	0.42	0.34	0.41	0.44
Probability of zero	0.02	0.01	0.01	0.01	0.01	0.01

The tract ID is AK-AP13The Mark3 Index is 46: **Polymetallic vein**

There is a 90% or greater chance of 10 or more deposits.

There is a 50% or greater chance of 40 or more deposits.

There is a 10% or greater chance of 90 or more deposits.

There is a 5% or greater chance of 90 or more deposits.

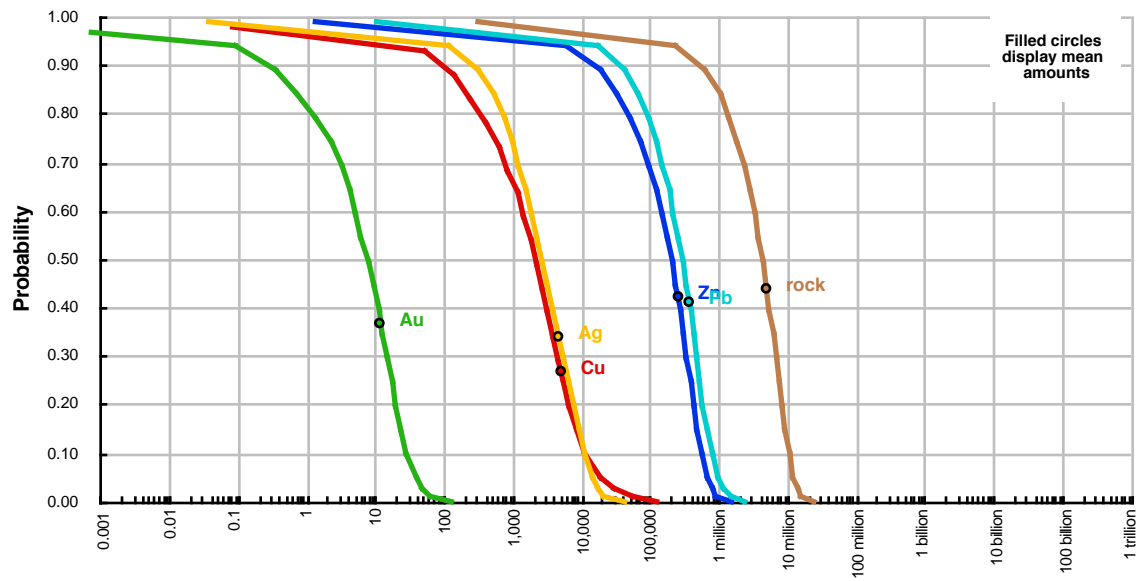
There is a 1% or greater chance of 90 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

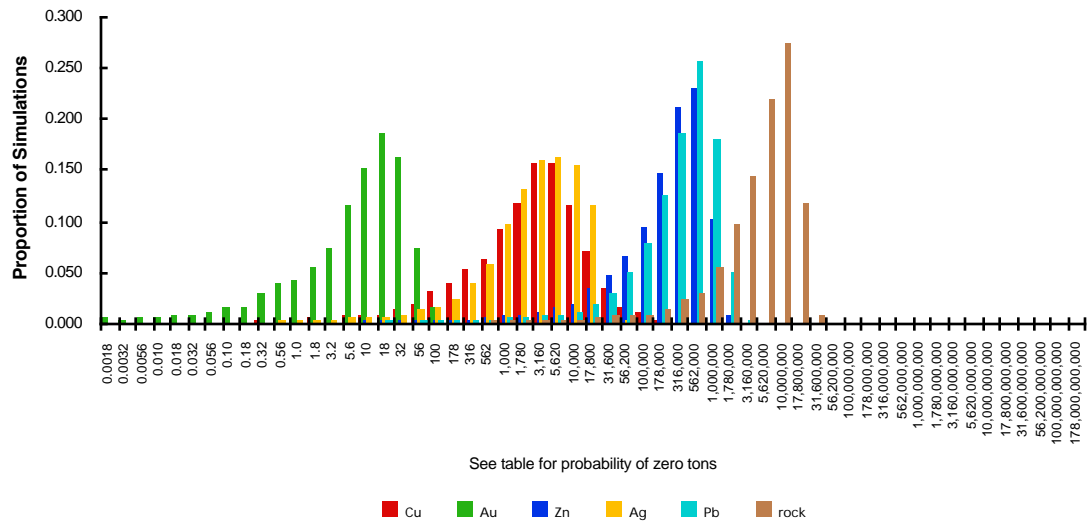
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	19	0	4,100	82	13,000	170,000
0.90	97	0	16,000	270	38,000	570,000
0.50	2,100	8	210,000	2,700	300,000	4,400,000
0.10	12,000	29	576,000	12,000	810,000	11,000,000
0.05	19,000	39	700,000	15,000	990,000	13,000,000
mean	5,000	12	260,000	4,600	370,000	5,100,000
Probability of mean	0.27	0.37	0.42	0.34	0.41	0.44
Probability of zero	0.02	0.01	0.01	0.01	0.01	0.01

The tract ID is AK-AP13

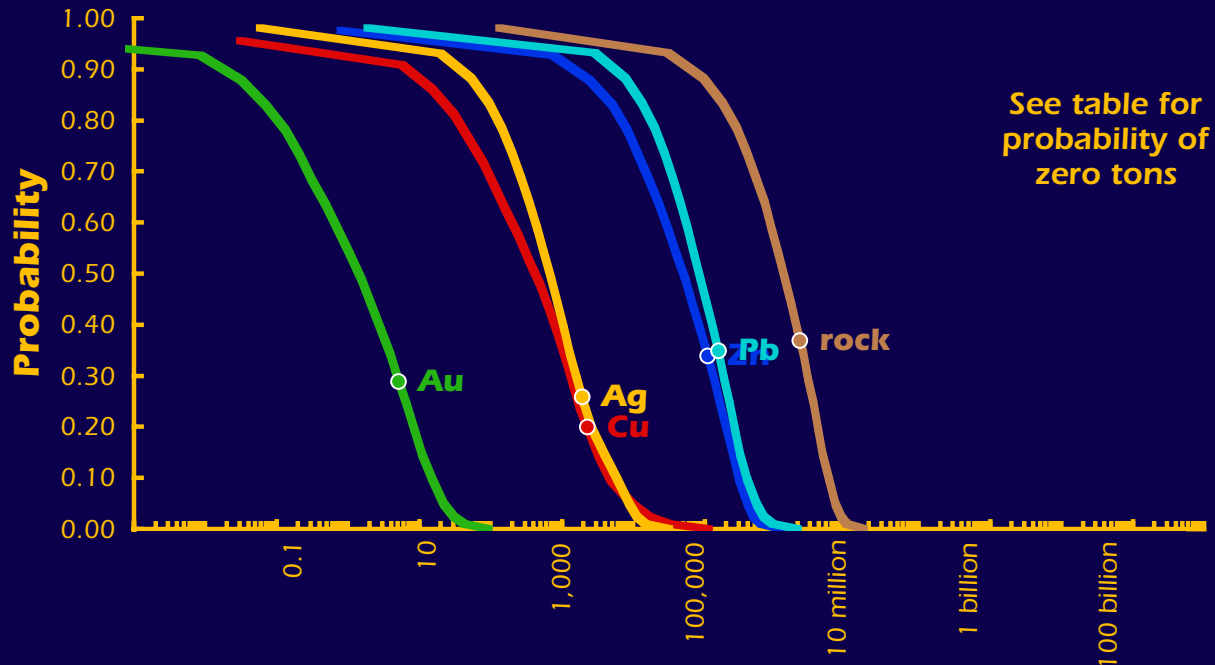
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

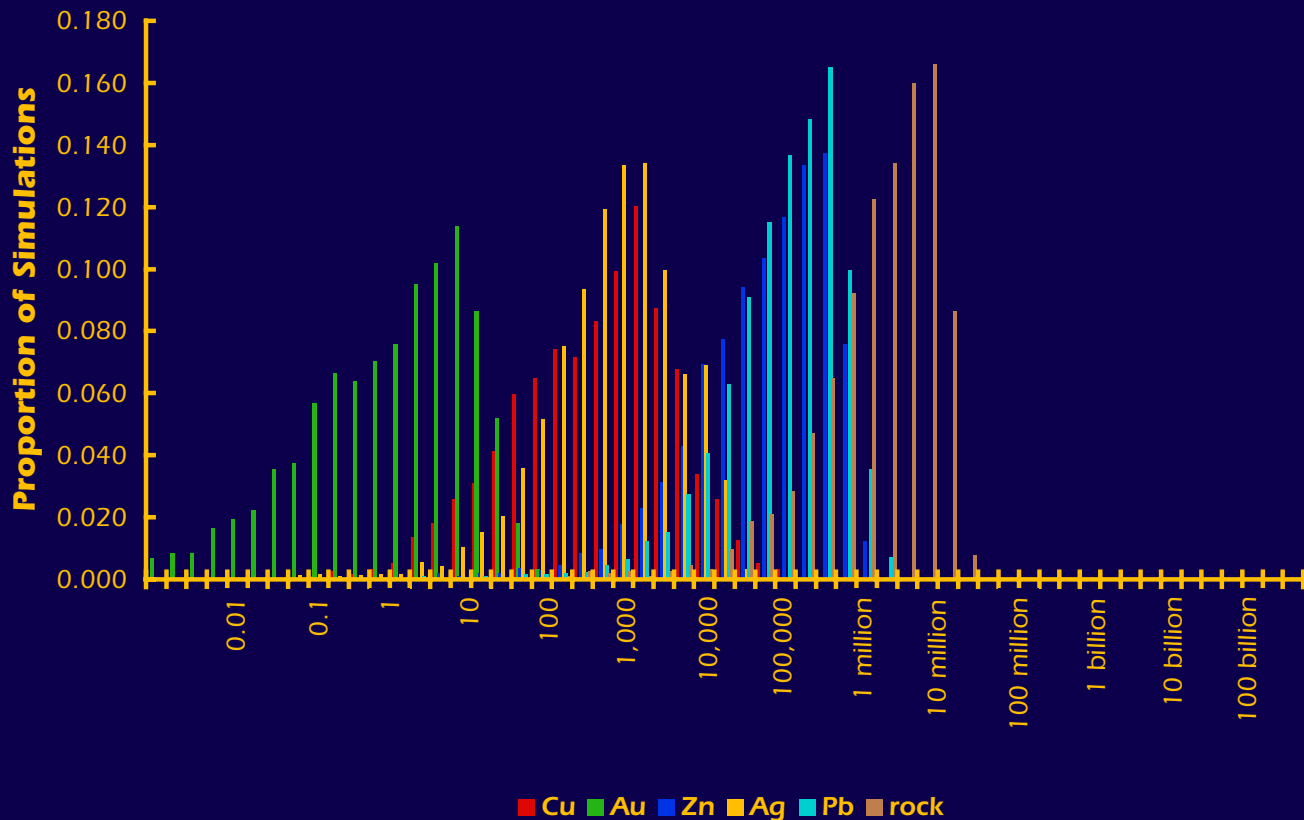


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-AP14

The Mark3 Index is 46:

Polymetallic vein

There is a 90% or greater chance of 5 or more deposits.

There is a 50% or greater chance of 10 or more deposits.

There is a 10% or greater chance of 45 or more deposits.

There is a 5% or greater chance of 45 or more deposits.

There is a 1% or greater chance of 45 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	1	0	250	10	1,600	18,000
0.90	7	0	1,600	43	5,900	73,000
0.50	430	1	50,000	680	84,000	1,300,000
0.10	4,600	15	300,000	5,900	390,000	5,500,000
0.05	9,600	22	400,000	8,800	530,000	6,800,000
mean	2,200	5	110,000	1,900	150,000	2,100,000
Probability of mean	0.20	0.29	0.34	0.26	0.35	0.37
Probability of zero	0.04	0.02	0.02	0.02	0.02	0.02

The tract ID is AK-AP14The Mark3 Index is 46: **Polymetallic vein**

There is a 90% or greater chance of 5 or more deposits.

There is a 50% or greater chance of 10 or more deposits.

There is a 10% or greater chance of 45 or more deposits.

There is a 5% or greater chance of 45 or more deposits.

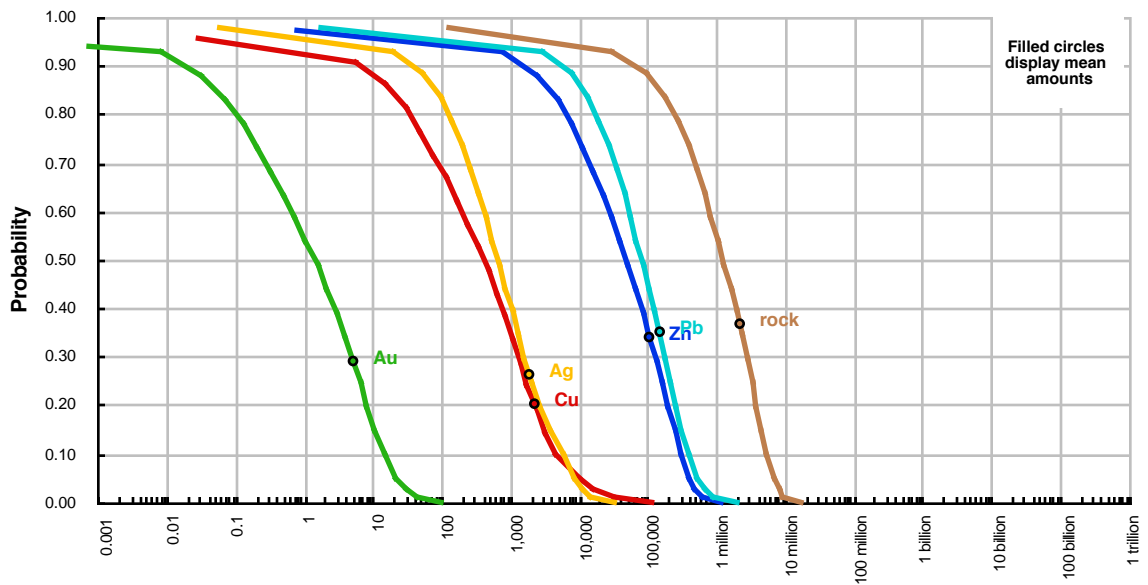
There is a 1% or greater chance of 45 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

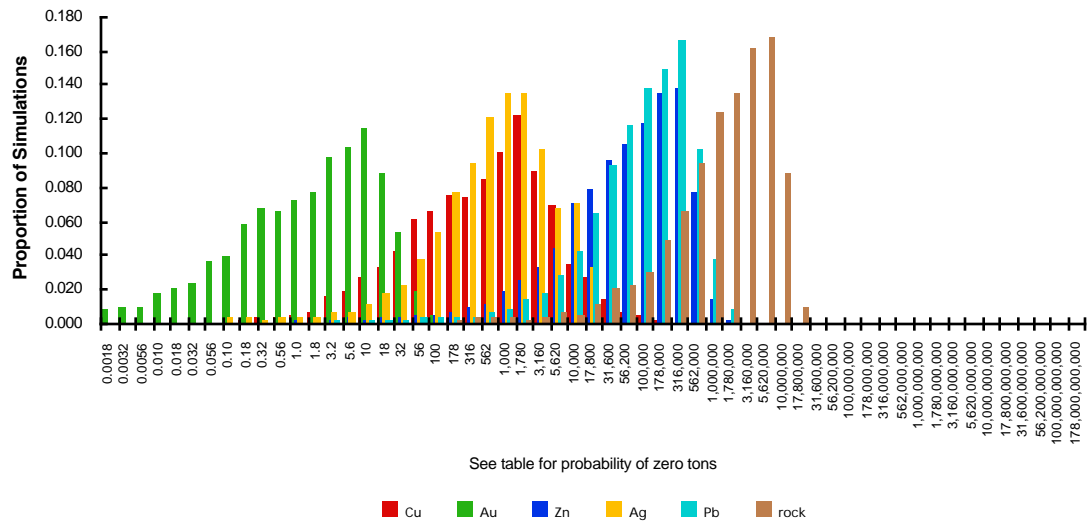
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	1	0	250	10	1,600	18,000
0.90	7	0	1,600	43	5,900	73,000
0.50	430	1	50,000	680	84,000	1,300,000
0.10	4,600	15	300,000	5,900	390,000	5,500,000
0.05	9,600	22	400,000	8,800	530,000	6,800,000
mean	2,200	5	110,000	1,900	150,000	2,100,000
Probability of mean	0.20	0.29	0.34	0.26	0.35	0.37
Probability of zero	0.04	0.02	0.02	0.02	0.02	0.02

The tract ID is AK-AP14

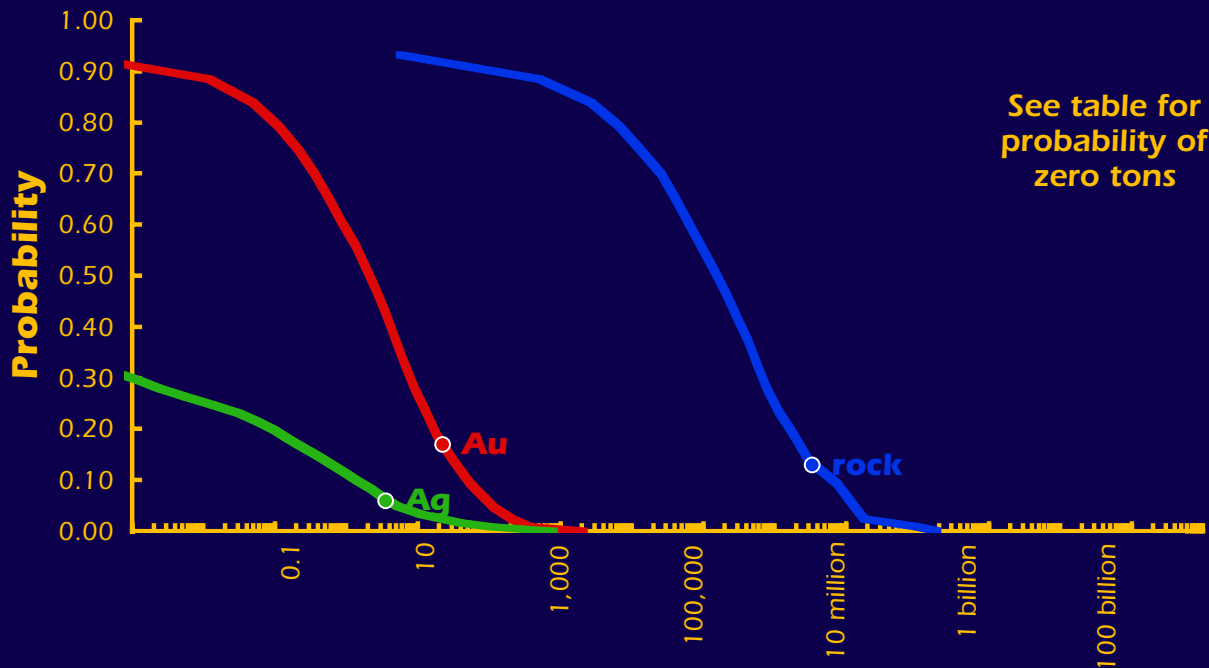
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

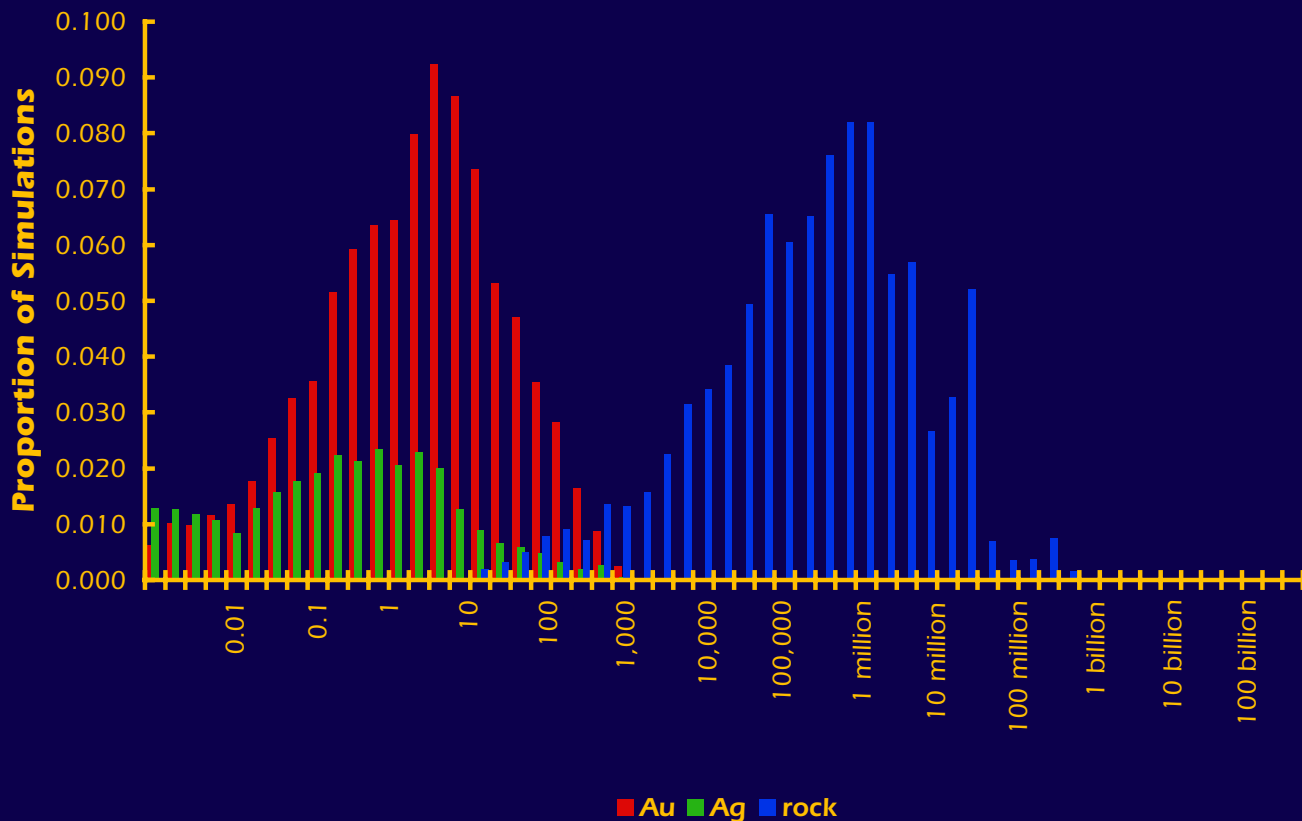


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-BR04

The Mark3 Index is 27:

Low sulfide Au-quartz vein

There is a 90% or greater chance of 1 or more deposits.
There is a 50% or greater chance of 2 or more deposits.
There is a 10% or greater chance of 5 or more deposits.
There is a 5% or greater chance of 10 or more deposits.
There is a 1% or greater chance of 15 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	240
0.50	2	0	160,000
0.10	51	1	6,650,000
0.05	110	5	13,000,000
mean	22	4	3,300,000
Probability of mean	0.17	0.06	0.13
Probability of zero	0.07	0.67	0.07

The tract ID is AK-BR04The Mark3 Index is 27: **Low sulfide Au-quartz vein**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 10 or more deposits.

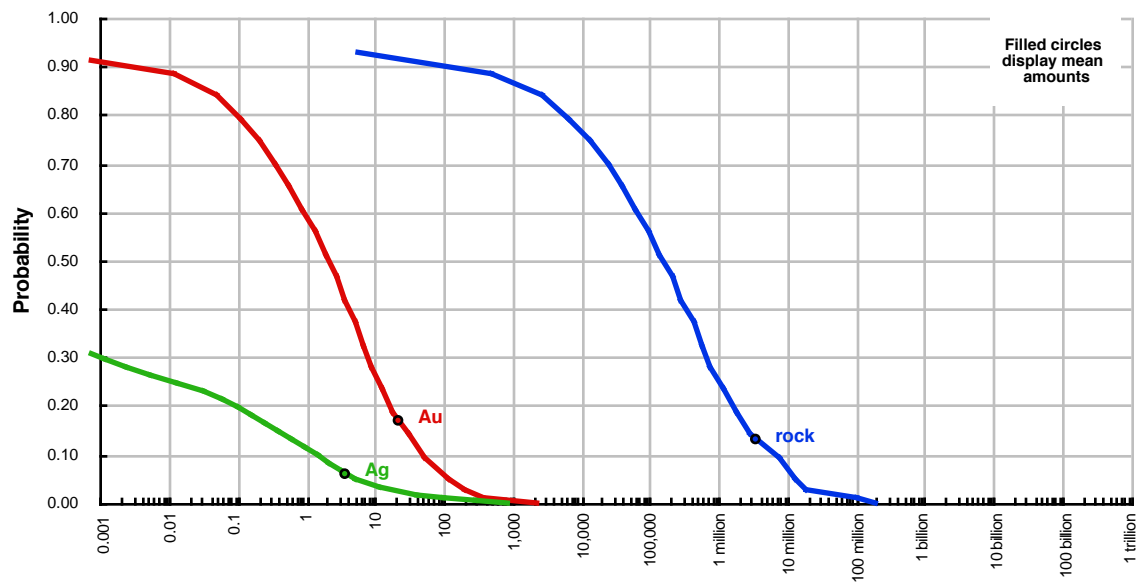
There is a 1% or greater chance of 15 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

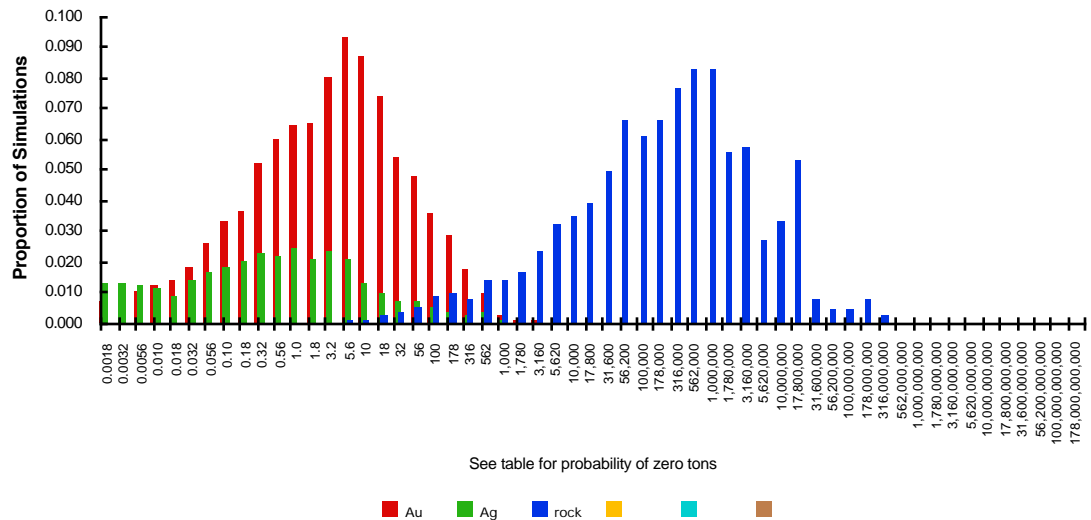
quantile	Au	Ag	rock	0	0	0
0.95	0	0	0	0	0	0
0.90	0	0	240	0	0	0
0.50	2	0	160,000	0	0	0
0.10	51	1	6,650,000	0	0	0
0.05	110	5	13,000,000	0	0	0
mean	22	4	3,300,000	0	0	0
Probability of mean	0.17	0.06	0.13	0.00	0.00	0.00
Probability of zero	0.07	0.67	0.07	0.00	0.00	0.00

The tract ID is AK-BR04

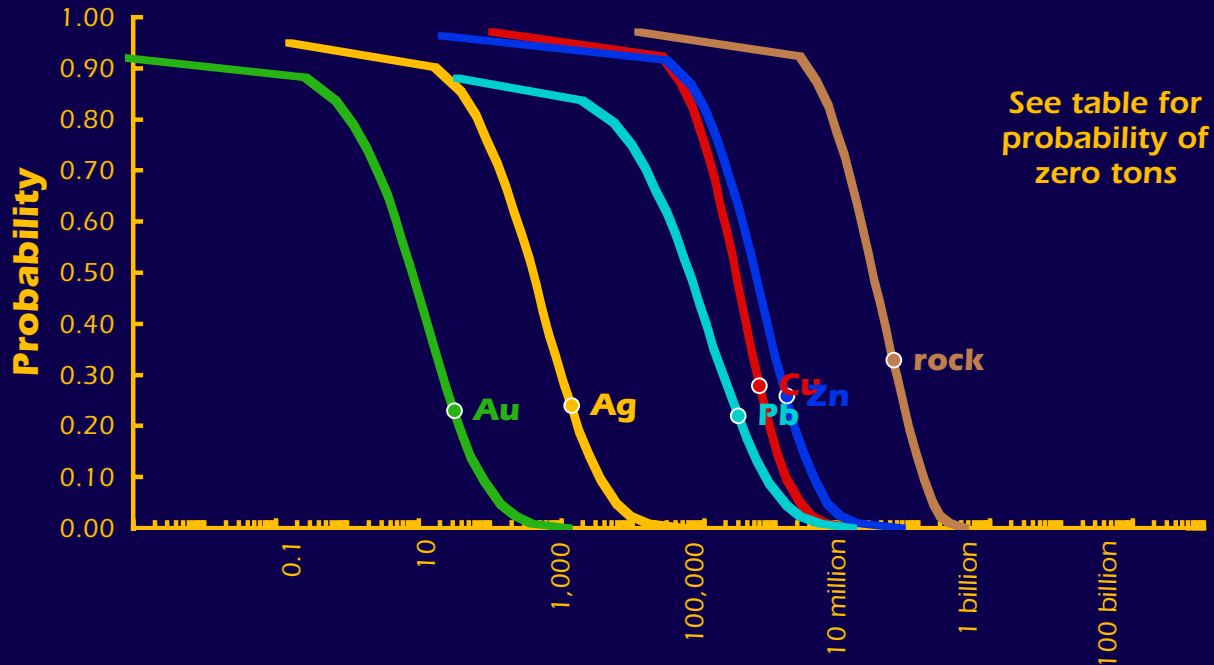
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

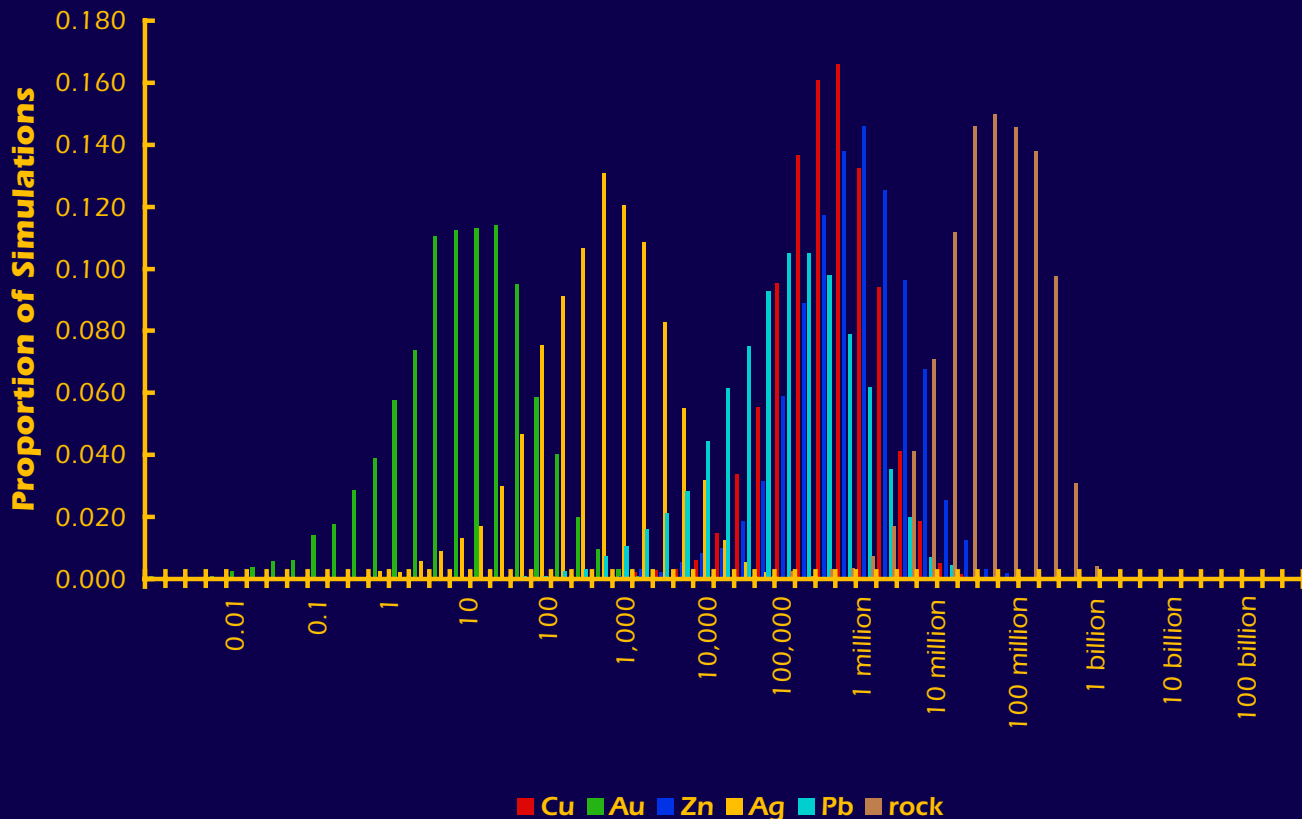


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-BR07

The Mark3 Index is 93:

Massive sulfide, kuroko

There is a 90% or greater chance of 3 or more deposits.

There is a 50% or greater chance of 5 or more deposits.

There is a 10% or greater chance of 7 or more deposits.

There is a 5% or greater chance of 10 or more deposits.

There is a 1% or greater chance of 15 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	14,000	0	5,900	0	0	1,100,000
0.90	35,000	0	41,000	18	0	3,000,000
0.50	280,000	8	520,000	400	62,000	23,000,000
0.10	1,400,000	76	3,440,000	3,400	720,000	120,000,000
0.05	2,200,000	140	5,100,000	5,800	1,300,000	160,000,000
mean	590,000	31	1,400,000	1,400	300,000	45,000,000
Probability of mean	0.28	0.23	0.26	0.24	0.22	0.33
Probability of zero	0.03	0.07	0.04	0.05	0.12	0.03

The tract ID is AK-BR07The Mark3 Index is 93: **Massive sulfide, kuroko**

There is a 90% or greater chance of 3 or more deposits.

There is a 50% or greater chance of 5 or more deposits.

There is a 10% or greater chance of 7 or more deposits.

There is a 5% or greater chance of 10 or more deposits.

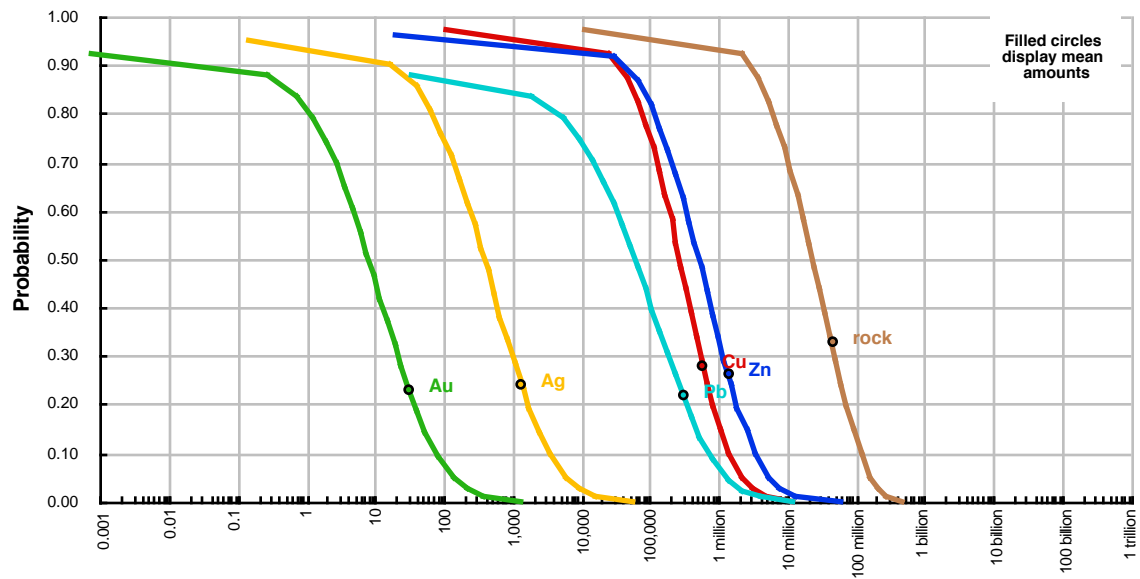
There is a 1% or greater chance of 15 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

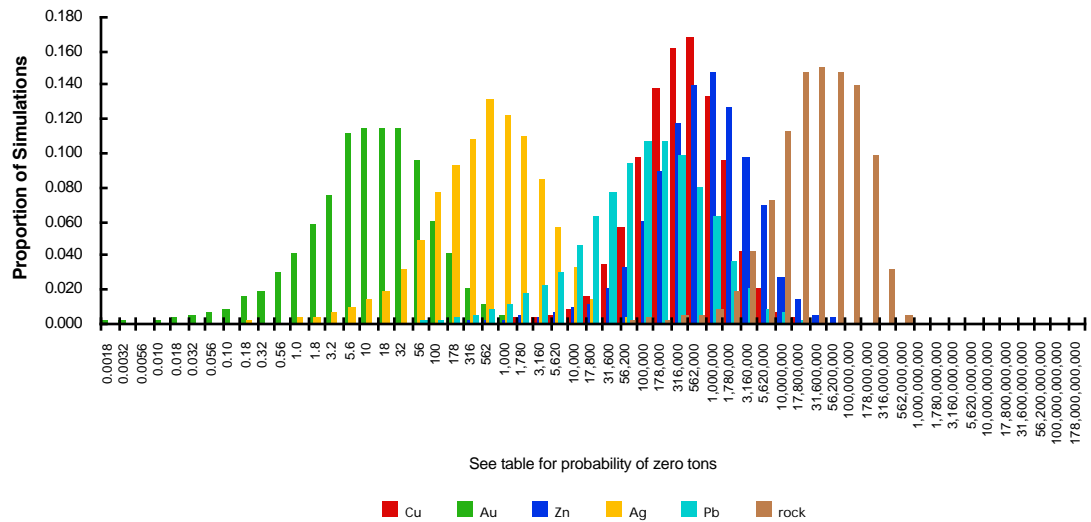
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	14,000	0	5,900	0	0	1,100,000
0.90	35,000	0	41,000	18	0	3,000,000
0.50	280,000	8	520,000	400	62,000	23,000,000
0.10	1,400,000	76	3,440,000	3,400	720,000	120,000,000
0.05	2,200,000	140	5,100,000	5,800	1,300,000	160,000,000
mean	590,000	31	1,400,000	1,400	300,000	45,000,000
Probability of mean	0.28	0.23	0.26	0.24	0.22	0.33
Probability of zero	0.03	0.07	0.04	0.05	0.12	0.03

The tract ID is AK-BR07

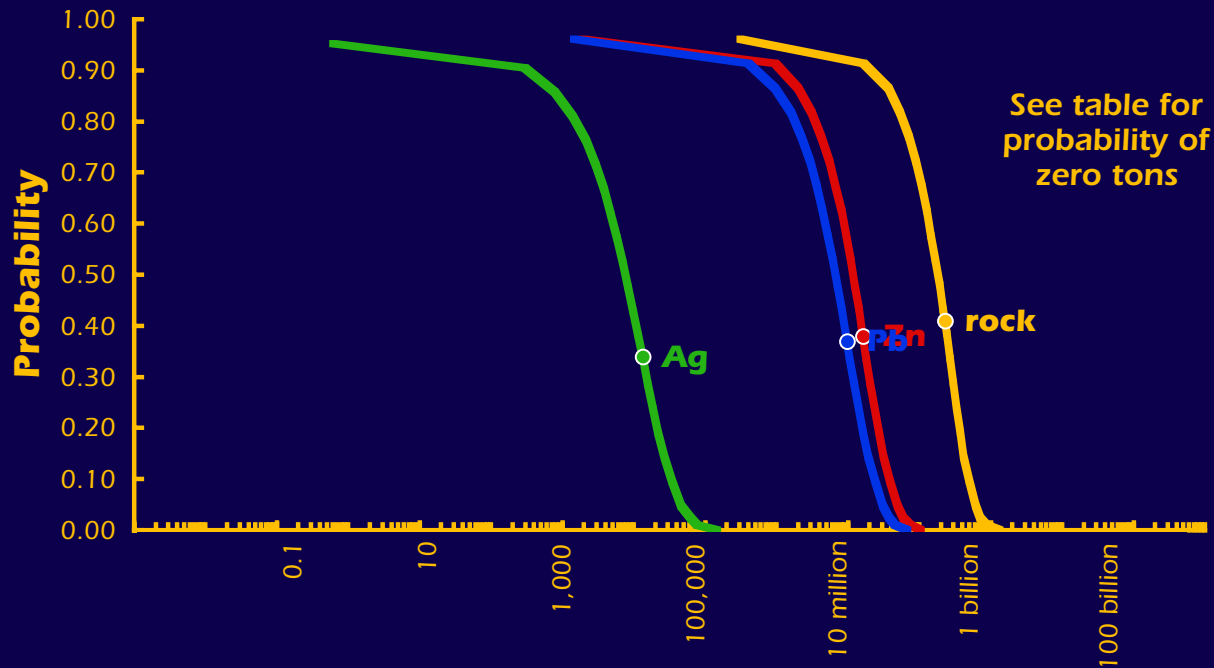
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

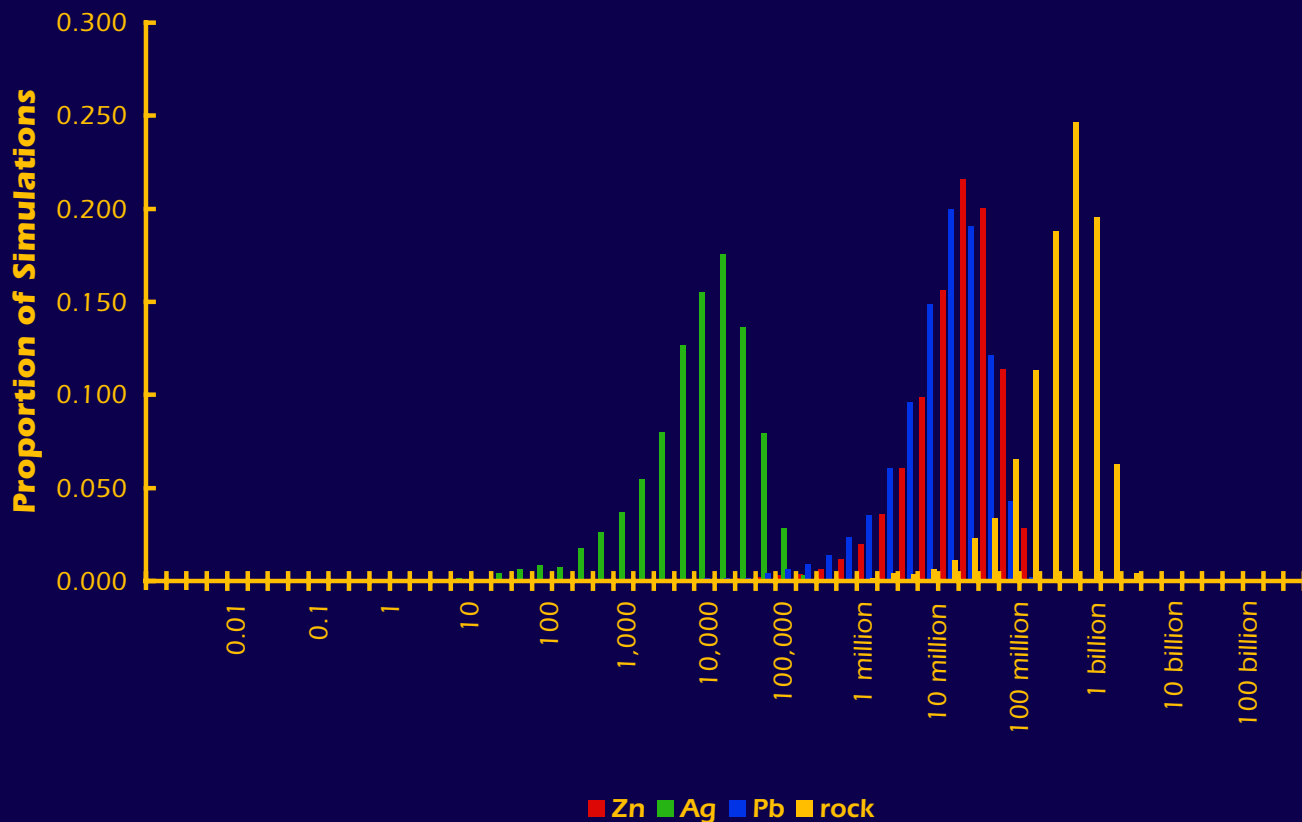


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-BR23

The Mark3 Index is 13:

Sedimentary exhalative Zn-Pb

There is a 90% or greater chance of 2 or more deposits.
There is a 50% or greater chance of 5 or more deposits.
There is a 10% or greater chance of 7 or more deposits.
There is a 5% or greater chance of 10 or more deposits.
There is a 1% or greater chance of 15 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Zn	Ag	Pb	rock
0.95	150,000	6	66,000	3,300,000
0.90	1,200,000	360	540,000	23,000,000
0.50	12,000,000	7,600	6,700,000	180,000,000
0.10	38,000,000	34,000	23,500,000	490,000,000
0.05	48,000,000	45,000	31,000,000	610,000,000
mean	16,000,000	13,000	9,700,000	230,000,000
Probability of mean	0.38	0.34	0.37	0.41
Probability of zero	0.04	0.05	0.04	0.04

The tract ID is AK-BR23The Mark3 Index is 13: **Sedimentary exhalative Zn-Pb**

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 5 or more deposits.

There is a 10% or greater chance of 7 or more deposits.

There is a 5% or greater chance of 10 or more deposits.

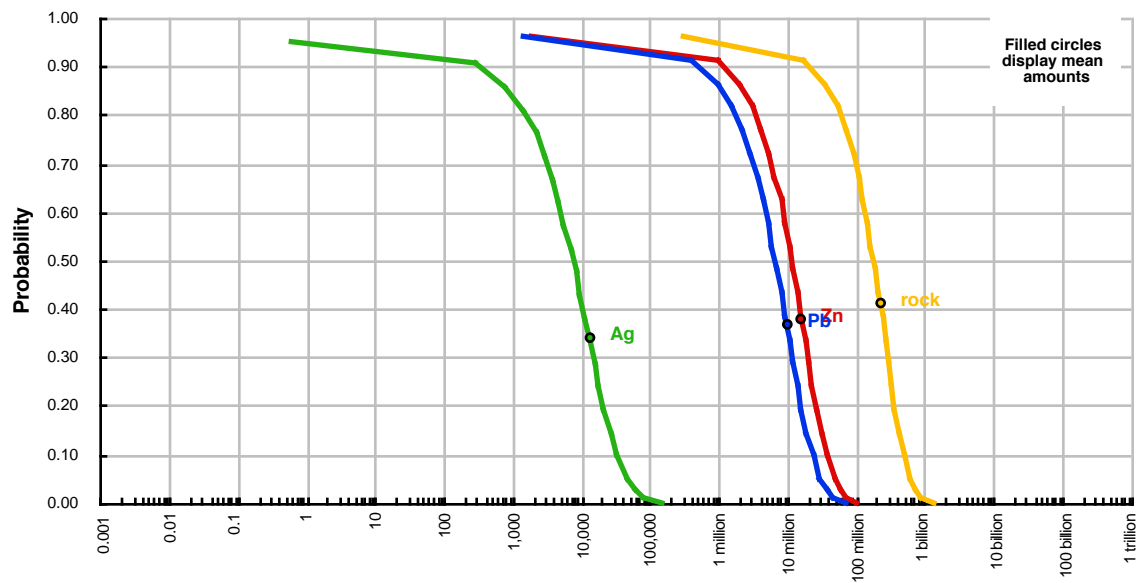
There is a 1% or greater chance of 15 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

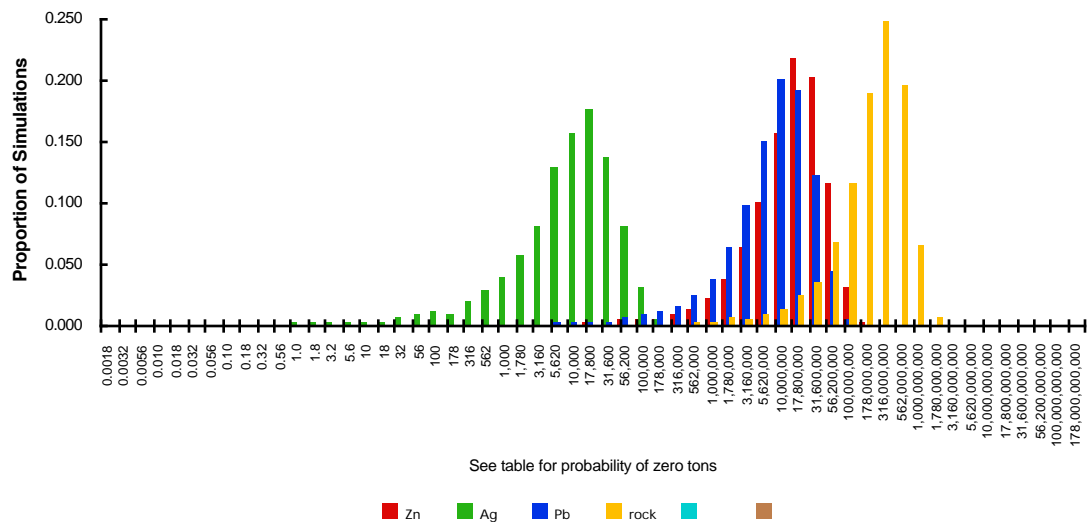
quantile	Zn	Ag	Pb	rock	0	0
0.95	150,000	6	66,000	3,300,000	0	0
0.90	1,200,000	360	540,000	23,000,000	0	0
0.50	12,000,000	7,600	6,700,000	180,000,000	0	0
0.10	38,000,000	34,000	23,500,000	490,000,000	0	0
0.05	48,000,000	45,000	31,000,000	610,000,000	0	0
mean	16,000,000	13,000	9,700,000	230,000,000	0	0
Probability of mean	0.38	0.34	0.37	0.41	0.00	0.00
Probability of zero	0.04	0.05	0.04	0.04	0.00	0.00

The tract ID is AK-BR23

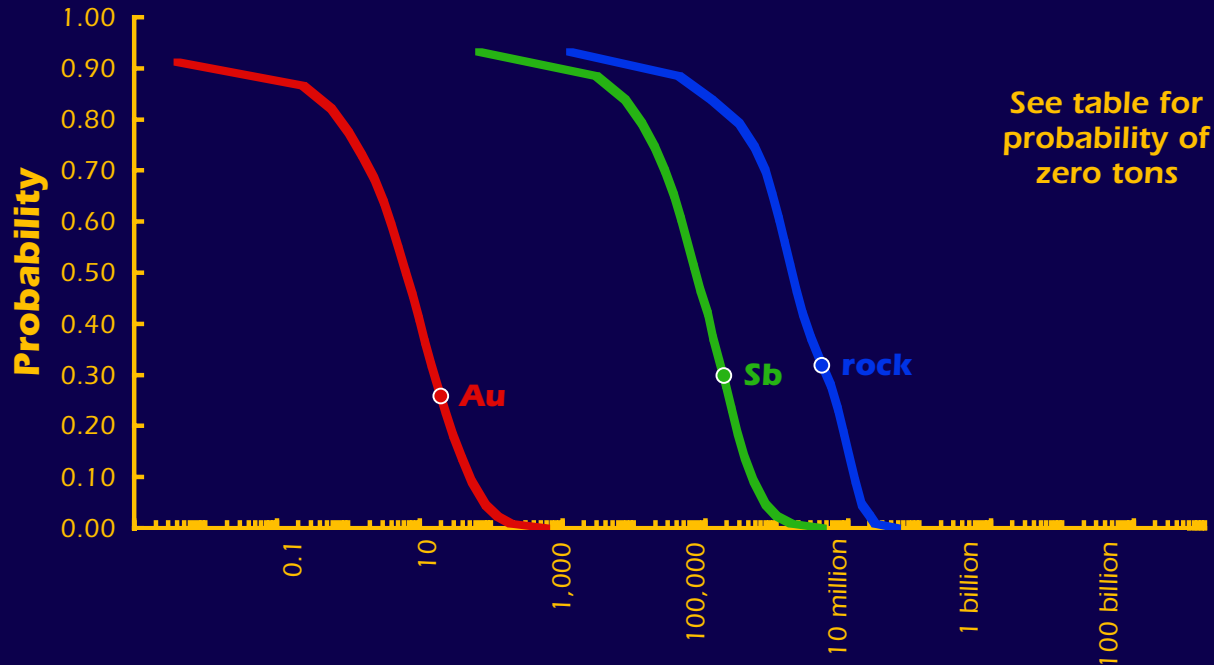
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

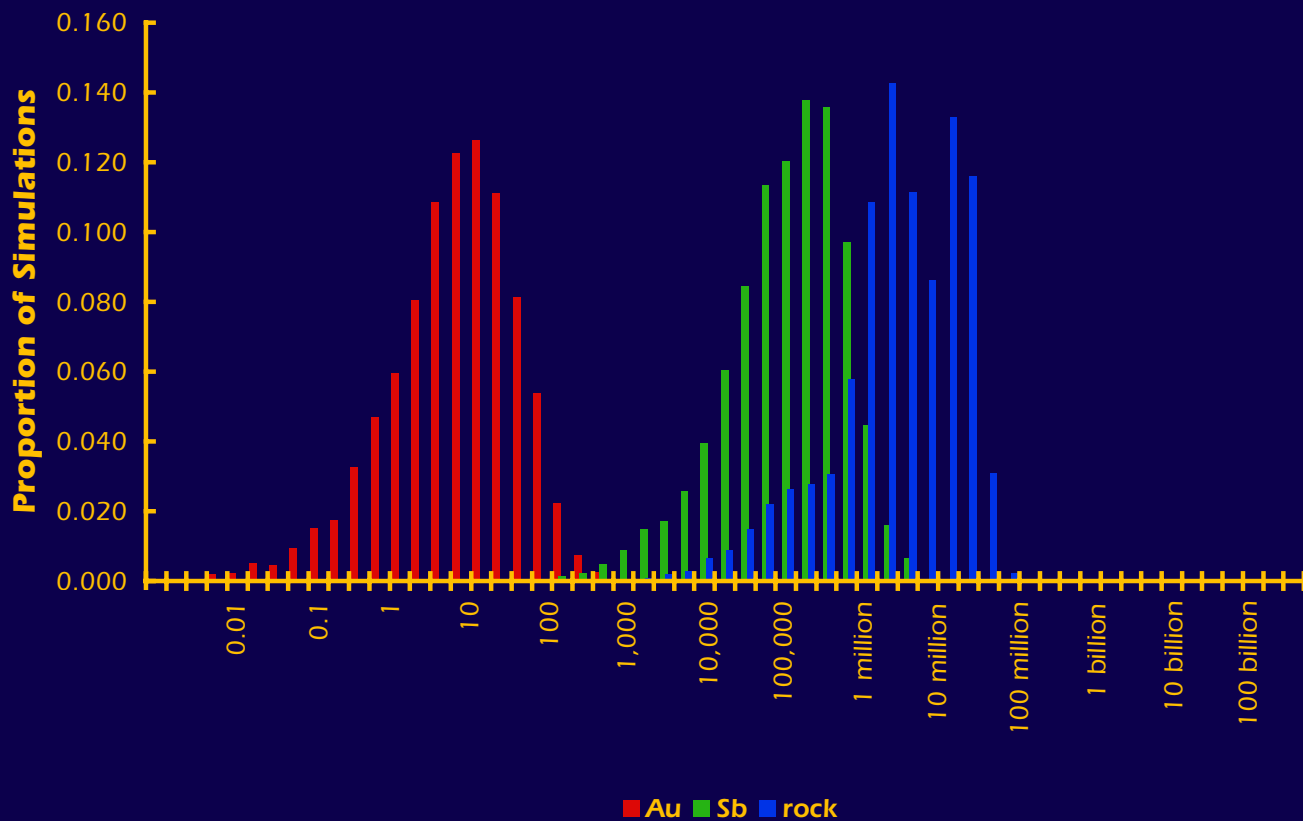


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-EC05

The Mark3 Index is 114:

Au-Sb vein

There is a 90% or greater chance of 1 or more deposits.
There is a 50% or greater chance of 3 or more deposits.
There is a 10% or greater chance of 5 or more deposits.
There is a 5% or greater chance of 8 or more deposits.
There is a 1% or greater chance of 12 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Sb	rock
0.95	0	0	0
0.90	0	1,800	27,000
0.50	6	74,000	1,600,000
0.10	51	450,000	12,200,000
0.05	80	660,000	15,000,000
mean	19	180,000	4,200,000
Probability of mean	0.26	0.30	0.32
Probability of zero	0.09	0.07	0.07

The tract ID is AK-EC05The Mark3 Index is 114: **Au-Sb vein**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 8 or more deposits.

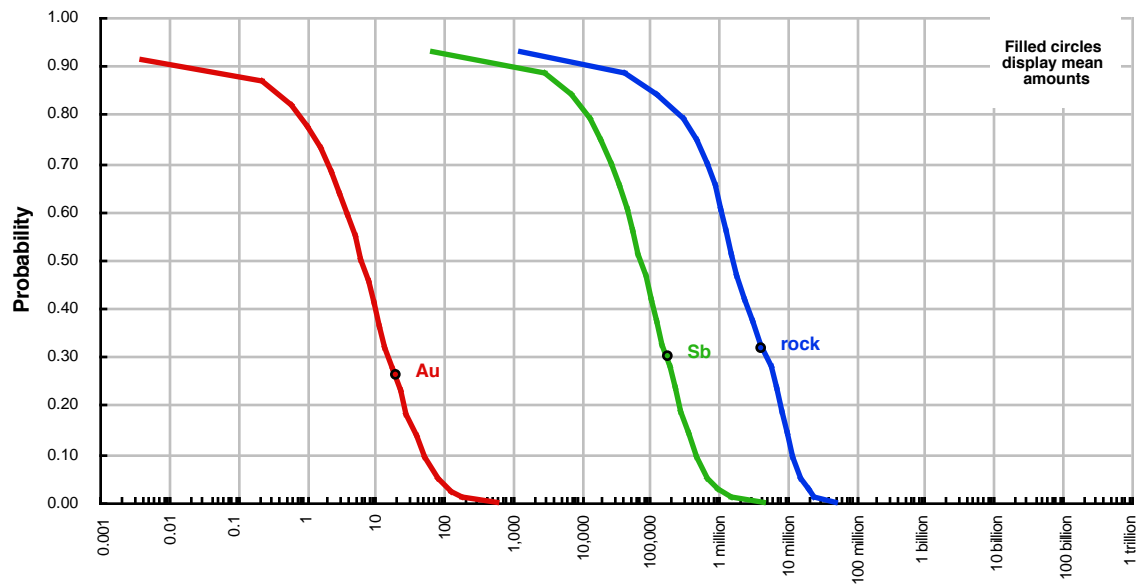
There is a 1% or greater chance of 12 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

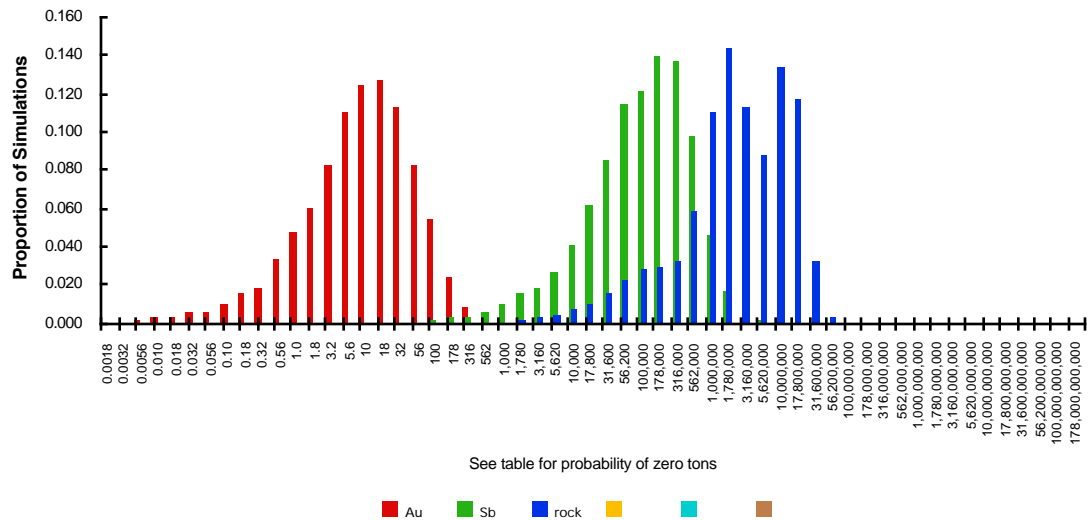
quantile	Au	Sb	rock	0	0	0
0.95	0	0	0	0	0	0
0.90	0	1,800	27,000	0	0	0
0.50	6	74,000	1,600,000	0	0	0
0.10	51	450,000	12,200,000	0	0	0
0.05	80	660,000	15,000,000	0	0	0
mean	19	180,000	4,200,000	0	0	0
Probability of mean	0.26	0.30	0.32	0.00	0.00	0.00
Probability of zero	0.09	0.07	0.07	0.00	0.00	0.00

The tract ID is AK-EC05

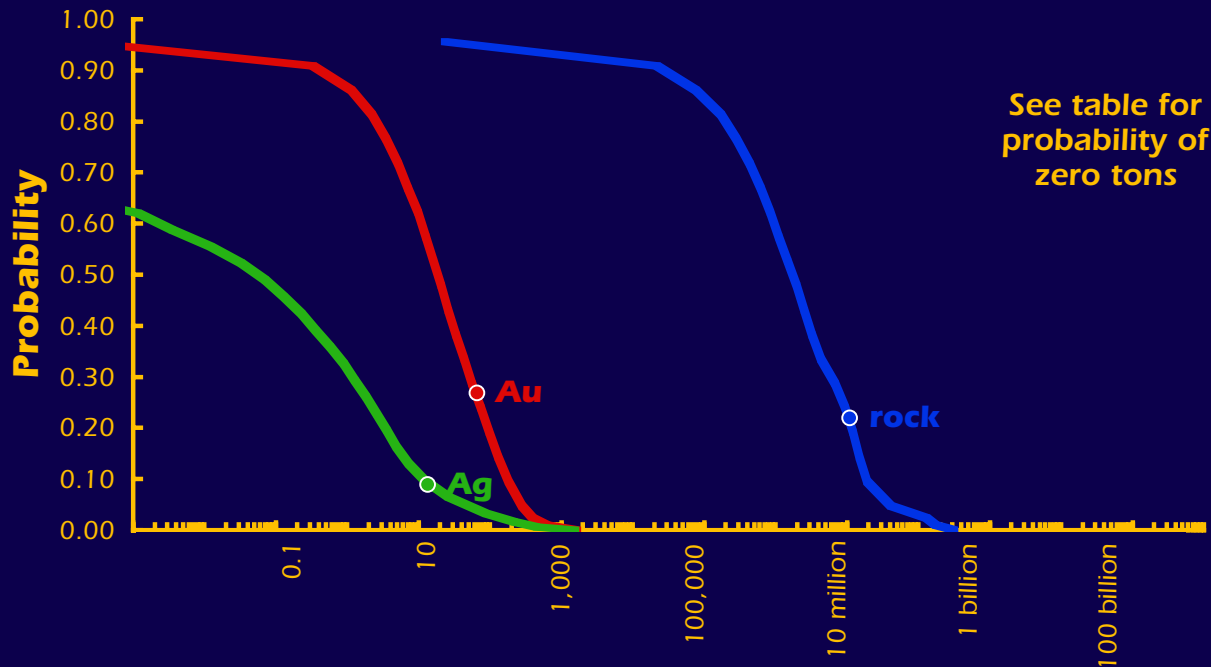
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)



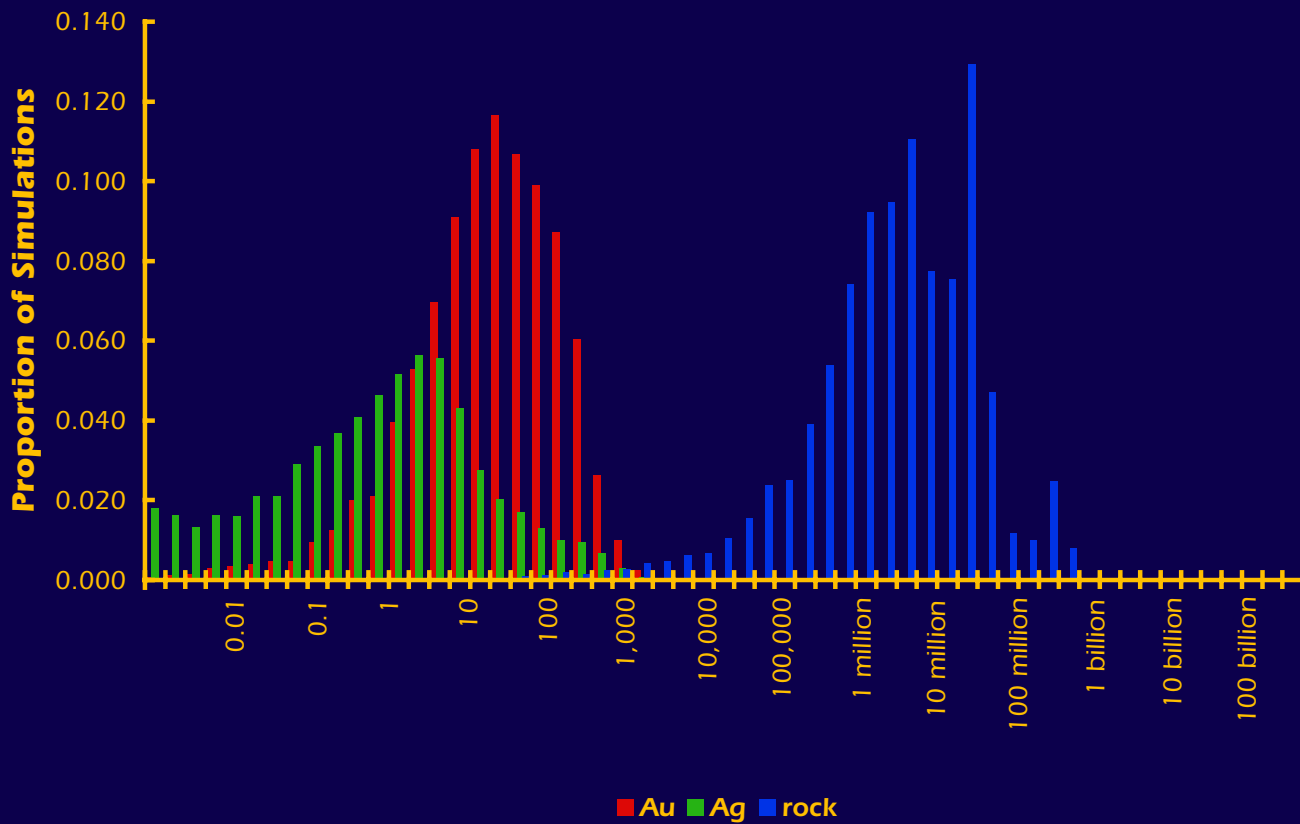
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



See table for
probability of
zero tons

Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-EC07

The Mark3 Index is 27:

Low sulfide Au-quartz vein

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 8 or more deposits.

There is a 10% or greater chance of 15 or more deposits.

There is a 5% or greater chance of 20 or more deposits.

There is a 1% or greater chance of 30 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	370
0.90	0	0	29,000
0.50	19	0	1,700,000
0.10	180	12	18,300,000
0.05	280	44	37,000,000
mean	64	13	11,000,000
Probability of mean	0.27	0.09	0.22
Probability of zero	0.04	0.35	0.04

The tract ID is AK-EC07The Mark3 Index is 27: **Low sulfide Au-quartz vein**

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 8 or more deposits.

There is a 10% or greater chance of 15 or more deposits.

There is a 5% or greater chance of 20 or more deposits.

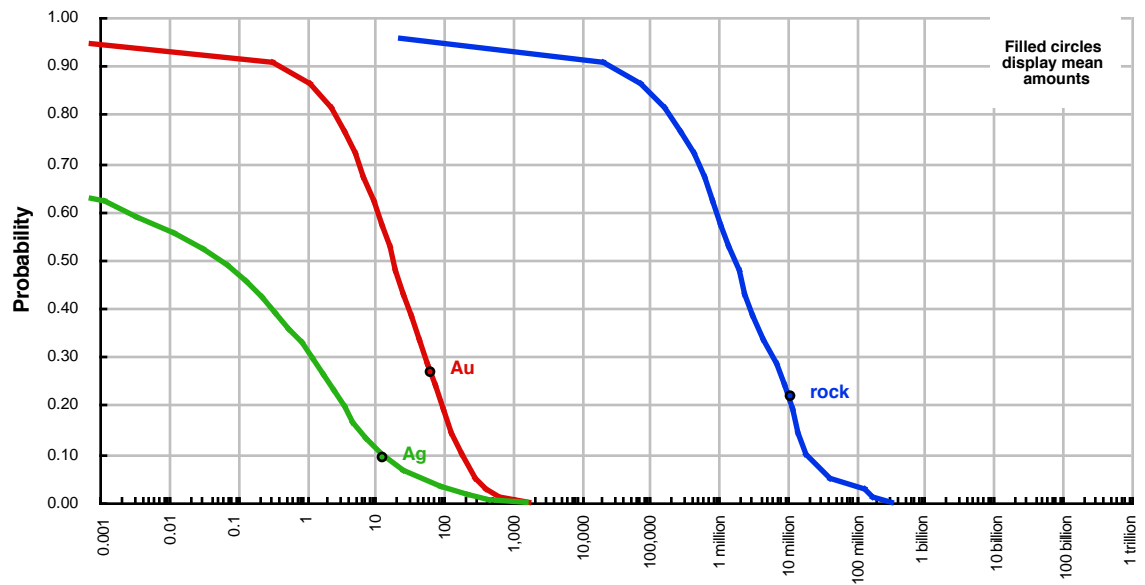
There is a 1% or greater chance of 30 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

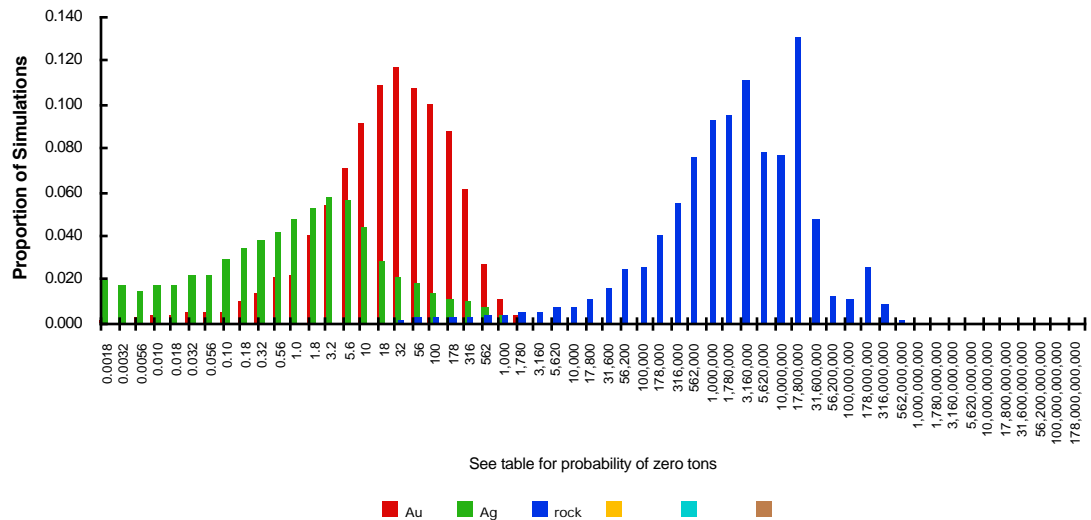
quantile	Au	Ag	rock	0	0	0
0.95	0	0	370	0	0	0
0.90	0	0	29,000	0	0	0
0.50	19	0	1,700,000	0	0	0
0.10	180	12	18,300,000	0	0	0
0.05	280	44	37,000,000	0	0	0
mean	64	13	11,000,000	0	0	0
Probability of mean	0.27	0.09	0.22	0.00	0.00	0.00
Probability of zero	0.04	0.35	0.04	0.00	0.00	0.00

The tract ID is AK-EC07

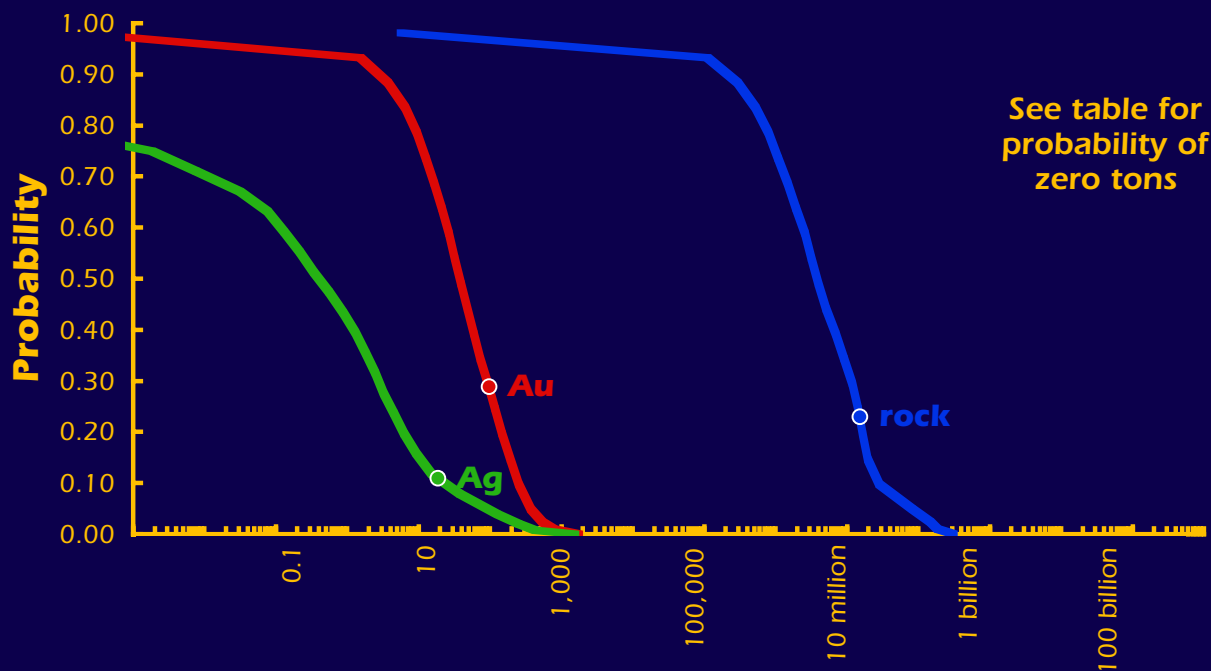
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

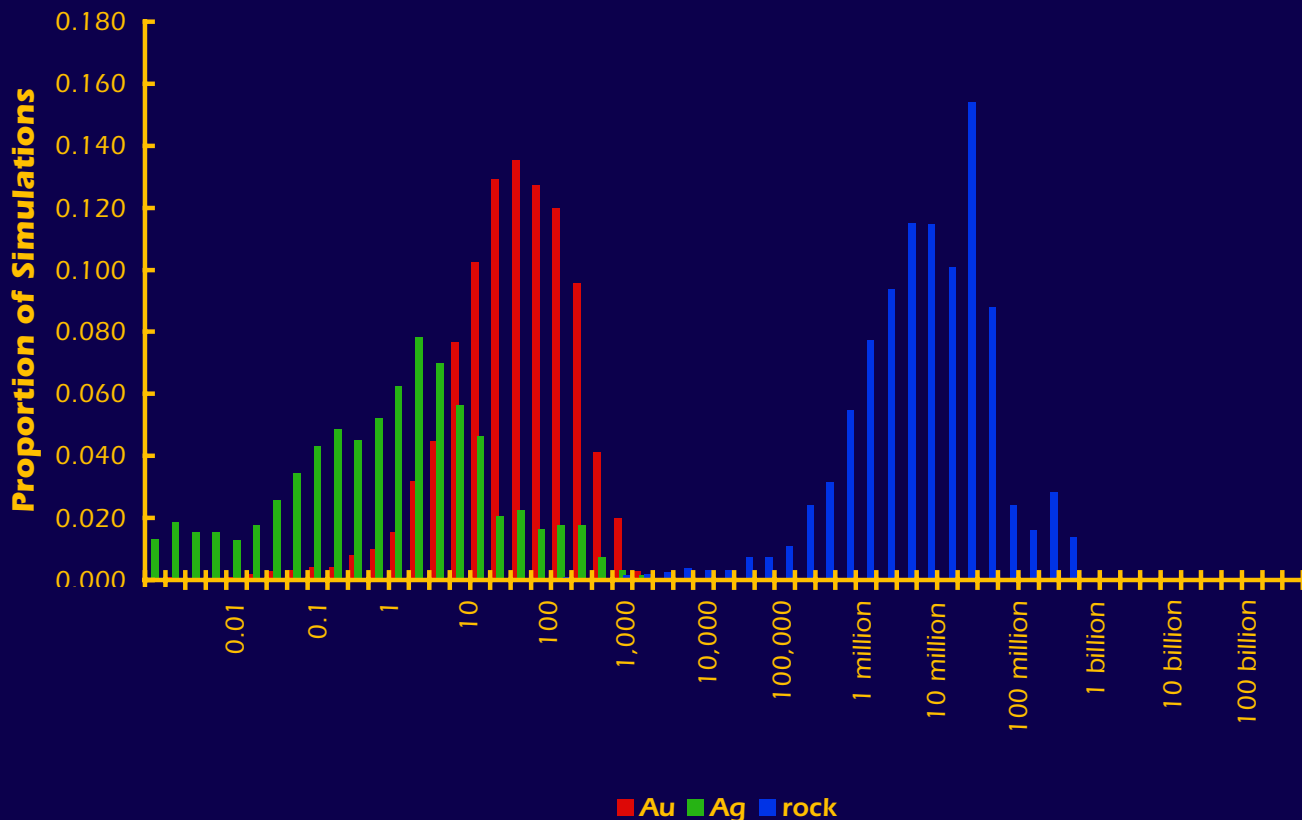


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-EC08

The Mark3 Index is 27:

Low sulfide Au-quartz vein

There is a 90% or greater chance of 5 or more deposits.
There is a 50% or greater chance of 12 or more deposits.
There is a 10% or greater chance of 20 or more deposits.
There is a 5% or greater chance of 30 or more deposits.
There is a 1% or greater chance of 50 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	1	0	47,000
0.90	3	0	230,000
0.50	38	0	3,800,000
0.10	250	21	27,600,000
0.05	370	92	82,000,000
mean	95	18	15,000,000
Probability of mean	0.29	0.11	0.23
Probability of zero	0.02	0.21	0.02

The tract ID is AK-EC08The Mark3 Index is 27: **Low sulfide Au-quartz vein**

There is a 90% or greater chance of 5 or more deposits.

There is a 50% or greater chance of 12 or more deposits.

There is a 10% or greater chance of 20 or more deposits.

There is a 5% or greater chance of 30 or more deposits.

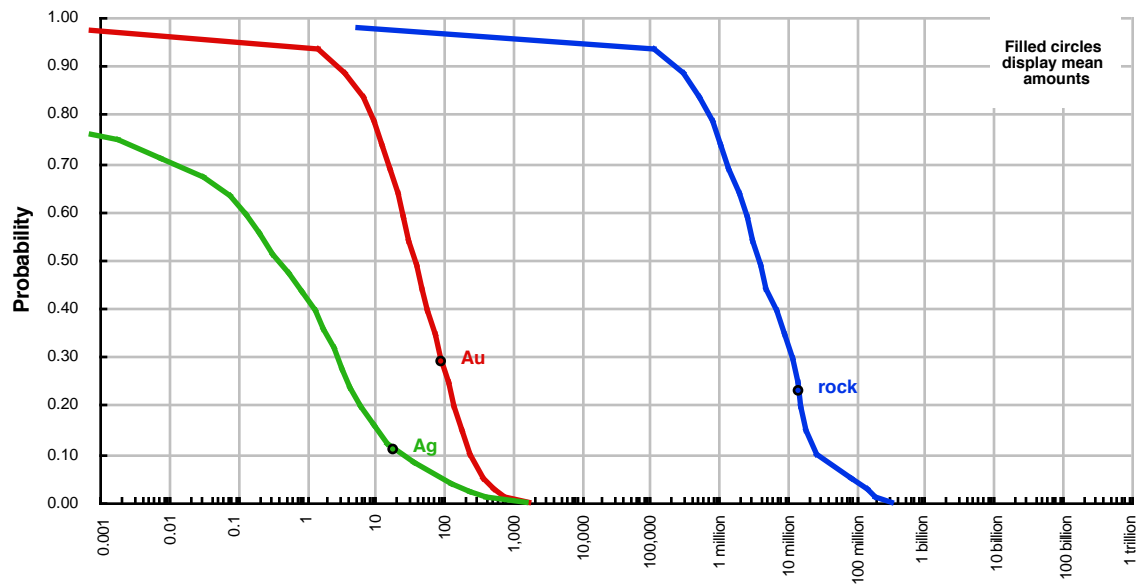
There is a 1% or greater chance of 50 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

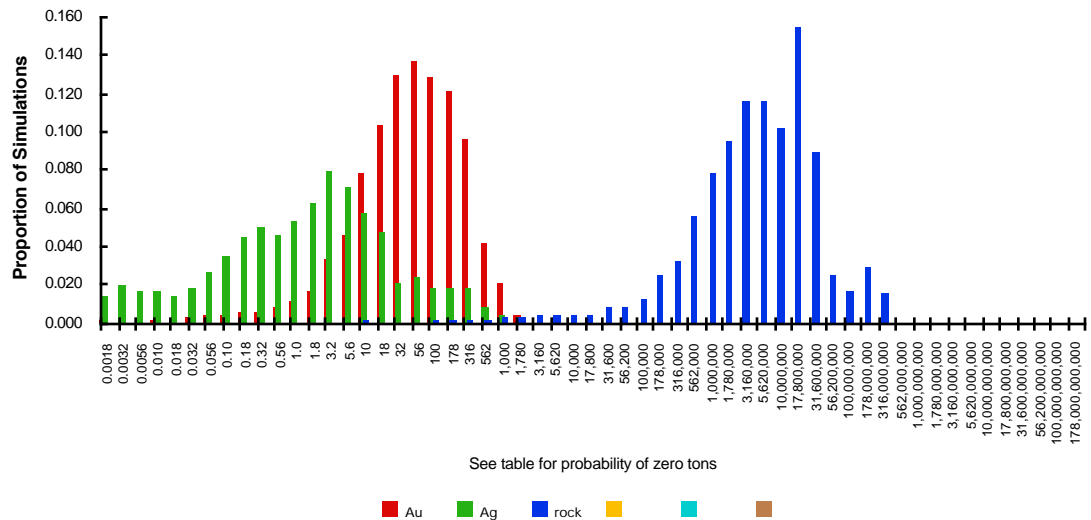
quantile	Au	Ag	rock	0	0	0
0.95	1	0	47,000	0	0	0
0.90	3	0	230,000	0	0	0
0.50	38	0	3,800,000	0	0	0
0.10	250	21	27,600,000	0	0	0
0.05	370	92	82,000,000	0	0	0
mean	95	18	15,000,000	0	0	0
Probability of mean	0.29	0.11	0.23	0.00	0.00	0.00
Probability of zero	0.02	0.21	0.02	0.00	0.00	0.00

The tract ID is AK-EC08

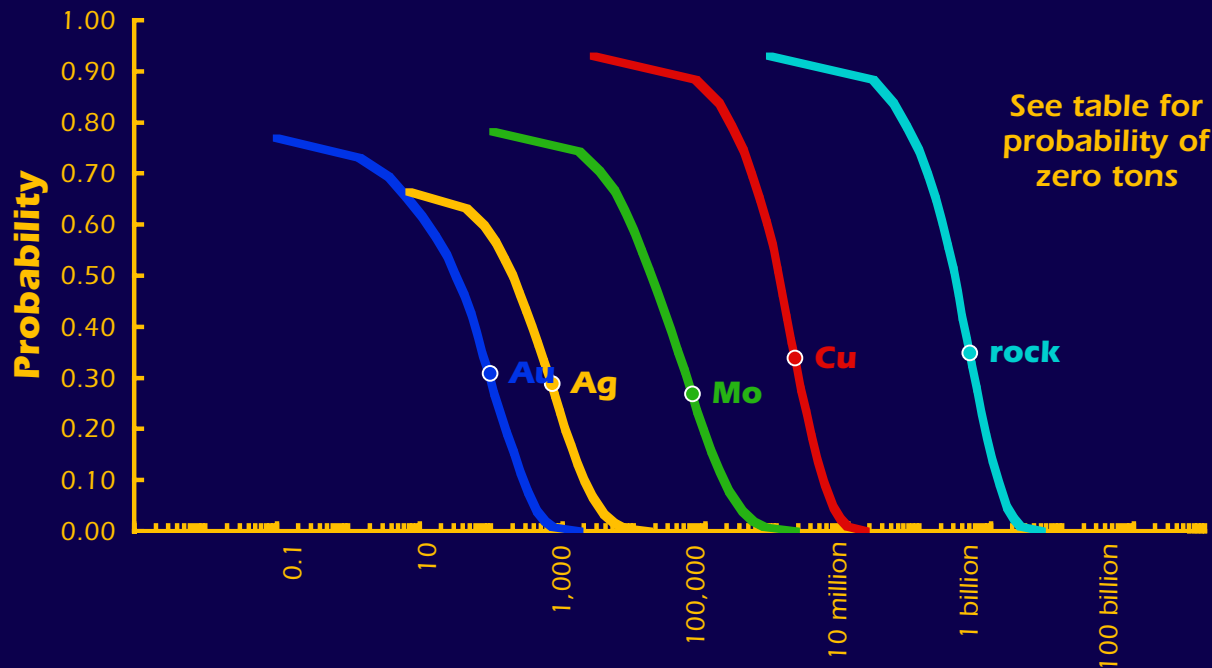
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

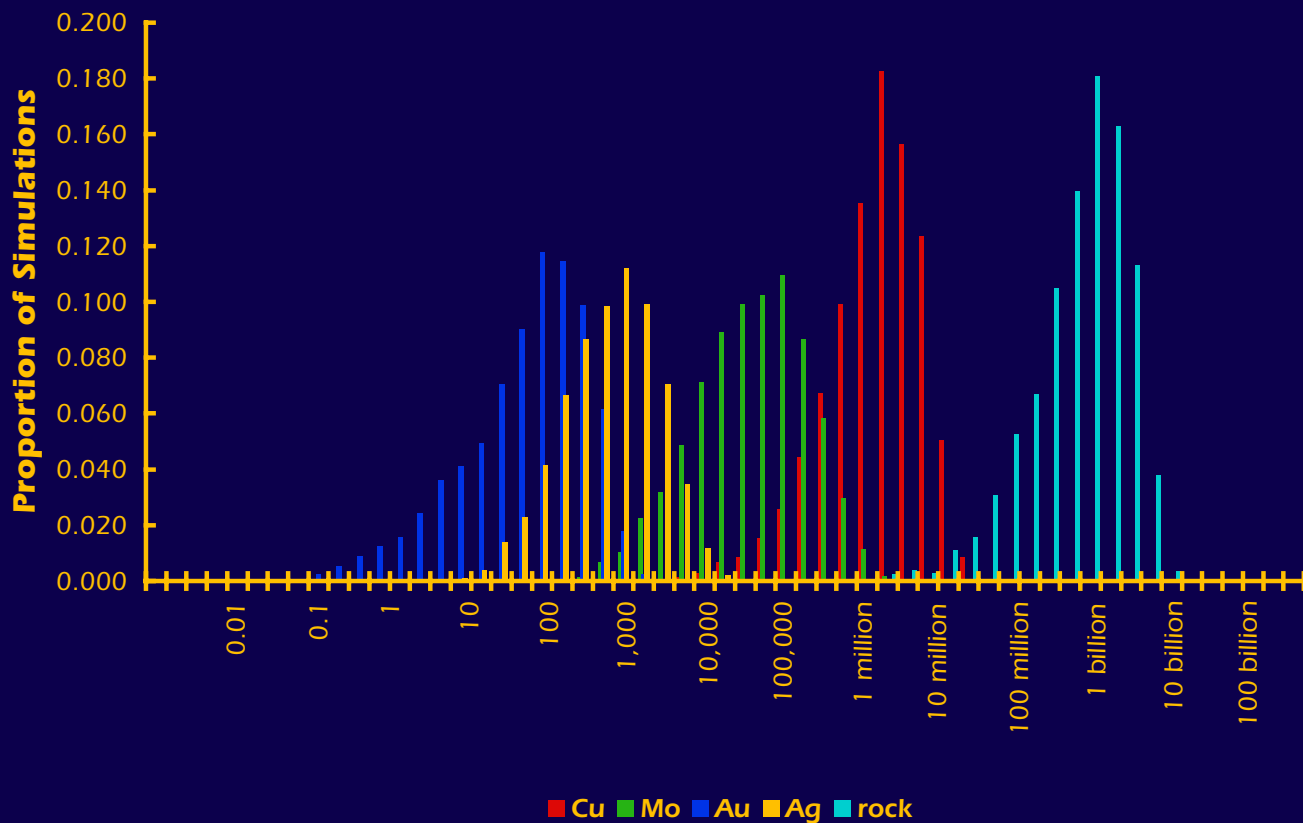


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-EC13

The Mark3 Index is 89:

Porphyry Cu (BC-AK)

There is a 90% or greater chance of 1 or more deposits.
There is a 50% or greater chance of 2 or more deposits.
There is a 10% or greater chance of 4 or more deposits.
There is a 5% or greater chance of 8 or more deposits.
There is a 1% or greater chance of 10 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	47,000	0	0	0	14,000,000
0.50	1,100,000	18,000	32	200	320,000,000
0.10	4,500,000	180,000	282	2,000	1,300,000,000
0.05	6,100,000	290,000	400	3,100	1,600,000,000
mean	1,800,000	65,000	95	710	500,000,000
Probability of mean	0.34	0.27	0.31	0.29	0.35
Probability of zero	0.07	0.22	0.23	0.34	0.07

The tract ID is AK-EC13The Mark3 Index is 89: **Porphyry Cu (BC-AK)**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 8 or more deposits.

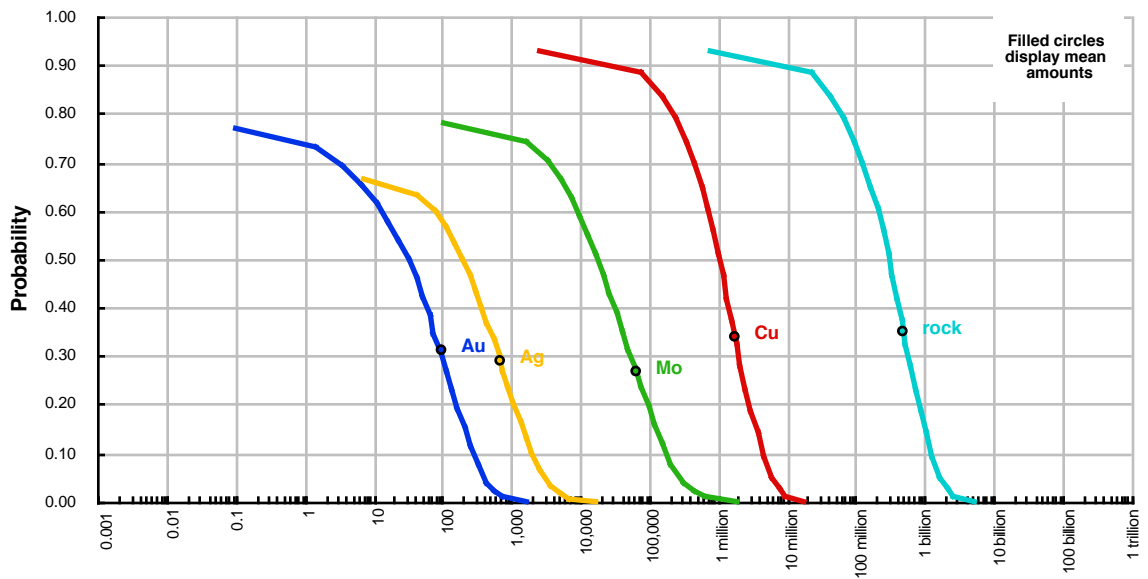
There is a 1% or greater chance of 10 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

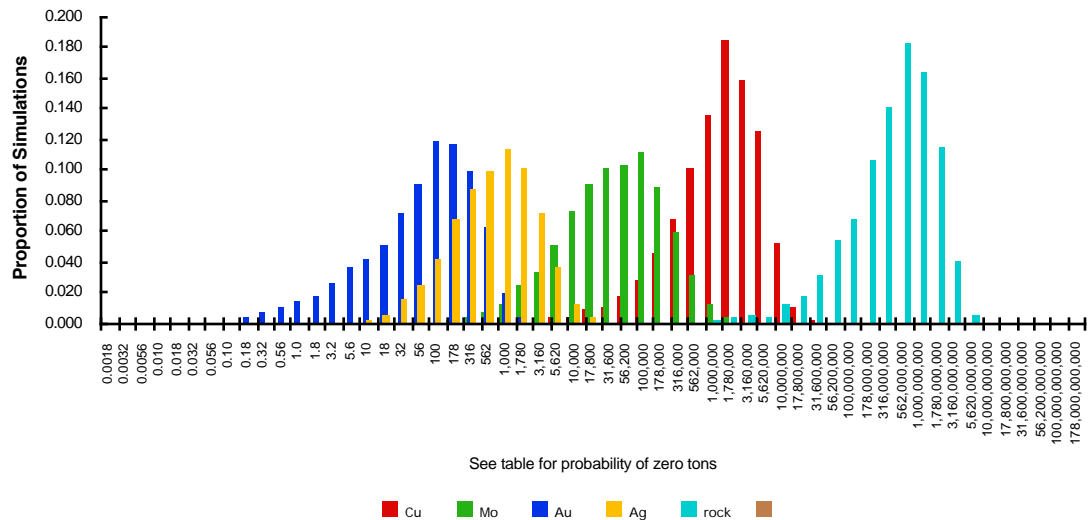
quantile	Cu	Mo	Au	Ag	rock	0
0.95	0	0	0	0	0	0
0.90	47,000	0	0	0	14,000,000	0
0.50	1,100,000	18,000	32	200	320,000,000	0
0.10	4,500,000	180,000	282	2,000	1,300,000,000	0
0.05	6,100,000	290,000	400	3,100	1,600,000,000	0
mean	1,800,000	65,000	95	710	500,000,000	0
Probability of mean	0.34	0.27	0.31	0.29	0.35	0.00
Probability of zero	0.07	0.22	0.23	0.34	0.07	0.00

The tract ID is AK-EC13

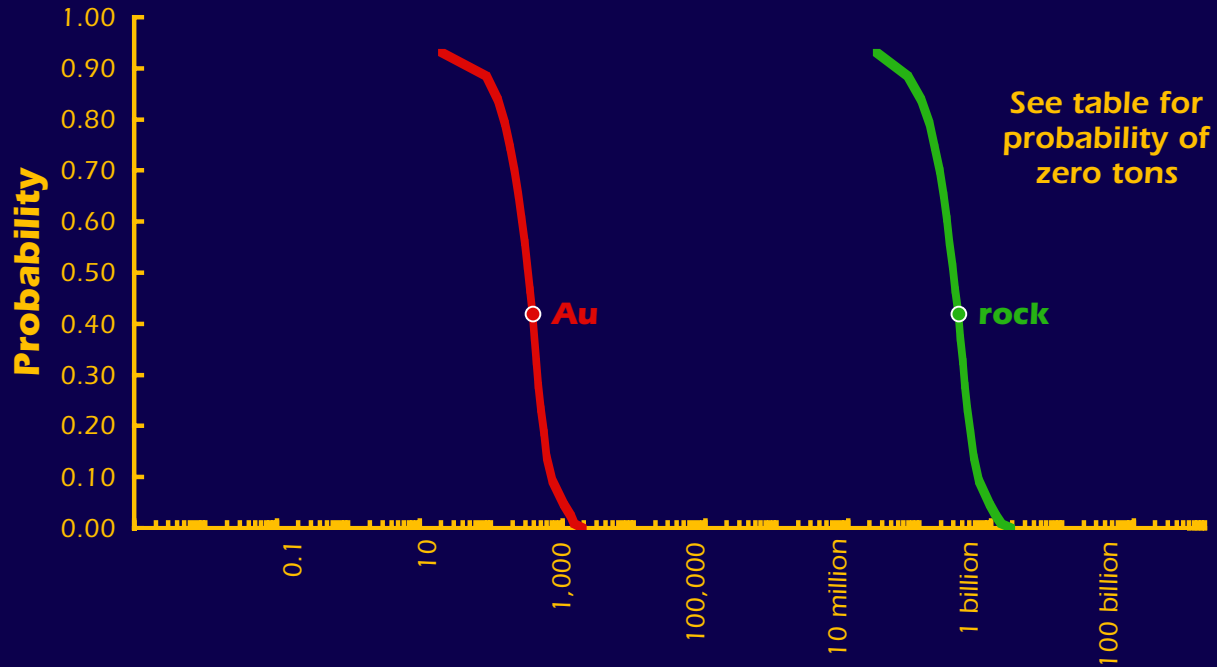
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

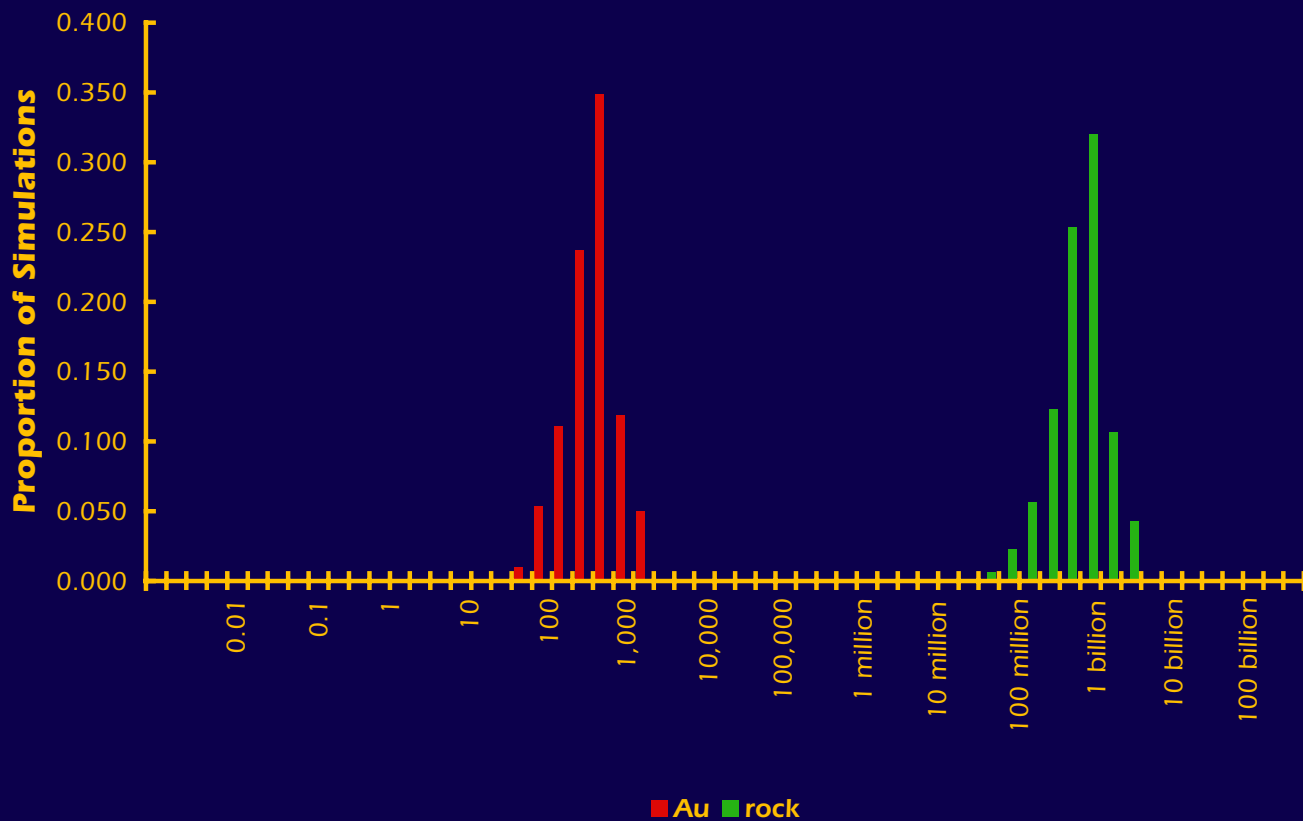


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-EC14

The Mark3 Index is 43:

Plutonic porphyry gold

There is a 90% or greater chance of 1 or more deposits.
There is a 50% or greater chance of 3 or more deposits.
There is a 10% or greater chance of 5 or more deposits.
There is a 5% or greater chance of 9 or more deposits.
There is a 1% or greater chance of 13 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	rock
0.95	0	0
0.90	77	59,000,000
0.50	330	300,000,000
0.10	690	670,000,000
0.05	1,000	930,000,000
mean	380	350,000,000
Probability of mean	0.42	0.42
Probability of zero	0.07	0.07

The tract ID is AK-EC14The Mark3 Index is 43: **Plutonic porphyry gold**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 9 or more deposits.

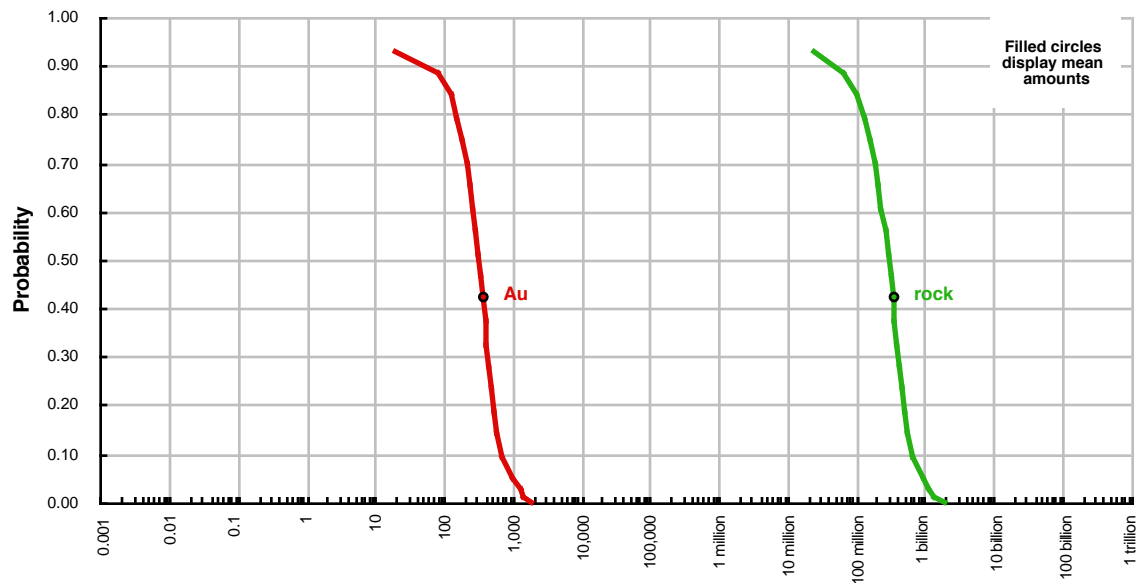
There is a 1% or greater chance of 13 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

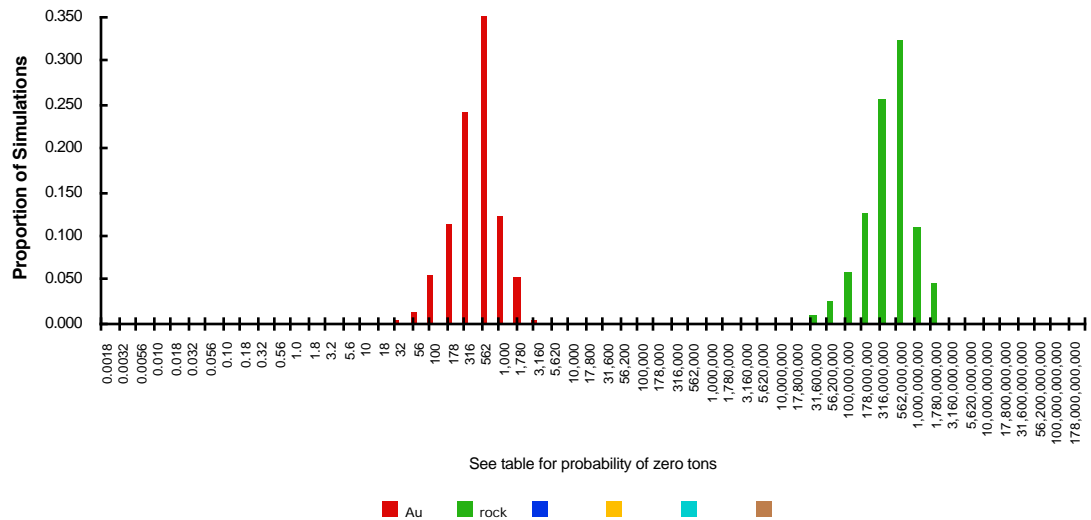
quantile	Au	rock	0	0	0	0
0.95	0	0	0	0	0	0
0.90	77	59,000,000	0	0	0	0
0.50	330	300,000,000	0	0	0	0
0.10	690	670,000,000	0	0	0	0
0.05	1,000	930,000,000	0	0	0	0
mean	380	350,000,000	0	0	0	0
Probability of mean	0.42	0.42	0.00	0.00	0.00	0.00
Probability of zero	0.07	0.07	0.00	0.00	0.00	0.00

The tract ID is AK-EC14

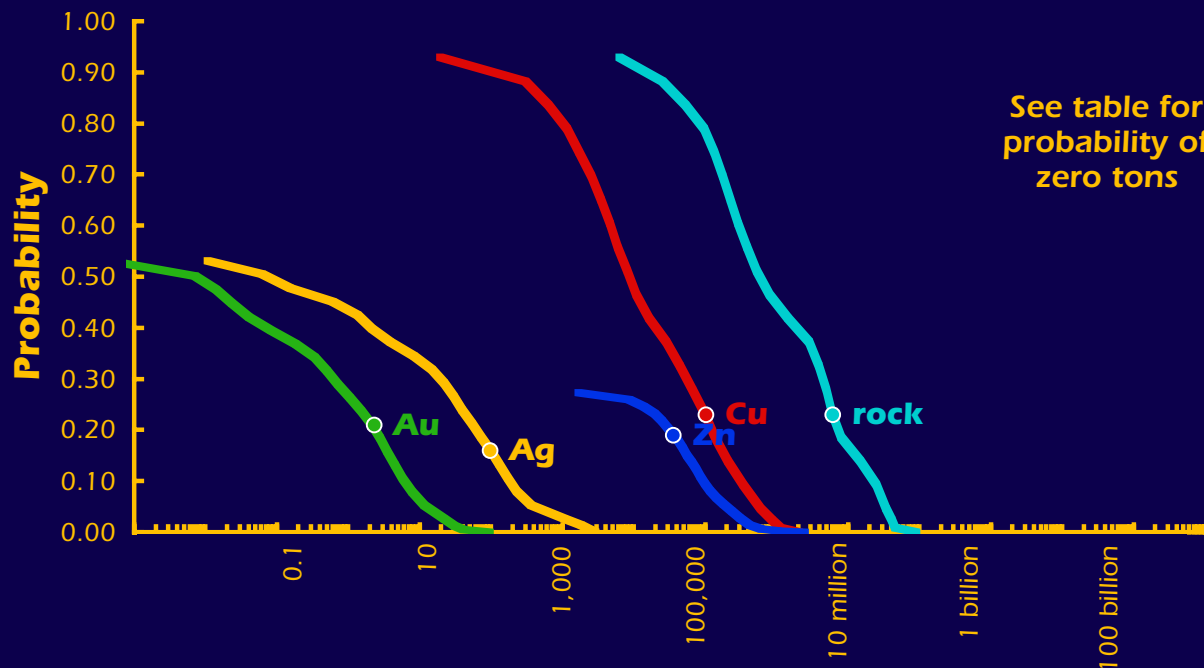
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

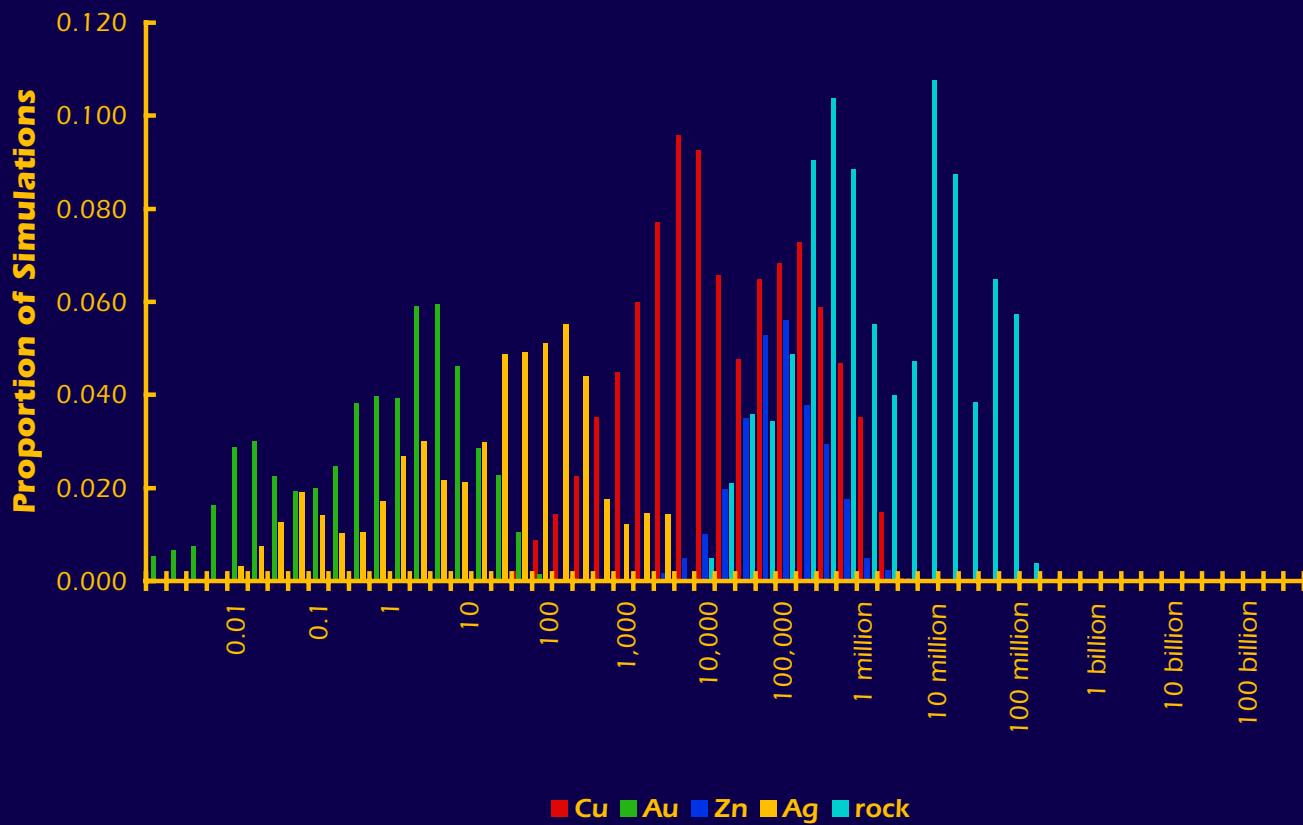


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SC03

The Mark3 Index is 30:

Massive sulfide, Besshi

There is a 90% or greater chance of 1 or more deposits.
There is a 50% or greater chance of 2 or more deposits.
There is a 10% or greater chance of 4 or more deposits.
There is a 5% or greater chance of 4 or more deposits.
There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	rock
0.95	0	0	0	0	0
0.90	200	0	0	0	19,000
0.50	8,600	0	0	0	570,000
0.10	310,000	6	92,400	180	23,000,000
0.05	570,000	13	200,000	410	34,000,000
mean	100,000	2	35,000	96	6,000,000
Probability of mean	0.23	0.21	0.19	0.16	0.23
Probability of zero	0.07	0.47	0.73	0.47	0.07

The tract ID is AK-SC03The Mark3 Index is 30: **Massive sulfide, Besshi**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

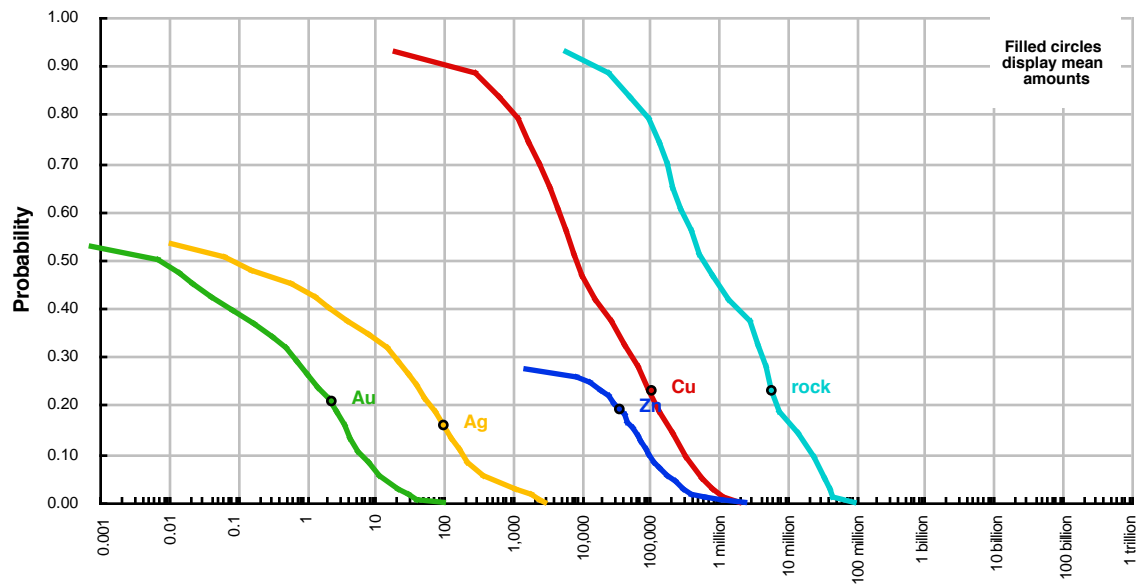
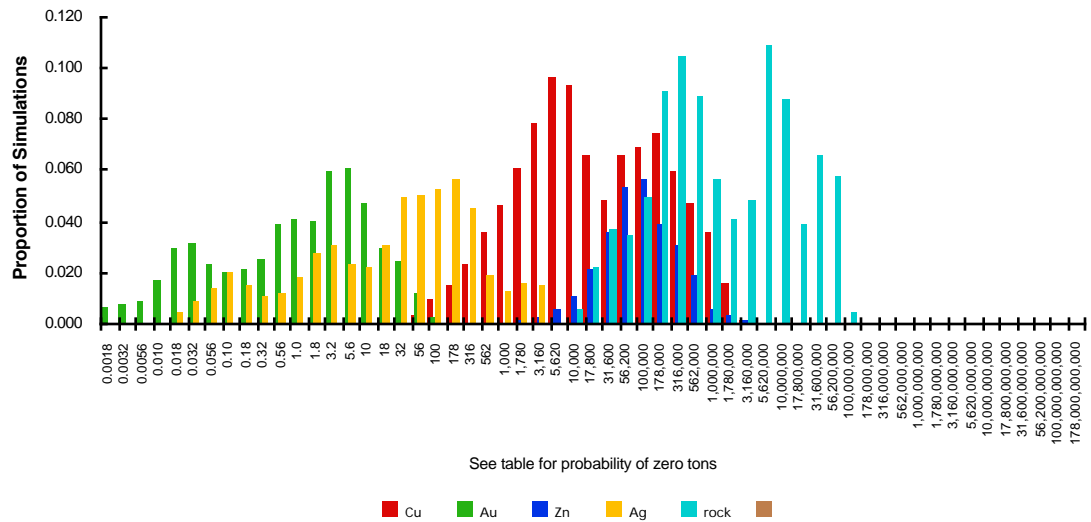
There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

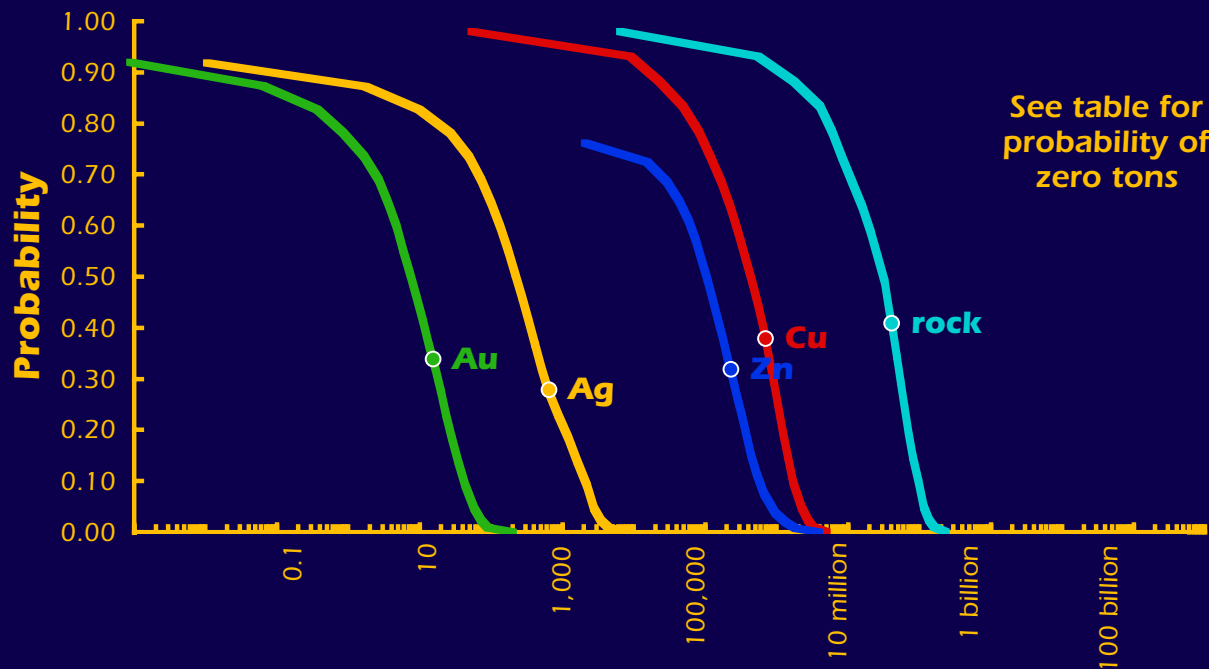
quantile	Cu	Au	Zn	Ag	rock	0
0.95	0	0	0	0	0	0
0.90	200	0	0	0	19,000	0
0.50	8,600	0	0	0	570,000	0
0.10	310,000	6	92,400	180	23,000,000	0
0.05	570,000	13	200,000	410	34,000,000	0
mean	100,000	2	35,000	96	6,000,000	0
Probability of mean	0.23	0.21	0.19	0.16	0.23	0.00
Probability of zero	0.07	0.47	0.73	0.47	0.07	0.00

The tract ID is AK-SC03

Cumulative Distributions of Contained Metal and Mineralized Rock

Histograms of Contained Metal and Mineralized Rock
(metric tons)

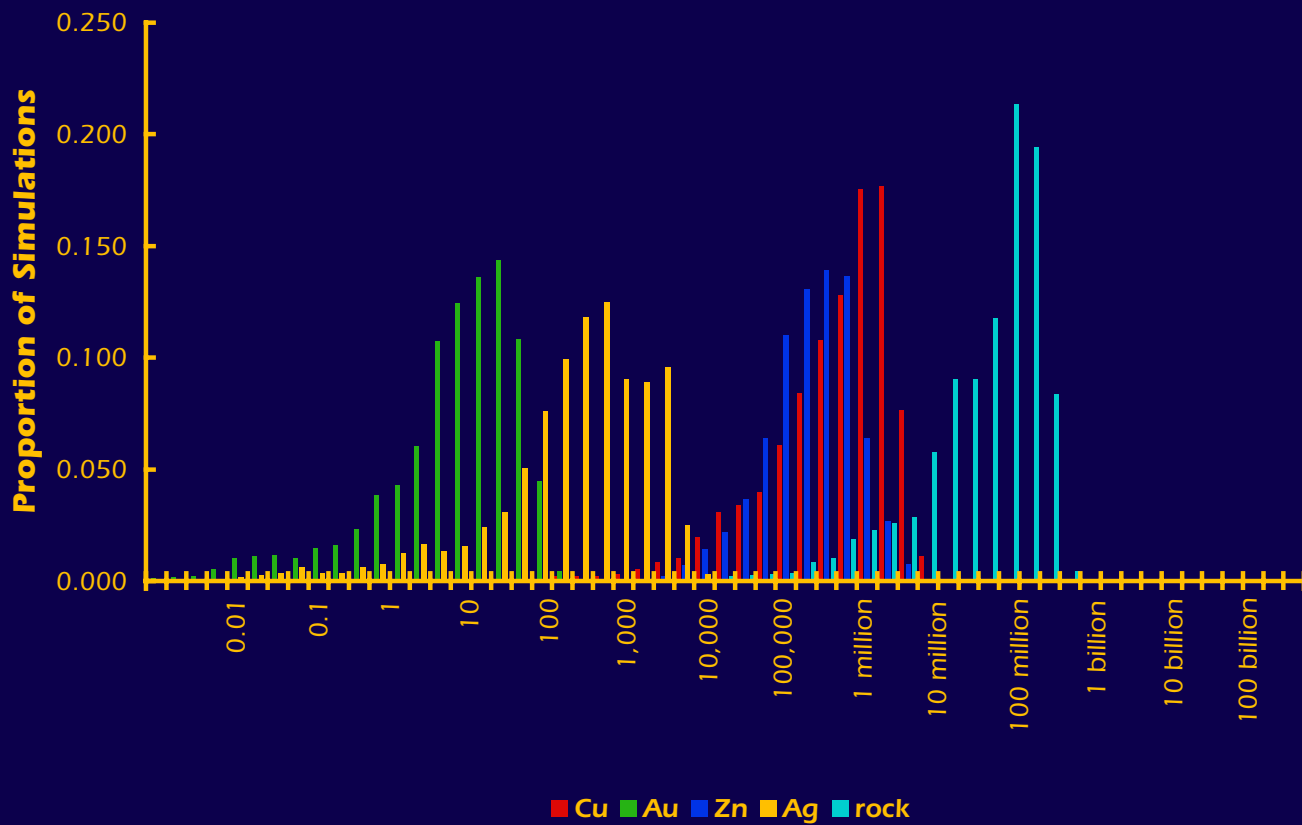
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



See table for
probability of
zero tons

Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SC04

The Mark3 Index is 30:

Massive sulfide, Besshi

There is a 90% or greater chance of 5 or more deposits.
There is a 50% or greater chance of 10 or more deposits.
There is a 10% or greater chance of 30 or more deposits.
There is a 5% or greater chance of 30 or more deposits.
There is a 1% or greater chance of 30 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	rock
0.95	4,400	0	0	0	300,000
0.90	16,000	0	0	0	1,200,000
0.50	440,000	8	100,000	220	31,000,000
0.10	1,700,000	42	560,000	2,100	96,000,000
0.05	2,200,000	56	820,000	2,700	120,000,000
mean	690,000	15	220,000	640	40,000,000
Probability of mean	0.38	0.34	0.32	0.28	0.41
Probability of zero	0.02	0.08	0.24	0.08	0.02

The tract ID is AK-SC04The Mark3 Index is 30: **Massive sulfide, Besshi**

There is a 90% or greater chance of 5 or more deposits.

There is a 50% or greater chance of 10 or more deposits.

There is a 10% or greater chance of 30 or more deposits.

There is a 5% or greater chance of 30 or more deposits.

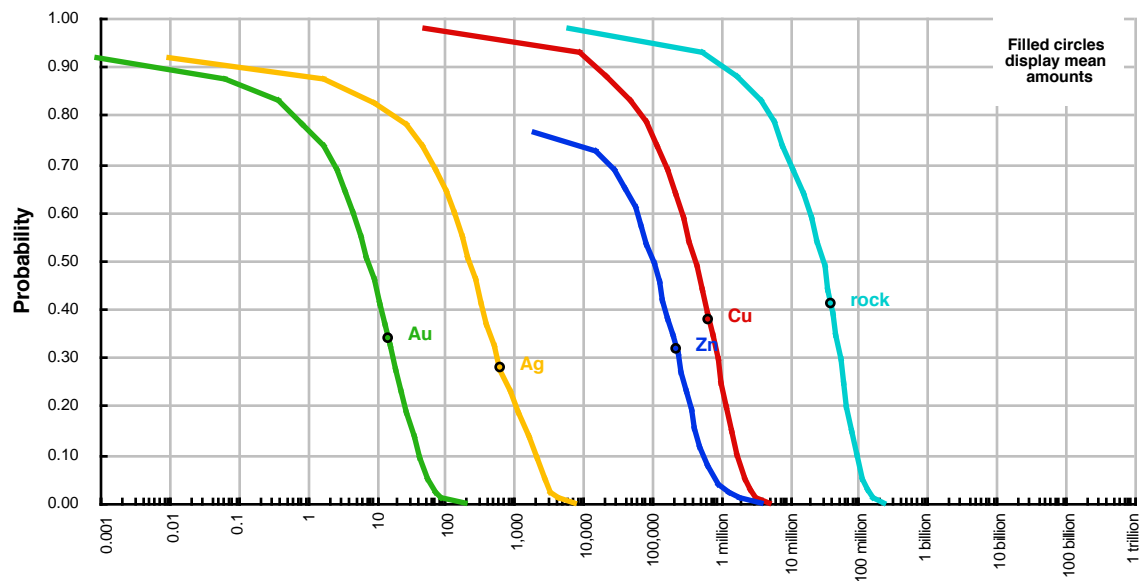
There is a 1% or greater chance of 30 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

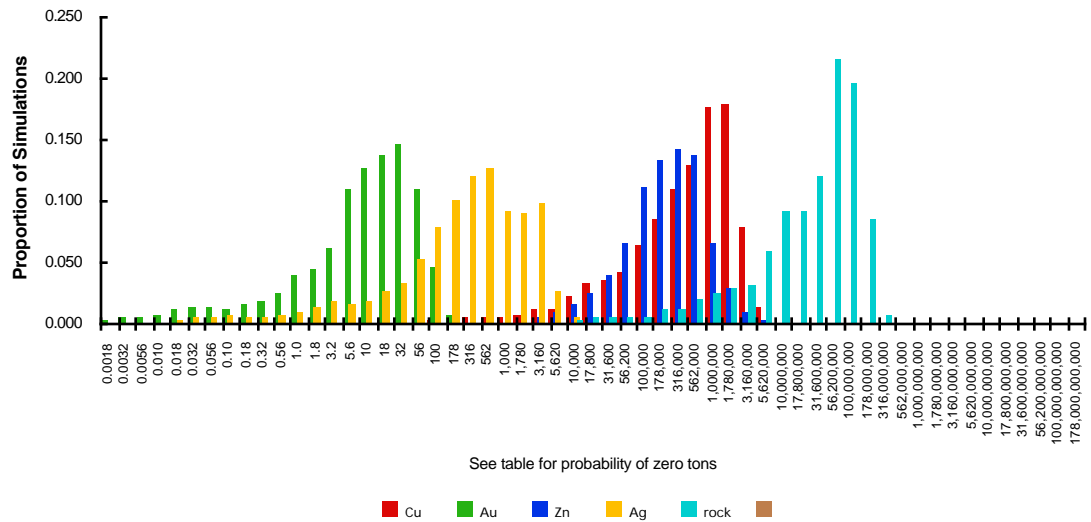
quantile	Cu	Au	Zn	Ag	rock	0
0.95	4,400	0	0	0	300,000	0
0.90	16,000	0	0	0	1,200,000	0
0.50	440,000	8	100,000	220	31,000,000	0
0.10	1,700,000	42	560,000	2,100	96,000,000	0
0.05	2,200,000	56	820,000	2,700	120,000,000	0
mean	690,000	15	220,000	640	40,000,000	0
Probability of mean	0.38	0.34	0.32	0.28	0.41	0.00
Probability of zero	0.02	0.08	0.24	0.08	0.02	0.00

The tract ID is AK-SC04

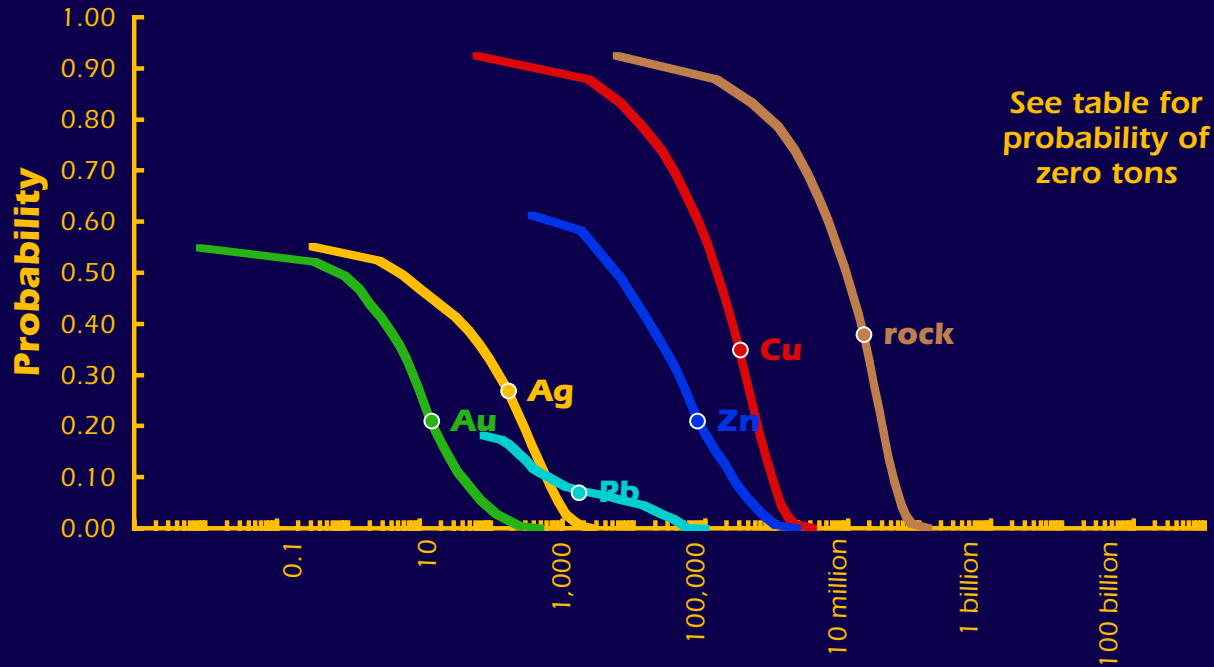
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

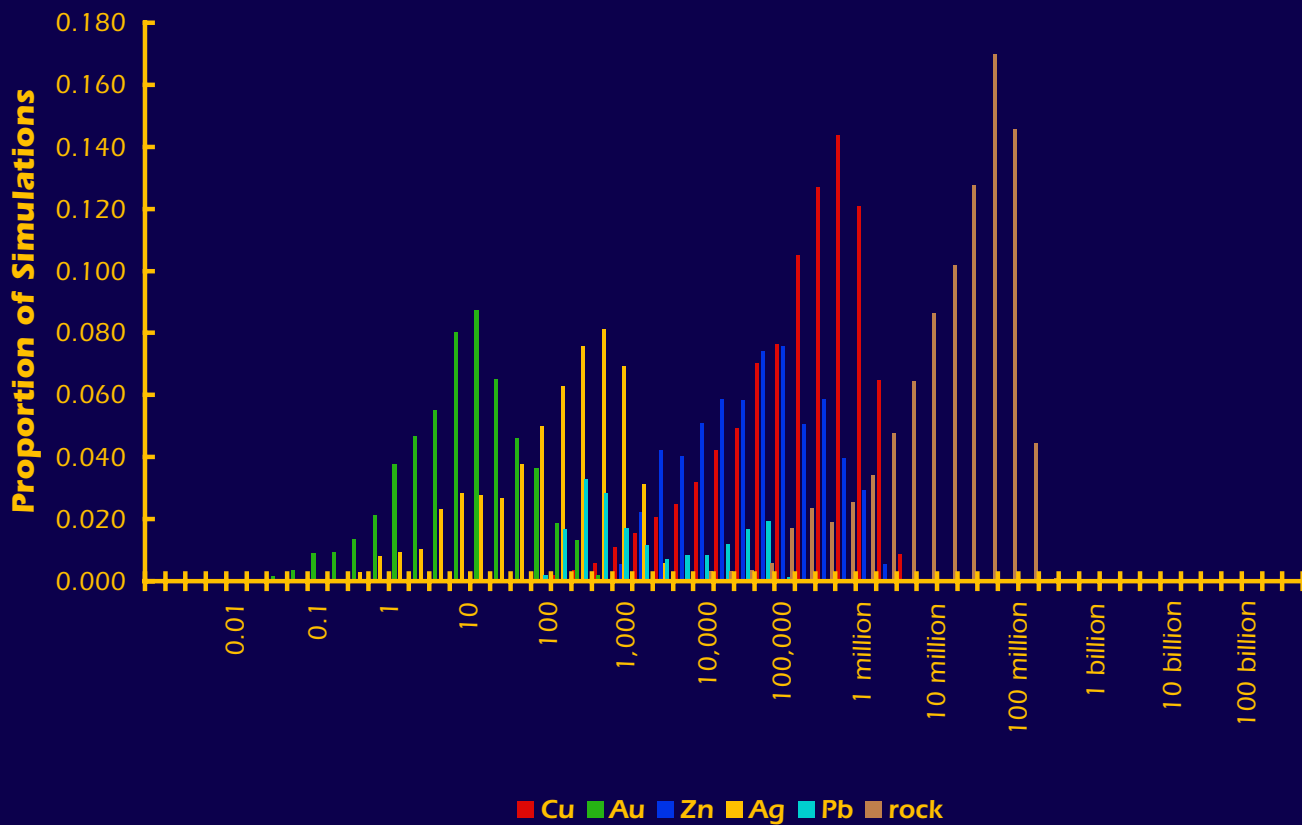


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SC06

The Mark3 Index is 11:

Massive sulfide, Cyprus

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 8 or more deposits.

There is a 5% or greater chance of 8 or more deposits.

There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	1,100	0	0	0	0	75,000
0.50	150,000	1	5,800	5	0	9,400,000
0.10	880,000	37	240,000	600	670	43,000,000
0.05	1,200,000	76	440,000	900	9,800	55,000,000
mean	310,000	15	78,000	170	1,700	16,000,000
Probability of mean	0.35	0.21	0.21	0.27	0.07	0.38
Probability of zero	0.08	0.45	0.39	0.45	0.82	0.08

The tract ID is AK-SC06The Mark3 Index is 11: **Massive sulfide, Cyprus**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

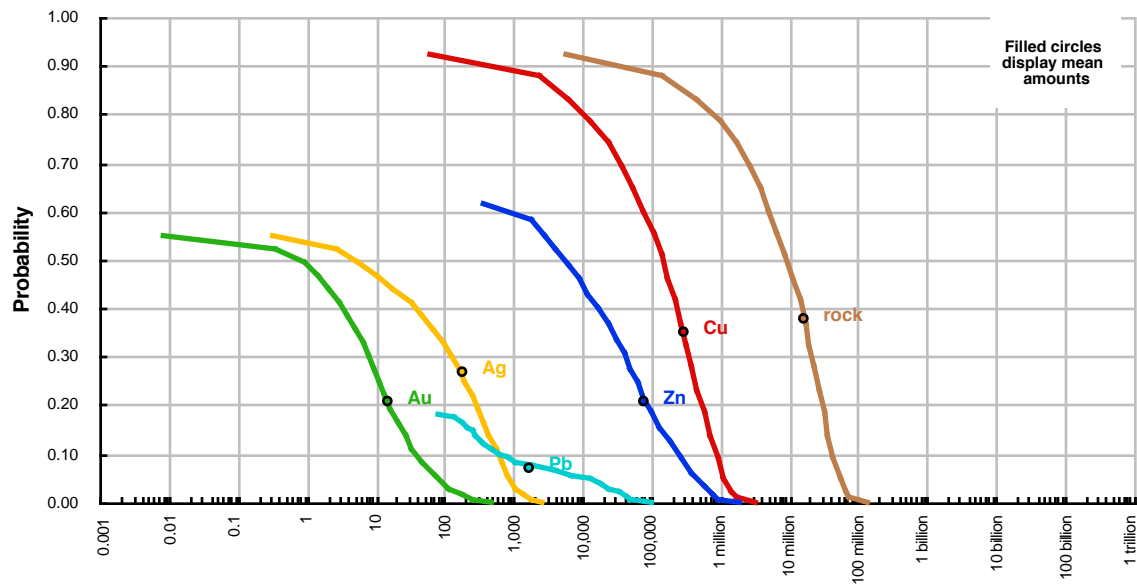
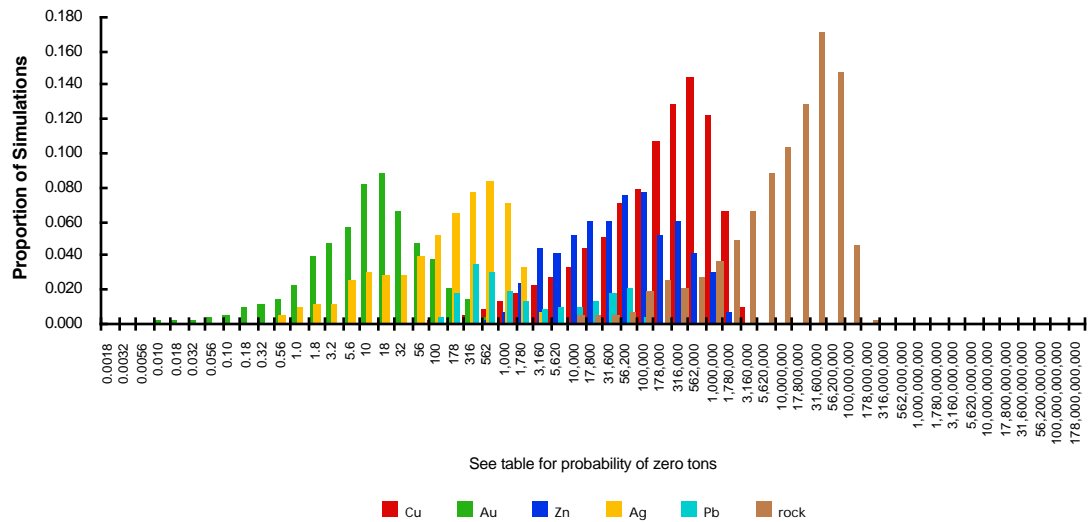
There is a 10% or greater chance of 8 or more deposits.

There is a 5% or greater chance of 8 or more deposits.

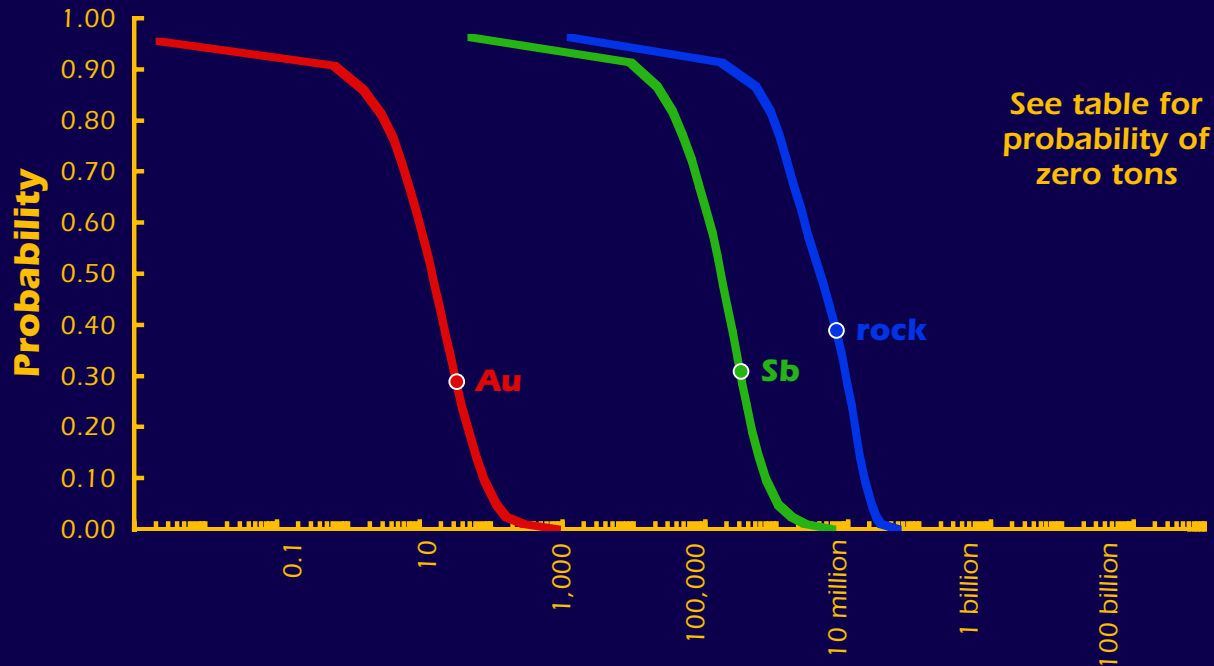
There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	1,100	0	0	0	0	75,000
0.50	150,000	1	5,800	5	0	9,400,000
0.10	880,000	37	240,000	600	670	43,000,000
0.05	1,200,000	76	440,000	900	9,800	55,000,000
mean	310,000	15	78,000	170	1,700	16,000,000
Probability of mean	0.35	0.21	0.21	0.27	0.07	0.38
Probability of zero	0.08	0.45	0.39	0.45	0.82	0.08

The tract ID is AK-SC06**Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

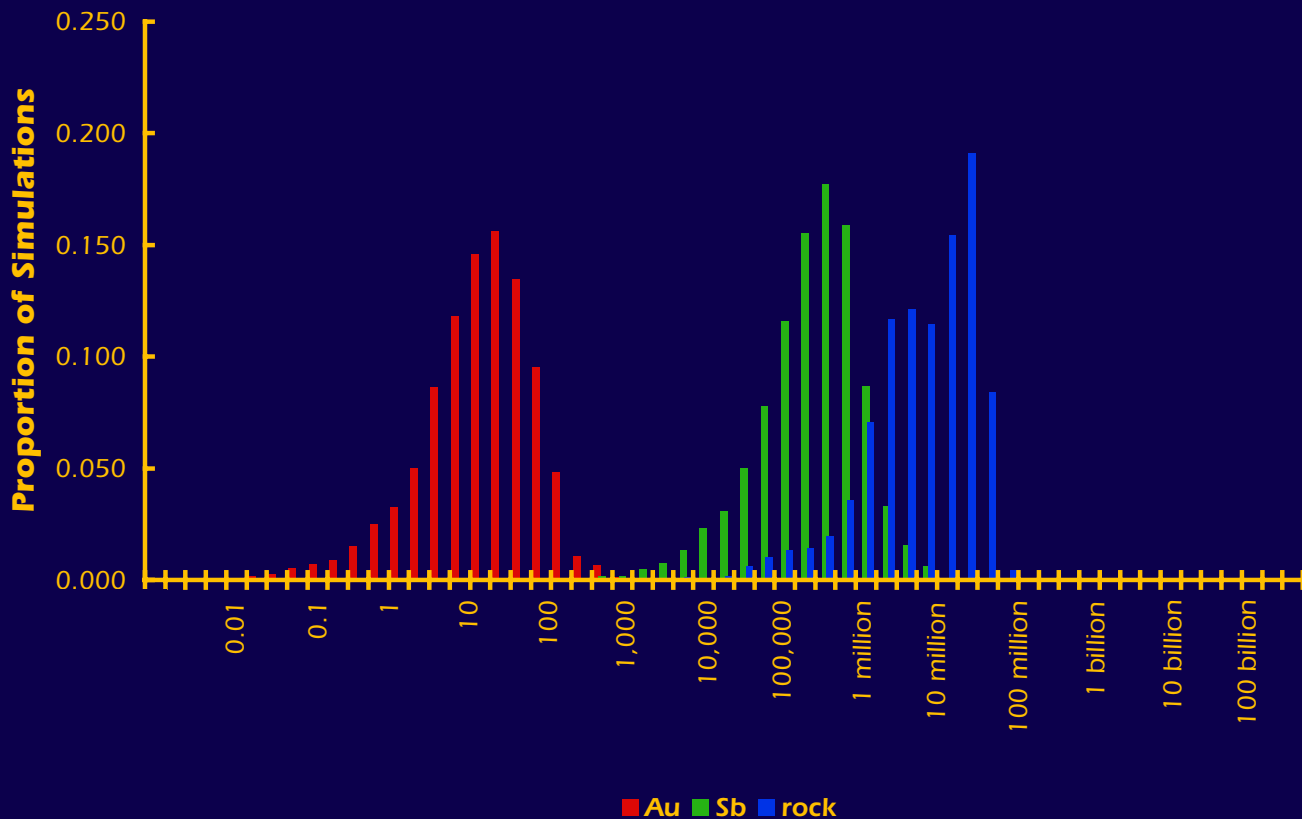
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



See table for
probability of
zero tons

Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SC07

The Mark3 Index is 114:

Au-Sb vein

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 4 or more deposits.

There is a 10% or greater chance of 10 or more deposits.

There is a 5% or greater chance of 10 or more deposits.

There is a 1% or greater chance of 10 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Sb	rock
0.95	0	2,100	33,000
0.90	1	12,000	270,000
0.50	15	170,000	4,100,000
0.10	78	710,000	17,000,000
0.05	120	1,000,000	21,000,000
mean	33	310,000	6,800,000
Probability of mean	0.29	0.31	0.39
Probability of zero	0.05	0.04	0.04

The tract ID is AK-SC07The Mark3 Index is 114: **Au-Sb vein**

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 4 or more deposits.

There is a 10% or greater chance of 10 or more deposits.

There is a 5% or greater chance of 10 or more deposits.

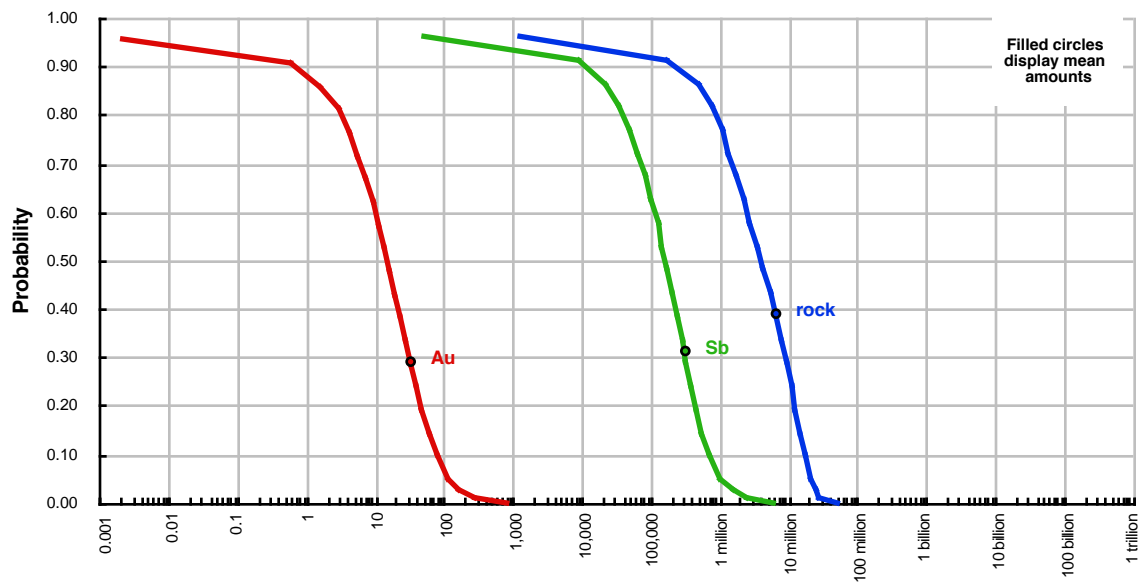
There is a 1% or greater chance of 10 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

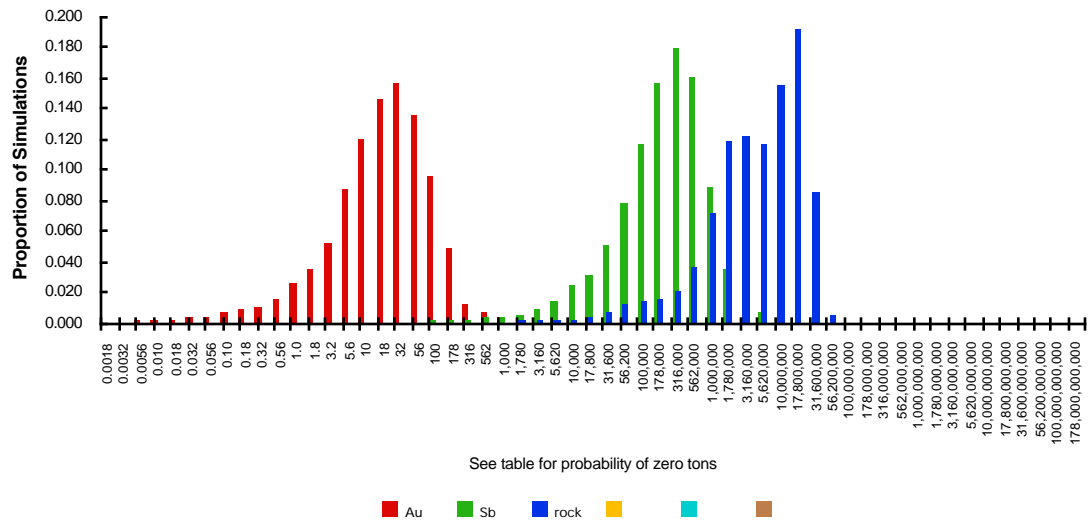
quantile	Au	Sb	rock	0	0	0
0.95	0	2,100	33,000	0	0	0
0.90	1	12,000	270,000	0	0	0
0.50	15	170,000	4,100,000	0	0	0
0.10	78	710,000	17,000,000	0	0	0
0.05	120	1,000,000	21,000,000	0	0	0
mean	33	310,000	6,800,000	0	0	0
Probability of mean	0.29	0.31	0.39	0.00	0.00	0.00
Probability of zero	0.05	0.04	0.04	0.00	0.00	0.00

The tract ID is AK-SC07

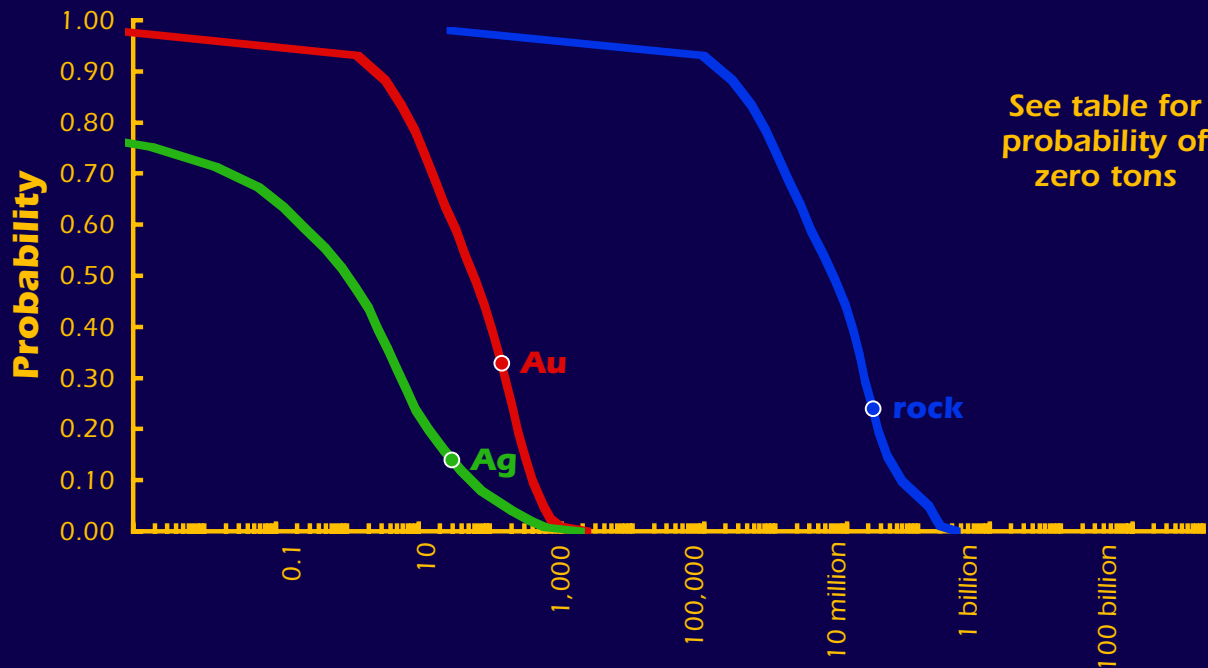
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)



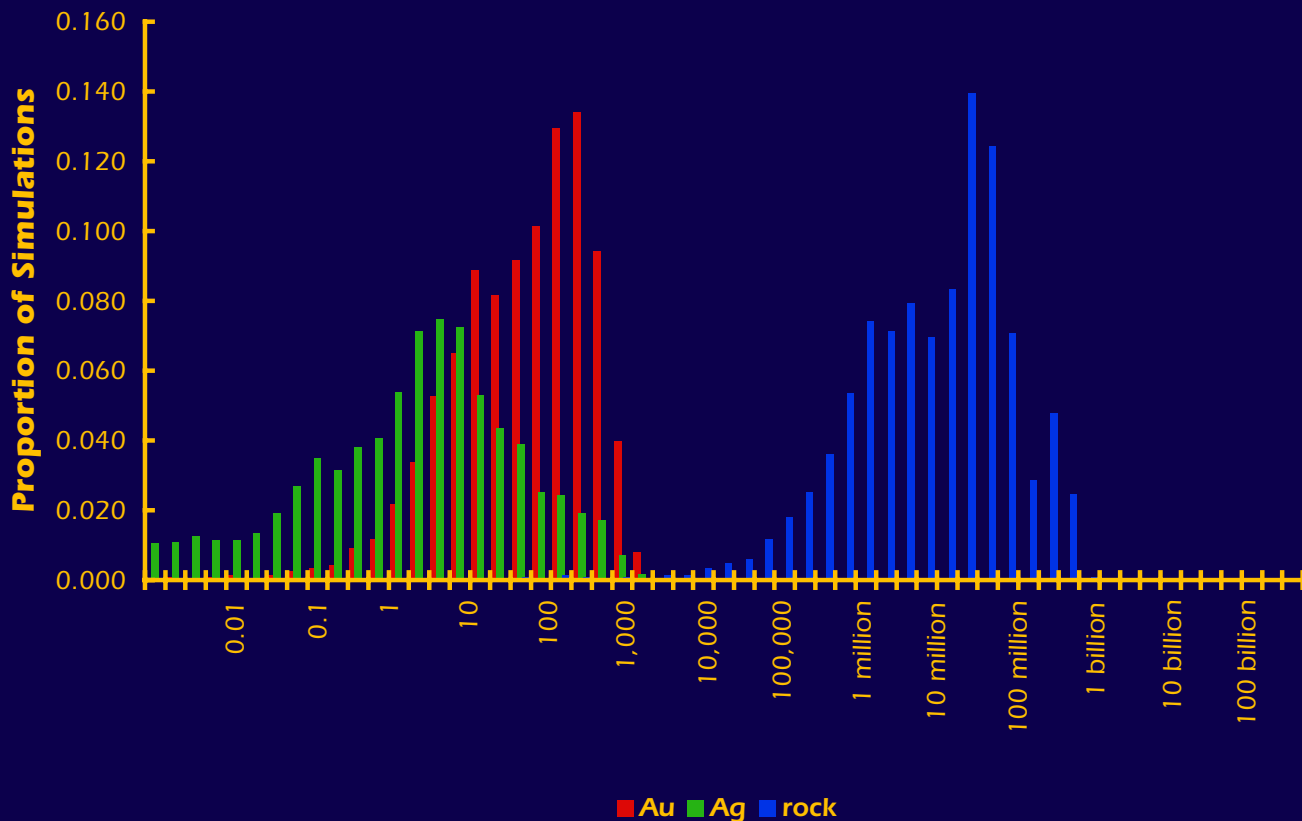
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



See table for
probability of
zero tons

Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SC08

The Mark3 Index is 27:

Low sulfide Au-quartz vein

There is a 90% or greater chance of 5 or more deposits.
There is a 50% or greater chance of 10 or more deposits.
There is a 10% or greater chance of 50 or more deposits.
There is a 5% or greater chance of 50 or more deposits.
There is a 1% or greater chance of 50 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	1	0	51,000
0.90	3	0	190,000
0.50	59	1	6,500,000
0.10	400	52	57,800,000
0.05	560	160	140,000,000
mean	140	29	23,000,000
Probability of mean	0.33	0.14	0.24
Probability of zero	0.02	0.21	0.02

The tract ID is AK-SC08The Mark3 Index is 27: **Low sulfide Au-quartz vein**

There is a 90% or greater chance of 5 or more deposits.

There is a 50% or greater chance of 10 or more deposits.

There is a 10% or greater chance of 50 or more deposits.

There is a 5% or greater chance of 50 or more deposits.

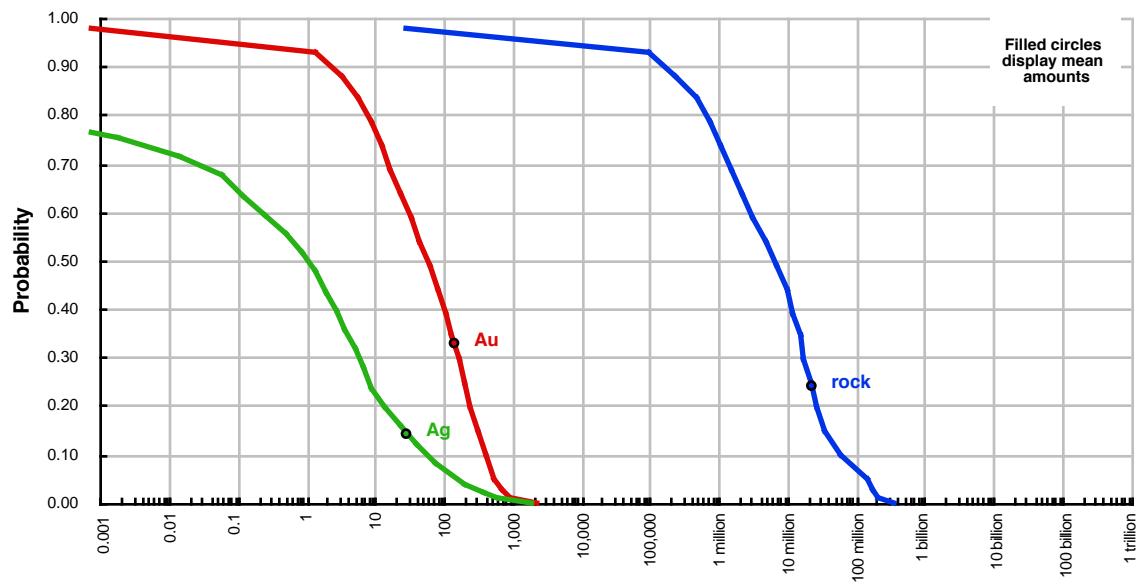
There is a 1% or greater chance of 50 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

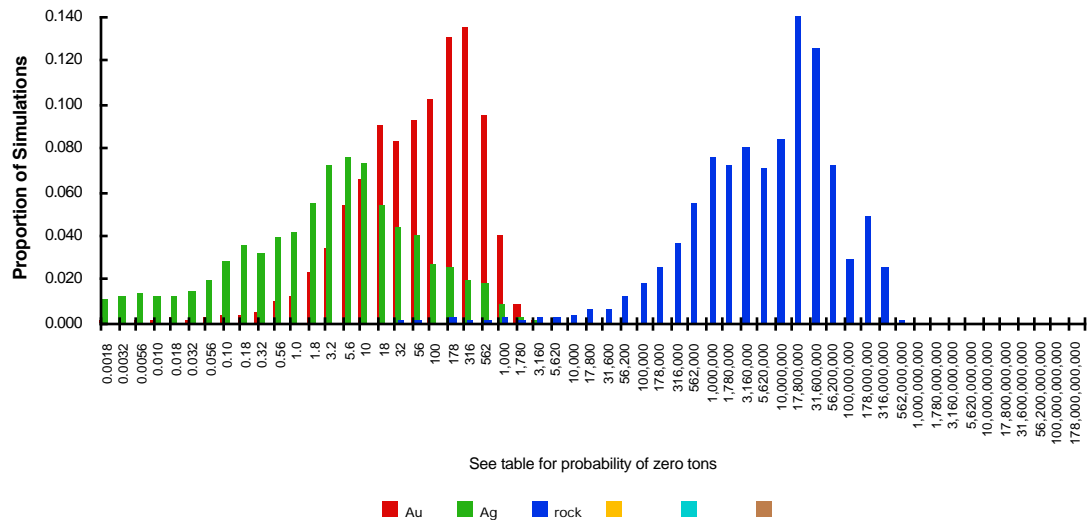
quantile	Au	Ag	rock	0	0	0
0.95	1	0	51,000	0	0	0
0.90	3	0	190,000	0	0	0
0.50	59	1	6,500,000	0	0	0
0.10	400	52	57,800,000	0	0	0
0.05	560	160	140,000,000	0	0	0
mean	140	29	23,000,000	0	0	0
Probability of mean	0.33	0.14	0.24	0.00	0.00	0.00
Probability of zero	0.02	0.21	0.02	0.00	0.00	0.00

The tract ID is AK-SC08

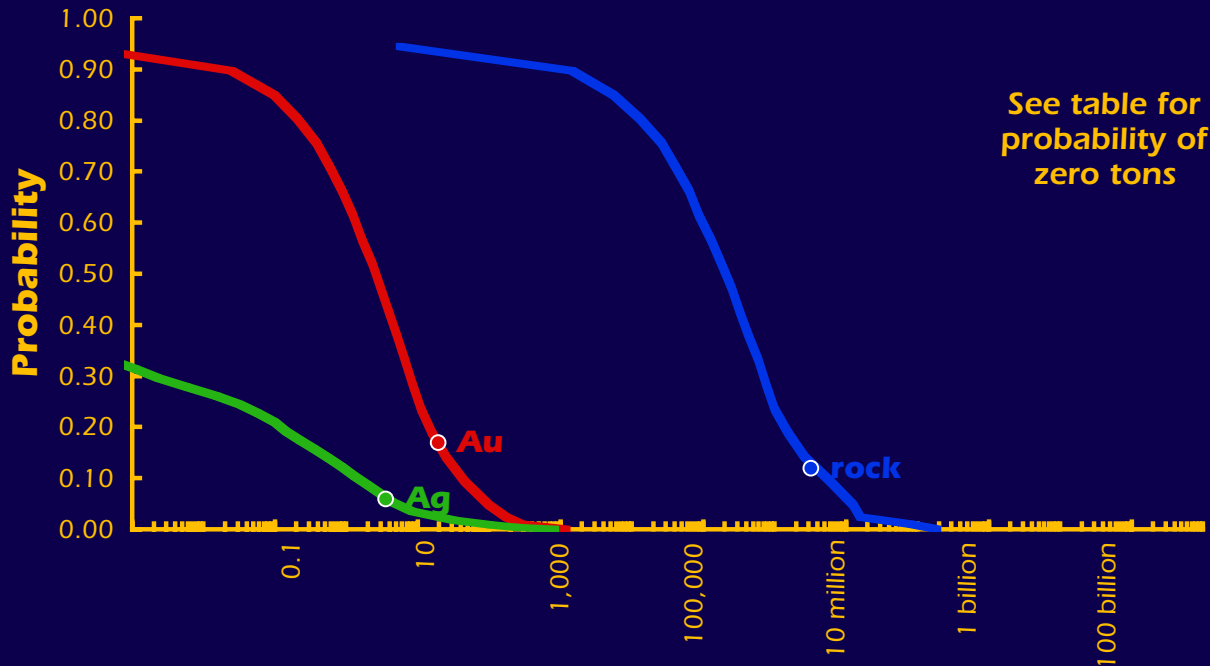
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

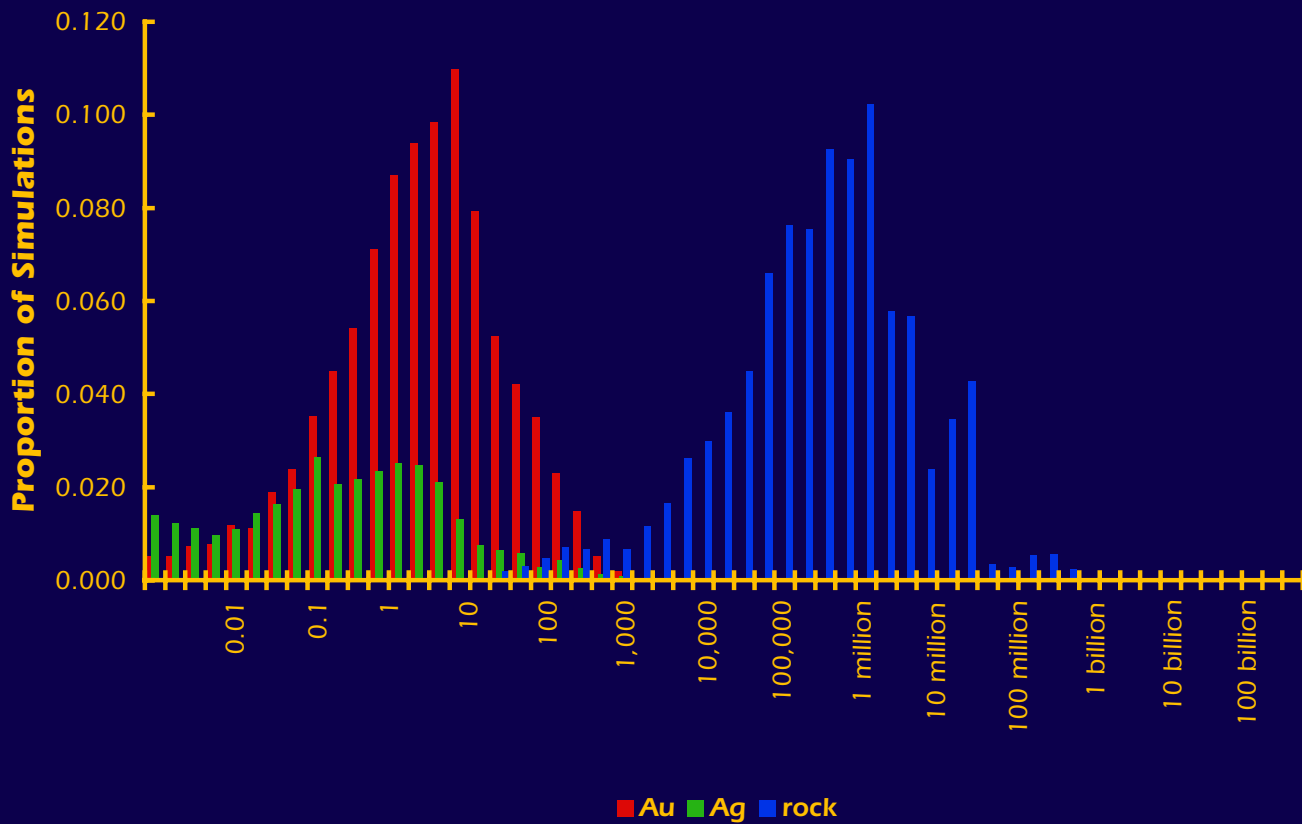


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SC10

The Mark3 Index is 27:

Low sulfide Au-quartz vein

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	1,300
0.50	3	0	200,000
0.10	41	1	5,210,000
0.05	94	5	12,000,000
mean	19	4	3,200,000
Probability of mean	0.17	0.06	0.12
Probability of zero	0.06	0.65	0.06

The tract ID is AK-SC10The Mark3 Index is 27: **Low sulfide Au-quartz vein**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

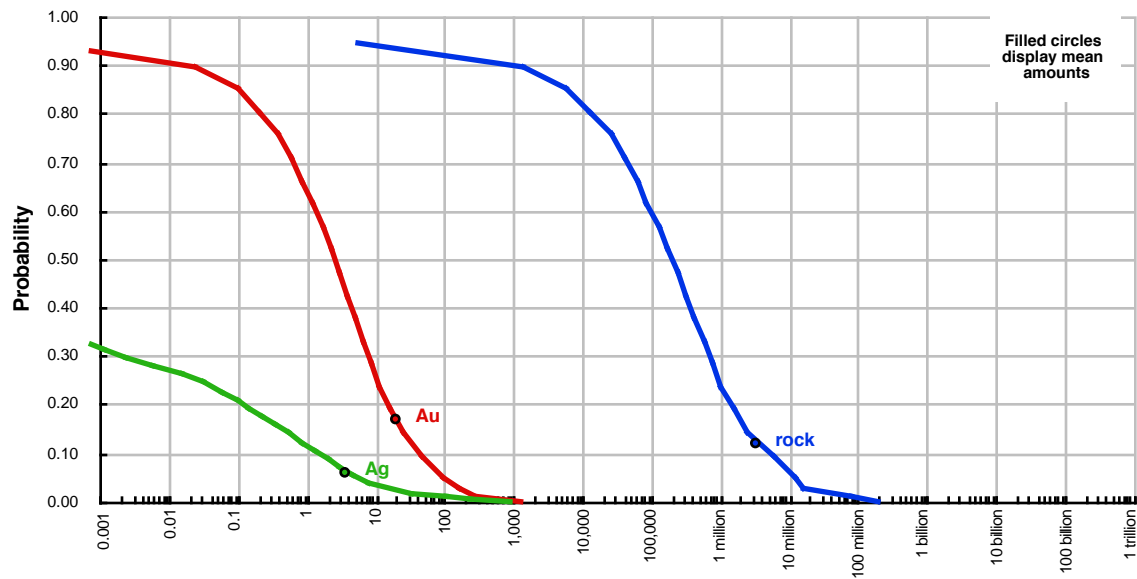
There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

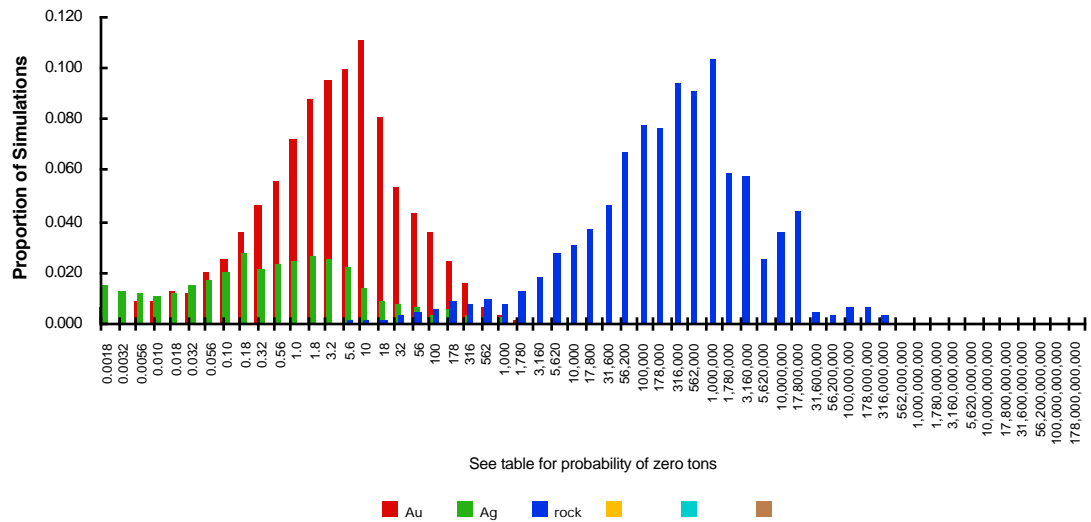
quantile	Au	Ag	rock	0	0	0
0.95	0	0	0	0	0	0
0.90	0	0	1,300	0	0	0
0.50	3	0	200,000	0	0	0
0.10	41	1	5,210,000	0	0	0
0.05	94	5	12,000,000	0	0	0
mean	19	4	3,200,000	0	0	0
Probability of mean	0.17	0.06	0.12	0.00	0.00	0.00
Probability of zero	0.06	0.65	0.06	0.00	0.00	0.00

The tract ID is AK-SC10

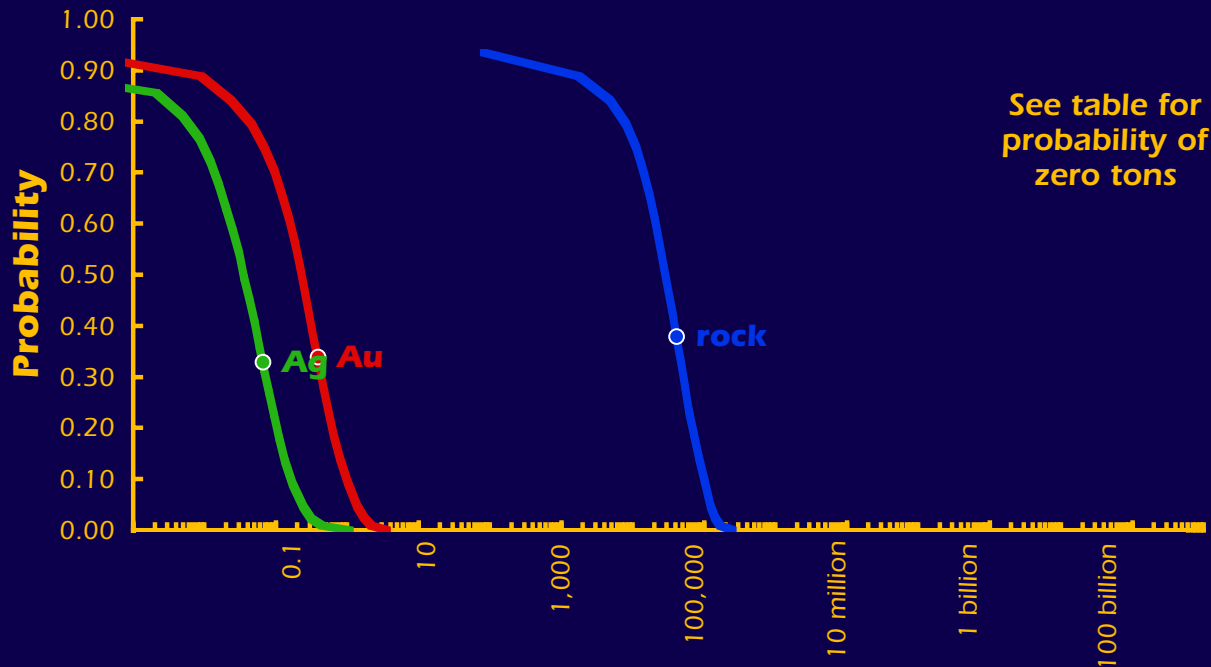
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)



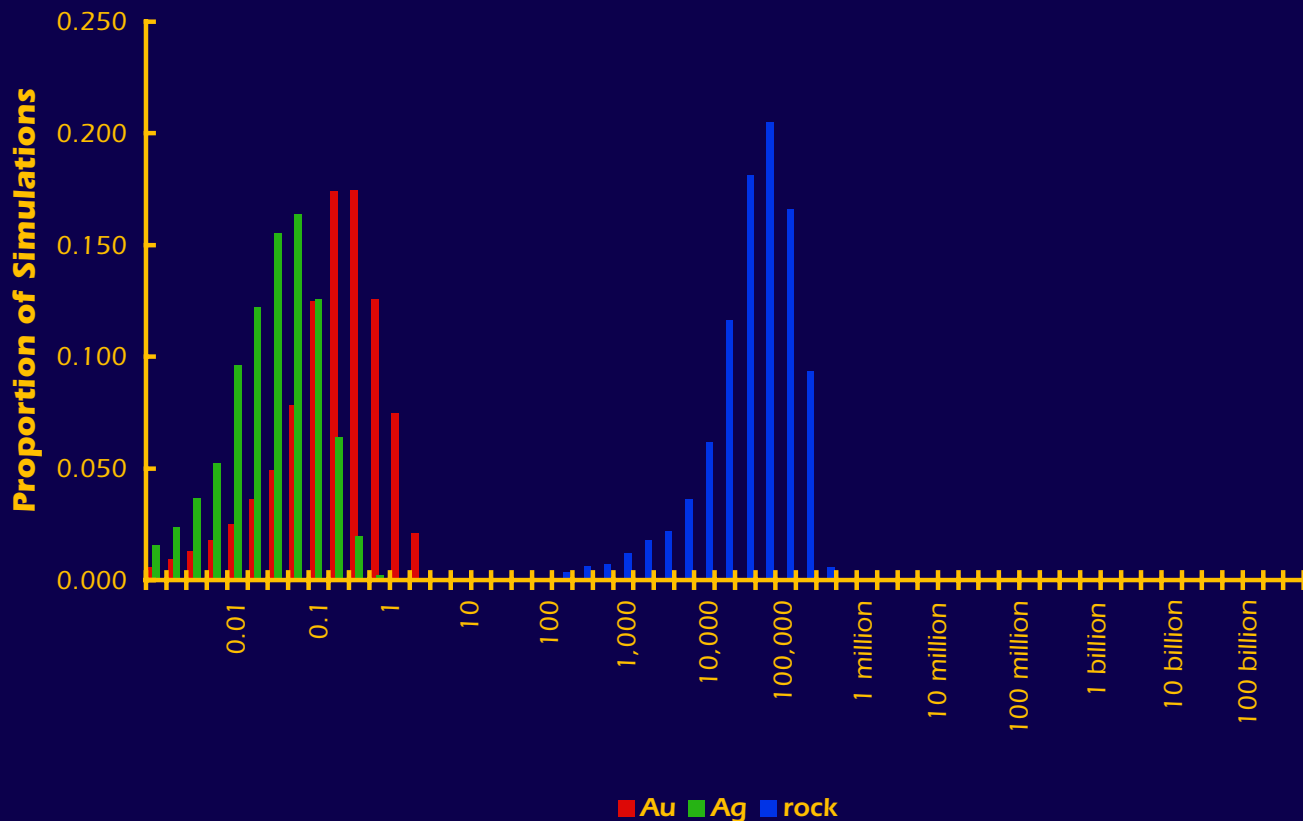
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



See table for
probability of
zero tons

Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SC11

The Mark3 Index is 26:

Low-sulfide Au-quartz vein, Chugach

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 5 or more deposits.

There is a 10% or greater chance of 7 or more deposits.

There is a 5% or greater chance of 7 or more deposits.

There is a 1% or greater chance of 7 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	1,200
0.50	0	0	29,000
0.10	1	0	99,500
0.05	1	0	120,000
mean	0	0	41,000
Probability of mean	0.34	0.33	0.38
Probability of zero	0.07	0.10	0.07

The tract ID is AK-SC11The Mark3 Index is 26: **Low-sulfide Au-quartz vein, Chugach**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 5 or more deposits.

There is a 10% or greater chance of 7 or more deposits.

There is a 5% or greater chance of 7 or more deposits.

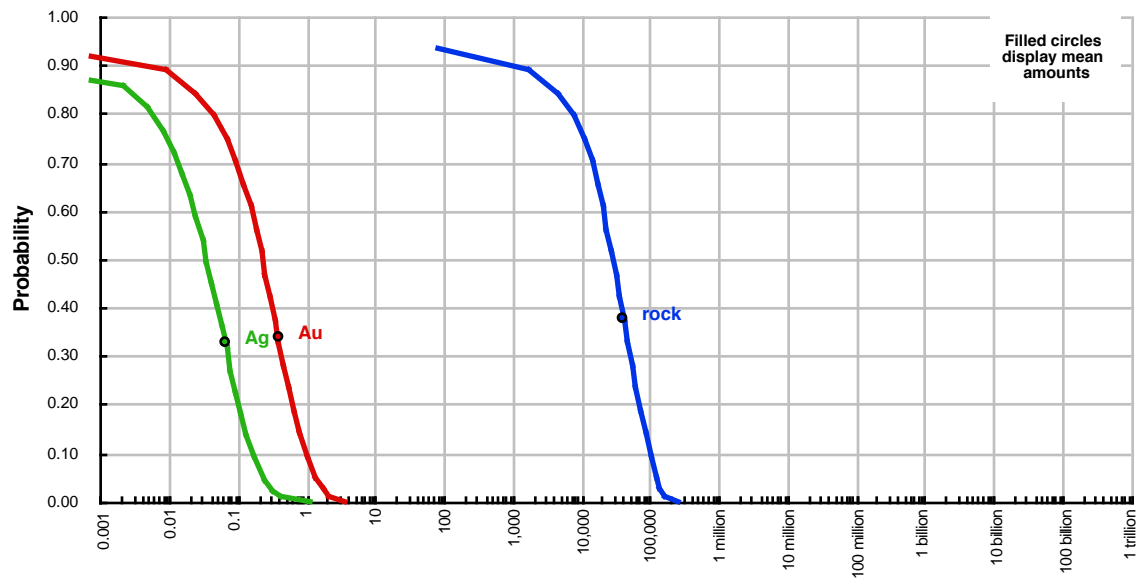
There is a 1% or greater chance of 7 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

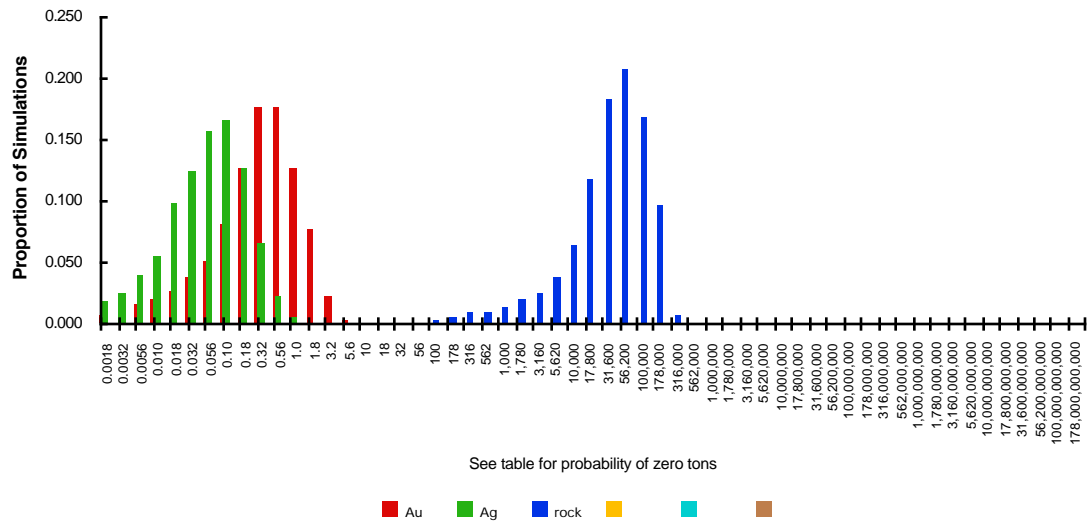
quantile	Au	Ag	rock	0	0	0
0.95	0	0	0	0	0	0
0.90	0	0	1,200	0	0	0
0.50	0	0	29,000	0	0	0
0.10	1	0	99,500	0	0	0
0.05	1	0	120,000	0	0	0
mean	0	0	41,000	0	0	0
Probability of mean	0.34	0.33	0.38	0.00	0.00	0.00
Probability of zero	0.07	0.10	0.07	0.00	0.00	0.00

The tract ID is AK-SC11

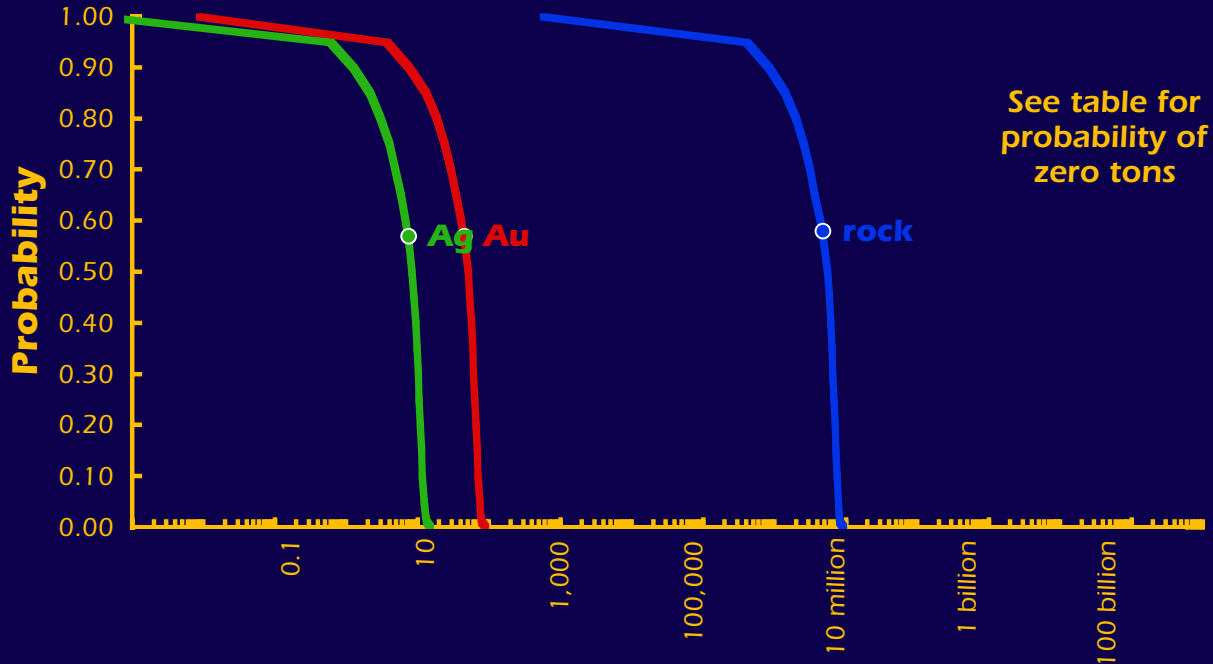
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)



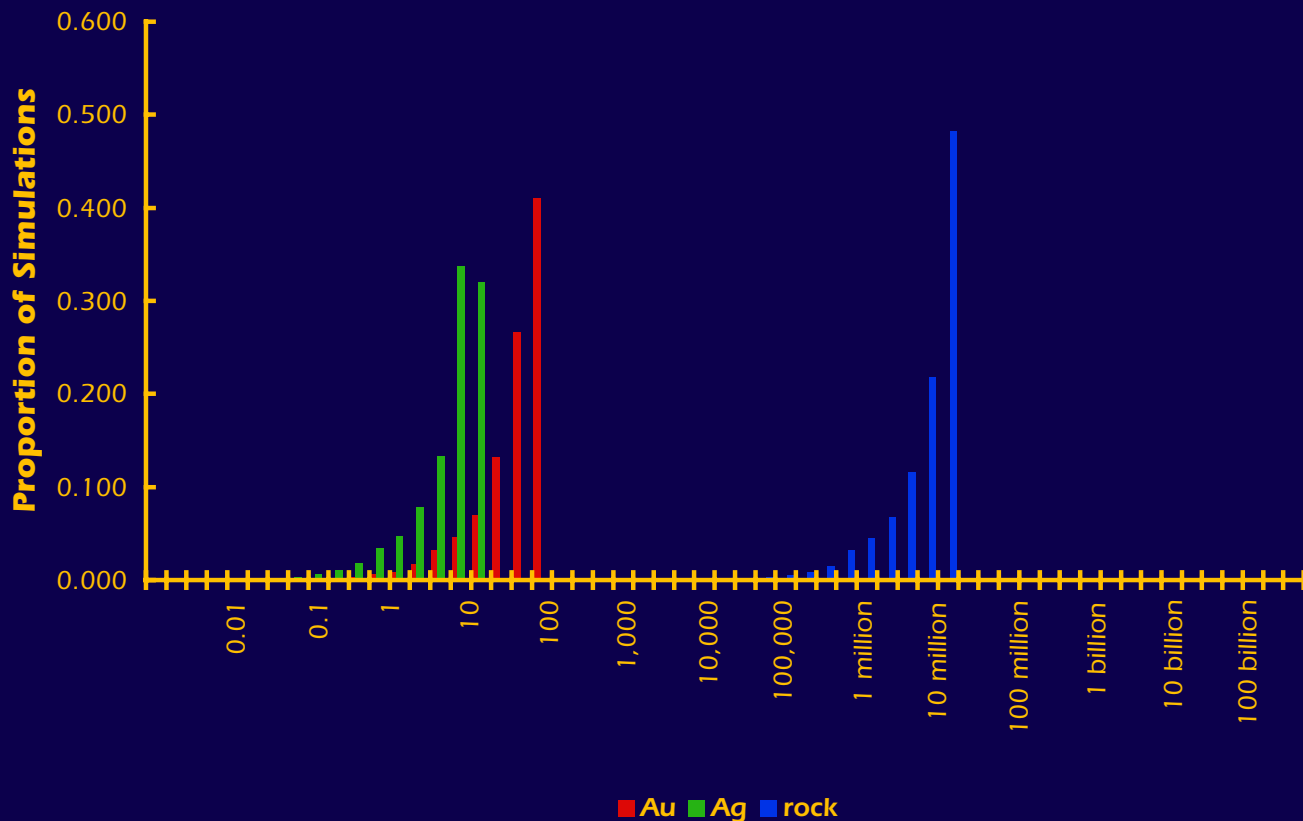
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



See table for
probability of
zero tons

Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SC12

The Mark3 Index is 26:

Low-sulfide Au-quartz vein, Chugach

There is a 90% or greater chance of 80 or more deposits.
There is a 50% or greater chance of 600 or more deposits.
There is a 10% or greater chance of 800 or more deposits.
There is a 5% or greater chance of 800 or more deposits.
There is a 1% or greater chance of 800 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	4	1	400,000
0.90	8	1	840,000
0.50	51	8	5,500,000
0.10	71	12	7,480,000
0.05	74	12	7,800,000
mean	44	7	4,700,000
Probability of mean	0.57	0.57	0.58
Probability of zero	0.00	0.00	0.00

The tract ID is AK-SC12The Mark3 Index is 26: **Low-sulfide Au-quartz vein, Chugach**

There is a 90% or greater chance of 80 or more deposits.

There is a 50% or greater chance of 600 or more deposits.

There is a 10% or greater chance of 800 or more deposits.

There is a 5% or greater chance of 800 or more deposits.

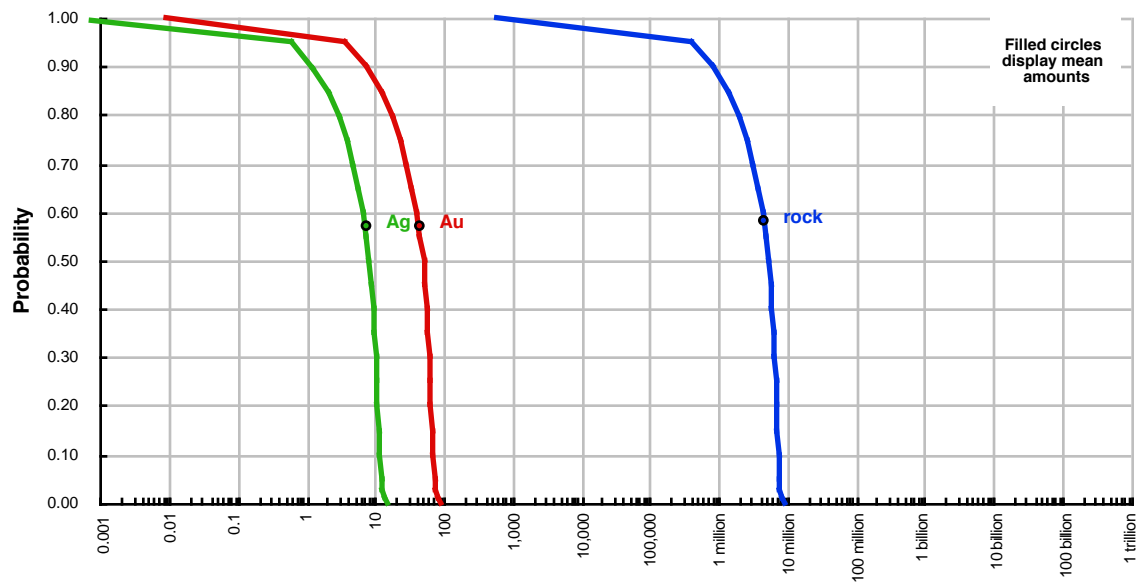
There is a 1% or greater chance of 800 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

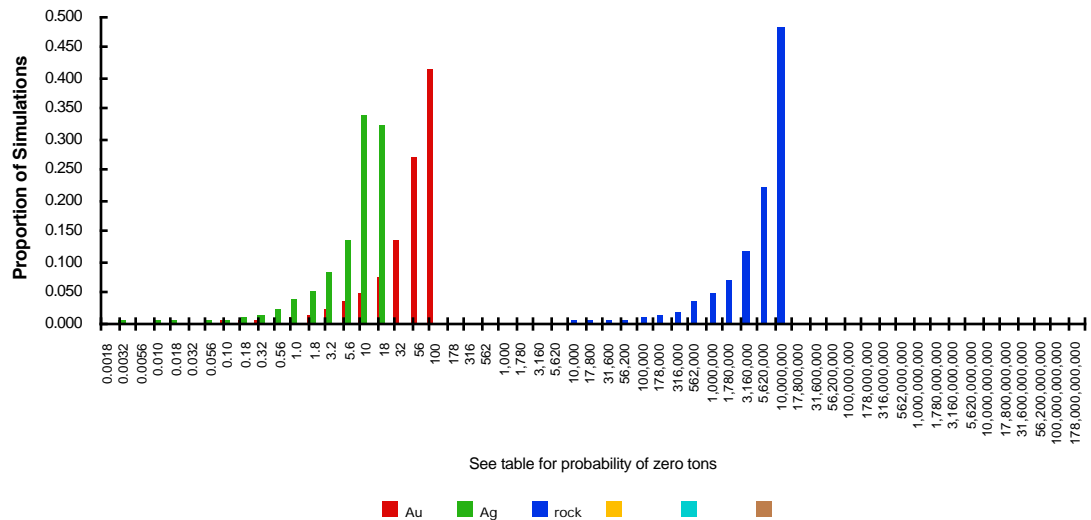
quantile	Au	Ag	rock	0	0	0
0.95	4	1	400,000	0	0	0
0.90	8	1	840,000	0	0	0
0.50	51	8	5,500,000	0	0	0
0.10	71	12	7,480,000	0	0	0
0.05	74	12	7,800,000	0	0	0
mean	44	7	4,700,000	0	0	0
Probability of mean	0.57	0.57	0.58	0.00	0.00	0.00
Probability of zero	0.00	0.00	0.00	0.00	0.00	0.00

The tract ID is AK-SC12

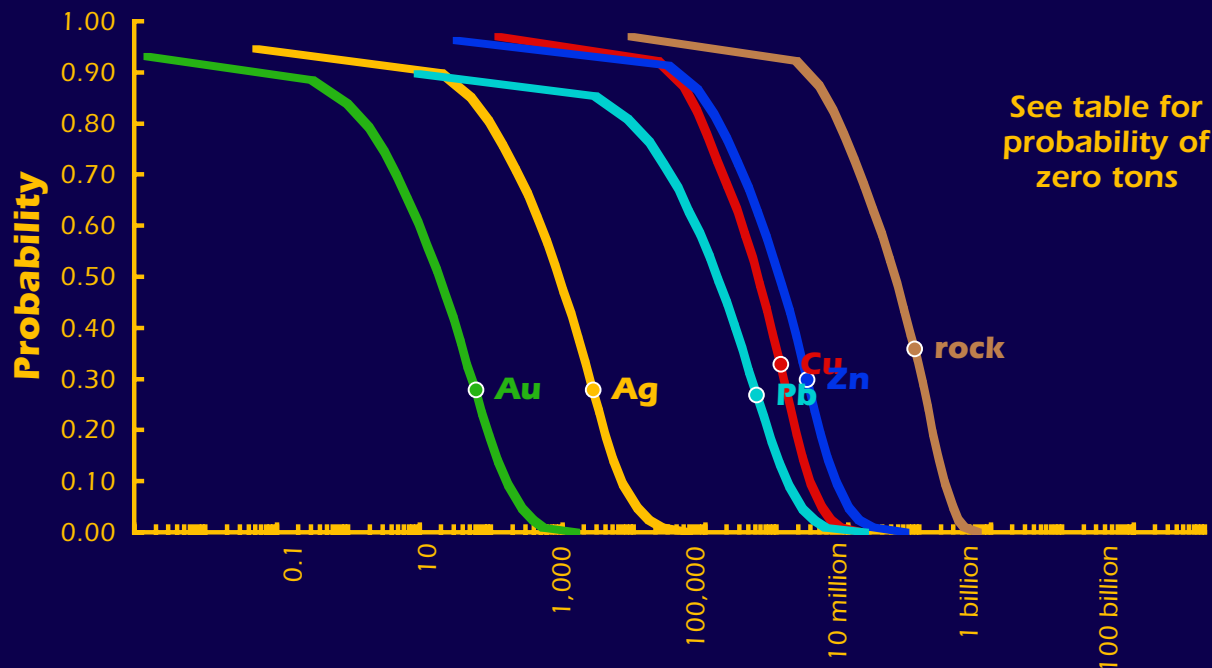
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

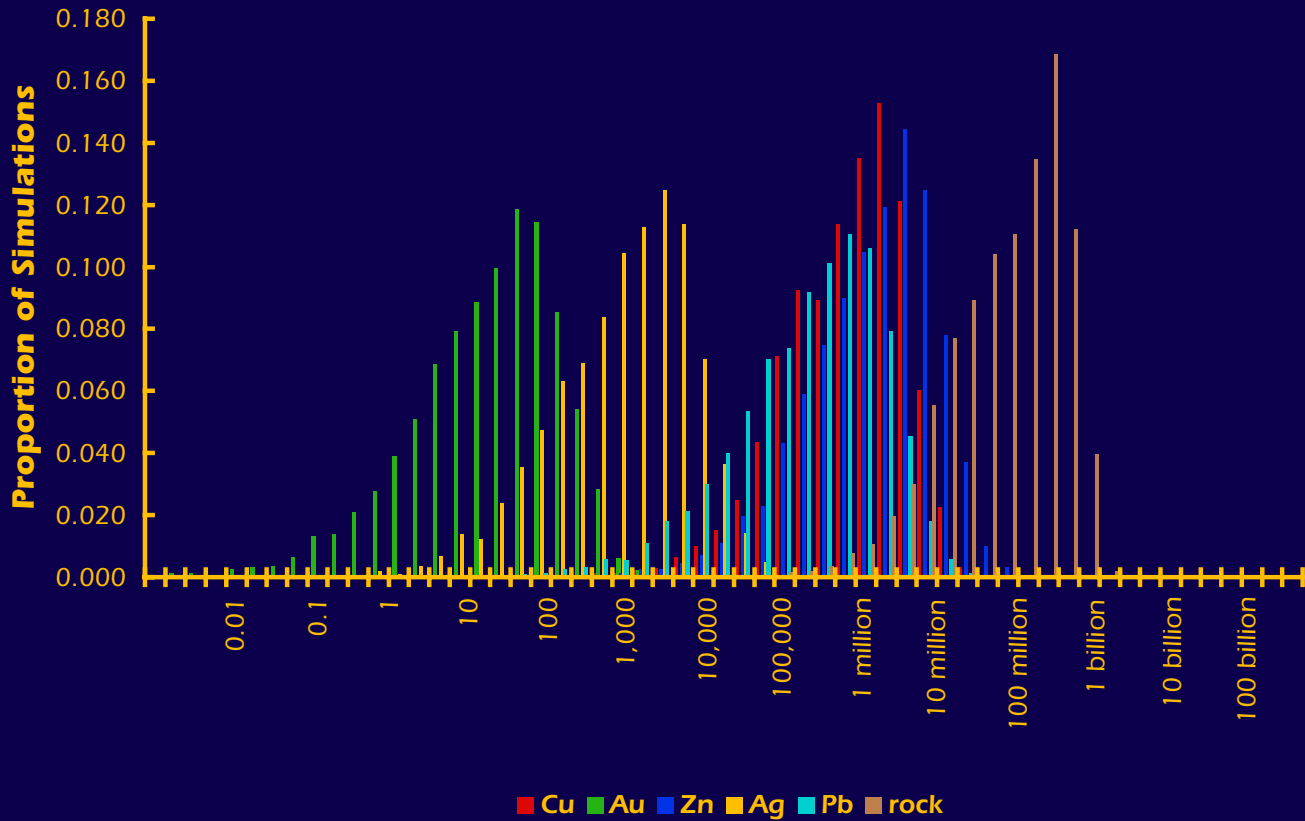


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SC14

The Mark3 Index is 93:

Massive sulfide, kuroko

There is a 90% or greater chance of 3 or more deposits.

There is a 50% or greater chance of 5 or more deposits.

There is a 10% or greater chance of 25 or more deposits.

There is a 5% or greater chance of 25 or more deposits.

There is a 1% or greater chance of 25 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	8,400	0	5,900	0	0	710,000
0.90	35,000	0	45,000	20	0	2,900,000
0.50	550,000	19	1,100,000	900	150,000	46,000,000
0.10	2,900,000	170	6,810,000	6,800	1,400,000	230,000,000
0.05	4,300,000	260	10,000,000	11,000	2,200,000	300,000,000
mean	1,100,000	61	2,600,000	2,600	520,000	85,000,000
Probability of mean	0.33	0.28	0.30	0.28	0.27	0.36
Probability of zero	0.03	0.07	0.04	0.05	0.10	0.03

The tract ID is AK-SC14The Mark3 Index is 93: **Massive sulfide, kuroko**

There is a 90% or greater chance of 3 or more deposits.

There is a 50% or greater chance of 5 or more deposits.

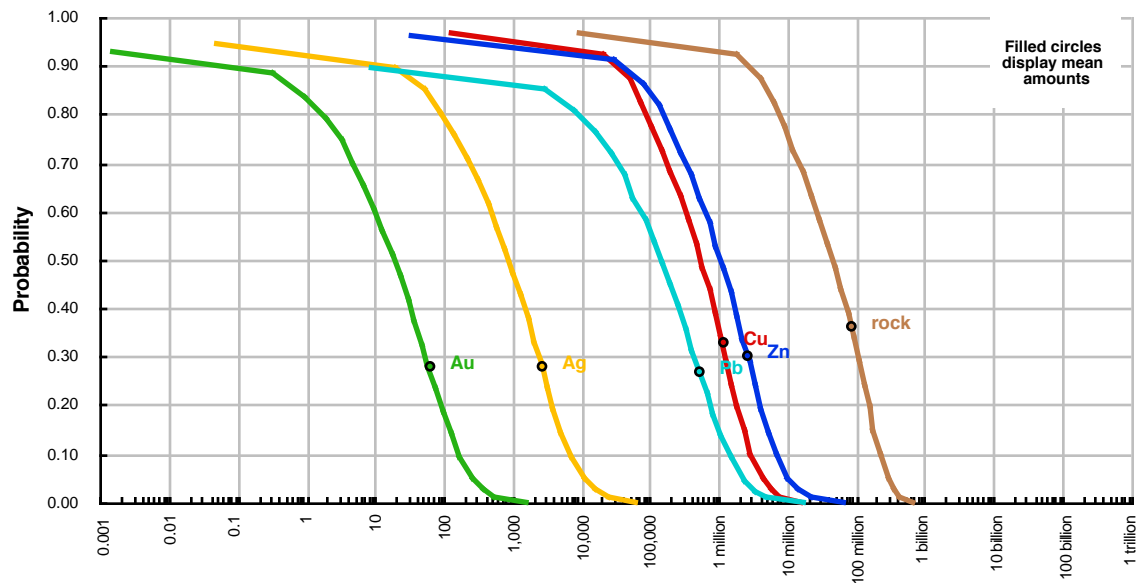
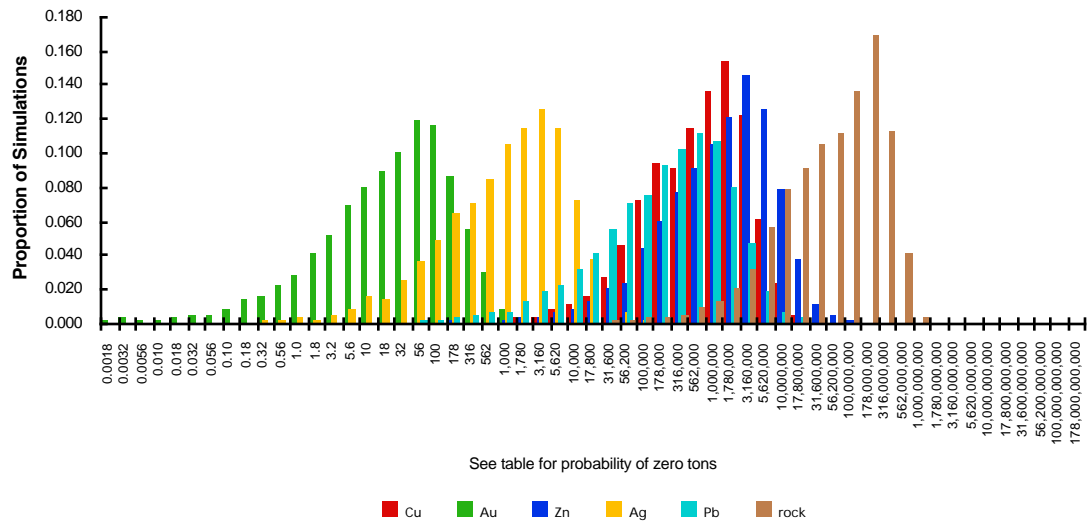
There is a 10% or greater chance of 25 or more deposits.

There is a 5% or greater chance of 25 or more deposits.

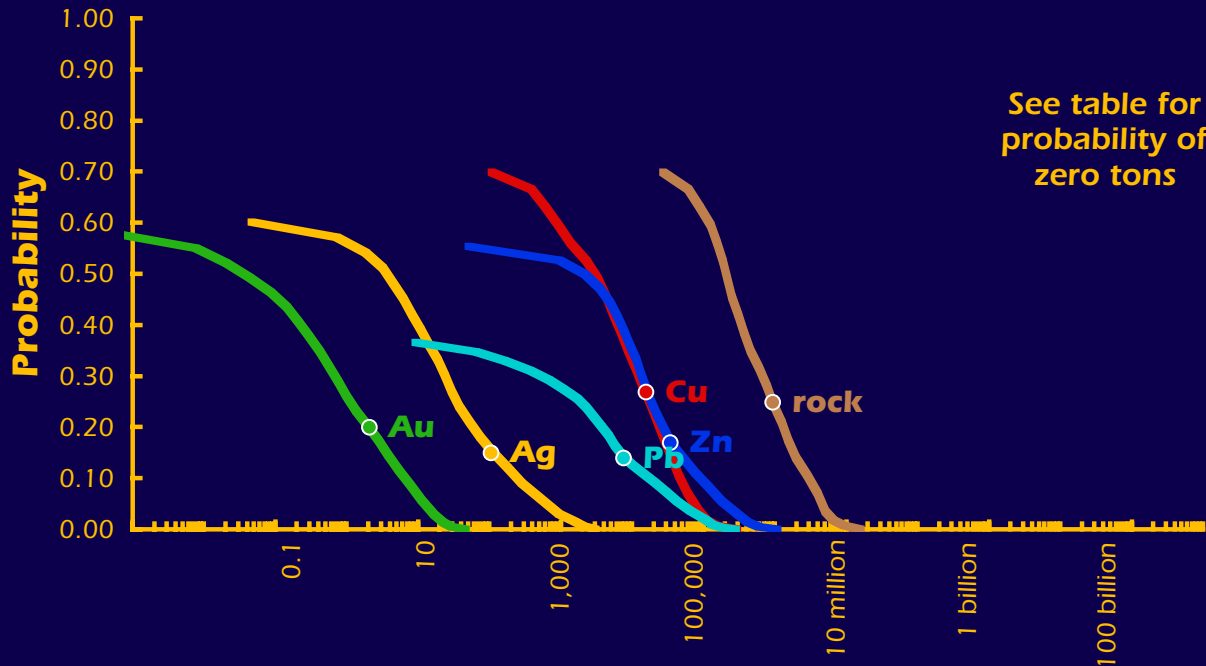
There is a 1% or greater chance of 25 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	8,400	0	5,900	0	0	710,000
0.90	35,000	0	45,000	20	0	2,900,000
0.50	550,000	19	1,100,000	900	150,000	46,000,000
0.10	2,900,000	170	6,810,000	6,800	1,400,000	230,000,000
0.05	4,300,000	260	10,000,000	11,000	2,200,000	300,000,000
mean	1,100,000	61	2,600,000	2,600	520,000	85,000,000
Probability of mean	0.33	0.28	0.30	0.28	0.27	0.36
Probability of zero	0.03	0.07	0.04	0.05	0.10	0.03

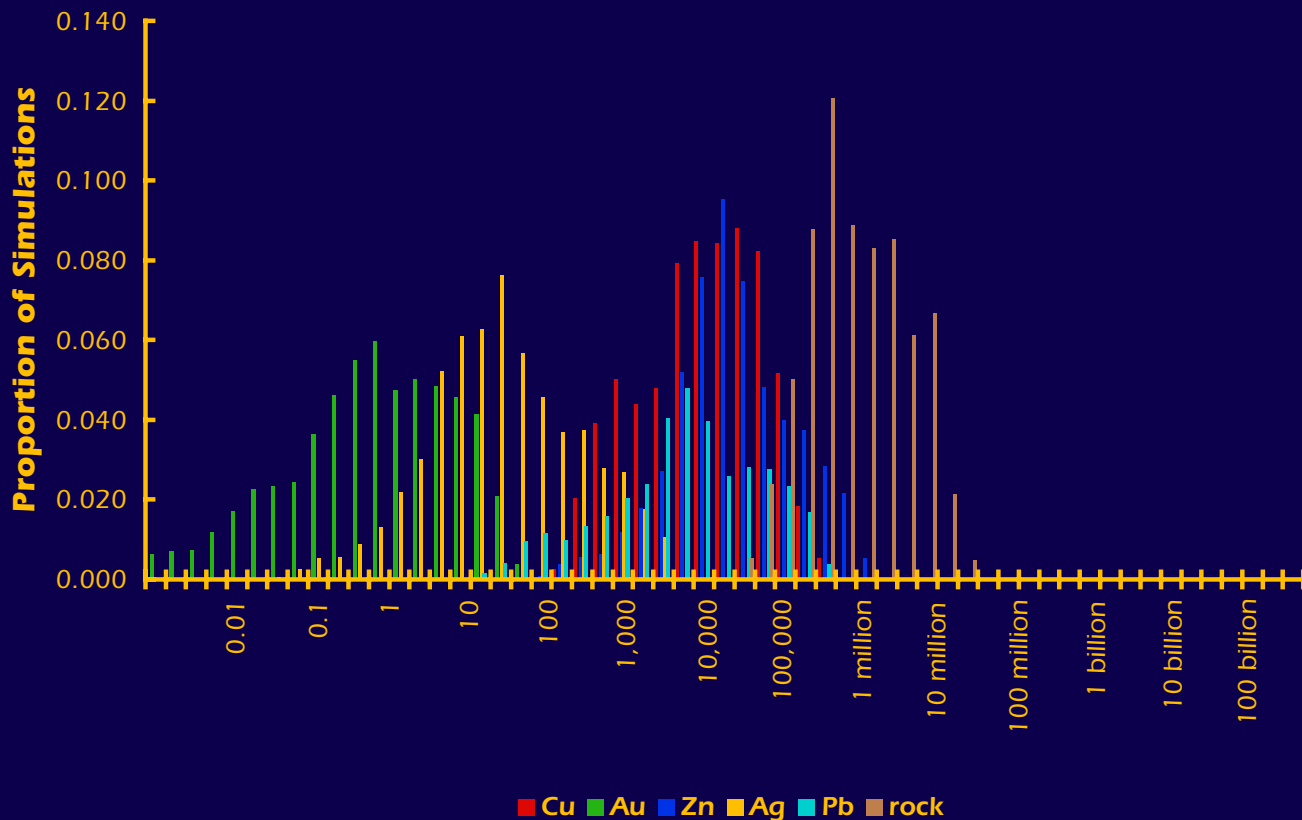
The tract ID is AK-SC14**Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SC15

The Mark3 Index is 44:

Massive sulfide, Sierran kuroko

There is a 90% or greater chance of 0 or more deposits.
There is a 50% or greater chance of 1 or more deposits.
There is a 10% or greater chance of 2 or more deposits.
There is a 5% or greater chance of 4 or more deposits.
There is a 1% or greater chance of 10 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	3,000	0	2,200	4	0	210,000
0.10	47,000	7	89,200	250	18,000	3,000,000
0.05	75,000	12	190,000	630	48,000	4,600,000
mean	15,000	2	34,000	100	7,500	910,000
Probability of mean	0.27	0.20	0.17	0.15	0.14	0.25
Probability of zero	0.30	0.42	0.45	0.40	0.63	0.30

The tract ID is AK-SC15The Mark3 Index is 44: **Massive sulfide, Sierran kuroko**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

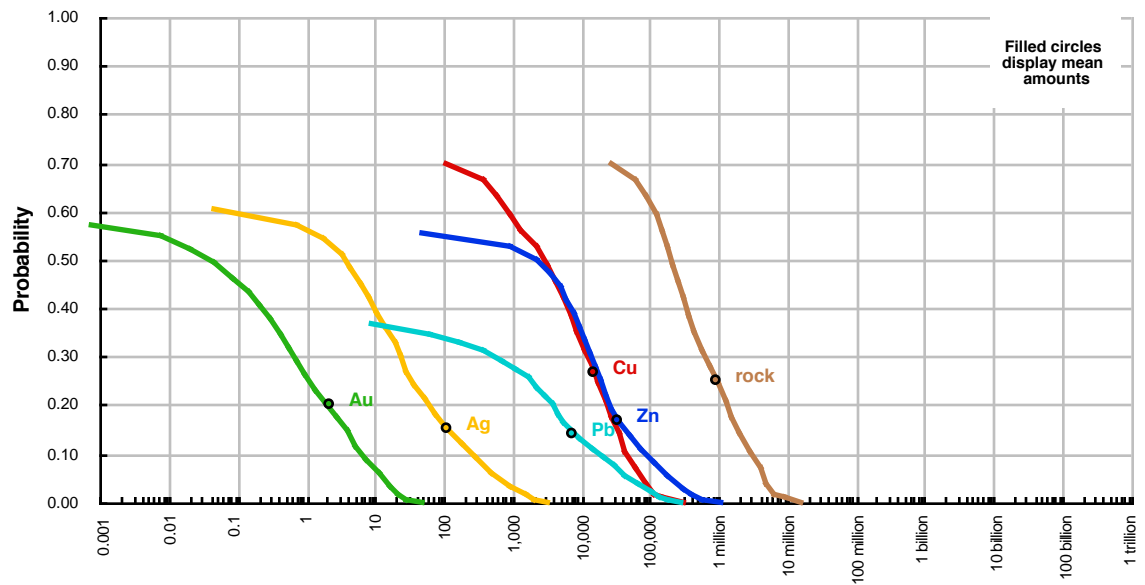
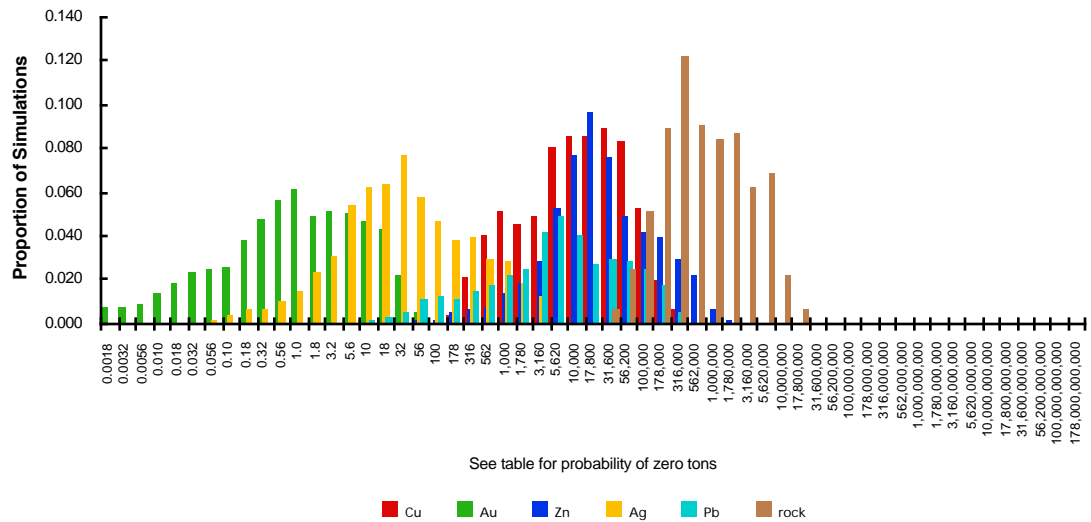
There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

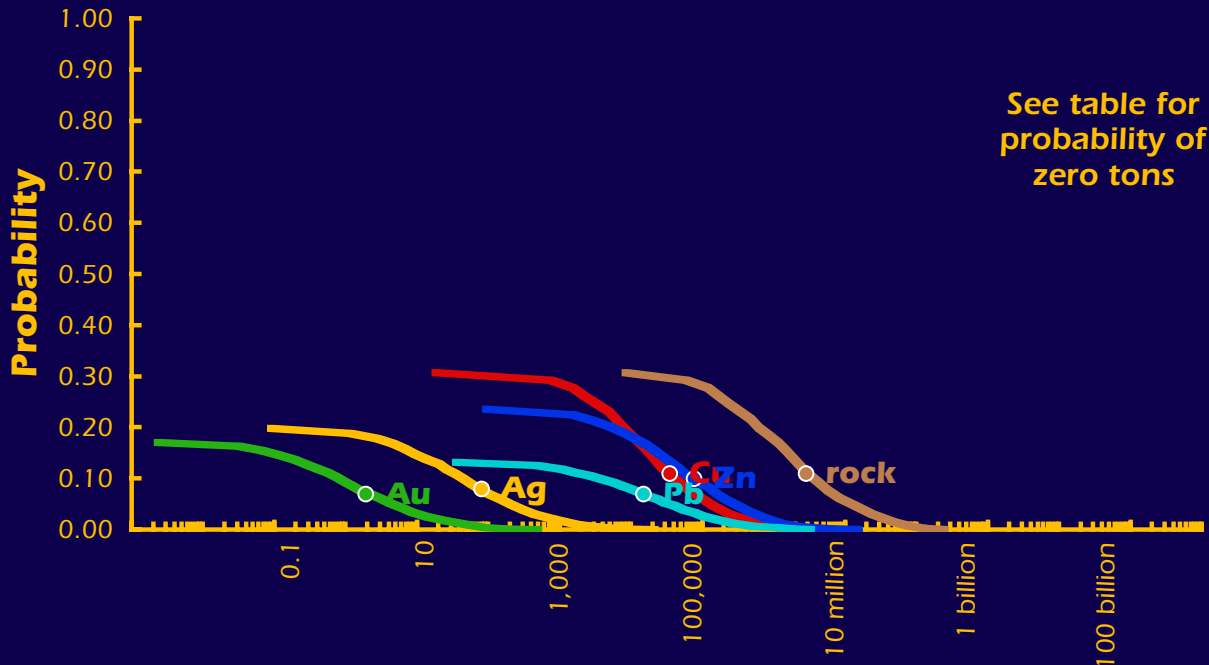
There is a 1% or greater chance of 10 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	3,000	0	2,200	4	0	210,000
0.10	47,000	7	89,200	250	18,000	3,000,000
0.05	75,000	12	190,000	630	48,000	4,600,000
mean	15,000	2	34,000	100	7,500	910,000
Probability of mean	0.27	0.20	0.17	0.15	0.14	0.25
Probability of zero	0.30	0.42	0.45	0.40	0.63	0.30

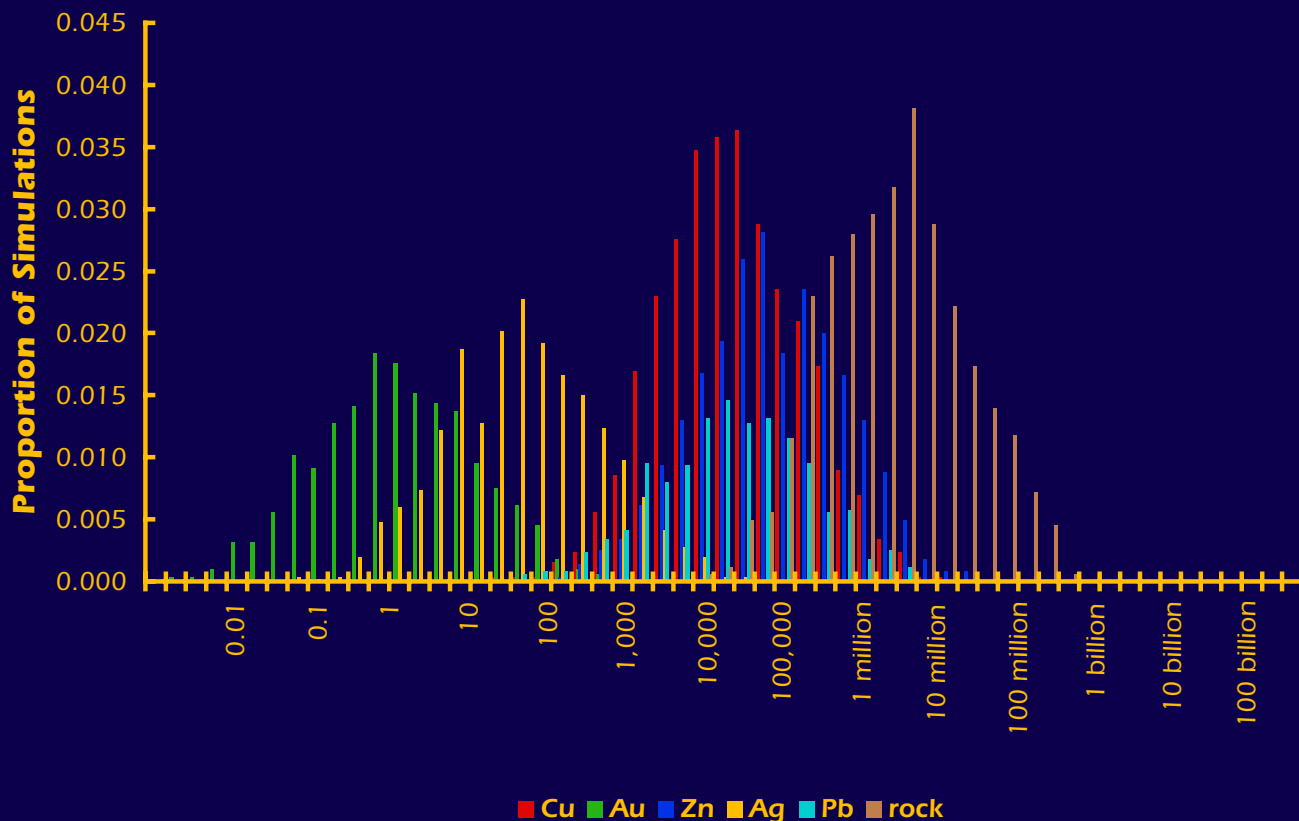
The tract ID is AK-SC15**Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SC16

The Mark3 Index is 93:

Massive sulfide, kuroko

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	41,000	1	74,800	43	3,500	3,700,000
0.05	130,000	5	290,000	210	33,000	13,000,000
mean	35,000	2	75,000	79	15,000	2,800,000
Probability of mean	0.11	0.07	0.10	0.08	0.07	0.11
Probability of zero	0.69	0.83	0.76	0.80	0.87	0.69

The tract ID is AK-SC16The Mark3 Index is 93: **Massive sulfide, kuroko**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

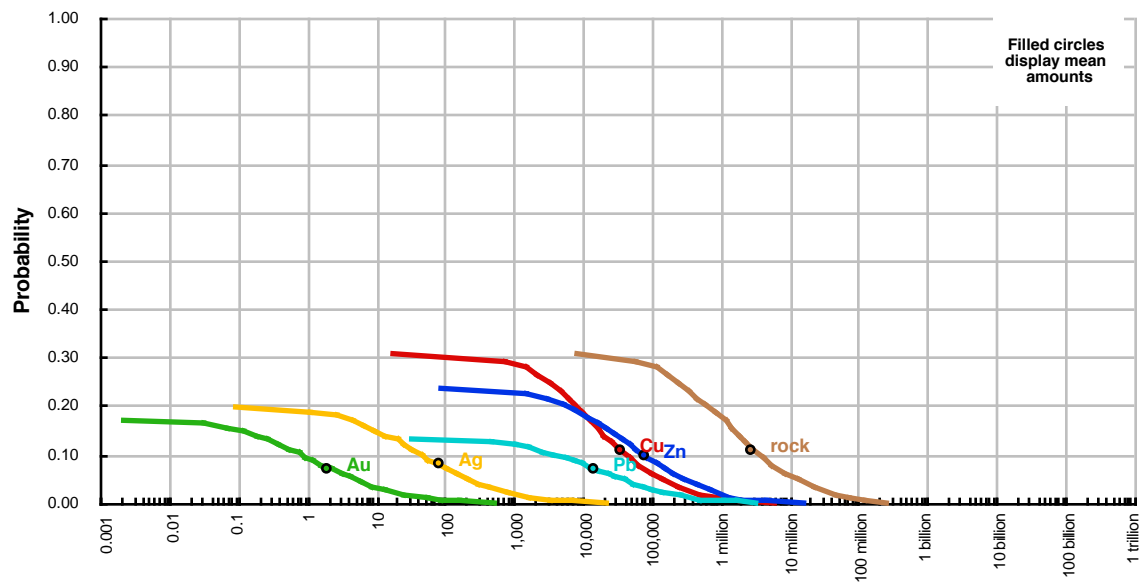
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

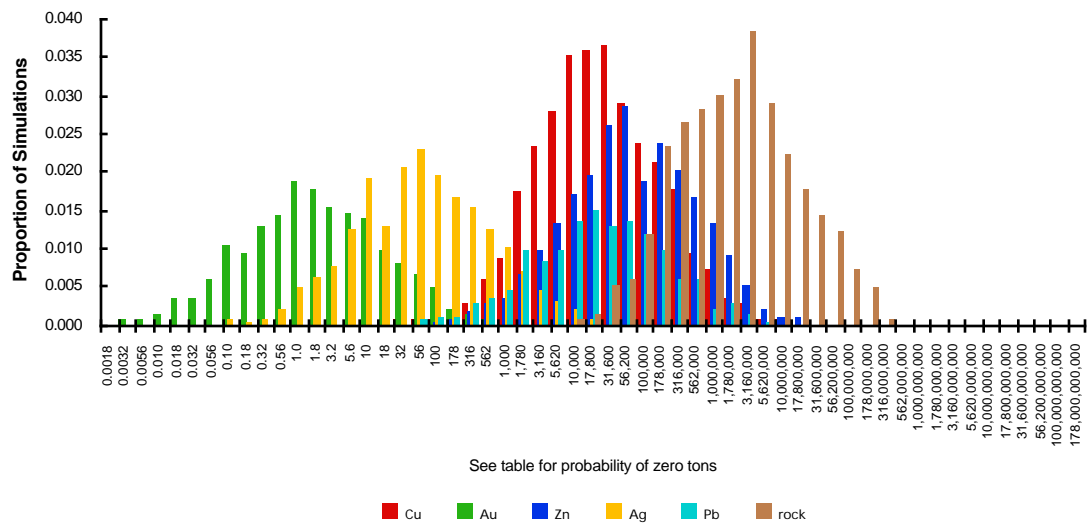
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	41,000	1	74,800	43	3,500	3,700,000
0.05	130,000	5	290,000	210	33,000	13,000,000
mean	35,000	2	75,000	79	15,000	2,800,000
Probability of mean	0.11	0.07	0.10	0.08	0.07	0.11
Probability of zero	0.69	0.83	0.76	0.80	0.87	0.69

The tract ID is AK-SC16

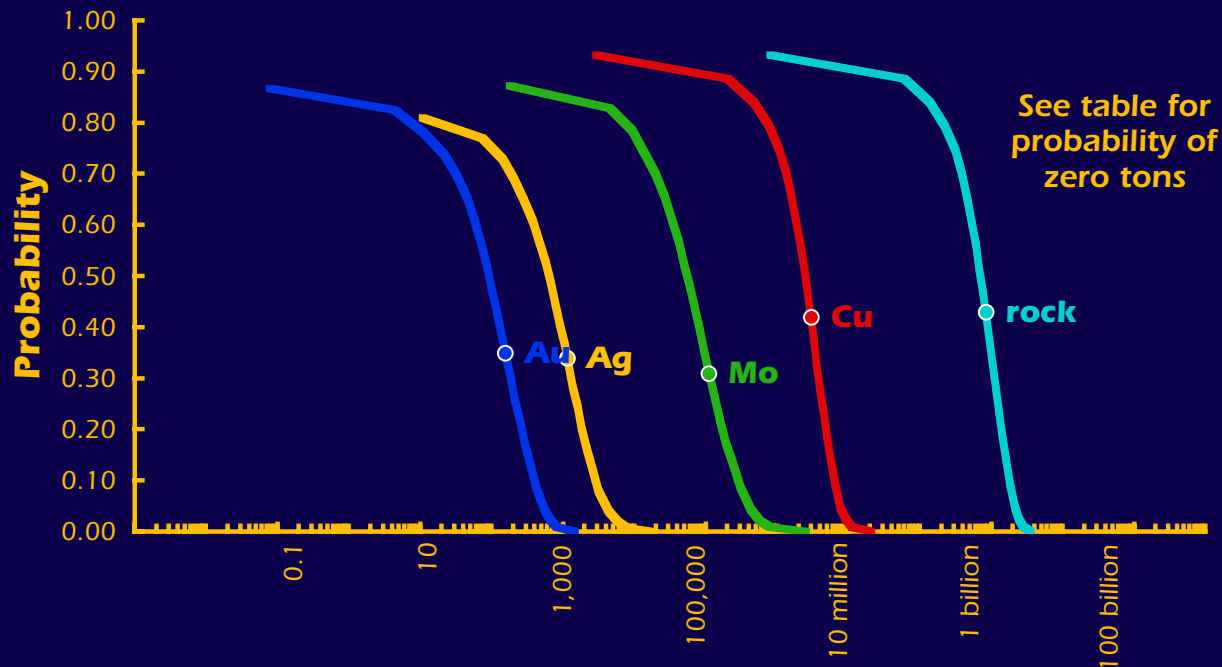
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

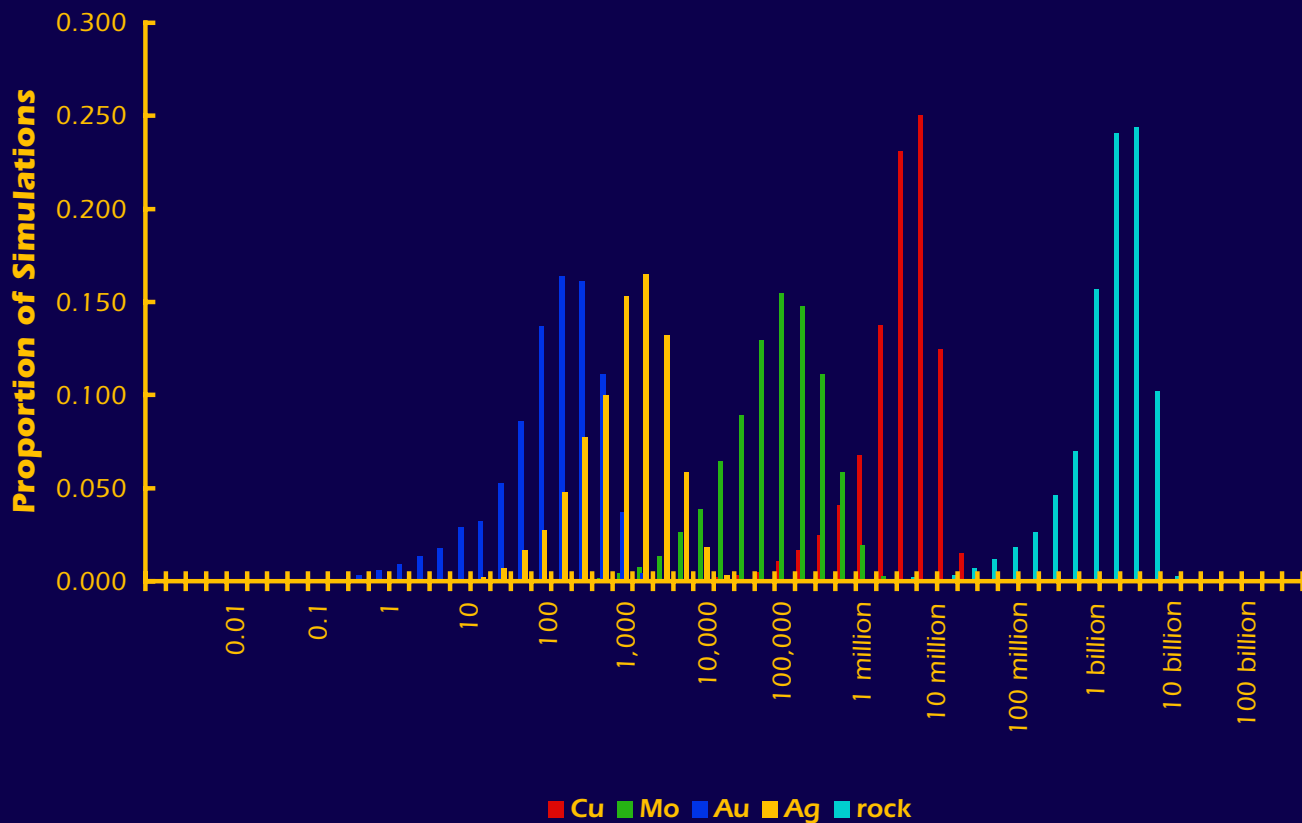


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SC20

The Mark3 Index is 89:

Porphyry Cu (BC-AK)

There is a 90% or greater chance of 1 or more deposits.
 There is a 50% or greater chance of 5 or more deposits.
 There is a 10% or greater chance of 7 or more deposits.
 There is a 5% or greater chance of 7 or more deposits.
 There is a 1% or greater chance of 7 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	150,000	0	0	0	41,000,000
0.50	2,500,000	55,000	92	640	710,000,000
0.10	6,300,000	280,000	395	2,900	1,800,000,000
0.05	7,600,000	410,000	520	4,000	2,100,000,000
mean	3,000,000	110,000	150	1,100	840,000,000
Probability of mean	0.42	0.31	0.35	0.34	0.43
Probability of zero	0.07	0.13	0.13	0.19	0.07

The tract ID is AK-SC20The Mark3 Index is 89: **Porphyry Cu (BC-AK)**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 5 or more deposits.

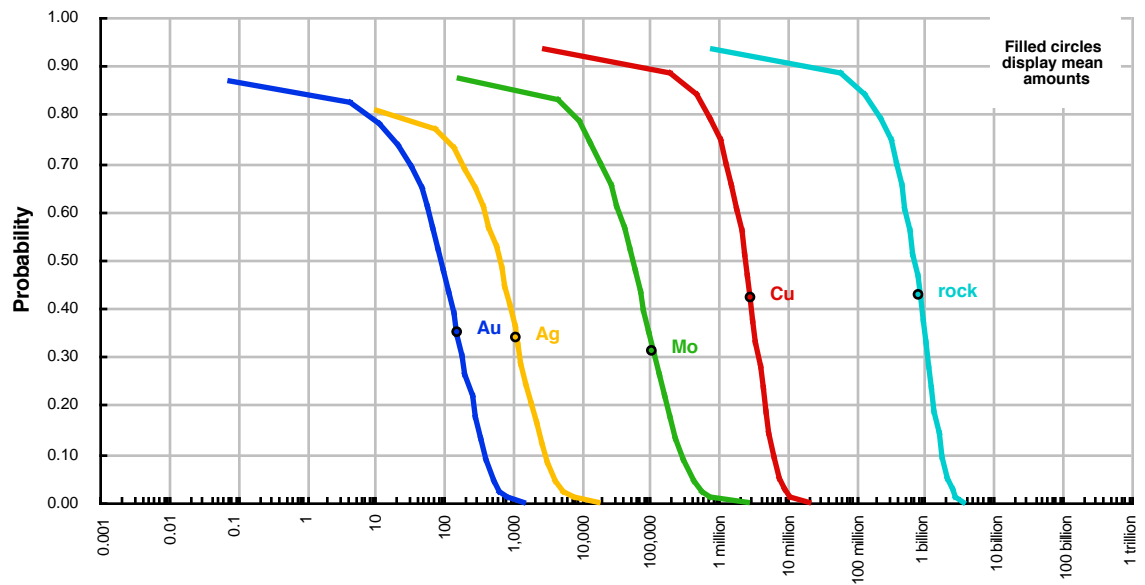
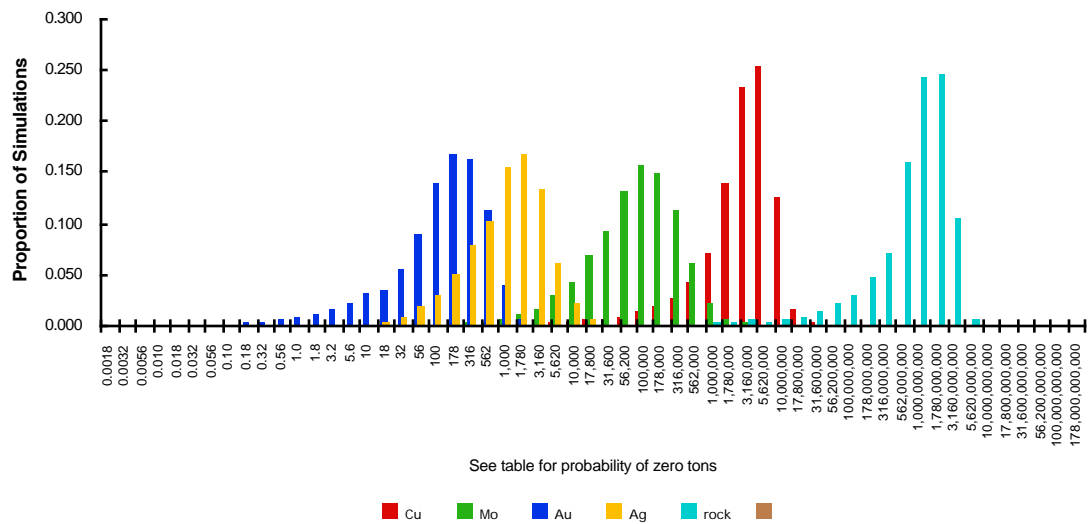
There is a 10% or greater chance of 7 or more deposits.

There is a 5% or greater chance of 7 or more deposits.

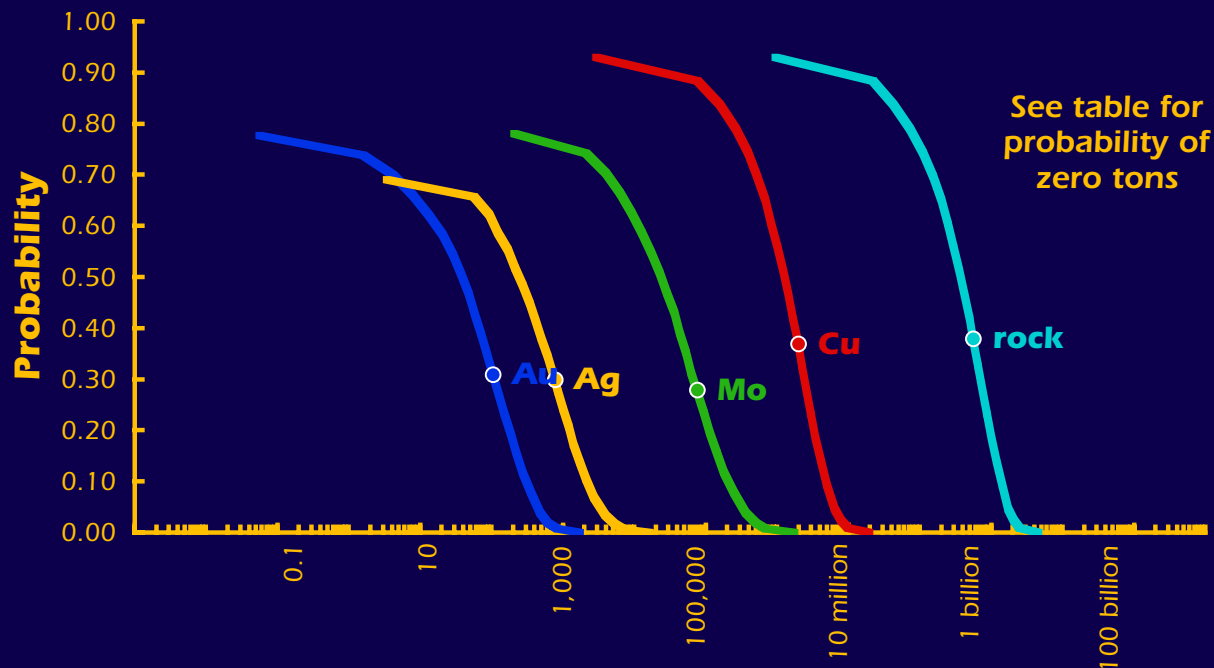
There is a 1% or greater chance of 7 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock	0
0.95	0	0	0	0	0	0
0.90	150,000	0	0	0	41,000,000	0
0.50	2,500,000	55,000	92	640	710,000,000	0
0.10	6,300,000	280,000	395	2,900	1,800,000,000	0
0.05	7,600,000	410,000	520	4,000	2,100,000,000	0
mean	3,000,000	110,000	150	1,100	840,000,000	0
Probability of mean	0.42	0.31	0.35	0.34	0.43	0.00
Probability of zero	0.07	0.13	0.13	0.19	0.07	0.00

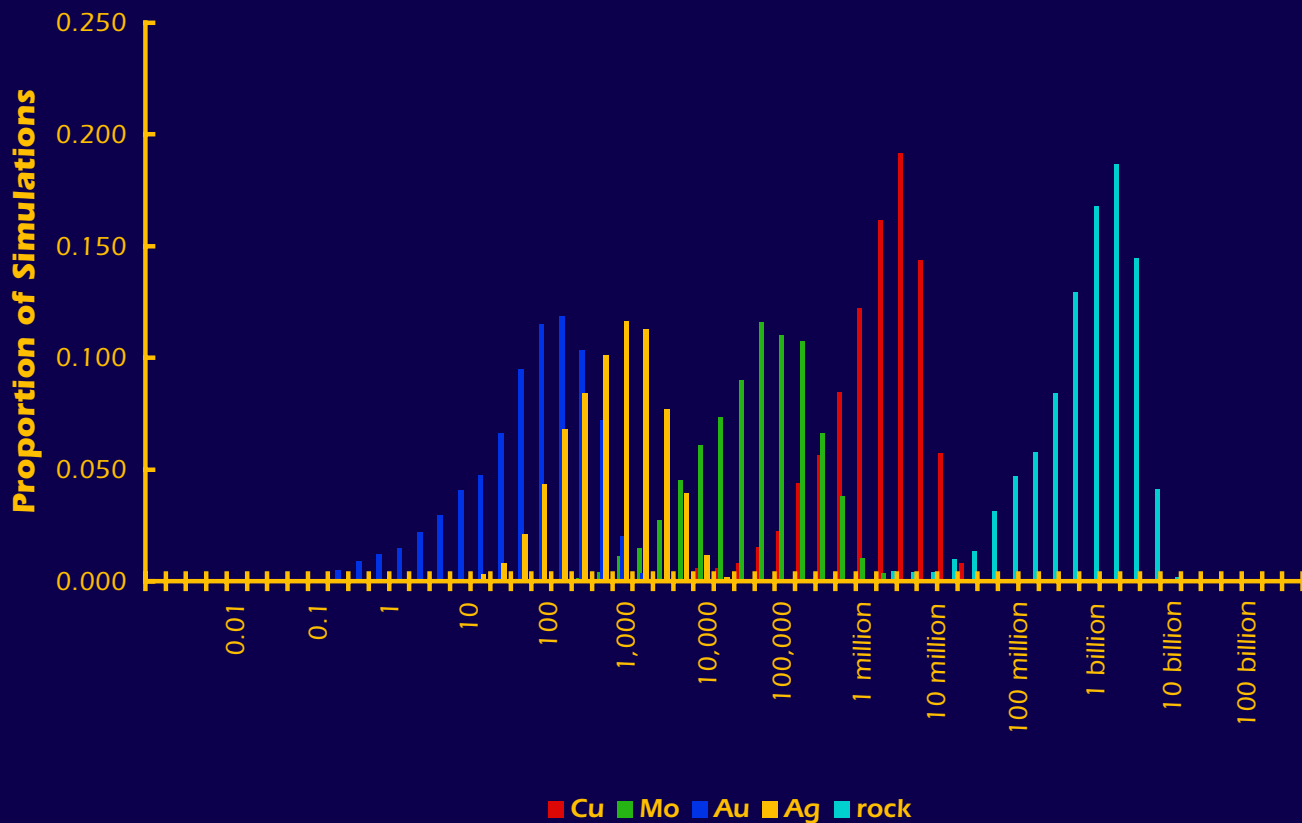
The tract ID is AK-SC20**Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SC21

The Mark3 Index is 89:

Porphyry Cu (BC-AK)

There is a 90% or greater chance of 1 or more deposits.
 There is a 50% or greater chance of 2 or more deposits.
 There is a 10% or greater chance of 6 or more deposits.
 There is a 5% or greater chance of 6 or more deposits.
 There is a 1% or greater chance of 6 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	46,000	0	0	0	13,000,000
0.50	1,300,000	24,000	39	240	370,000,000
0.10	4,800,000	210,000	308	2,200	1,400,000,000
0.05	6,200,000	320,000	440	3,300	1,700,000,000
mean	2,000,000	75,000	100	770	550,000,000
Probability of mean	0.37	0.28	0.31	0.30	0.38
Probability of zero	0.07	0.22	0.22	0.31	0.07

The tract ID is AK-SC21The Mark3 Index is 89: **Porphyry Cu (BC-AK)**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

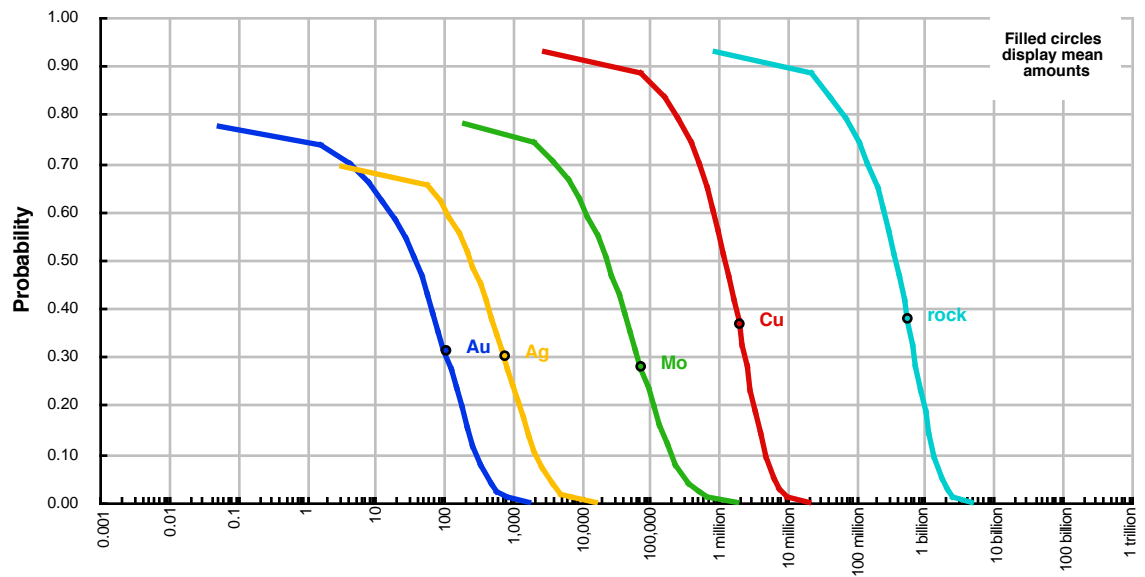
There is a 1% or greater chance of 6 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

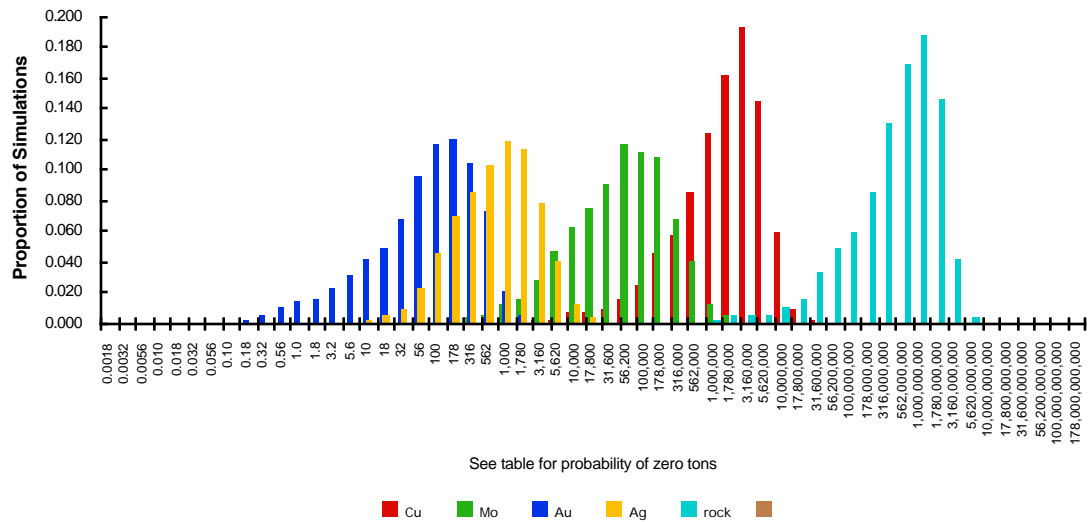
quantile	Cu	Mo	Au	Ag	rock	0
0.95	0	0	0	0	0	0
0.90	46,000	0	0	0	13,000,000	0
0.50	1,300,000	24,000	39	240	370,000,000	0
0.10	4,800,000	210,000	308	2,200	1,400,000,000	0
0.05	6,200,000	320,000	440	3,300	1,700,000,000	0
mean	2,000,000	75,000	100	770	550,000,000	0
Probability of mean	0.37	0.28	0.31	0.30	0.38	0.00
Probability of zero	0.07	0.22	0.22	0.31	0.07	0.00

The tract ID is AK-SC21

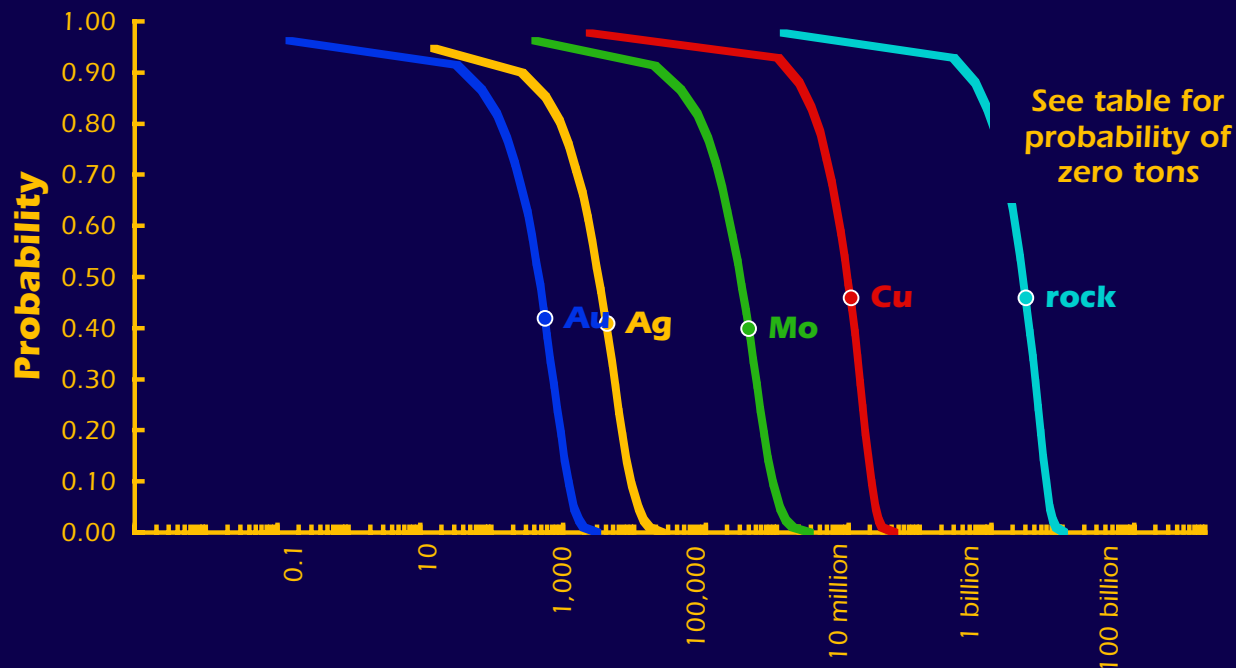
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

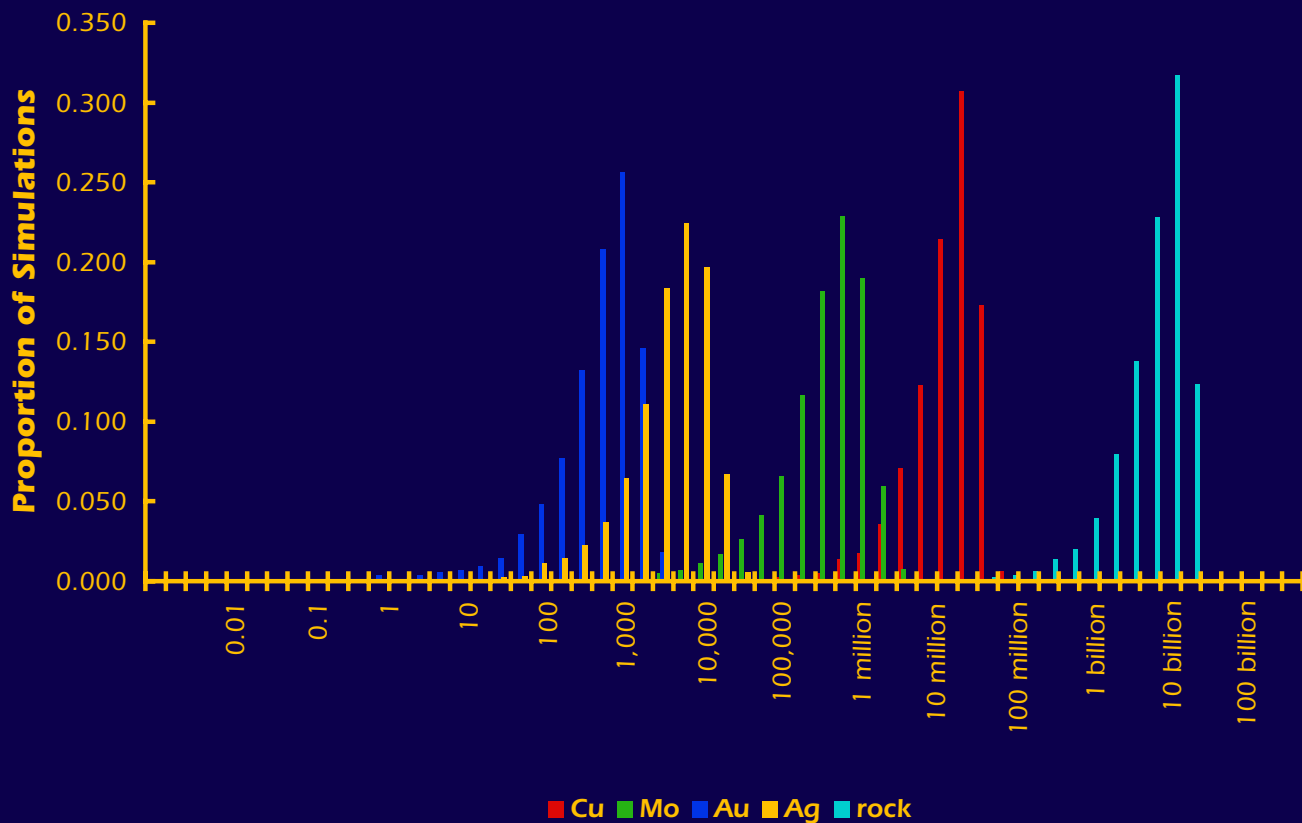


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SC22

The Mark3 Index is 89:

Porphyry Cu (BC-AK)

There is a 90% or greater chance of 4 or more deposits.
There is a 50% or greater chance of 15 or more deposits.
There is a 10% or greater chance of 30 or more deposits.
There is a 5% or greater chance of 30 or more deposits.
There is a 1% or greater chance of 30 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	530,000	4,500	4	0	160,000,000
0.90	1,700,000	26,000	46	270	490,000,000
0.50	9,600,000	300,000	460	3,100	2,800,000,000
0.10	21,000,000	870,000	1,190	9,000	5,900,000,000
0.05	24,000,000	1,100,000	1,400	11,000	6,600,000,000
mean	11,000,000	400,000	550	4,100	3,000,000,000
Probability of mean	0.46	0.40	0.42	0.41	0.46
Probability of zero	0.02	0.04	0.04	0.05	0.02

The tract ID is AK-SC22The Mark3 Index is 89: **Porphyry Cu (BC-AK)**

There is a 90% or greater chance of 4 or more deposits.

There is a 50% or greater chance of 15 or more deposits.

There is a 10% or greater chance of 30 or more deposits.

There is a 5% or greater chance of 30 or more deposits.

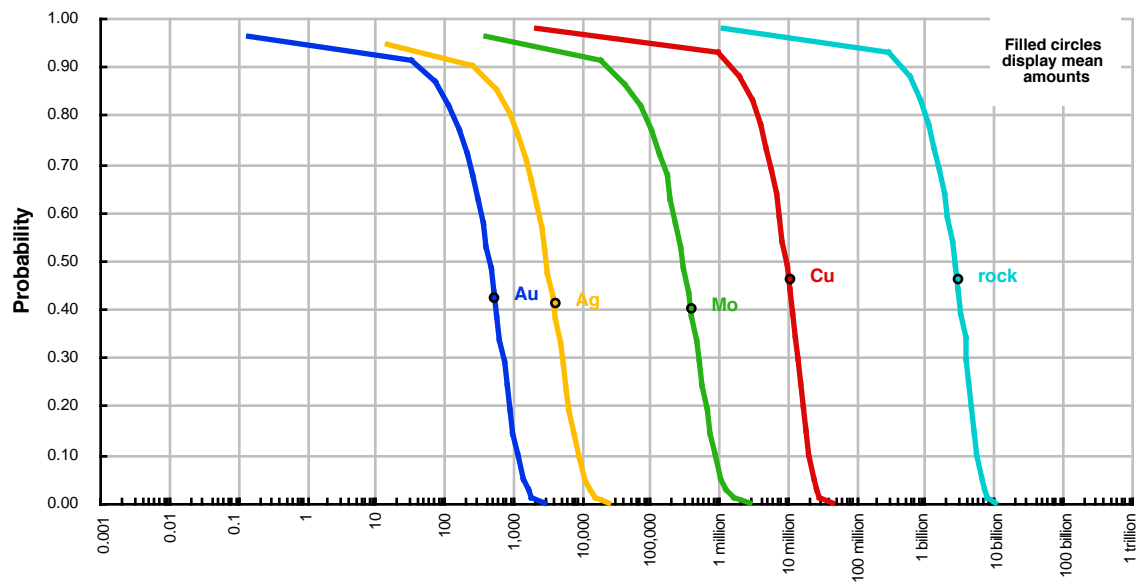
There is a 1% or greater chance of 30 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

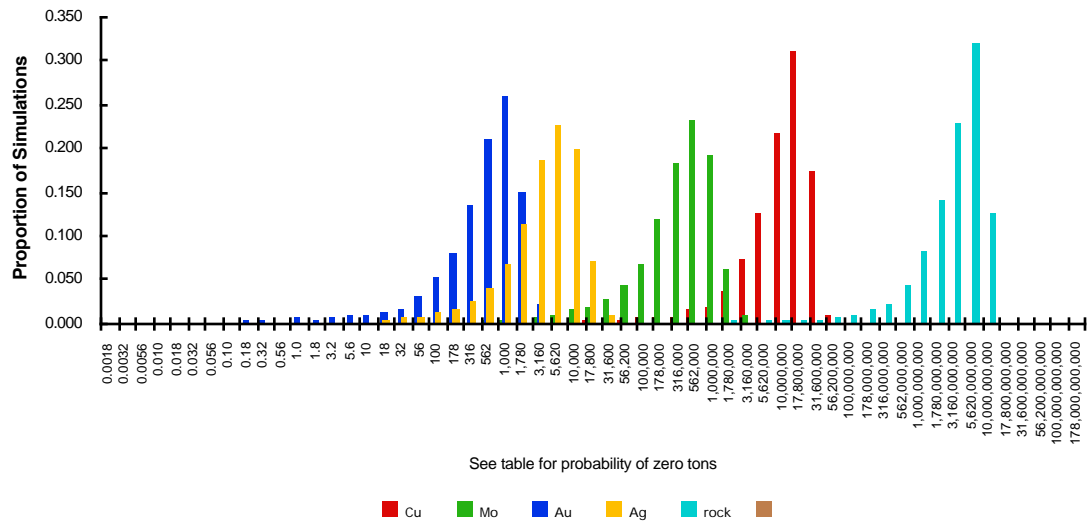
quantile	Cu	Mo	Au	Ag	rock	0
0.95	530,000	4,500	4	0	160,000,000	0
0.90	1,700,000	26,000	46	270	490,000,000	0
0.50	9,600,000	300,000	460	3,100	2,800,000,000	0
0.10	21,000,000	870,000	1,190	9,000	5,900,000,000	0
0.05	24,000,000	1,100,000	1,400	11,000	6,600,000,000	0
mean	11,000,000	400,000	550	4,100	3,000,000,000	0
Probability of mean	0.46	0.40	0.42	0.41	0.46	0.00
Probability of zero	0.02	0.04	0.04	0.05	0.02	0.00

The tract ID is AK-SC22

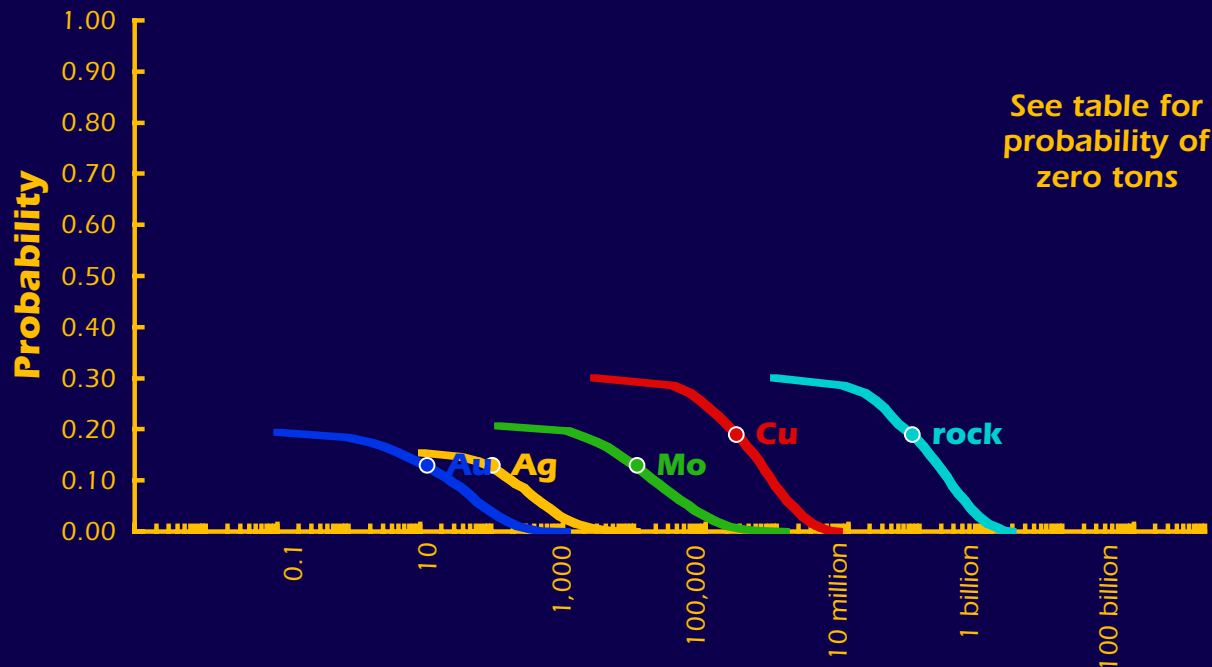
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

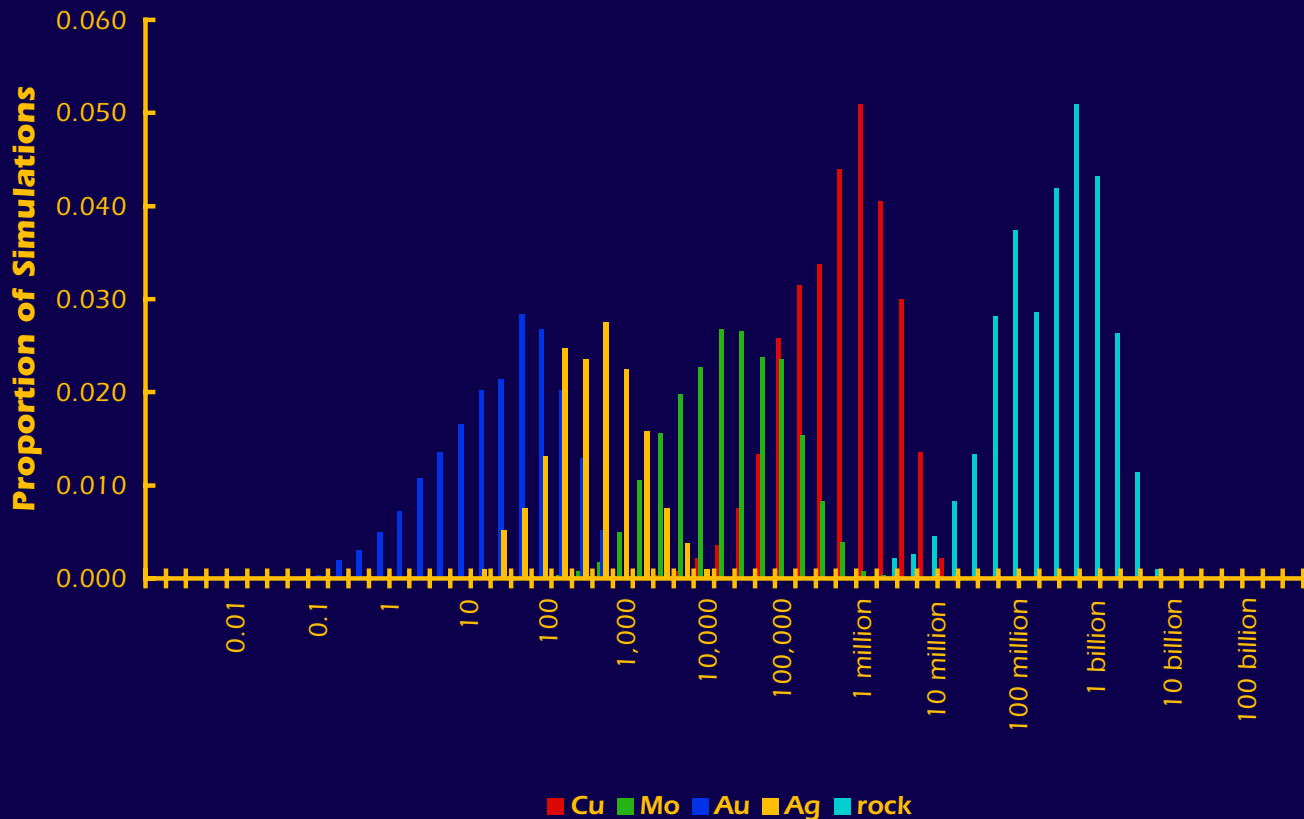


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SC23

The Mark3 Index is 89:

Porphyry Cu (BC-AK)

There is a 90% or greater chance of 0 or more deposits.
 There is a 50% or greater chance of 0 or more deposits.
 There is a 10% or greater chance of 1 or more deposits.
 There is a 5% or greater chance of 2 or more deposits.
 There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	850,000	19,000	27	190	260,000,000
0.05	1,600,000	60,000	76	580	500,000,000
mean	270,000	11,000	12	100	78,000,000
Probability of mean	0.19	0.13	0.13	0.13	0.19
Probability of zero	0.70	0.79	0.81	0.85	0.70

The tract ID is AK-SC23The Mark3 Index is 89: **Porphyry Cu (BC-AK)**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

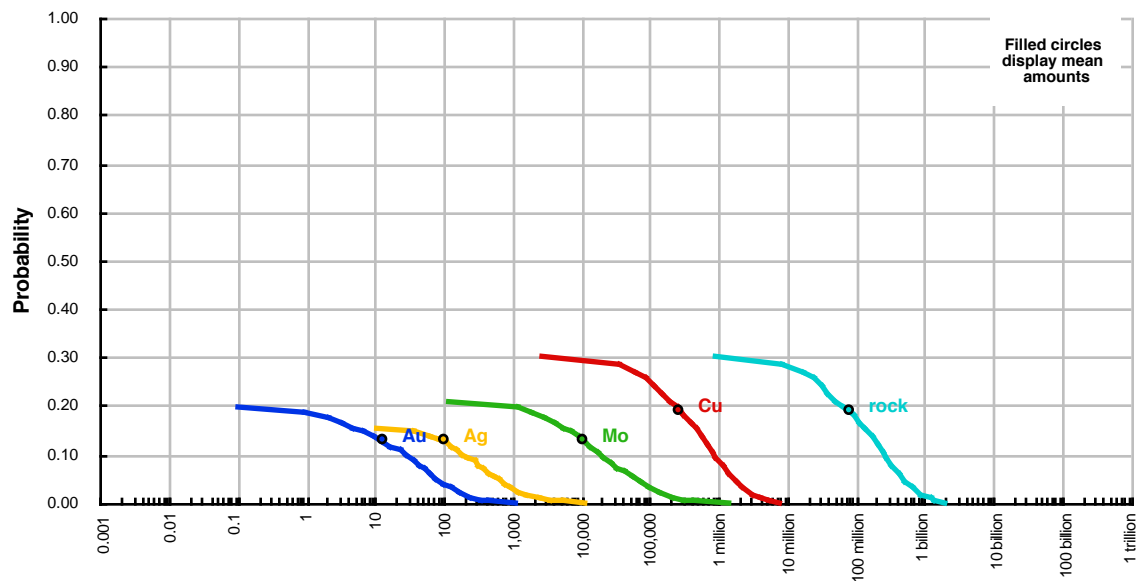
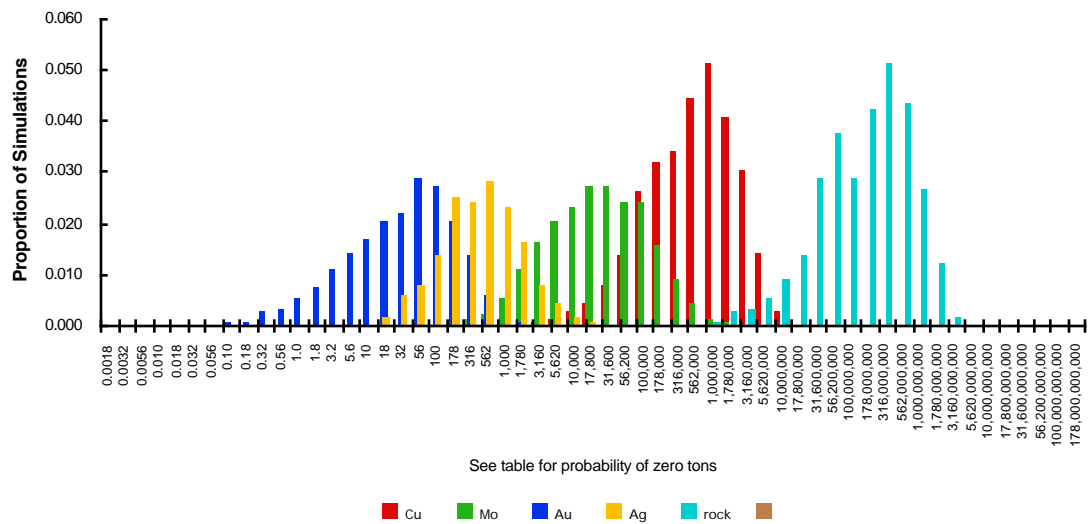
There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

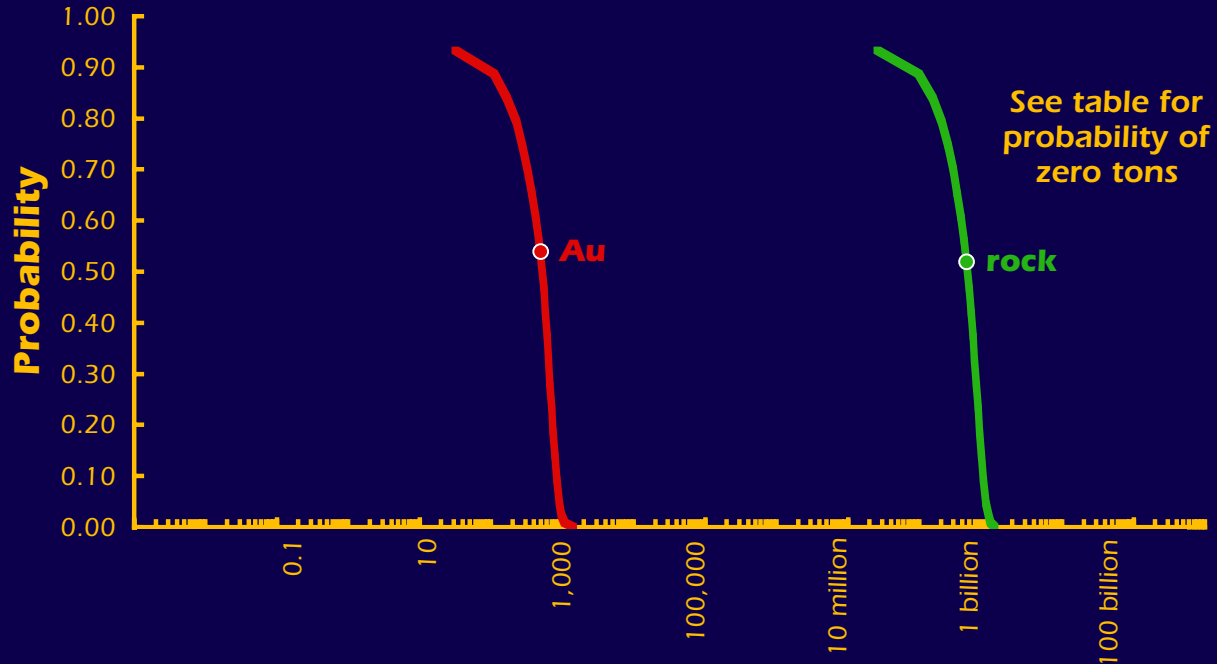
There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock	0
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	850,000	19,000	27	190	260,000,000	0
0.05	1,600,000	60,000	76	580	500,000,000	0
mean	270,000	11,000	12	100	78,000,000	0
Probability of mean	0.19	0.13	0.13	0.13	0.19	0.00
Probability of zero	0.70	0.79	0.81	0.85	0.70	0.00

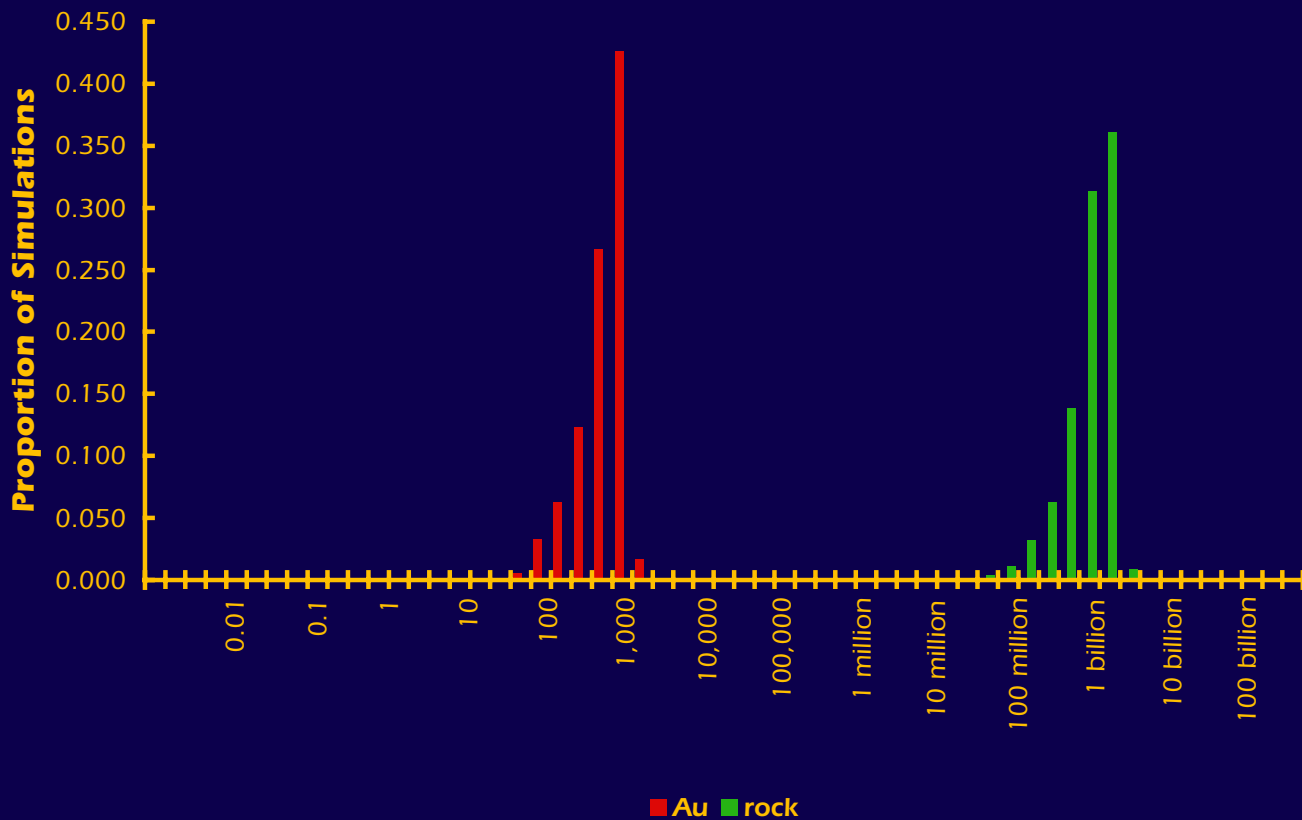
The tract ID is AK-SC23**Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SC24

The Mark3 Index is 43:

Plutonic porphyry gold

There is a 90% or greater chance of 1 or more deposits.
There is a 50% or greater chance of 5 or more deposits.
There is a 10% or greater chance of 7 or more deposits.
There is a 5% or greater chance of 7 or more deposits.
There is a 1% or greater chance of 7 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	rock
0.95	0	0
0.90	95	81,000,000
0.50	520	470,000,000
0.10	830	780,000,000
0.05	900	860,000,000
mean	490	450,000,000
Probability of mean	0.54	0.52
Probability of zero	0.07	0.07

The tract ID is AK-SC24The Mark3 Index is 43: **Plutonic porphyry gold**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 5 or more deposits.

There is a 10% or greater chance of 7 or more deposits.

There is a 5% or greater chance of 7 or more deposits.

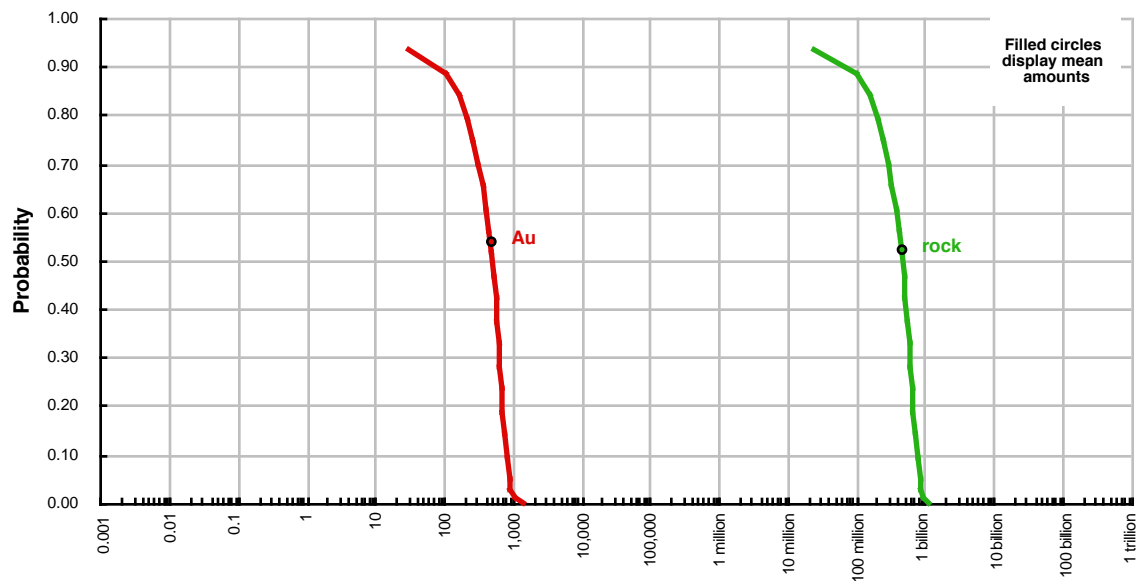
There is a 1% or greater chance of 7 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

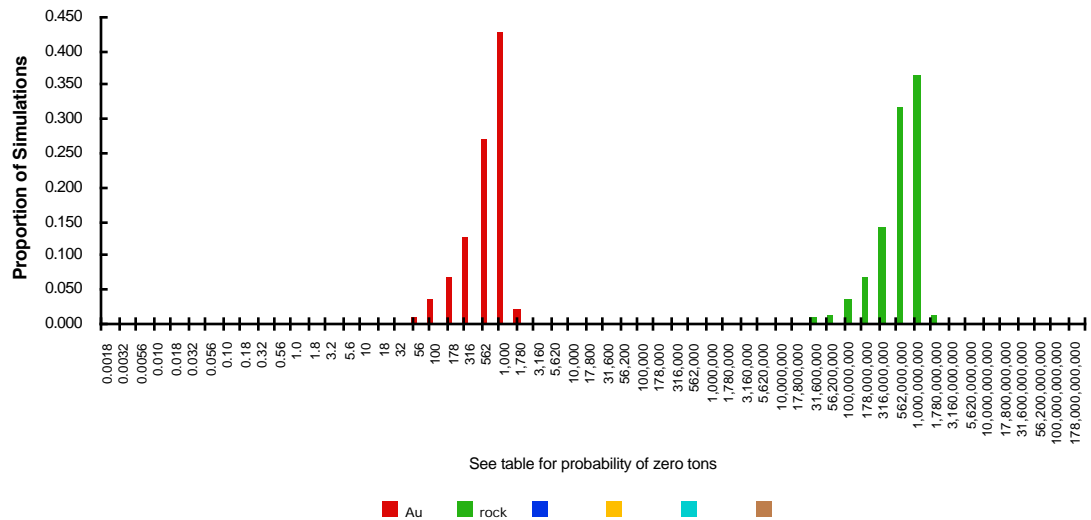
quantile	Au	rock	0	0	0	0
0.95	0	0	0	0	0	0
0.90	95	81,000,000	0	0	0	0
0.50	520	470,000,000	0	0	0	0
0.10	830	780,000,000	0	0	0	0
0.05	900	860,000,000	0	0	0	0
mean	490	450,000,000	0	0	0	0
Probability of mean	0.54	0.52	0.00	0.00	0.00	0.00
Probability of zero	0.07	0.07	0.00	0.00	0.00	0.00

The tract ID is AK-SC24

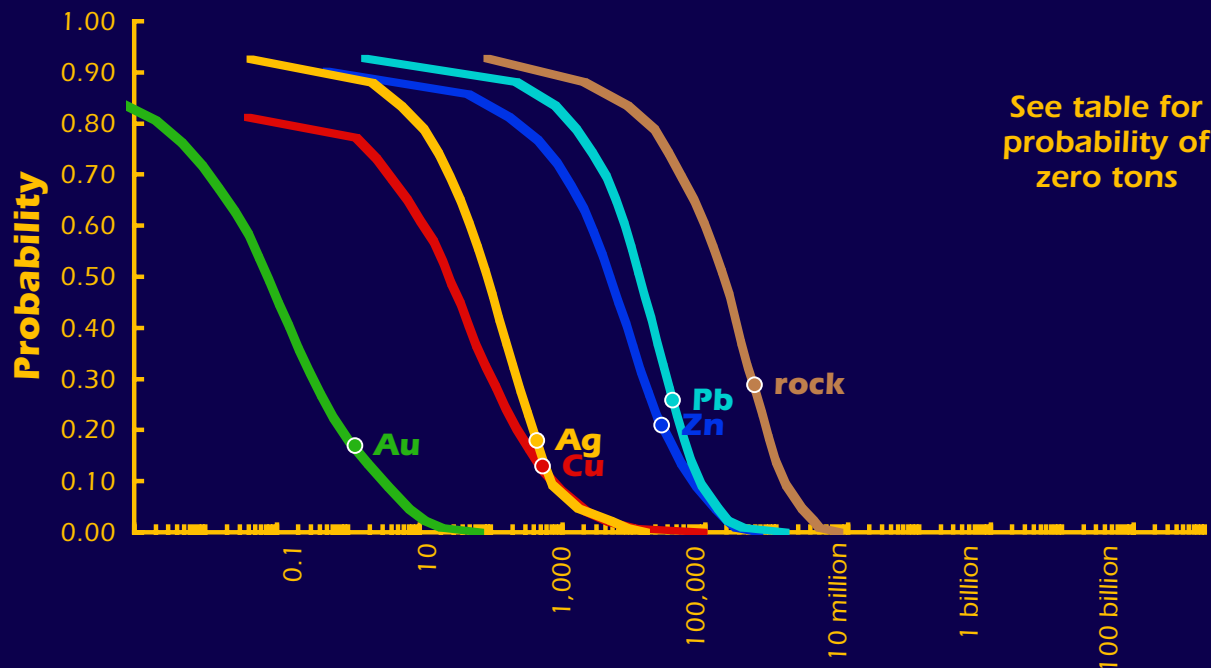
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)



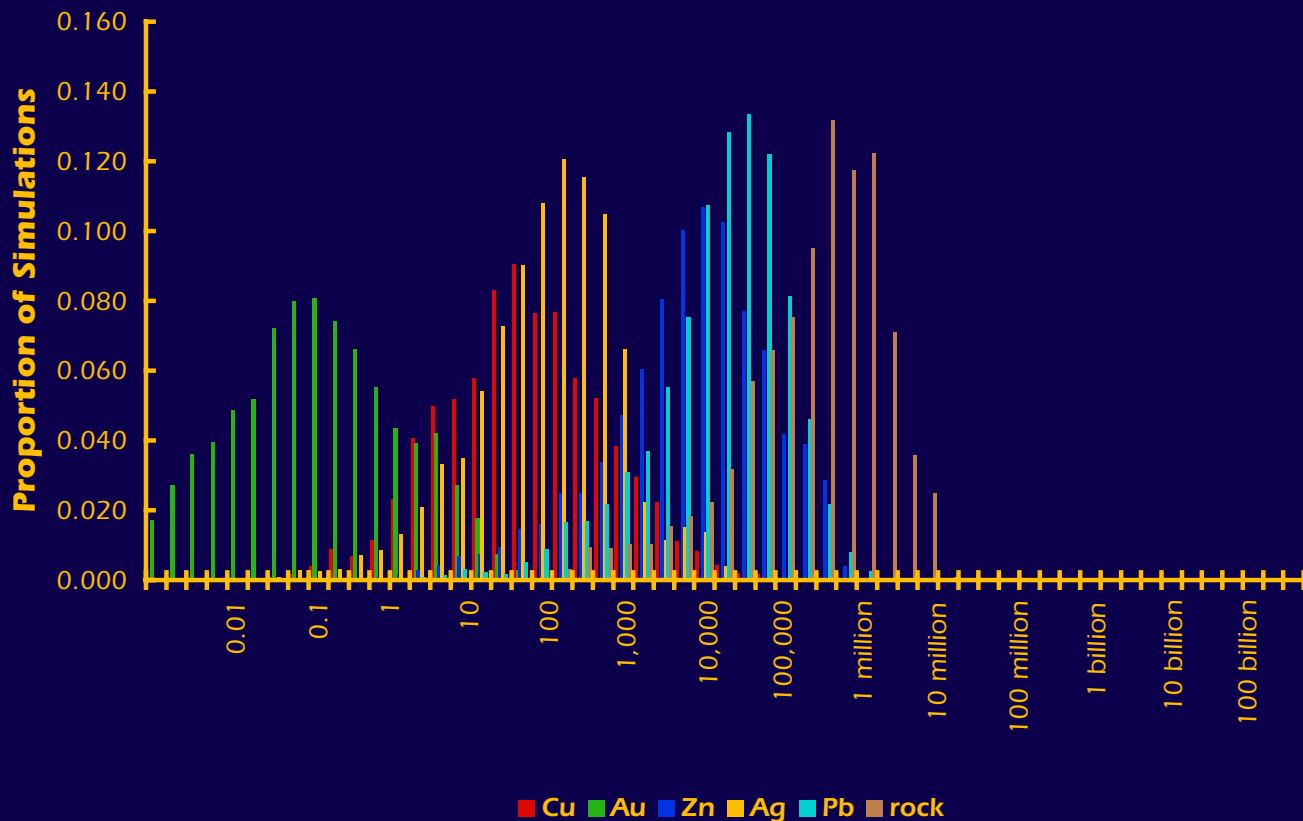
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



See table for
probability of
zero tons

Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SC28

The Mark3 Index is 46:

Polymetallic vein

There is a 90% or greater chance of 1 or more deposits.
There is a 50% or greater chance of 5 or more deposits.
There is a 10% or greater chance of 7 or more deposits.
There is a 5% or greater chance of 7 or more deposits.
There is a 1% or greater chance of 7 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	2	1	110	770
0.50	26	0	4,700	90	12,000	180,000
0.10	720	3	67,500	680	83,000	1,300,000
0.05	1,800	6	140,000	1,500	150,000	2,200,000
mean	510	1	24,000	430	34,000	480,000
Probability of mean	0.13	0.17	0.21	0.18	0.26	0.29
Probability of zero	0.19	0.10	0.10	0.07	0.07	0.07

The tract ID is AK-SC28The Mark3 Index is 46: **Polymetallic vein**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 5 or more deposits.

There is a 10% or greater chance of 7 or more deposits.

There is a 5% or greater chance of 7 or more deposits.

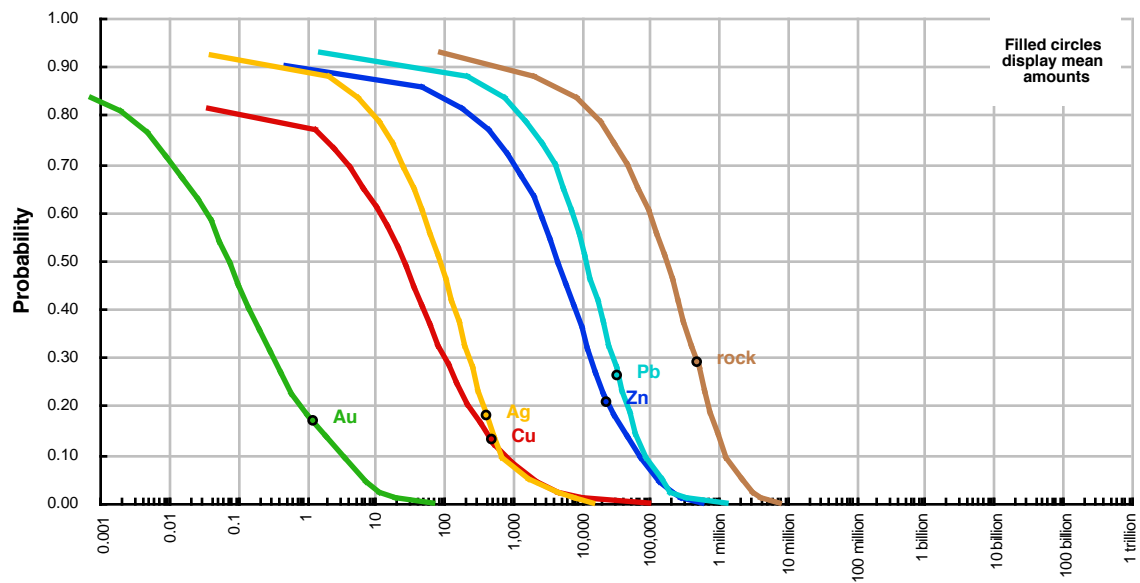
There is a 1% or greater chance of 7 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

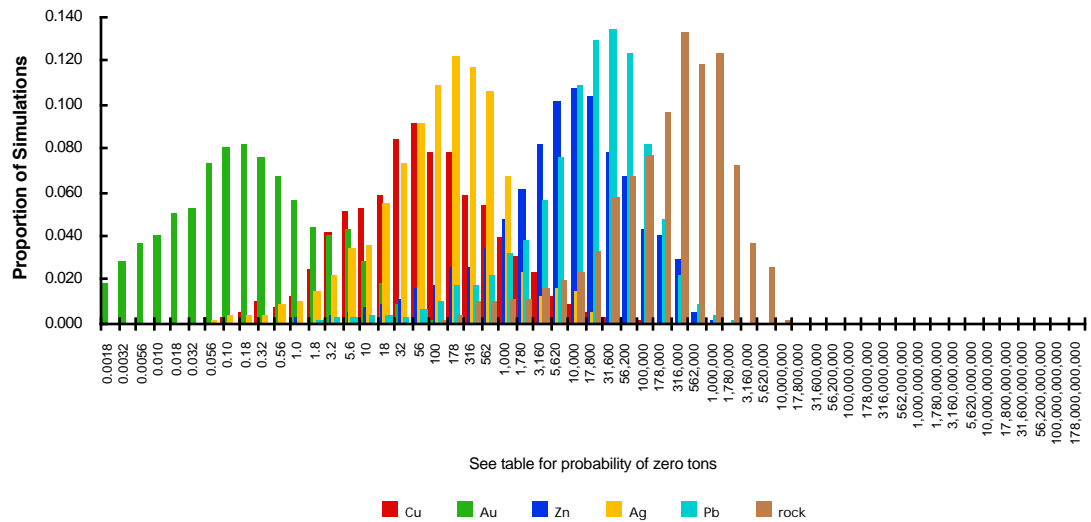
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	2	1	110	770
0.50	26	0	4,700	90	12,000	180,000
0.10	720	3	67,500	680	83,000	1,300,000
0.05	1,800	6	140,000	1,500	150,000	2,200,000
mean	510	1	24,000	430	34,000	480,000
Probability of mean	0.13	0.17	0.21	0.18	0.26	0.29
Probability of zero	0.19	0.10	0.10	0.07	0.07	0.07

The tract ID is AK-SC28

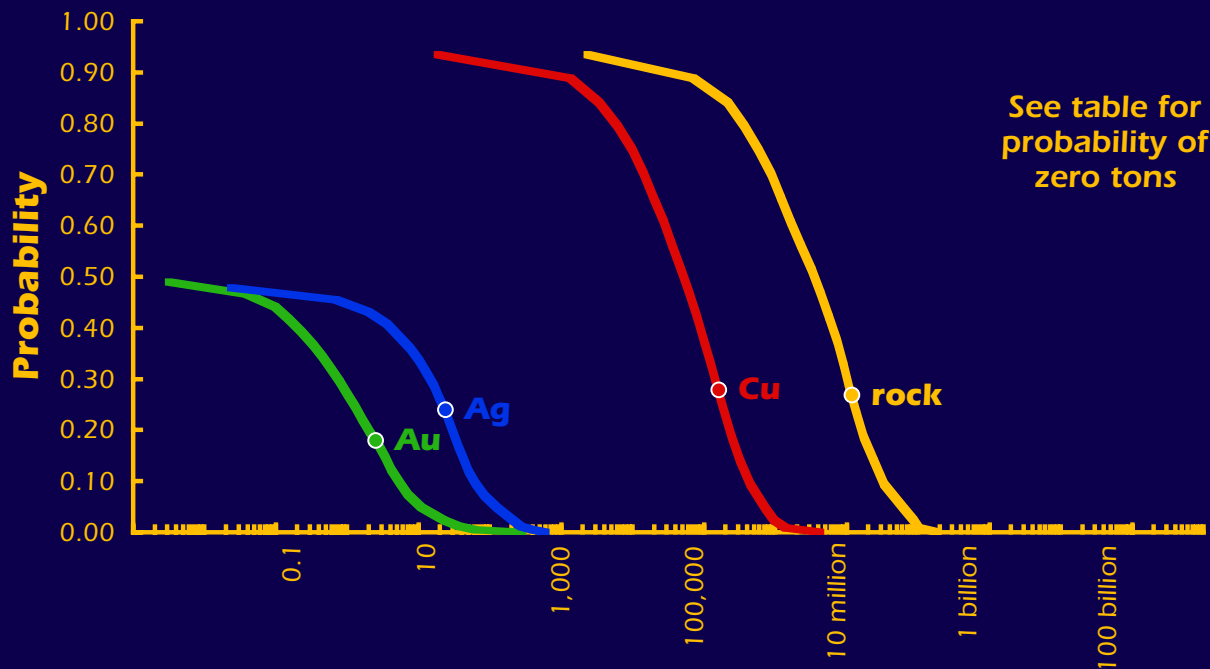
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

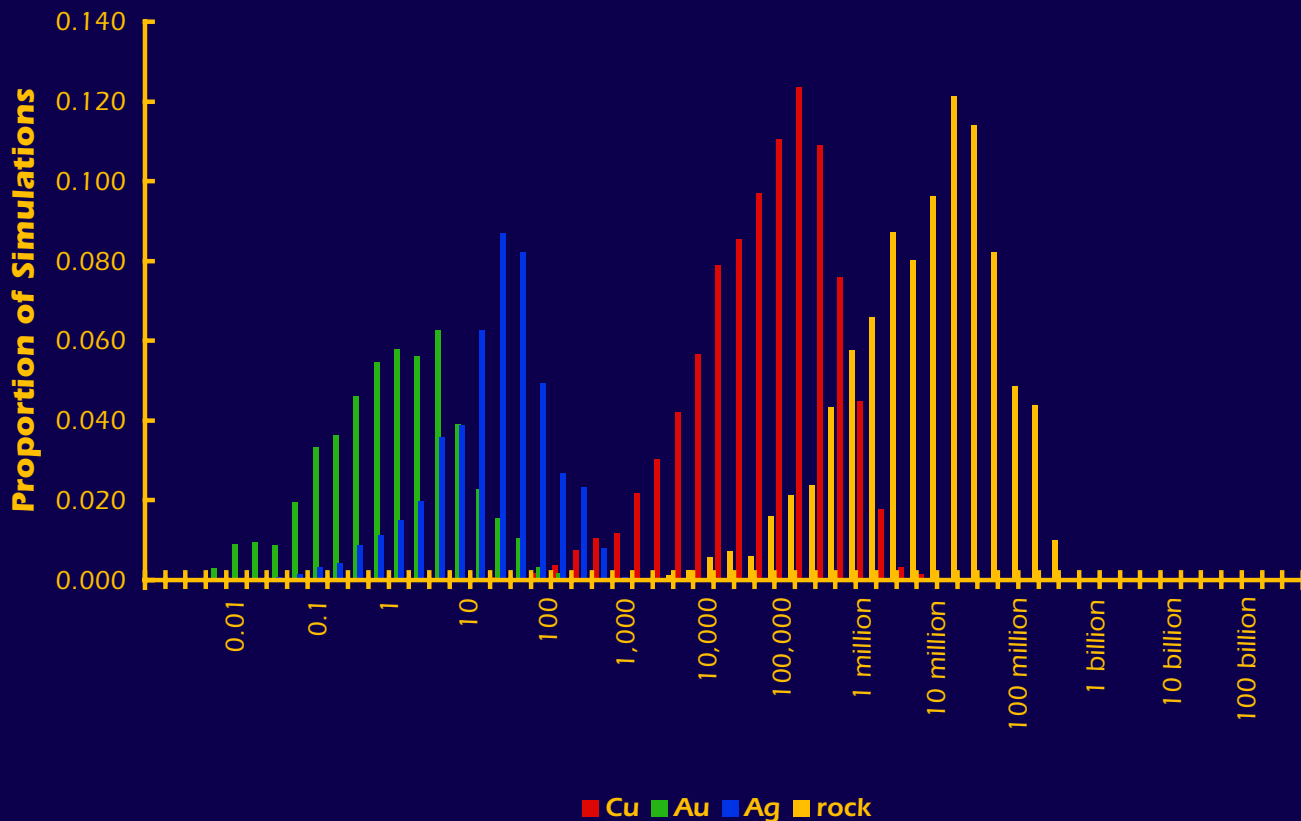


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SC31

The Mark3 Index is 8:

Skarn Cu

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

There is a 1% or greater chance of 6 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	970	0	0	50,000
0.50	52,000	0	0	3,600,000
0.10	420,000	5	61	32,000,000
0.05	690,000	11	120	61,000,000
mean	160,000	2	23	12,000,000
Probability of mean	0.28	0.18	0.24	0.27
Probability of zero	0.07	0.51	0.52	0.07

The tract ID is AK-SC31The Mark3 Index is 8: **Skarn Cu**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

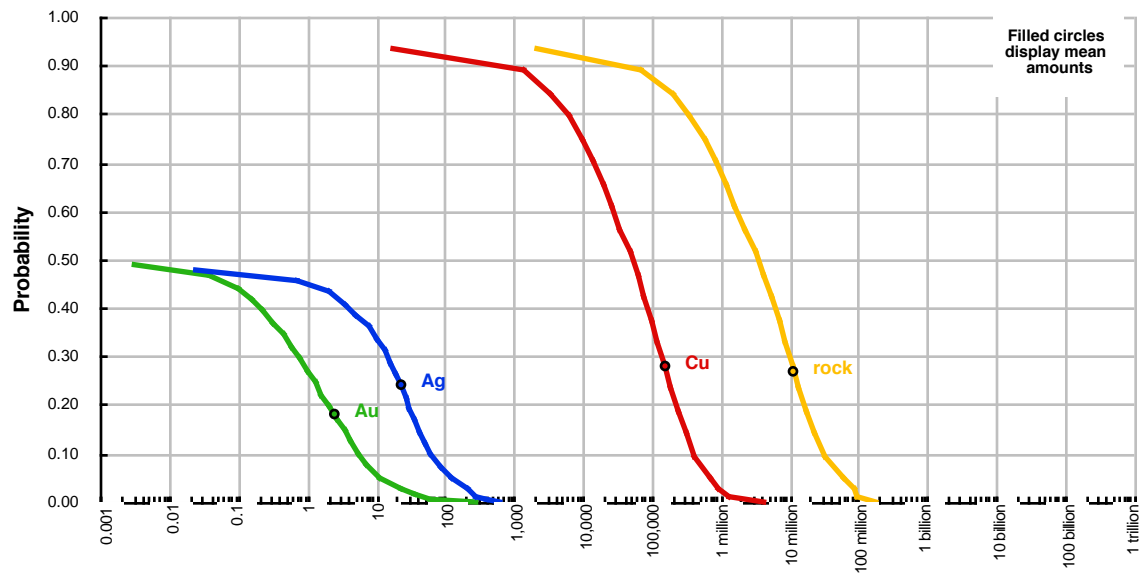
There is a 1% or greater chance of 6 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

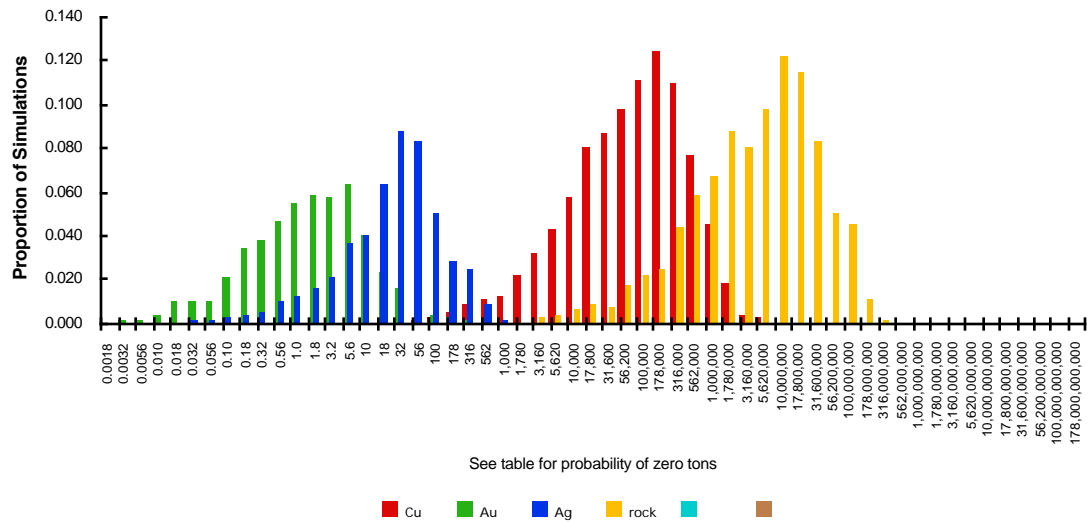
quantile	Cu	Au	Ag	rock	0	0
0.95	0	0	0	0	0	0
0.90	970	0	0	50,000	0	0
0.50	52,000	0	0	3,600,000	0	0
0.10	420,000	5	61	32,000,000	0	0
0.05	690,000	11	120	61,000,000	0	0
mean	160,000	2	23	12,000,000	0	0
Probability of mean	0.28	0.18	0.24	0.27	0.00	0.00
Probability of zero	0.07	0.51	0.52	0.07	0.00	0.00

The tract ID is AK-SC31

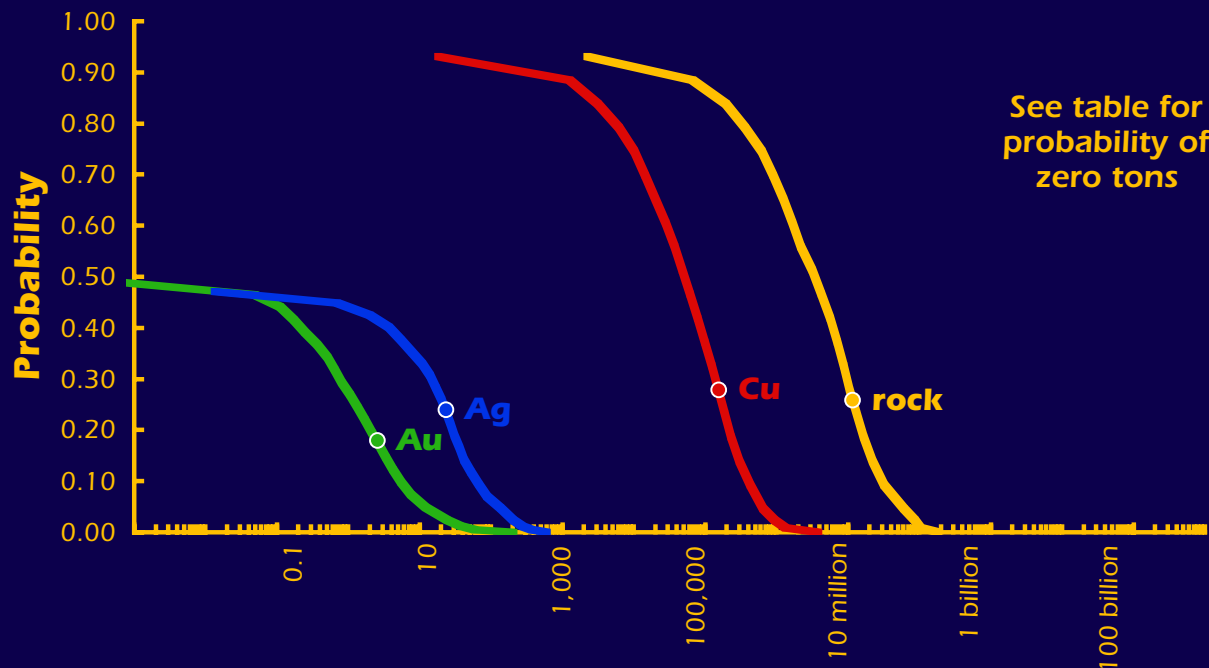
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

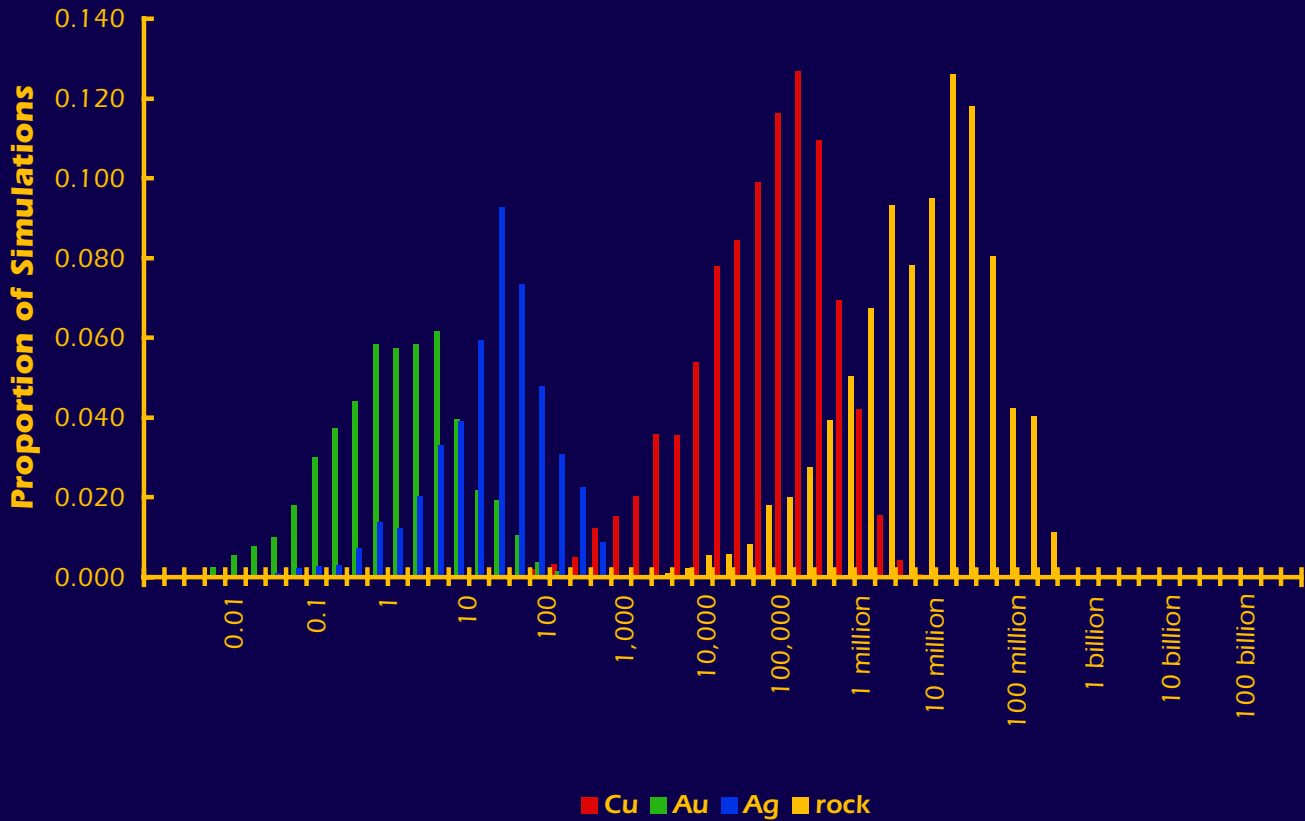


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SC32

The Mark3 Index is 8:

Skarn Cu

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

There is a 1% or greater chance of 6 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	780	0	0	41,000
0.50	52,000	0	0	3,400,000
0.10	400,000	5	64	30,000,000
0.05	620,000	12	130	59,000,000
mean	150,000	3	23	11,000,000
Probability of mean	0.28	0.18	0.24	0.26
Probability of zero	0.07	0.51	0.53	0.07

The tract ID is AK-SC32The Mark3 Index is 8: **Skarn Cu**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

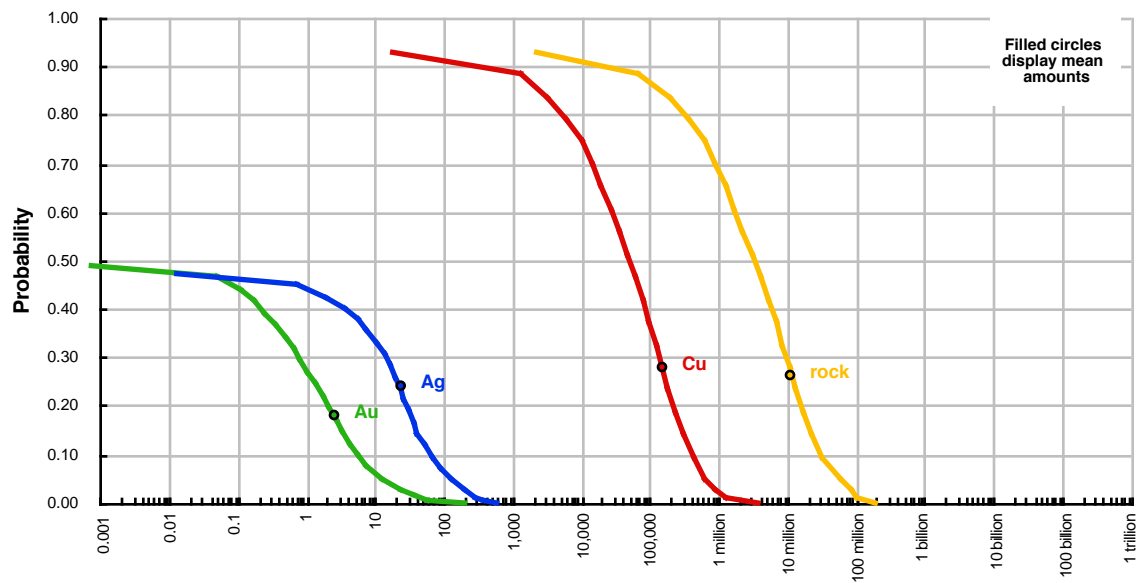
There is a 1% or greater chance of 6 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

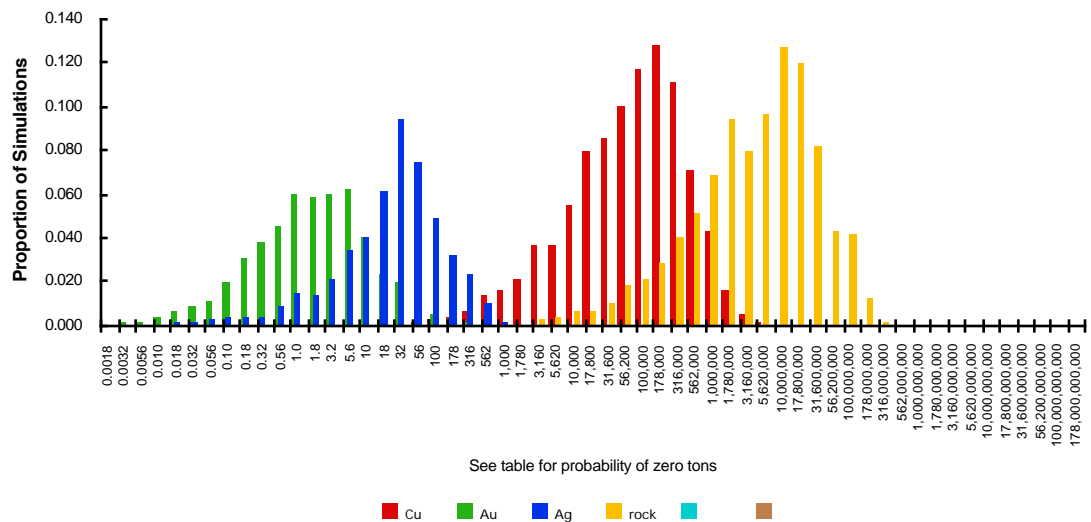
quantile	Cu	Au	Ag	rock	0	0
0.95	0	0	0	0	0	0
0.90	780	0	0	41,000	0	0
0.50	52,000	0	0	3,400,000	0	0
0.10	400,000	5	64	30,000,000	0	0
0.05	620,000	12	130	59,000,000	0	0
mean	150,000	3	23	11,000,000	0	0
Probability of mean	0.28	0.18	0.24	0.26	0.00	0.00
Probability of zero	0.07	0.51	0.53	0.07	0.00	0.00

The tract ID is AK-SC32

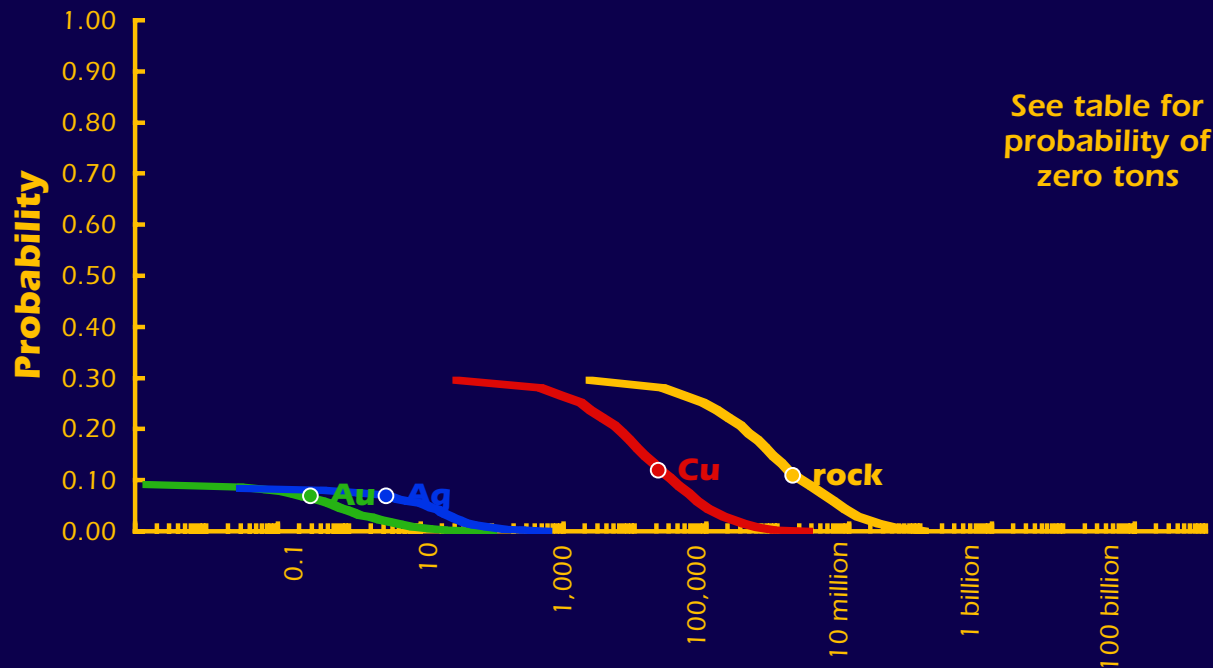
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

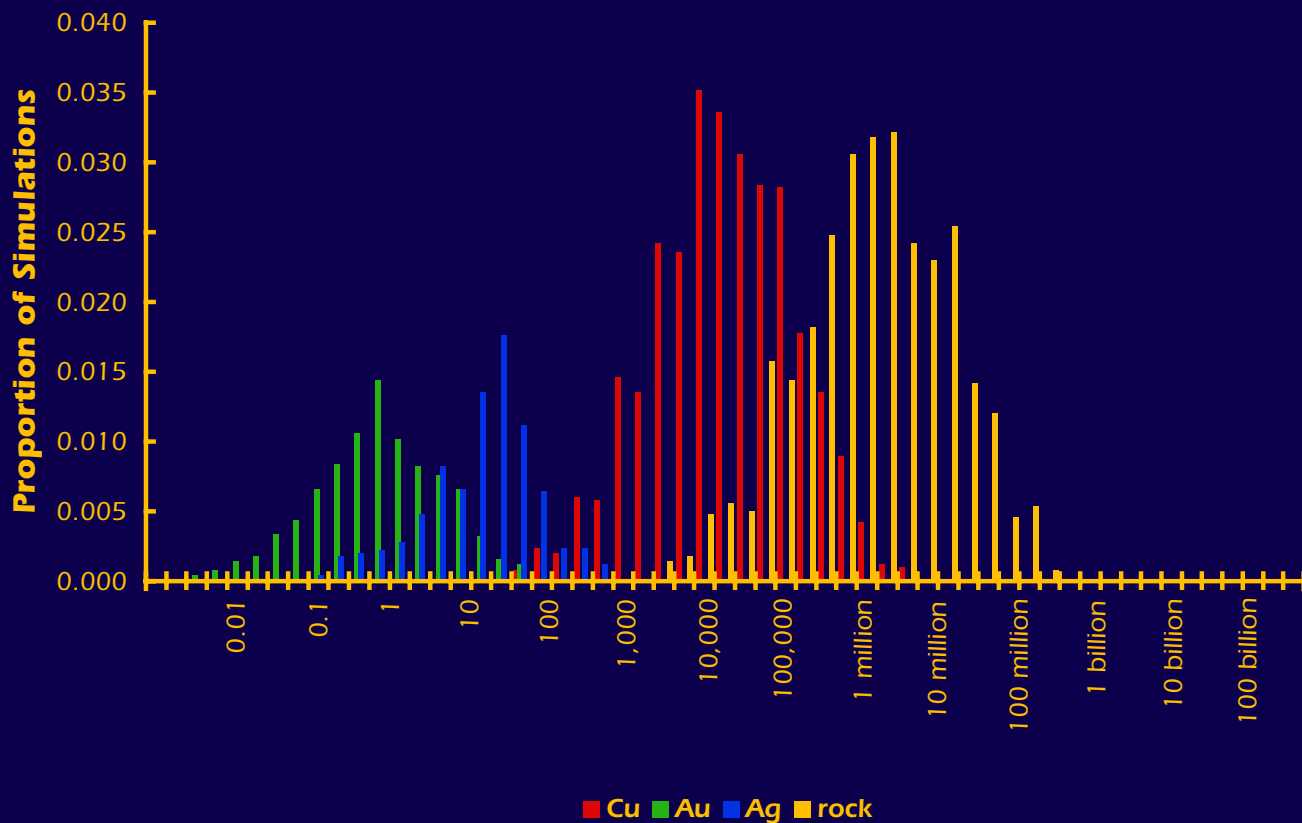


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SC33

The Mark3 Index is 8:

Skarn Cu

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	34,000	0	0	2,200,000
0.05	95,000	1	13	7,500,000
mean	21,000	0	3	1,600,000
Probability of mean	0.12	0.07	0.07	0.11
Probability of zero	0.70	0.91	0.92	0.70

The tract ID is AK-SC33The Mark3 Index is 8: **Skarn Cu**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

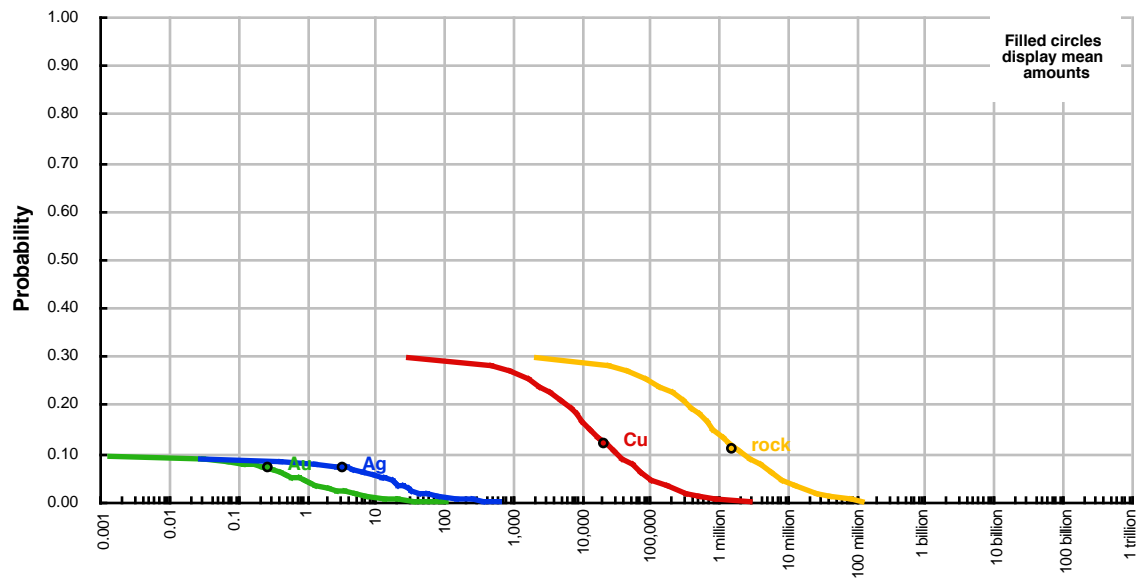
There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

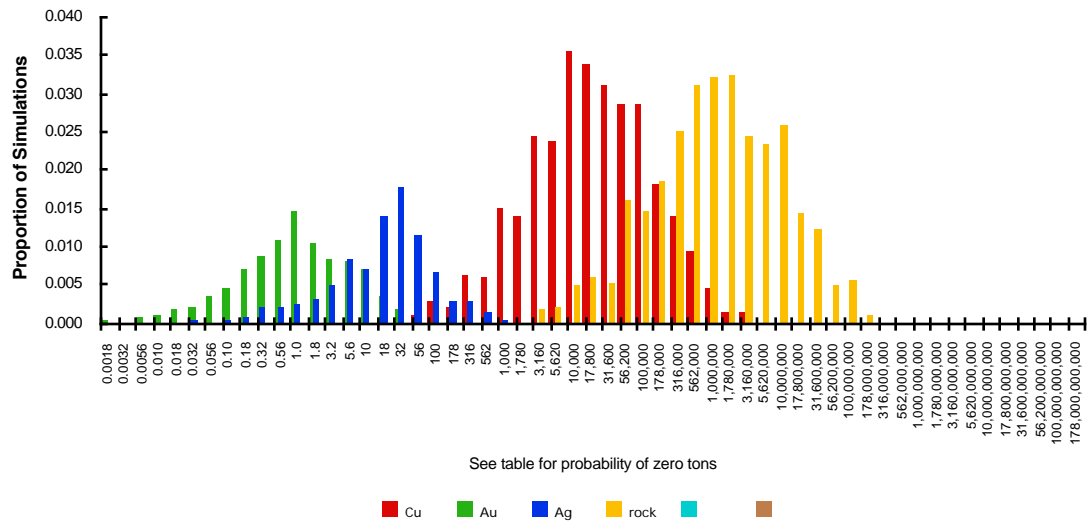
quantile	Cu	Au	Ag	rock	0	0
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	34,000	0	0	2,200,000	0	0
0.05	95,000	1	13	7,500,000	0	0
mean	21,000	0	3	1,600,000	0	0
Probability of mean	0.12	0.07	0.07	0.11	0.00	0.00
Probability of zero	0.70	0.91	0.92	0.70	0.00	0.00

The tract ID is AK-SC33

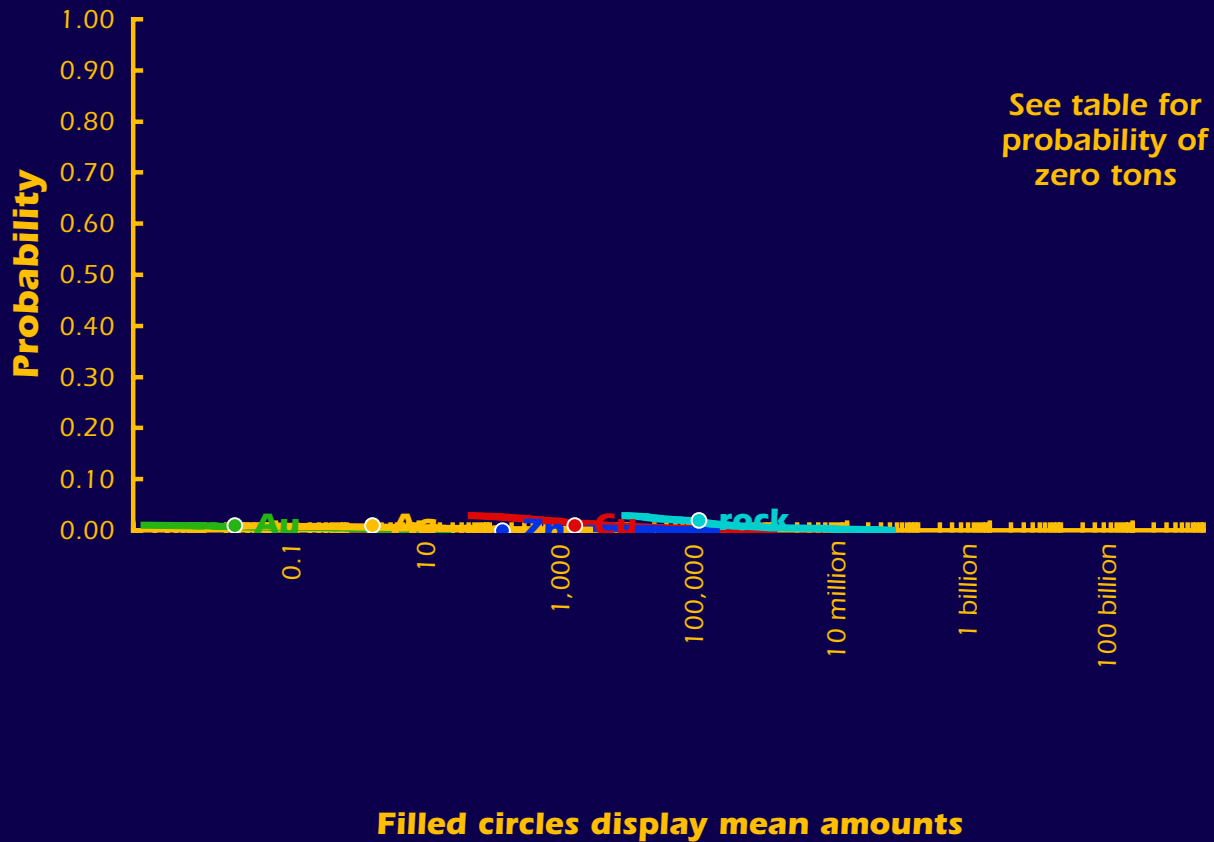
Cumulative Distributions of Contained Metal and Mineralized Rock



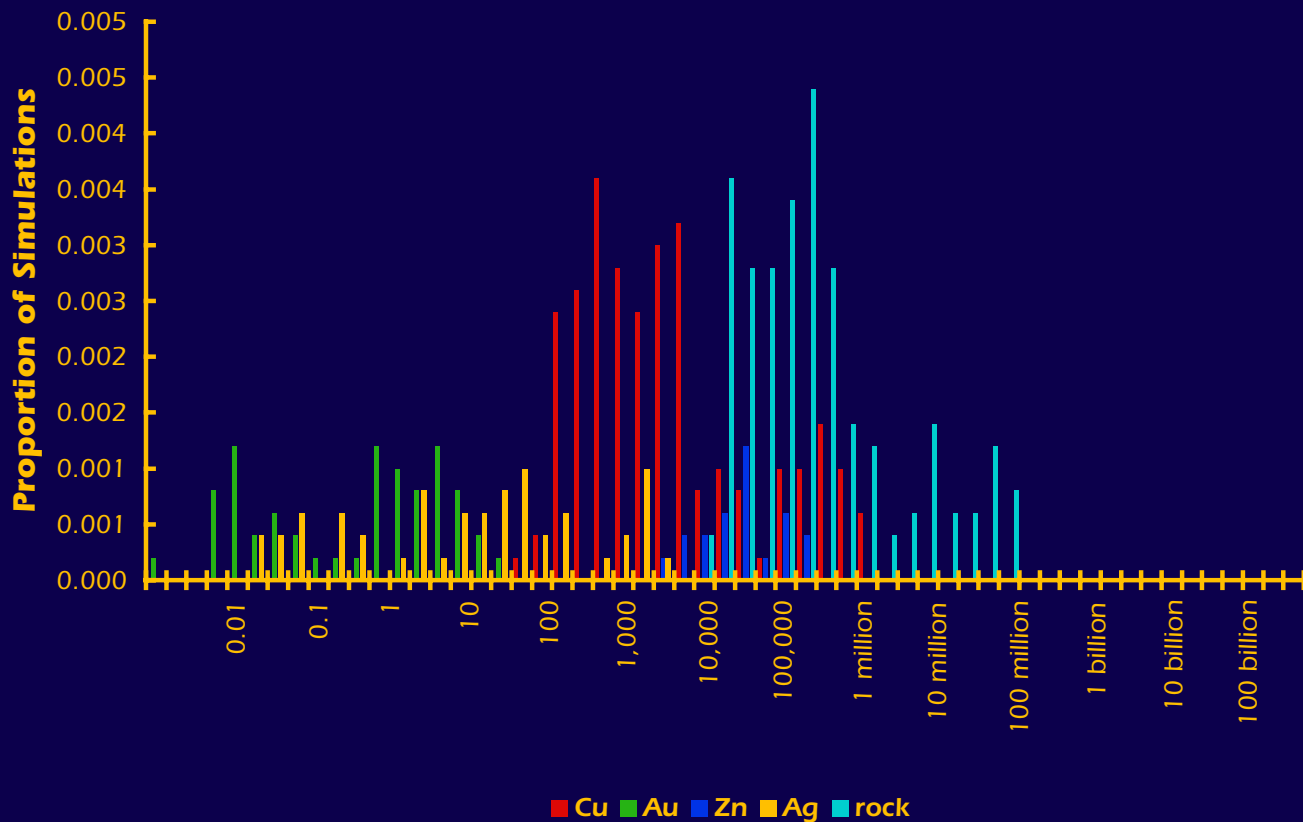
Histograms of Contained Metal and Mineralized Rock (metric tons)



Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SE01

The Mark3 Index is 30:

Massive sulfide, Besshi

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	0	0	0	0	0
mean	1,500	0	150	2	84,000
Probability of mean	0.01	0.01	0.00	0.01	0.02
Probability of zero	0.97	0.99	1.00	0.99	0.97

The tract ID is AK-SE01The Mark3 Index is 30: **Massive sulfide, Besshi**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

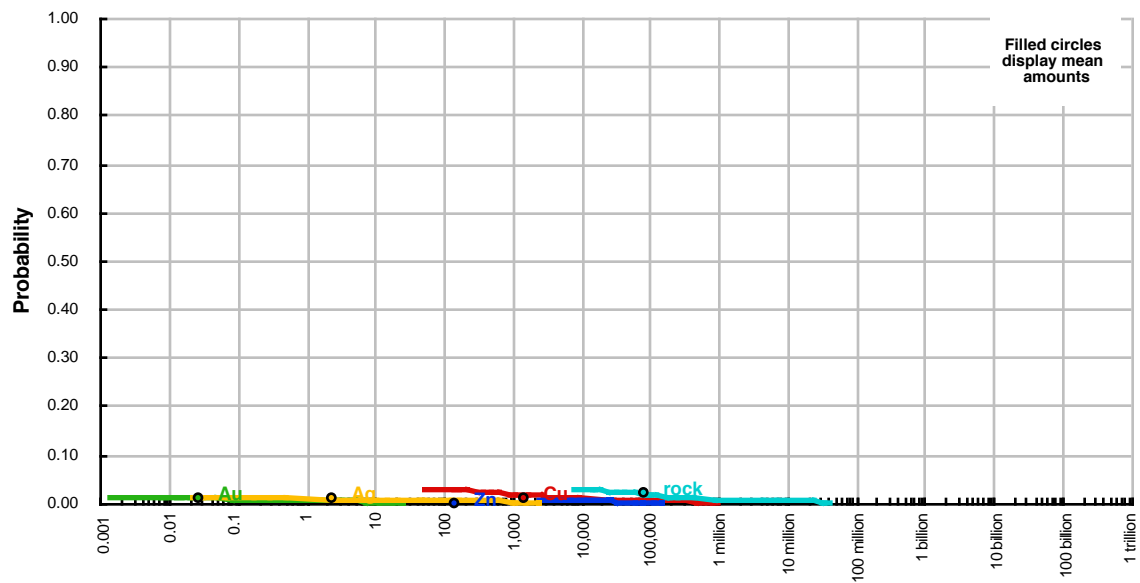
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

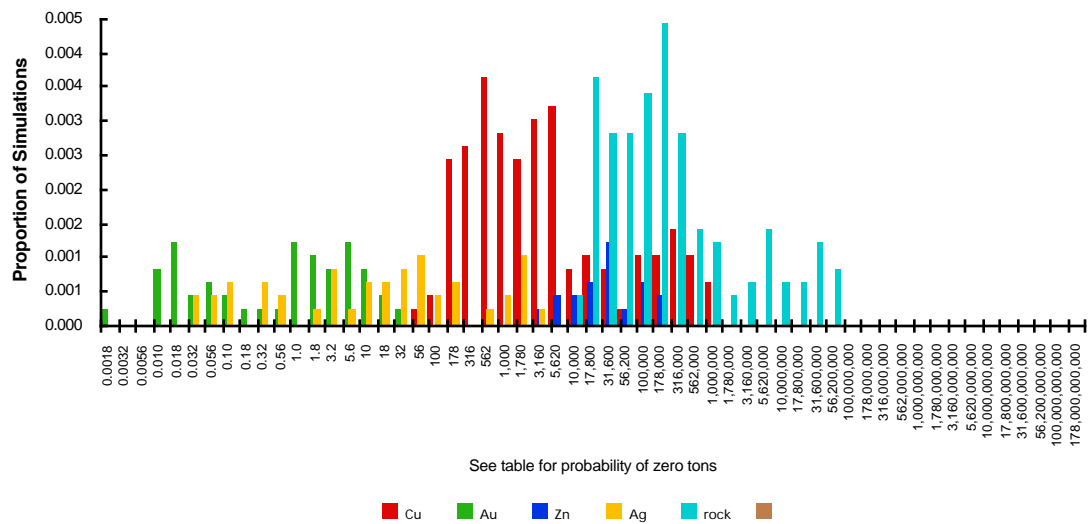
quantile	Cu	Au	Zn	Ag	rock	0
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	1,500	0	150	2	84,000	0
Probability of mean	0.01	0.01	0.00	0.01	0.02	0.00
Probability of zero	0.97	0.99	1.00	0.99	0.97	0.00

The tract ID is AK-SE01

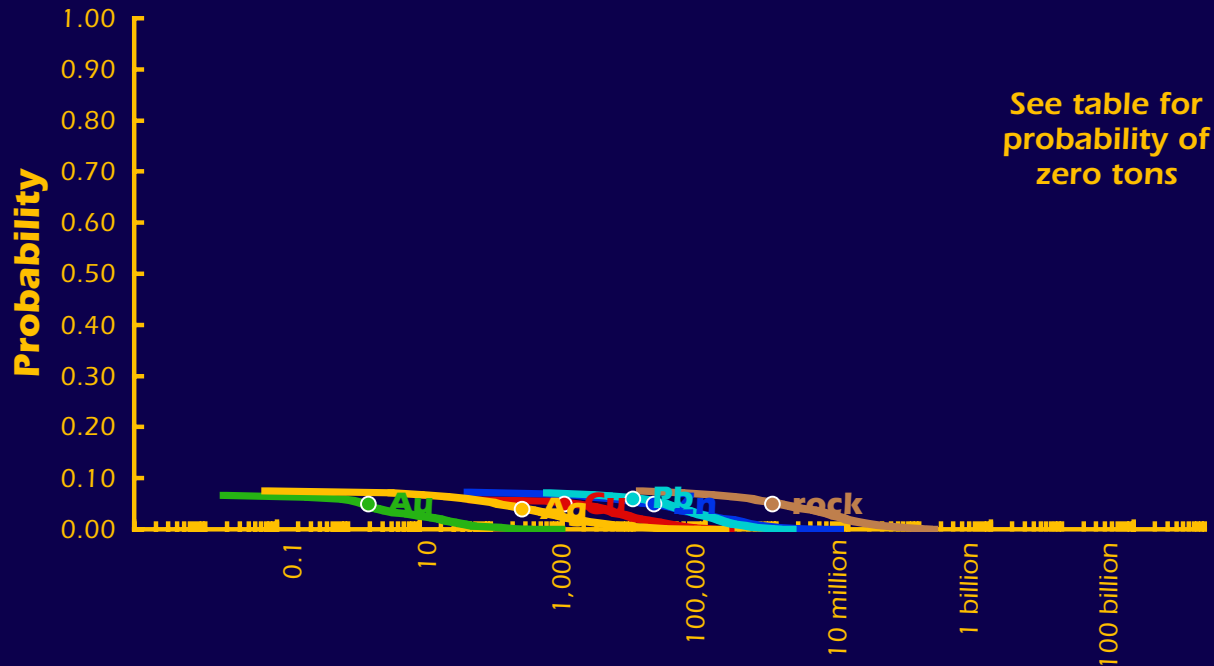
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

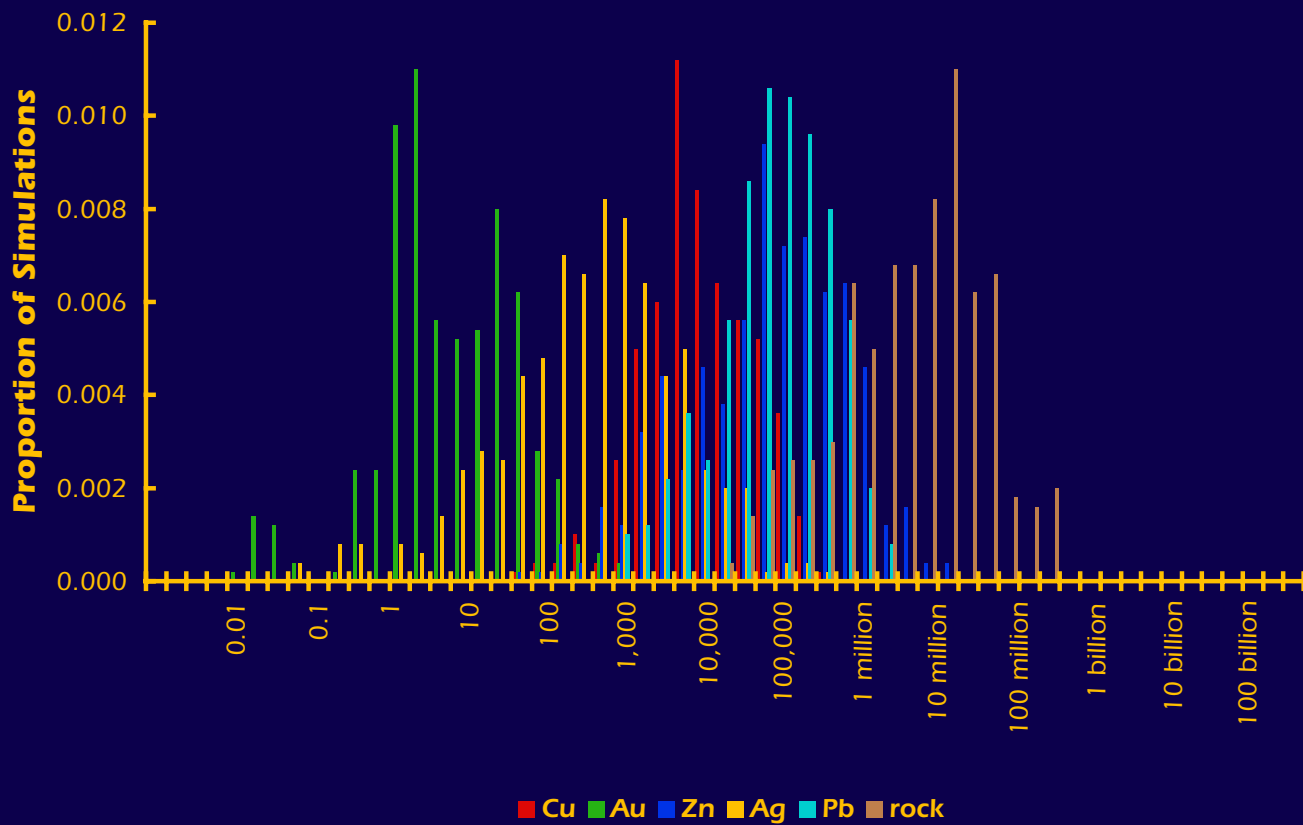


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SE02

The Mark3 Index is 58:

Epithermal vein, Creede

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	1,500	2	19,000	120	29,000	1,100,000
mean	1,000	2	19,000	270	9,500	870,000
Probability of mean	0.05	0.05	0.05	0.04	0.06	0.05
Probability of zero	0.94	0.93	0.93	0.93	0.93	0.93

The tract ID is AK-SE02The Mark3 Index is 58: **Epithermal vein, Creede**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

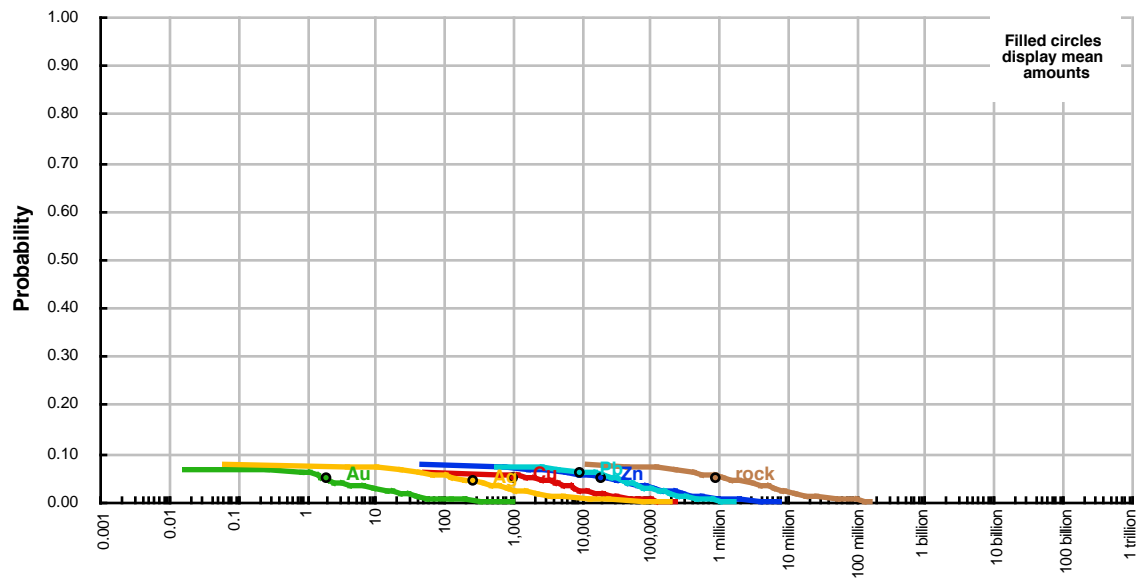
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

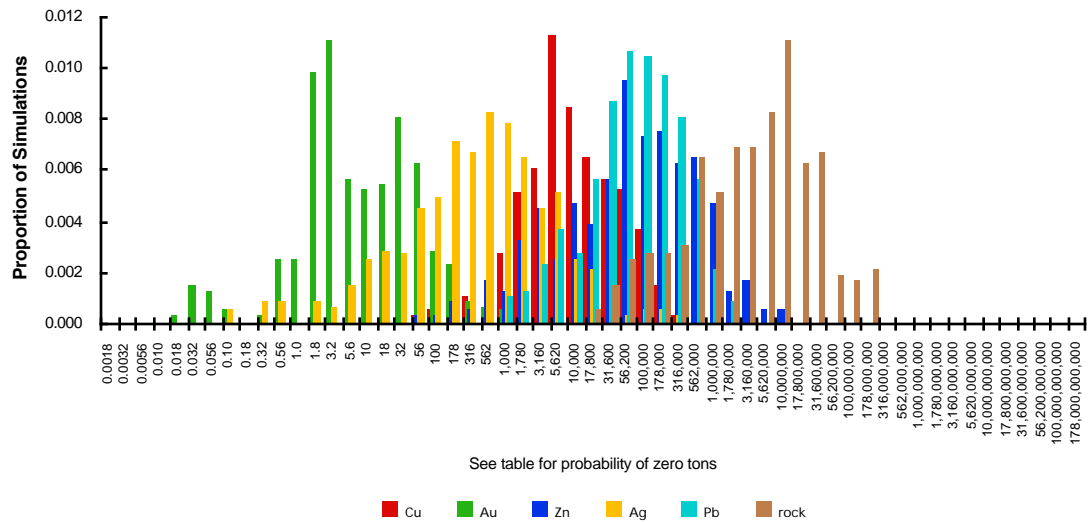
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	1,500	2	19,000	120	29,000	1,100,000
mean	1,000	2	19,000	270	9,500	870,000
Probability of mean	0.05	0.05	0.05	0.04	0.06	0.05
Probability of zero	0.94	0.93	0.93	0.93	0.93	0.93

The tract ID is AK-SE02

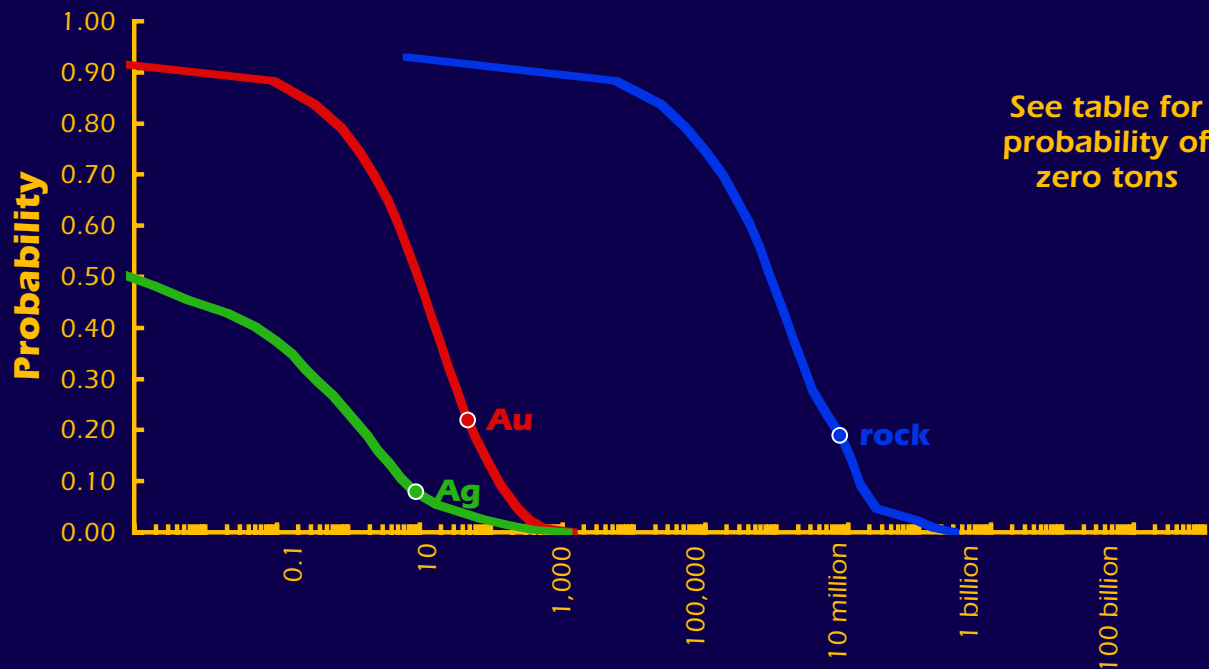
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)



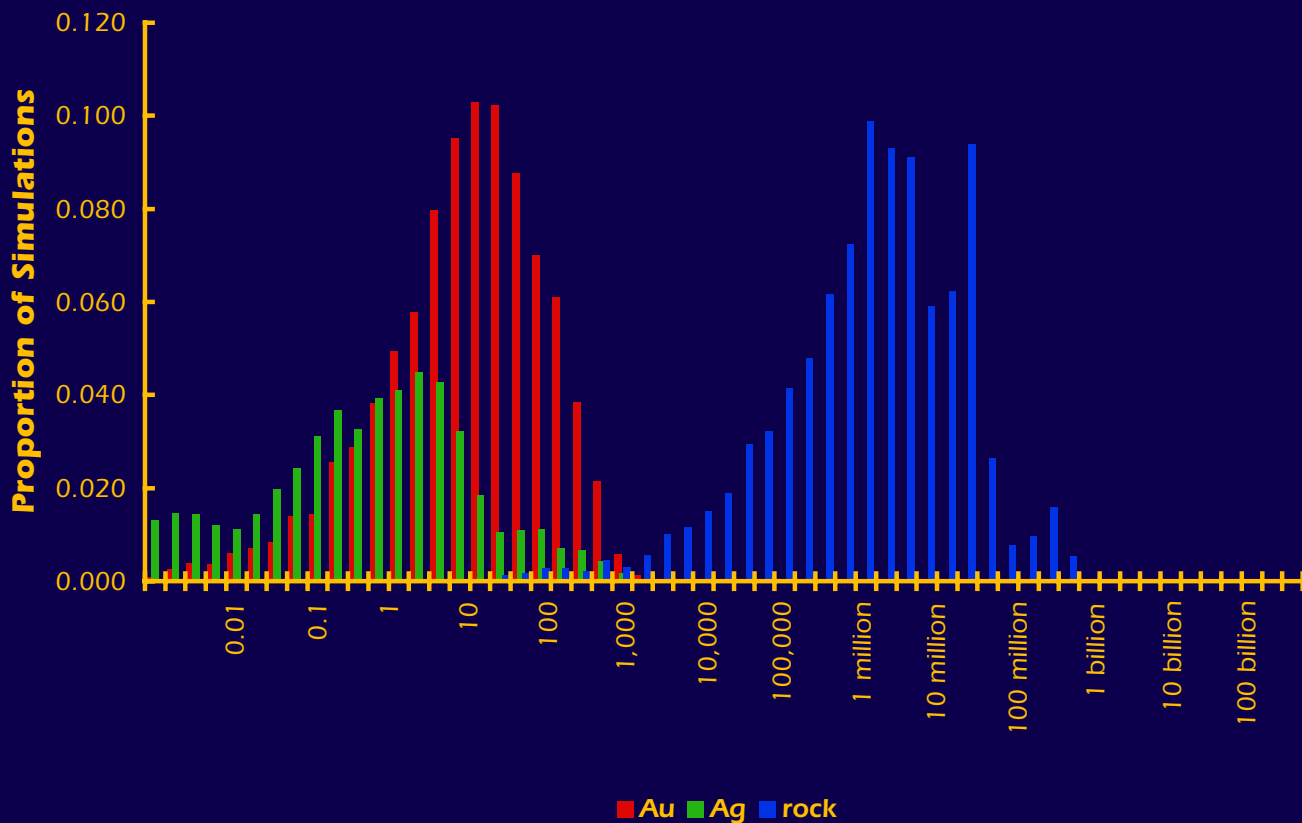
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



See table for
probability of
zero tons

Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SE03

The Mark3 Index is 27:

Low sulfide Au-quartz vein

There is a 90% or greater chance of 1 or more deposits.
There is a 50% or greater chance of 5 or more deposits.
There is a 10% or greater chance of 13 or more deposits.
There is a 5% or greater chance of 14 or more deposits.
There is a 1% or greater chance of 17 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	2,400
0.50	10	0	810,000
0.10	130	6	14,300,000
0.05	230	21	23,000,000
mean	46	9	7,600,000
Probability of mean	0.22	0.08	0.19
Probability of zero	0.07	0.46	0.07

The tract ID is AK-SE03The Mark3 Index is 27: **Low sulfide Au-quartz vein**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 5 or more deposits.

There is a 10% or greater chance of 13 or more deposits.

There is a 5% or greater chance of 14 or more deposits.

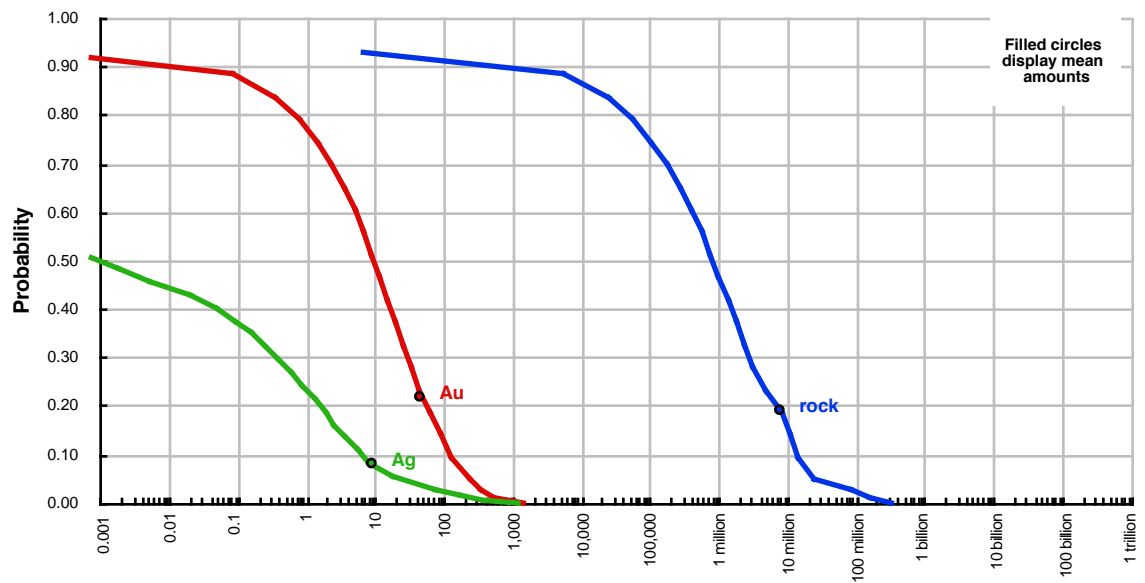
There is a 1% or greater chance of 17 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

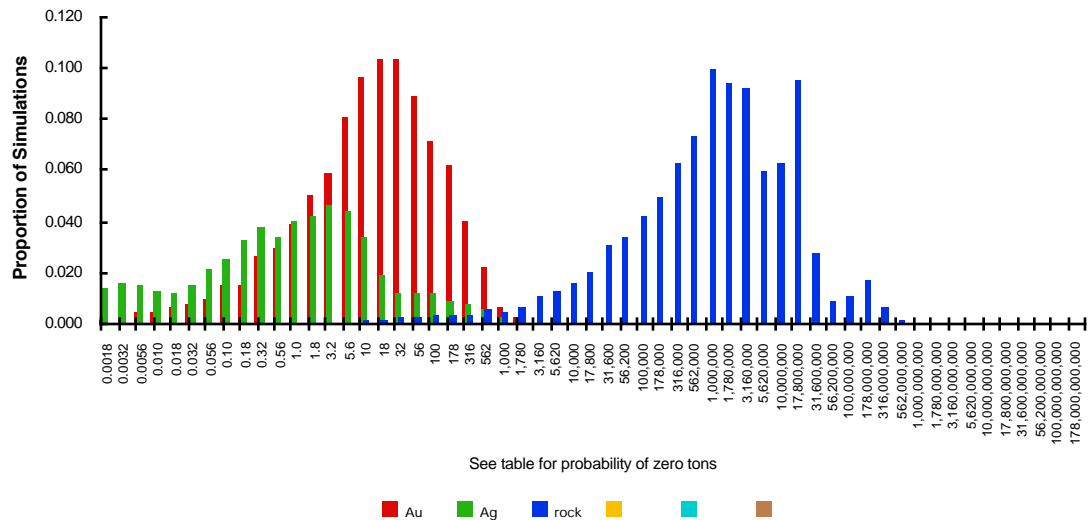
quantile	Au	Ag	rock	0	0	0
0.95	0	0	0	0	0	0
0.90	0	0	2,400	0	0	0
0.50	10	0	810,000	0	0	0
0.10	130	6	14,300,000	0	0	0
0.05	230	21	23,000,000	0	0	0
mean	46	9	7,600,000	0	0	0
Probability of mean	0.22	0.08	0.19	0.00	0.00	0.00
Probability of zero	0.07	0.46	0.07	0.00	0.00	0.00

The tract ID is AK-SE03

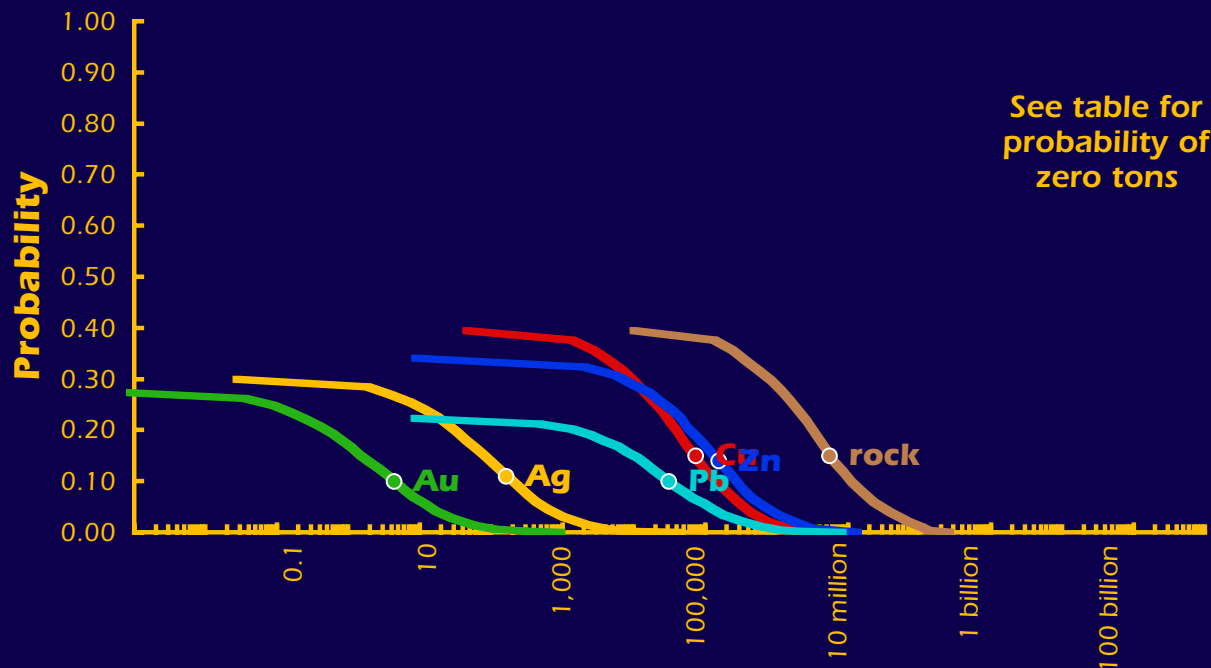
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

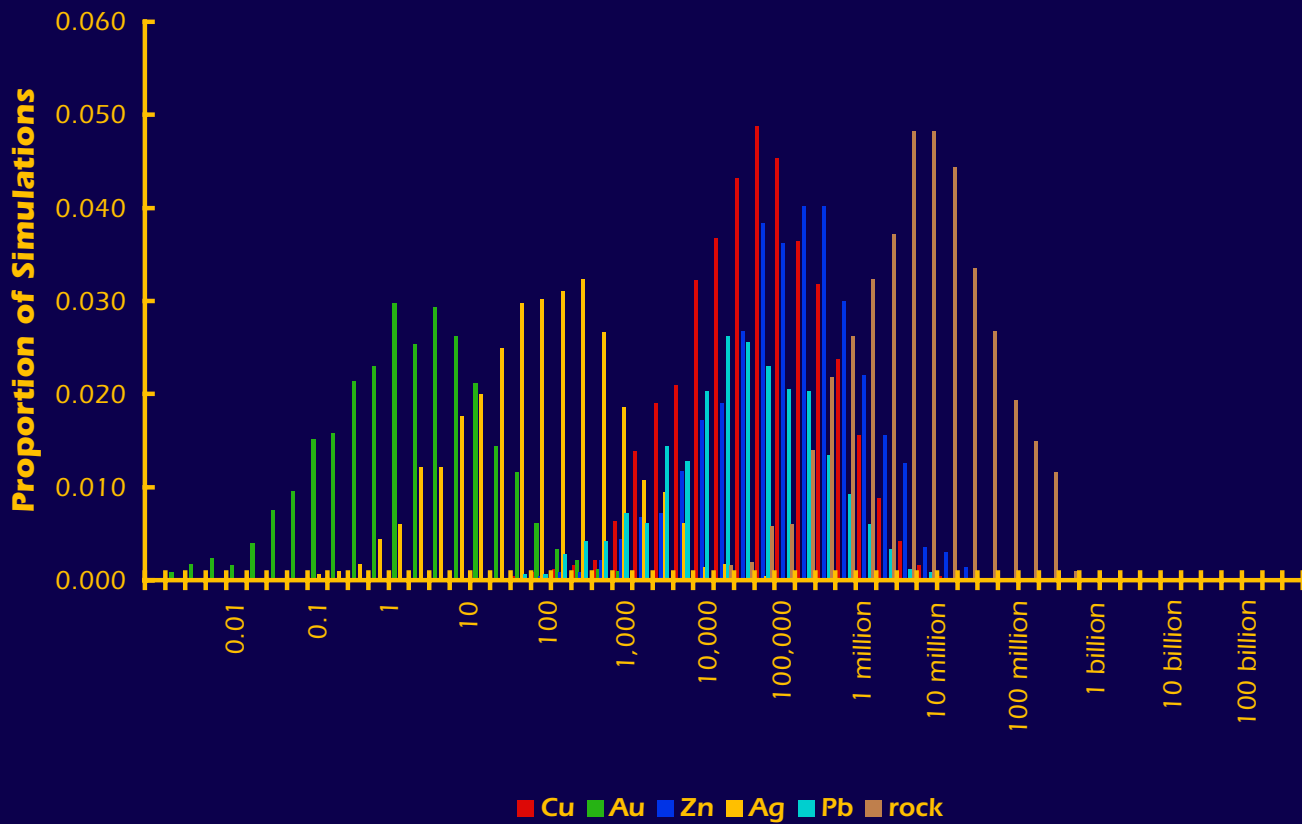


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SE04

The Mark3 Index is 93:

Massive sulfide, kuroko

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	140,000	4	269,000	200	30,000	11,000,000
0.05	340,000	14	680,000	550	110,000	29,000,000
mean	72,000	4	150,000	160	30,000	5,400,000
Probability of mean	0.15	0.10	0.14	0.11	0.10	0.15
Probability of zero	0.60	0.72	0.66	0.70	0.78	0.60

The tract ID is AK-SE04The Mark3 Index is 93: **Massive sulfide, kuroko**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

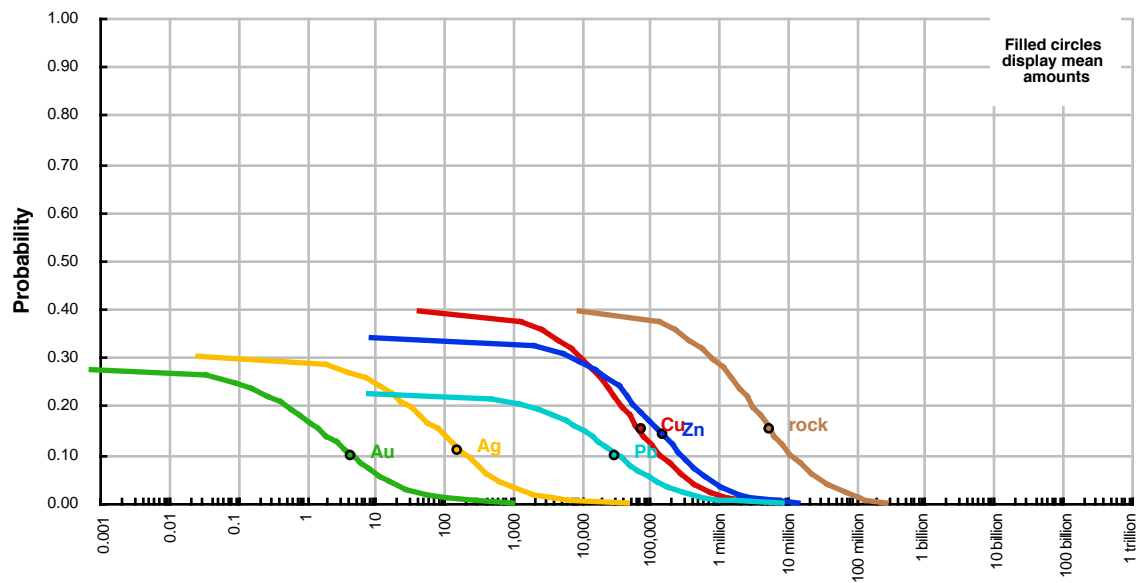
There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

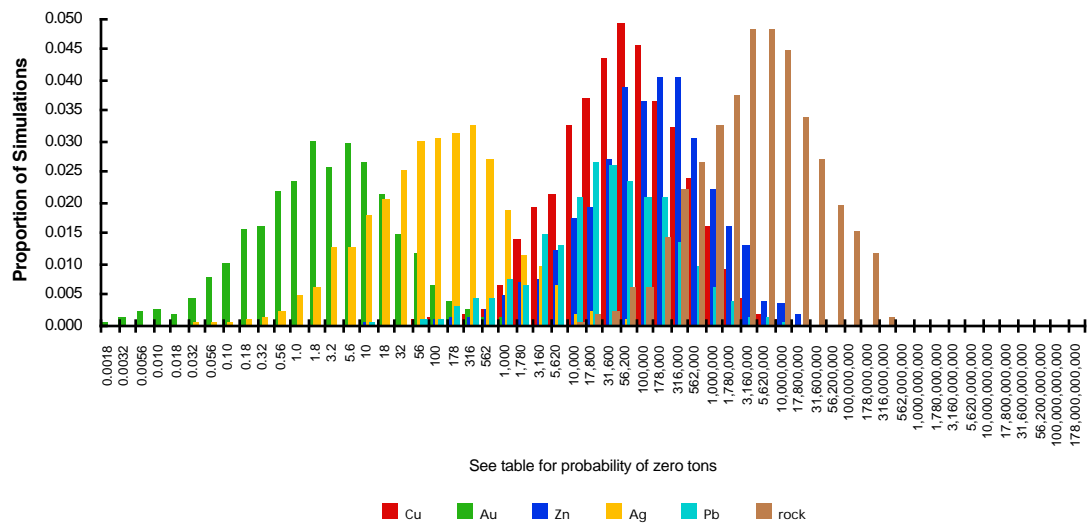
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	140,000	4	269,000	200	30,000	11,000,000
0.05	340,000	14	680,000	550	110,000	29,000,000
mean	72,000	4	150,000	160	30,000	5,400,000
Probability of mean	0.15	0.10	0.14	0.11	0.10	0.15
Probability of zero	0.60	0.72	0.66	0.70	0.78	0.60

The tract ID is AK-SE04

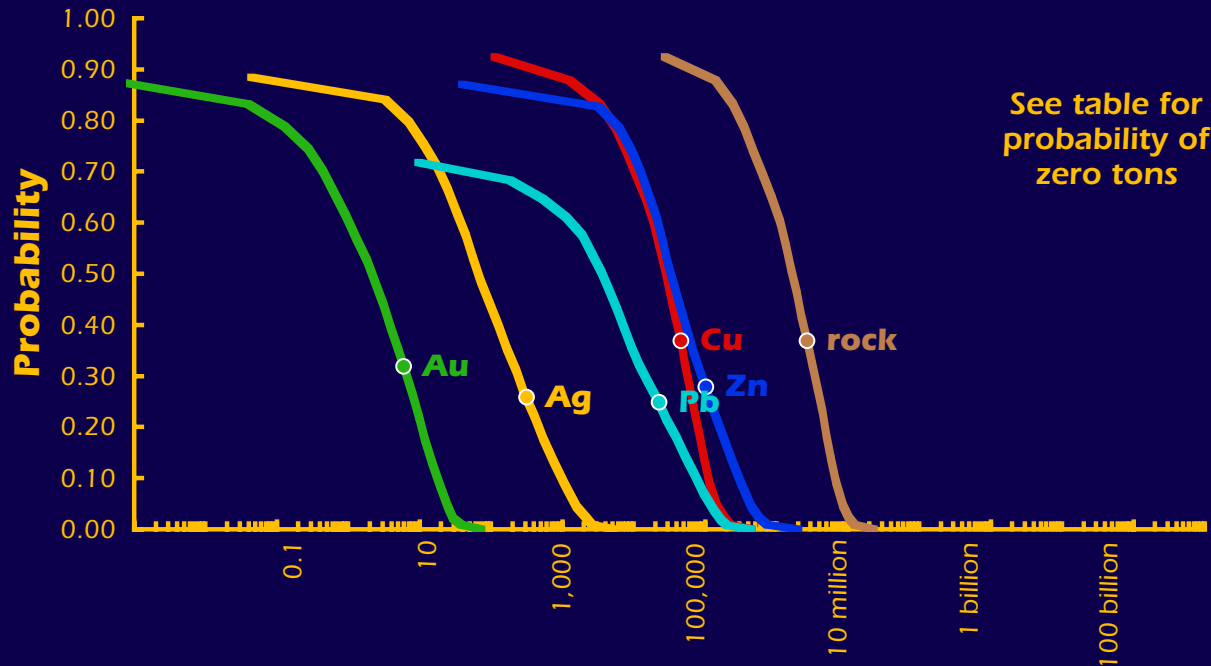
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

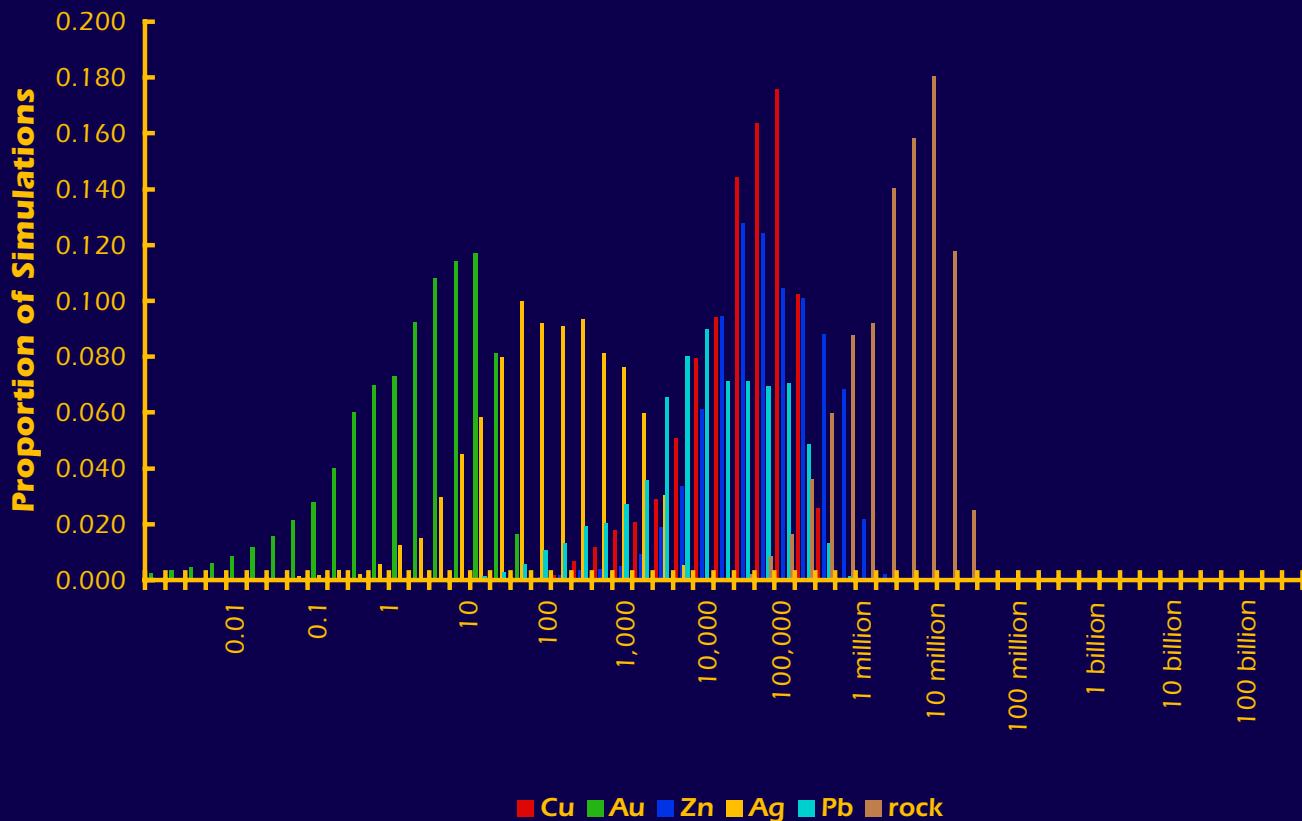


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SE05

The Mark3 Index is 44:

Massive sulfide, Sierran kuroko

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 7 or more deposits.

There is a 5% or greater chance of 9 or more deposits.

There is a 1% or greater chance of 13 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	680	0	0	0	0	96,000
0.50	29,000	2	33,000	67	3,600	1,700,000
0.10	110,000	18	299,000	970	75,000	6,600,000
0.05	140,000	24	420,000	1,500	110,000	8,300,000
mean	45,000	6	100,000	310	22,000	2,700,000
Probability of mean	0.37	0.32	0.28	0.26	0.25	0.37
Probability of zero	0.08	0.12	0.13	0.11	0.28	0.08

The tract ID is AK-SE05The Mark3 Index is 44: **Massive sulfide, Sierran kuroko**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 7 or more deposits.

There is a 5% or greater chance of 9 or more deposits.

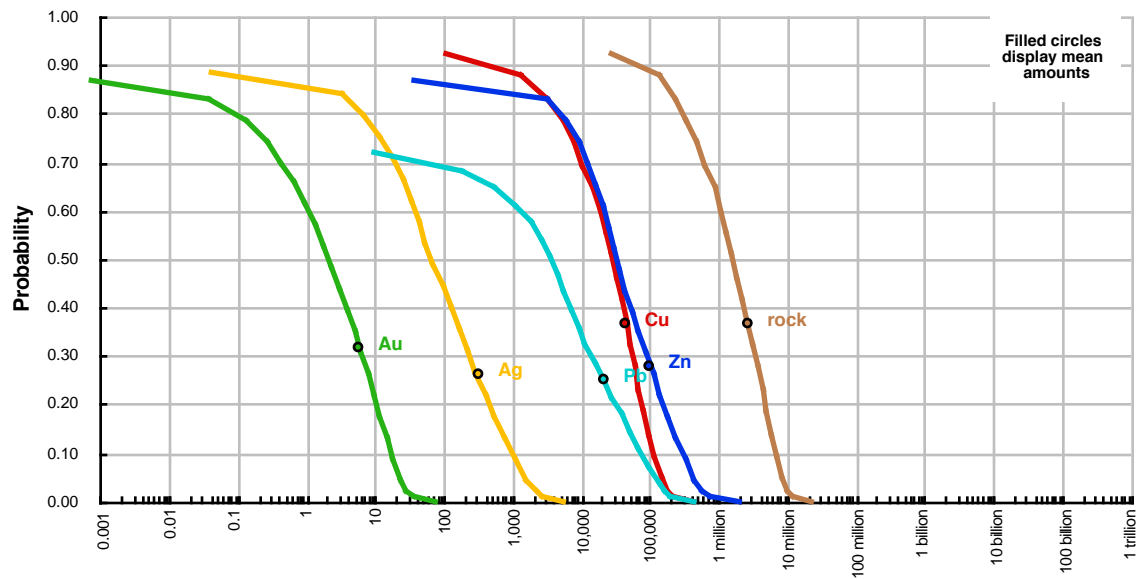
There is a 1% or greater chance of 13 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

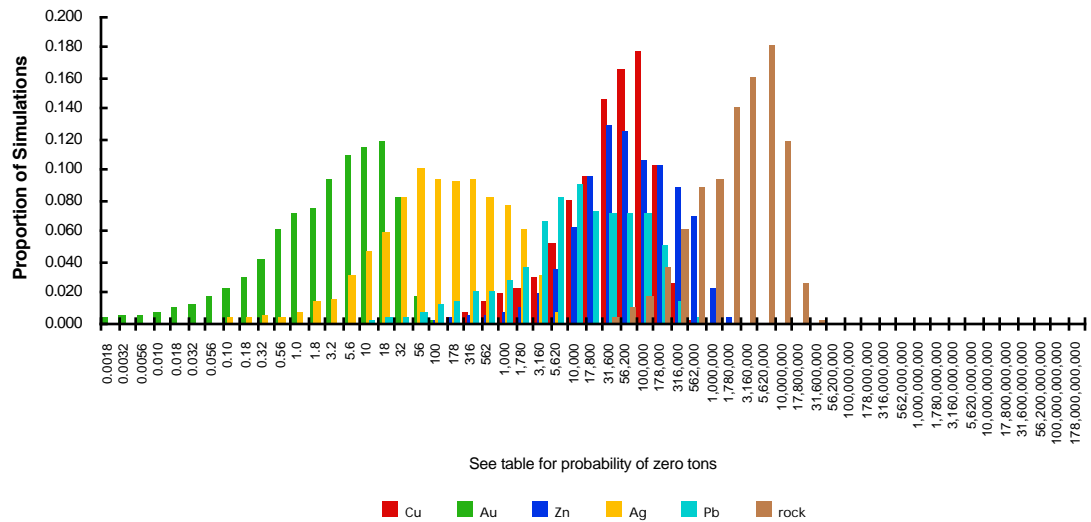
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	680	0	0	0	0	96,000
0.50	29,000	2	33,000	67	3,600	1,700,000
0.10	110,000	18	299,000	970	75,000	6,600,000
0.05	140,000	24	420,000	1,500	110,000	8,300,000
mean	45,000	6	100,000	310	22,000	2,700,000
Probability of mean	0.37	0.32	0.28	0.26	0.25	0.37
Probability of zero	0.08	0.12	0.13	0.11	0.28	0.08

The tract ID is AK-SE05

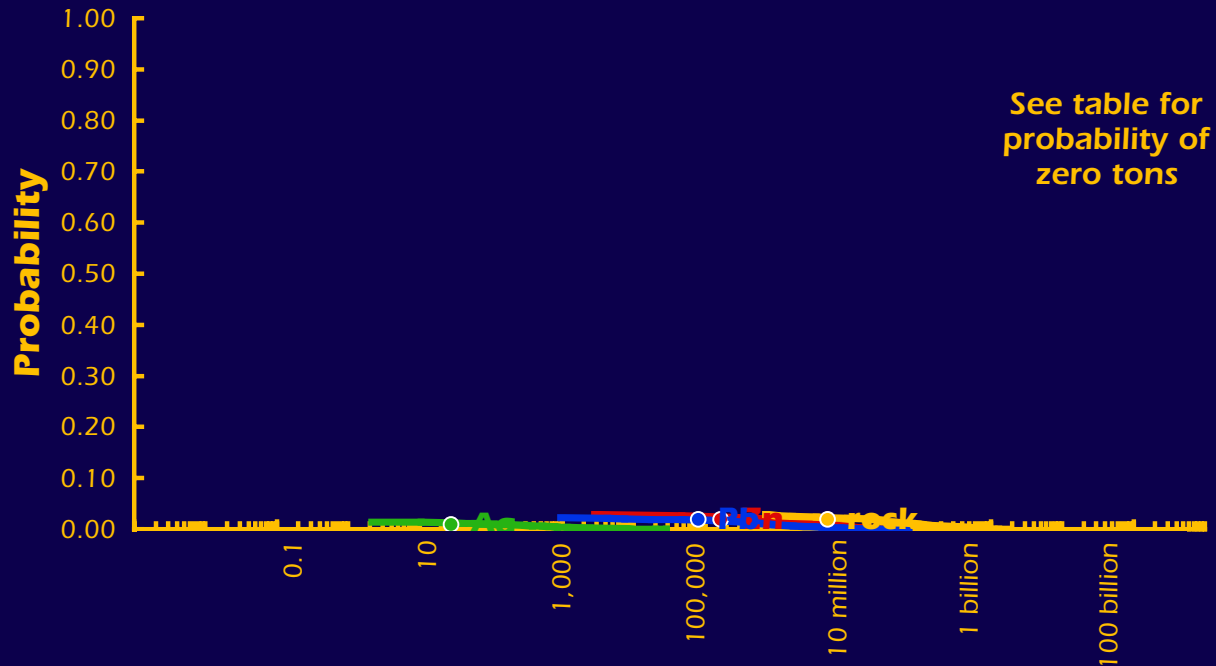
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

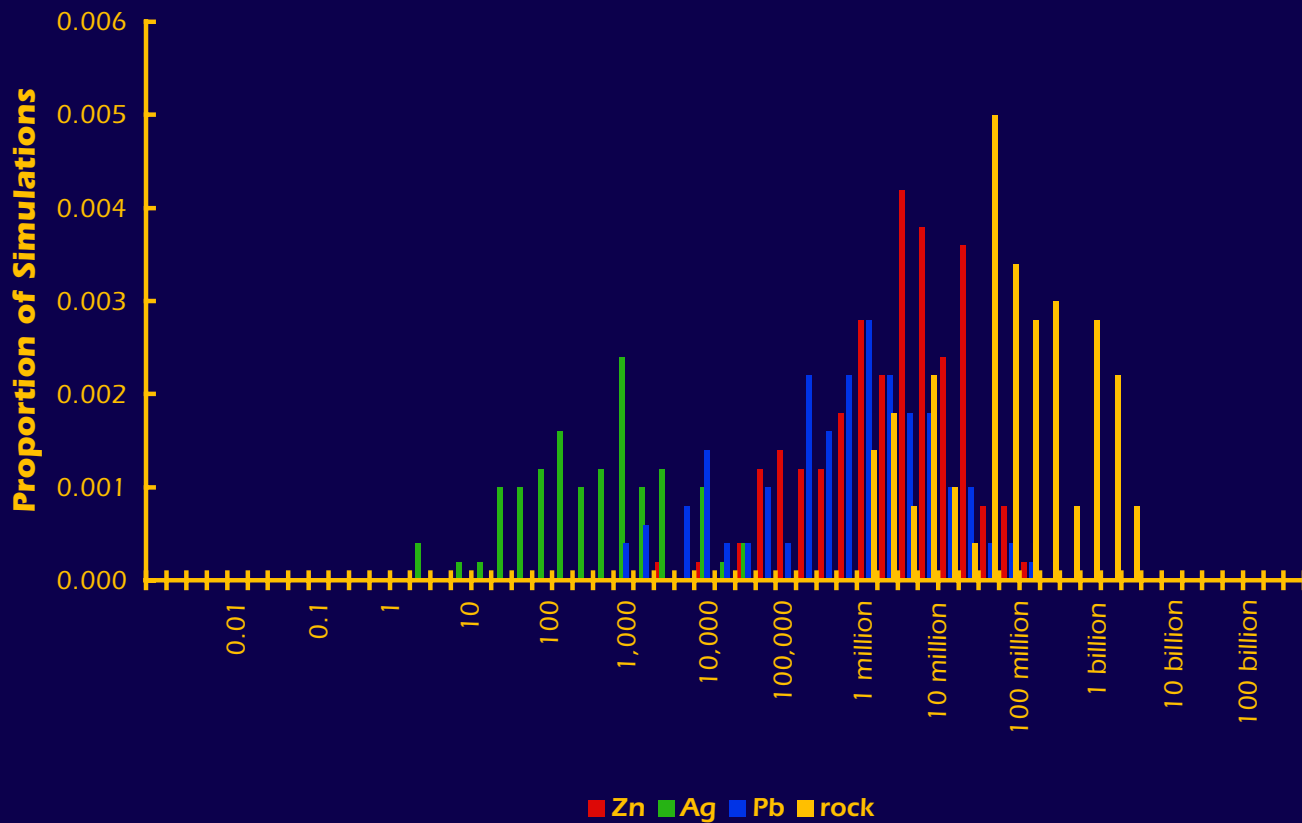


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SE06

The Mark3 Index is 108:

Mississippi Valley

There is a 90% or greater chance of 0 or more deposits.
There is a 50% or greater chance of 0 or more deposits.
There is a 10% or greater chance of 0 or more deposits.
There is a 5% or greater chance of 0 or more deposits.
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Zn	Ag	Pb	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	0	0	0	0
mean	160,000	27	78,000	5,100,000
Probability of mean	0.02	0.01	0.02	0.02
Probability of zero	0.97	0.99	0.98	0.97

The tract ID is AK-SE06The Mark3 Index is 108: **Mississippi Valley**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

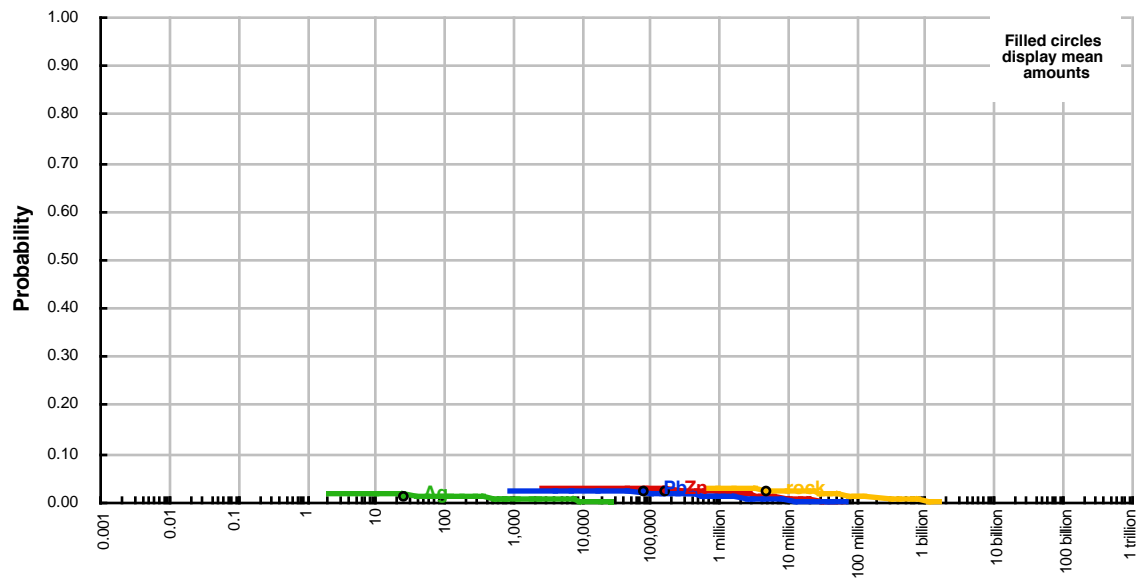
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

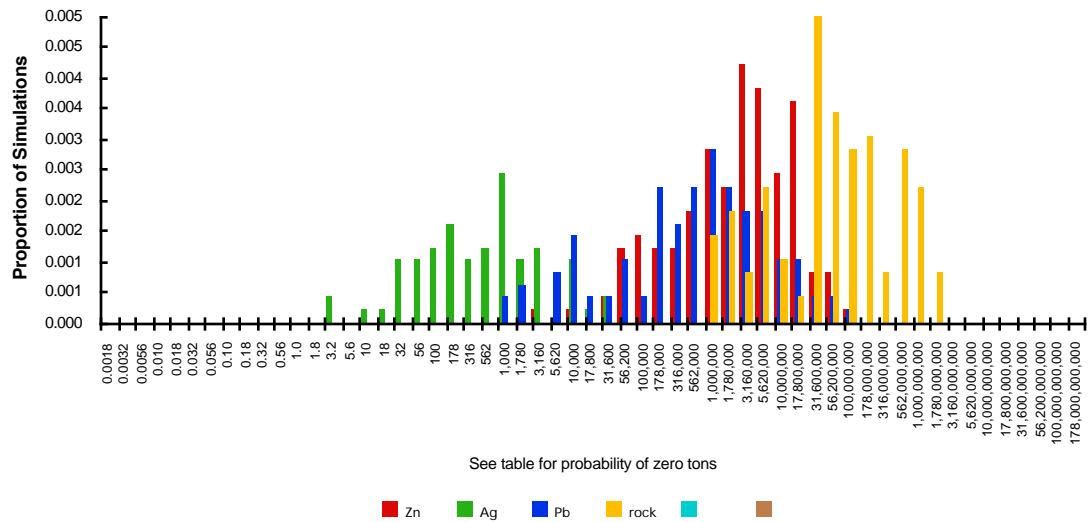
quantile	Zn	Ag	Pb	rock	0	0
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	160,000	27	78,000	5,100,000	0	0
Probability of mean	0.02	0.01	0.02	0.02	0.00	0.00
Probability of zero	0.97	0.99	0.98	0.97	0.00	0.00

The tract ID is AK-SE06

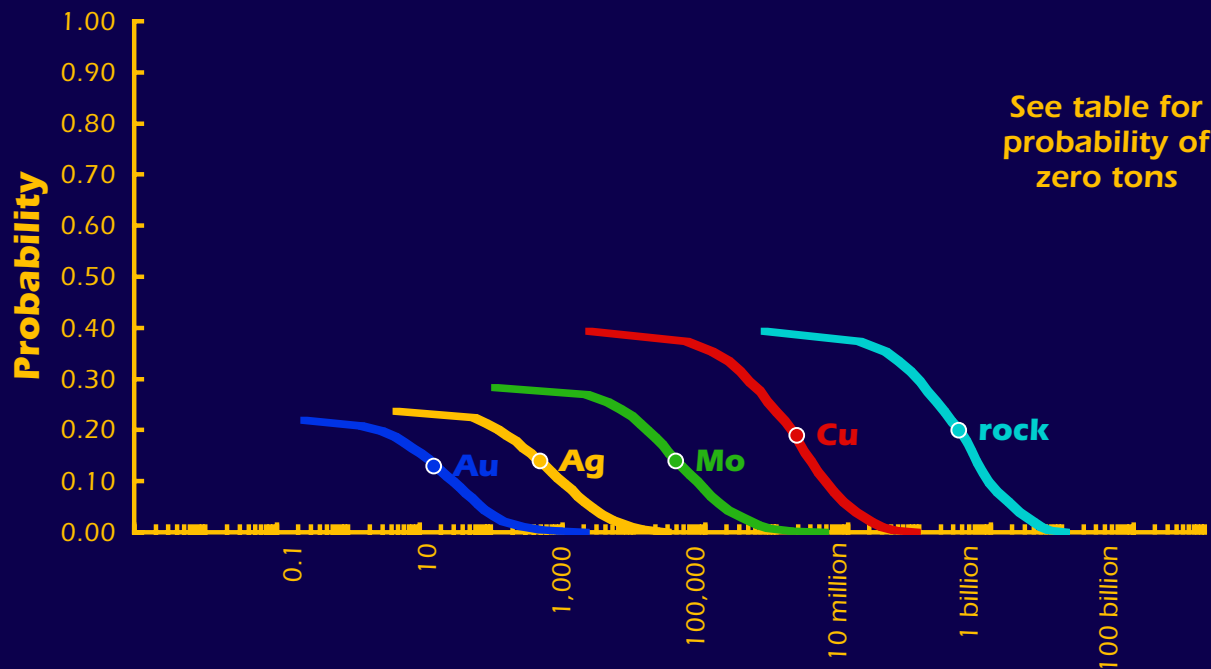
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

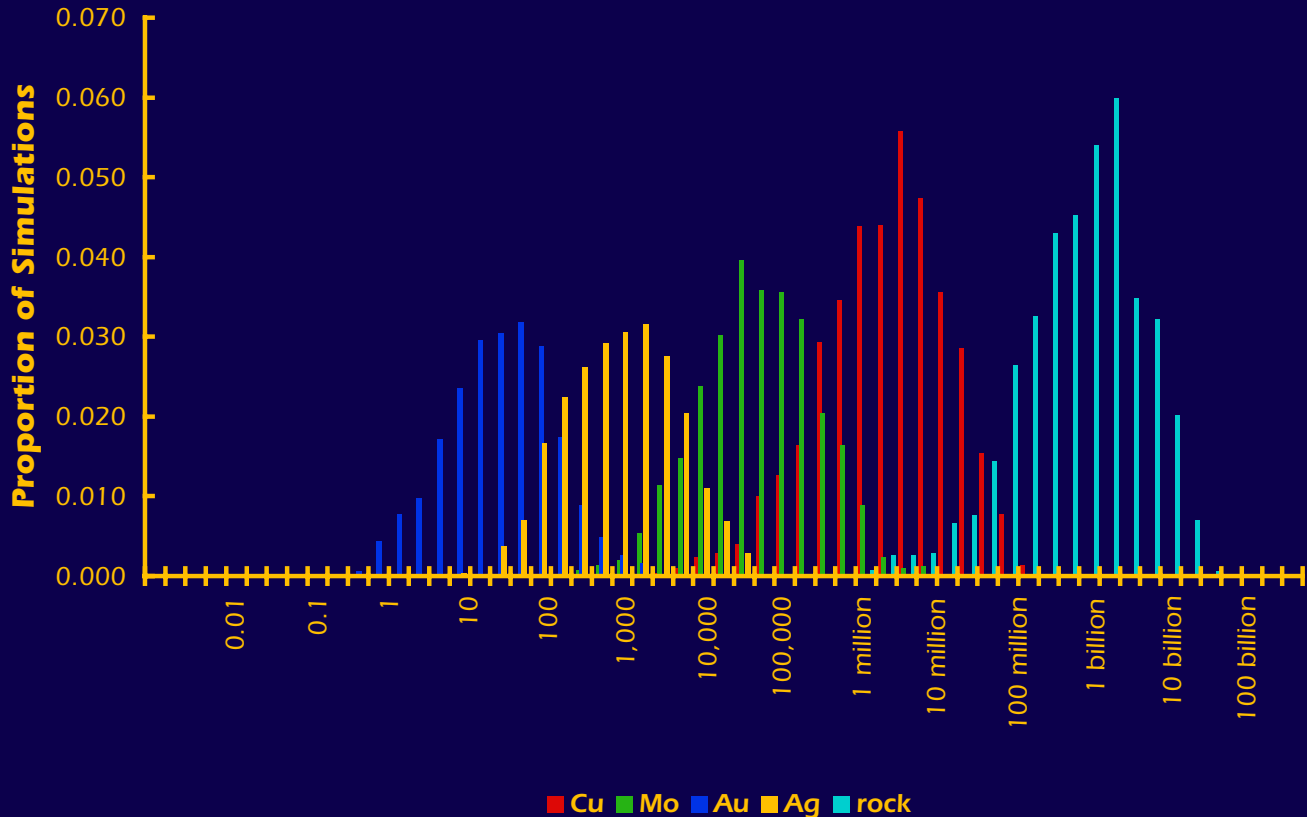


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SE07

The Mark3 Index is 81:

Porphyry Cu (North America)

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

There is a 1% or greater chance of 7 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	4,900,000	76,000	30	1,000	930,000,000
0.05	11,000,000	180,000	73	2,500	2,100,000,000
mean	1,900,000	38,000	16	480	350,000,000
Probability of mean	0.19	0.14	0.13	0.14	0.20
Probability of zero	0.61	0.72	0.78	0.76	0.61

The tract ID is AK-SE07The Mark3 Index is 81: **Porphyry Cu (North America)**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

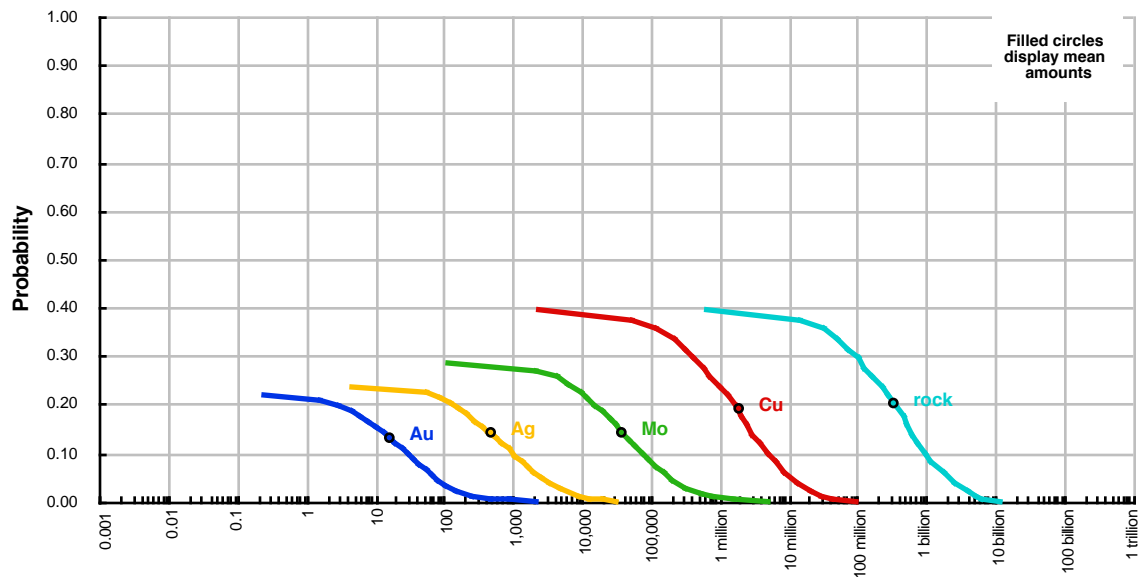
There is a 1% or greater chance of 7 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

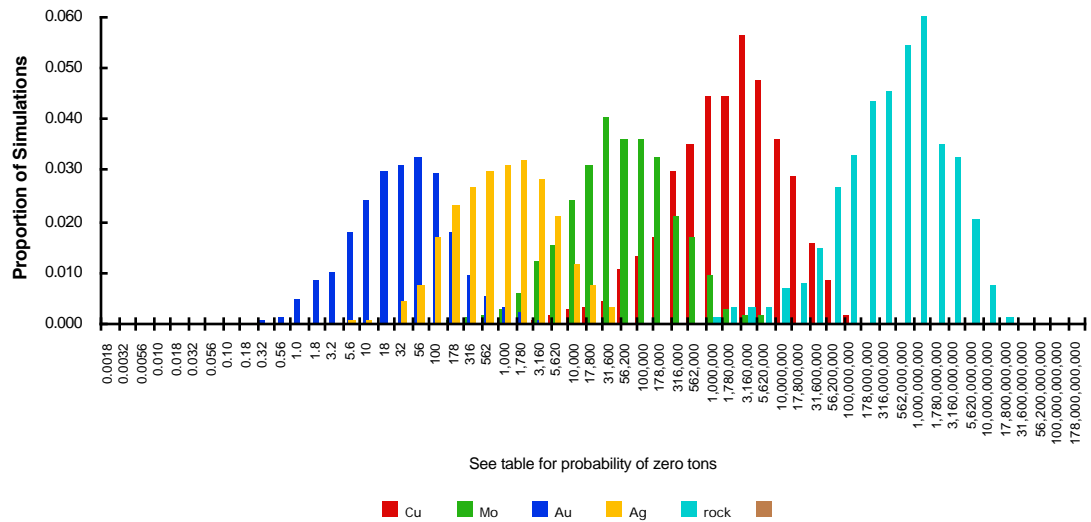
quantile	Cu	Mo	Au	Ag	rock	0
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	4,900,000	76,000	30	1,000	930,000,000	0
0.05	11,000,000	180,000	73	2,500	2,100,000,000	0
mean	1,900,000	38,000	16	480	350,000,000	0
Probability of mean	0.19	0.14	0.13	0.14	0.20	0.00
Probability of zero	0.61	0.72	0.78	0.76	0.61	0.00

The tract ID is AK-SE07

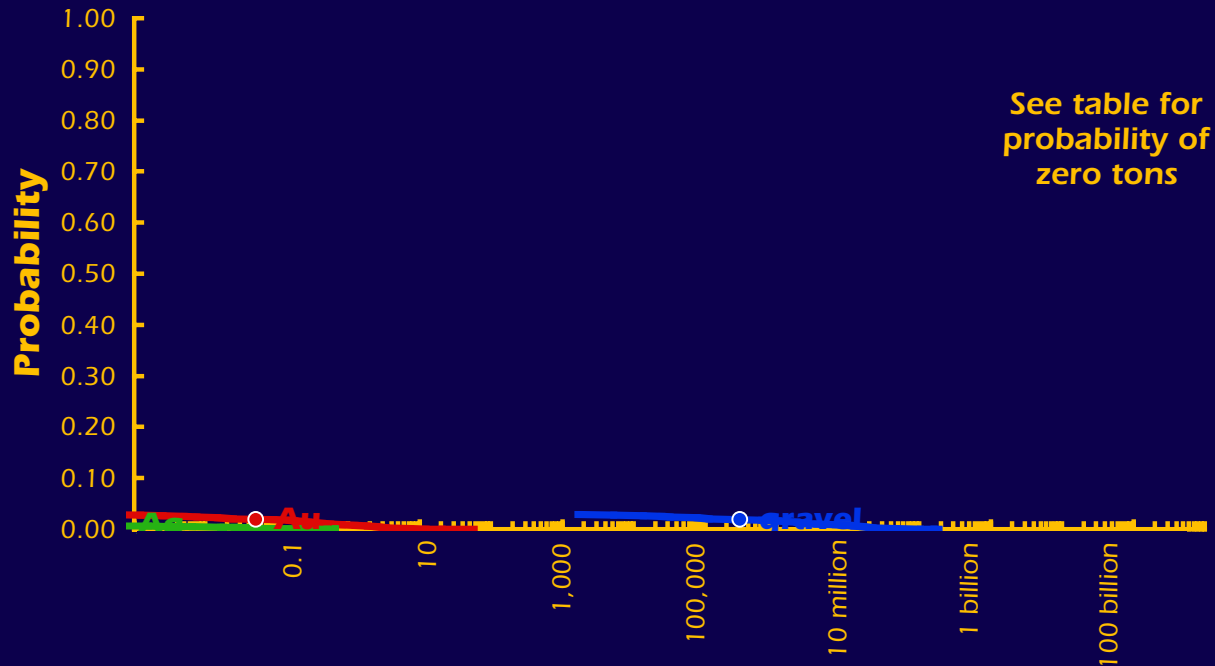
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

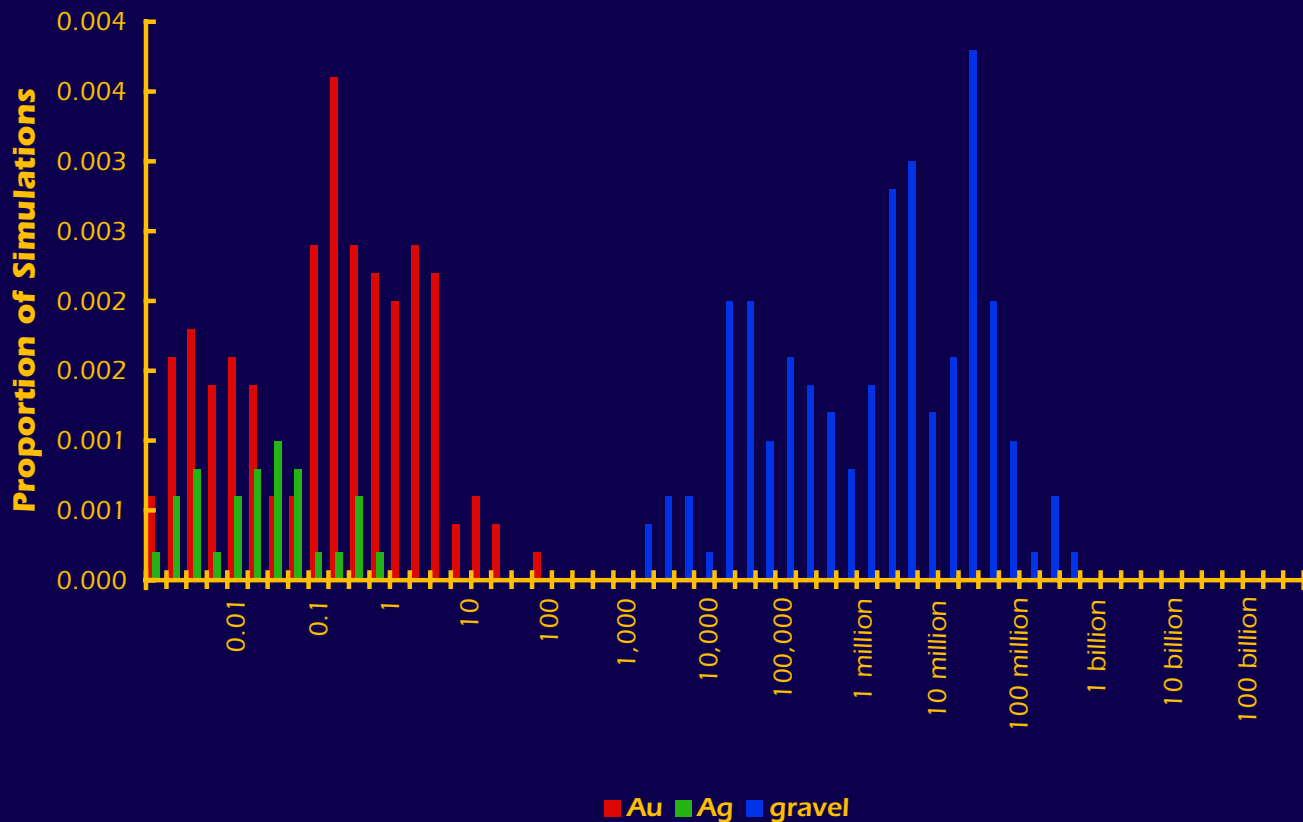


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SE08

The Mark3 Index is 54:

Placer Au-PGE Natomas-Copper Canyon

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized material (metric tons)

quantile	Au	Ag	gravel
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	0	0
0.05	0	0	0
mean	0	0	300,000
Probability of mean	0.02	0.01	0.02
Probability of zero	0.97	0.99	0.97

The tract ID is AK-SE08The Mark3 Index is 54: **Placer Au-PGE Natomas-Copper Canyon**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

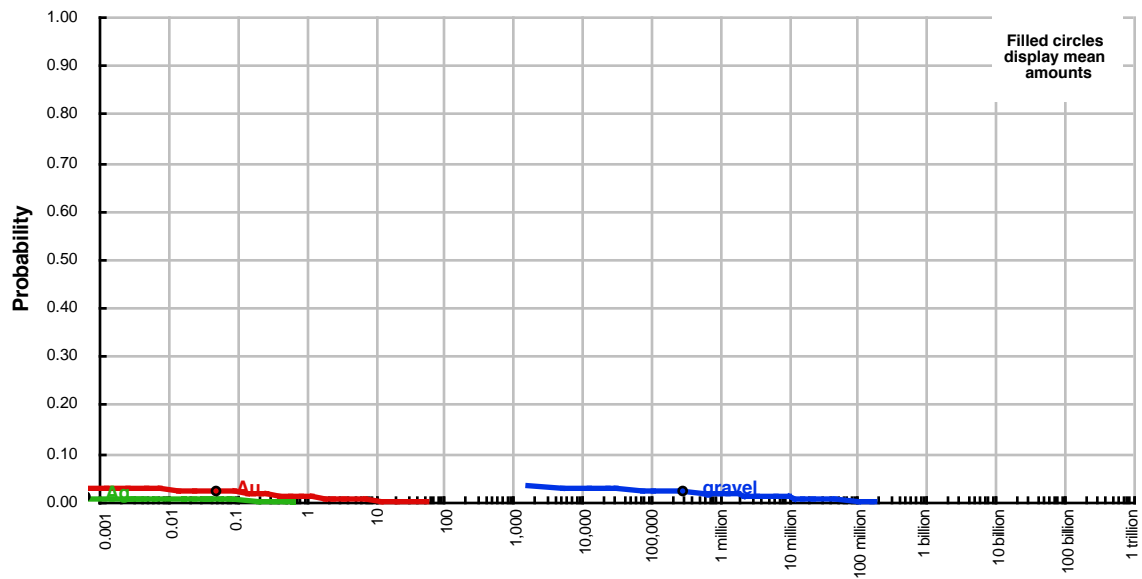
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

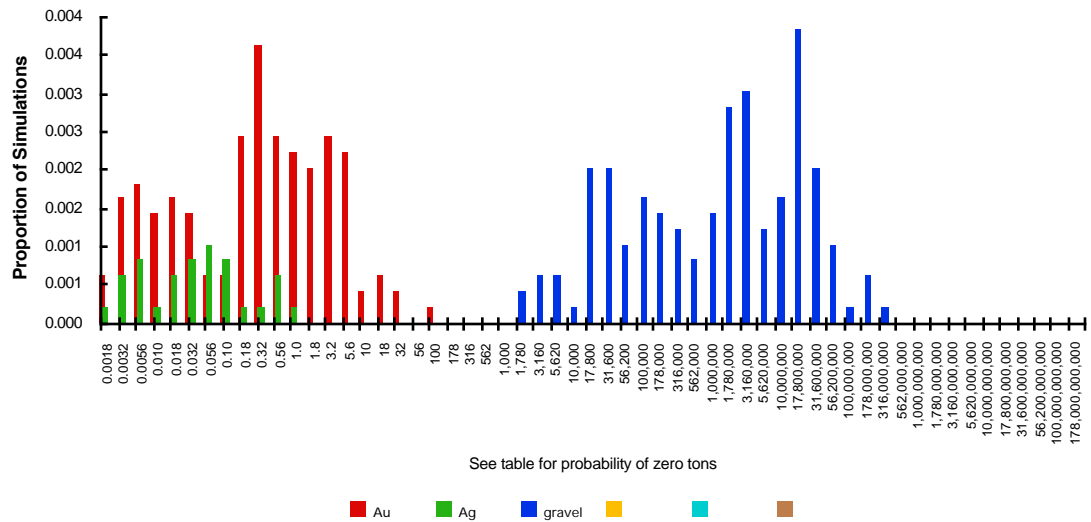
quantile	Au	Ag	gravel	0	0	0
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	0	0	300,000	0	0	0
Probability of mean	0.02	0.01	0.02	0.00	0.00	0.00
Probability of zero	0.97	0.99	0.97	0.00	0.00	0.00

The tract ID is AK-SE08

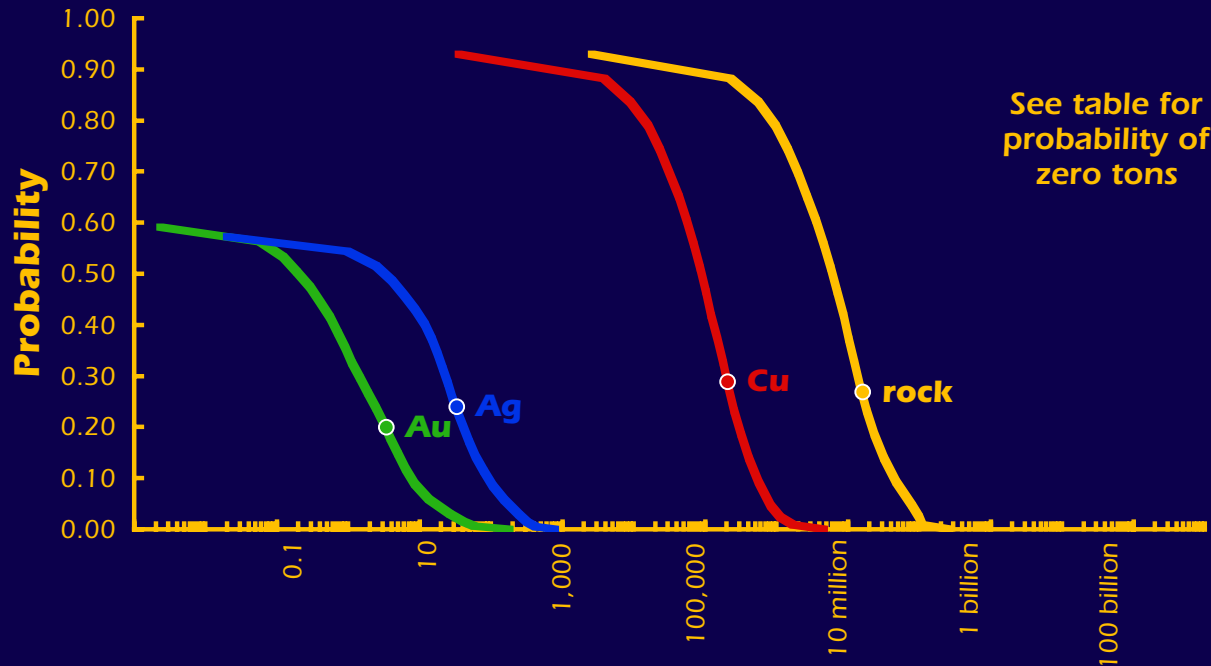
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

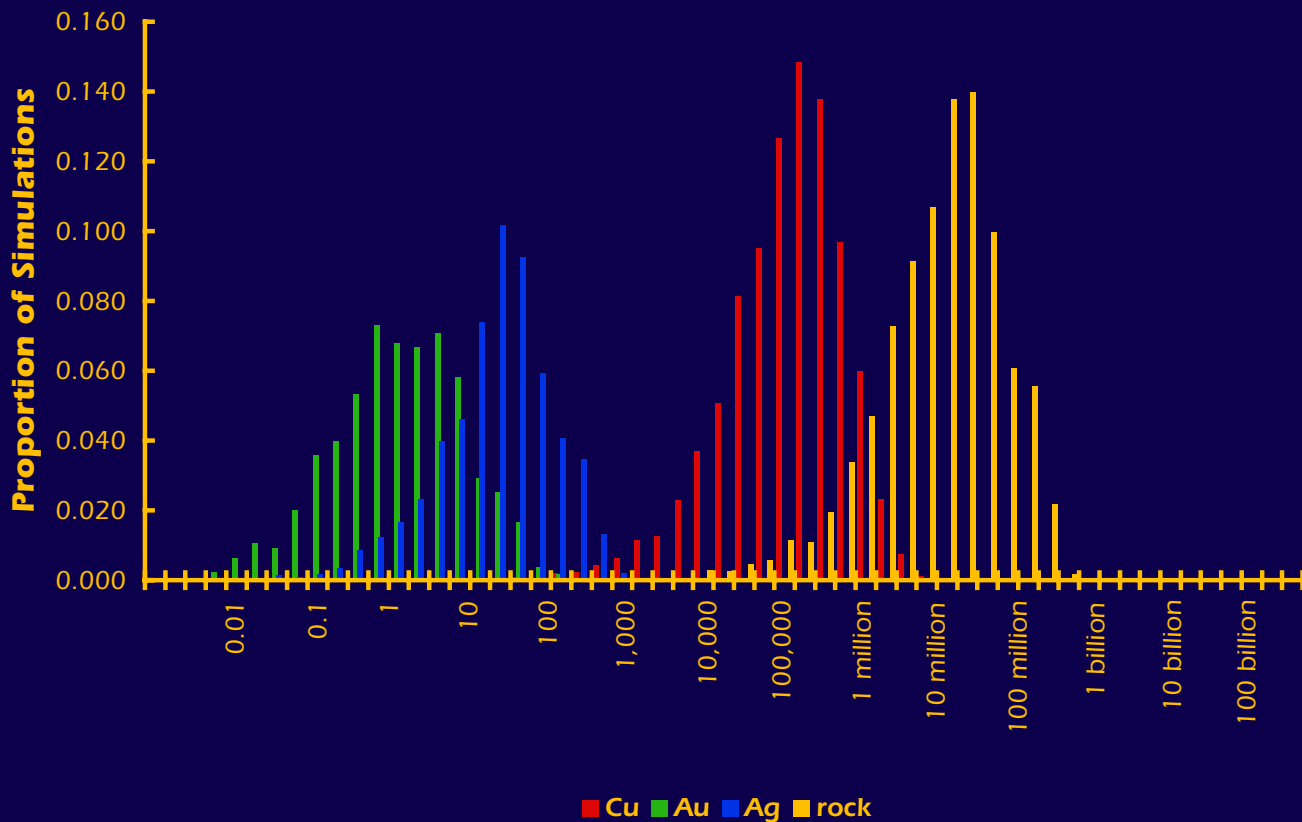


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SE09

The Mark3 Index is 8:

Skarn Cu

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 4 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 7 or more deposits.

There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	1,900	0	0	100,000
0.50	90,000	0	3	6,100,000
0.10	530,000	8	90	44,000,000
0.05	800,000	17	180	78,000,000
mean	200,000	3	33	16,000,000
Probability of mean	0.29	0.20	0.24	0.27
Probability of zero	0.07	0.41	0.43	0.07

The tract ID is AK-SE09The Mark3 Index is 8: **Skarn Cu**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 4 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 7 or more deposits.

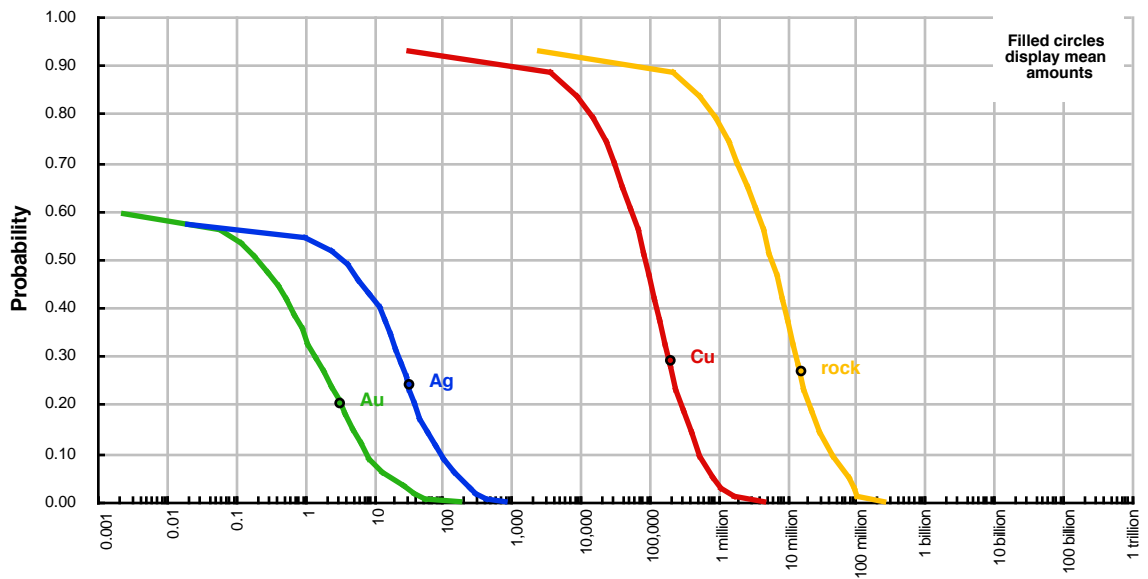
There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

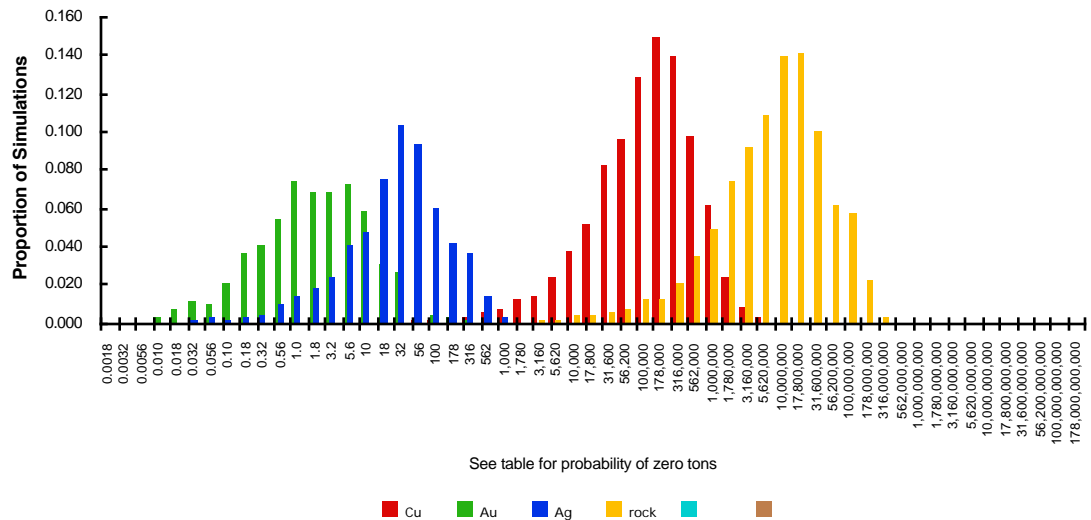
quantile	Cu	Au	Ag	rock	0	0
0.95	0	0	0	0	0	0
0.90	1,900	0	0	100,000	0	0
0.50	90,000	0	3	6,100,000	0	0
0.10	530,000	8	90	44,000,000	0	0
0.05	800,000	17	180	78,000,000	0	0
mean	200,000	3	33	16,000,000	0	0
Probability of mean	0.29	0.20	0.24	0.27	0.00	0.00
Probability of zero	0.07	0.41	0.43	0.07	0.00	0.00

The tract ID is AK-SE09

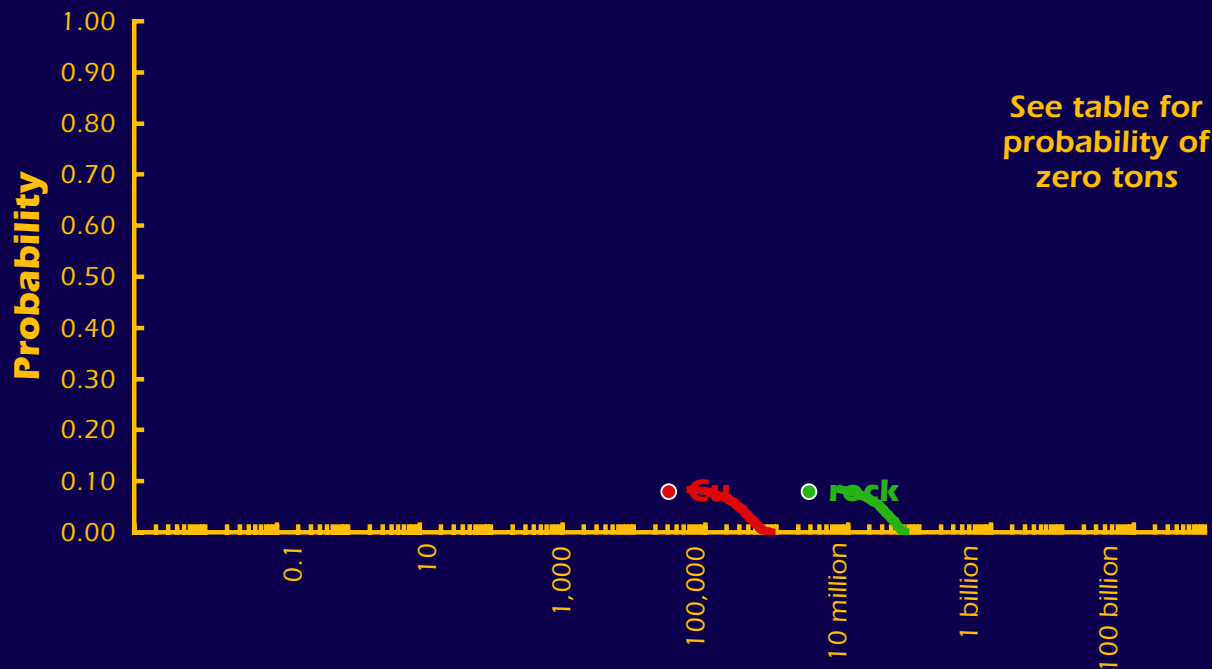
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

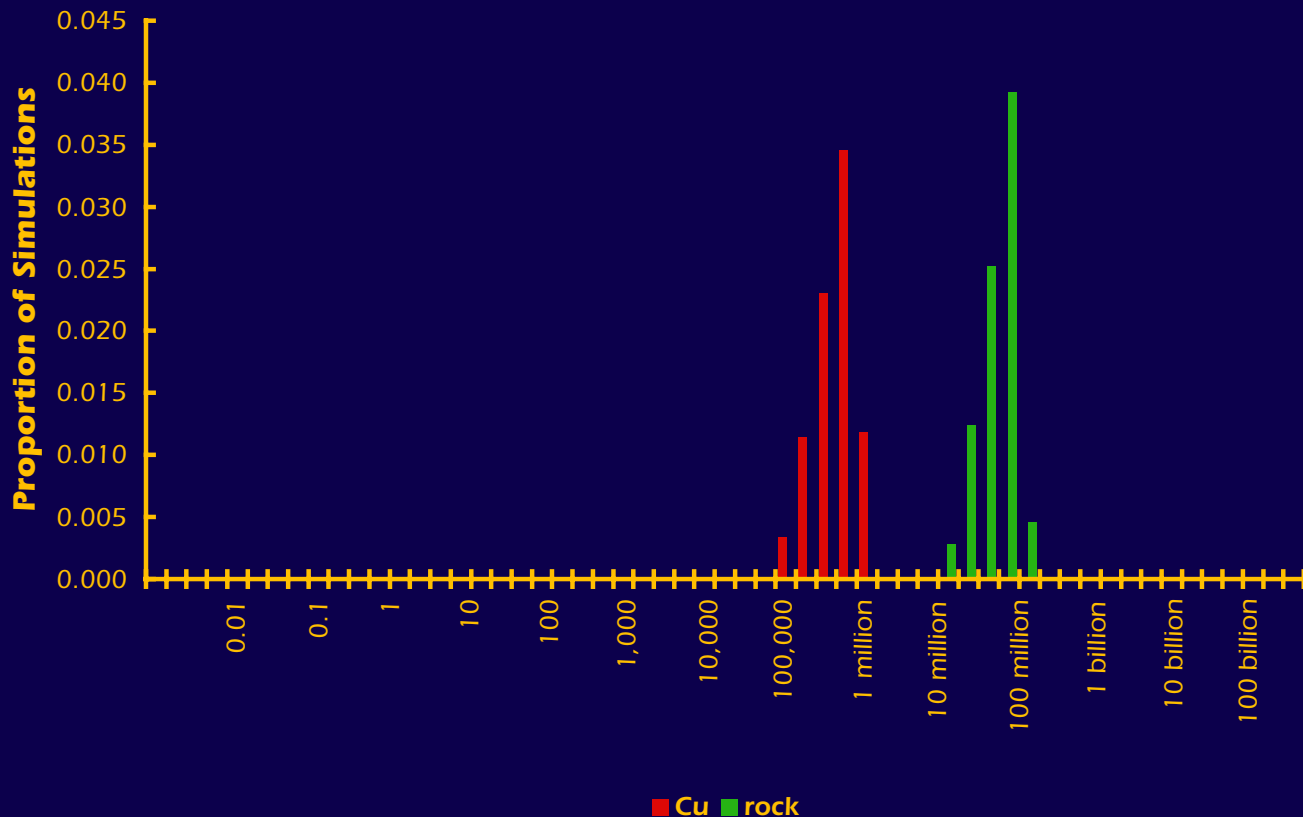


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SE10

The Mark3 Index is 118:

Basaltic Cu, Michigan

There is a 90% or greater chance of 0 or more deposits.
There is a 50% or greater chance of 0 or more deposits.
There is a 10% or greater chance of 0 or more deposits.
There is a 5% or greater chance of 2 or more deposits.
There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	rock
0.95	0	0
0.90	0	0
0.50	0	0
0.10	0	0
0.05	300,000	29,000,000
mean	30,000	2,800,000
Probability of mean	0.08	0.08
Probability of zero	0.92	0.92

The tract ID is AK-SE10The Mark3 Index is 118: **Basaltic Cu, Michigan**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

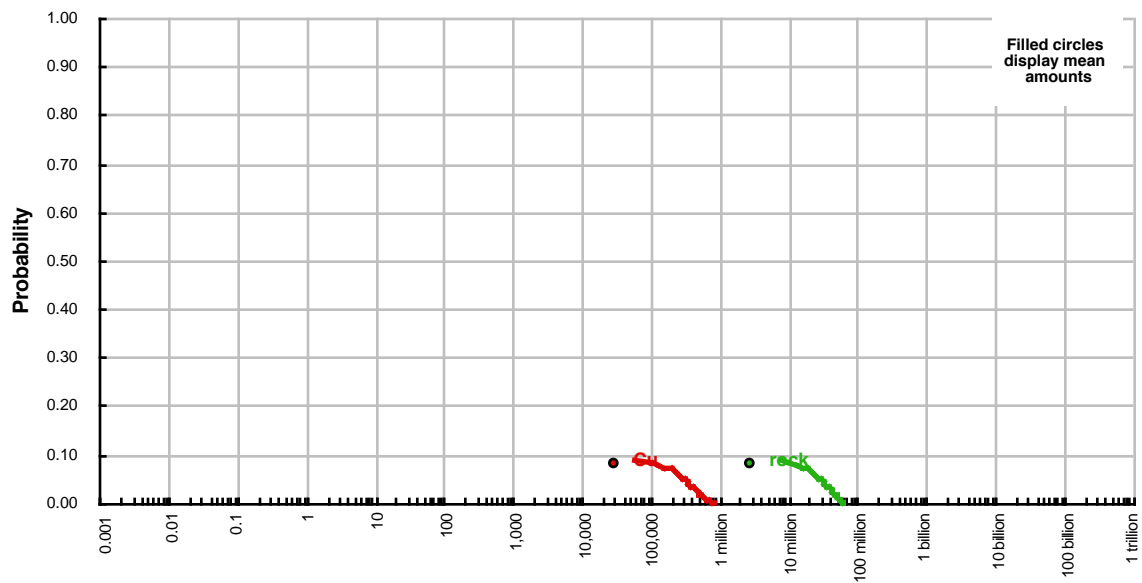
There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

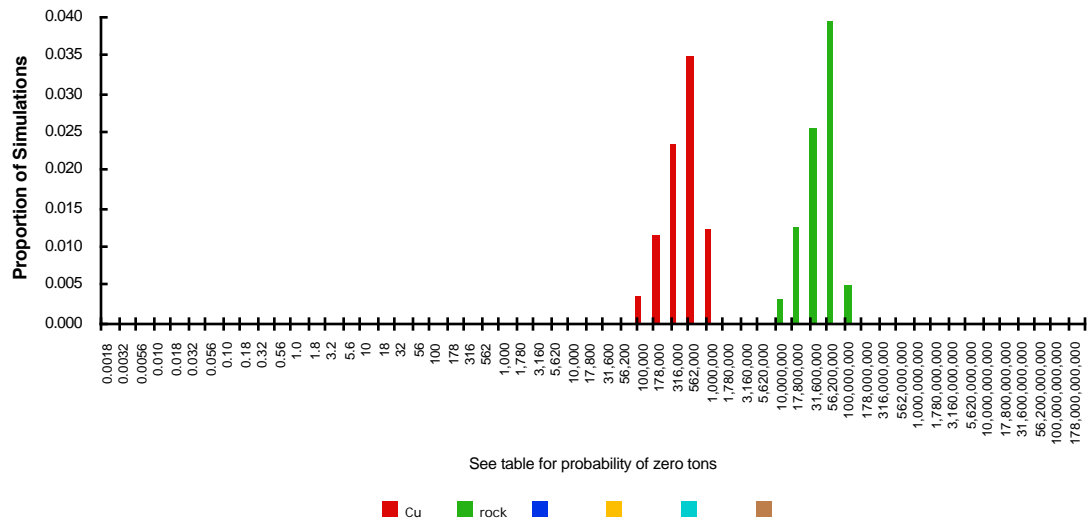
quantile	Cu	rock	0	0	0	0
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	300,000	29,000,000	0	0	0	0
mean	30,000	2,800,000	0	0	0	0
Probability of mean	0.08	0.08	0.00	0.00	0.00	0.00
Probability of zero	0.92	0.92	0.00	0.00	0.00	0.00

The tract ID is AK-SE10

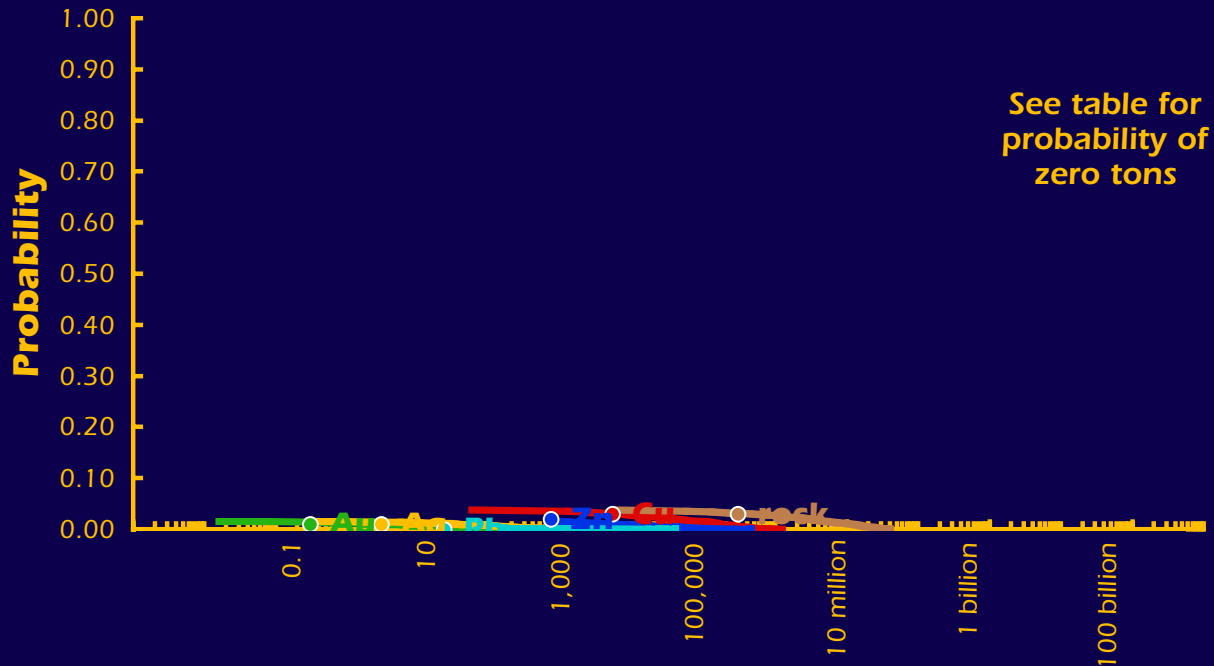
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

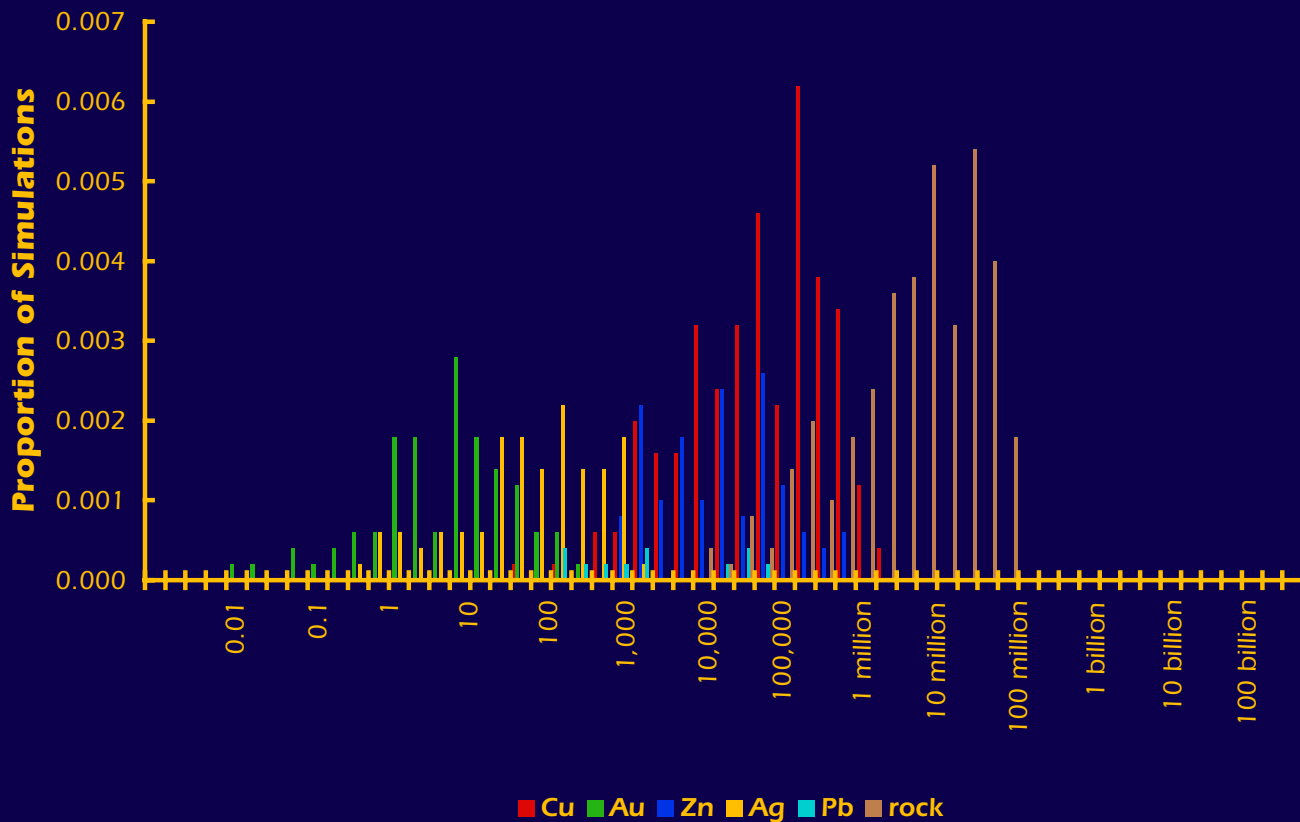


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SE11

The Mark3 Index is 11:

Massive sulfide, Cyprus

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	5,100	0	700	3	23	300,000
Probability of mean	0.03	0.01	0.02	0.01	0.00	0.03
Probability of zero	0.96	0.98	0.98	0.98	1.00	0.96

The tract ID is AK-SE11The Mark3 Index is 11: **Massive sulfide, Cyprus**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

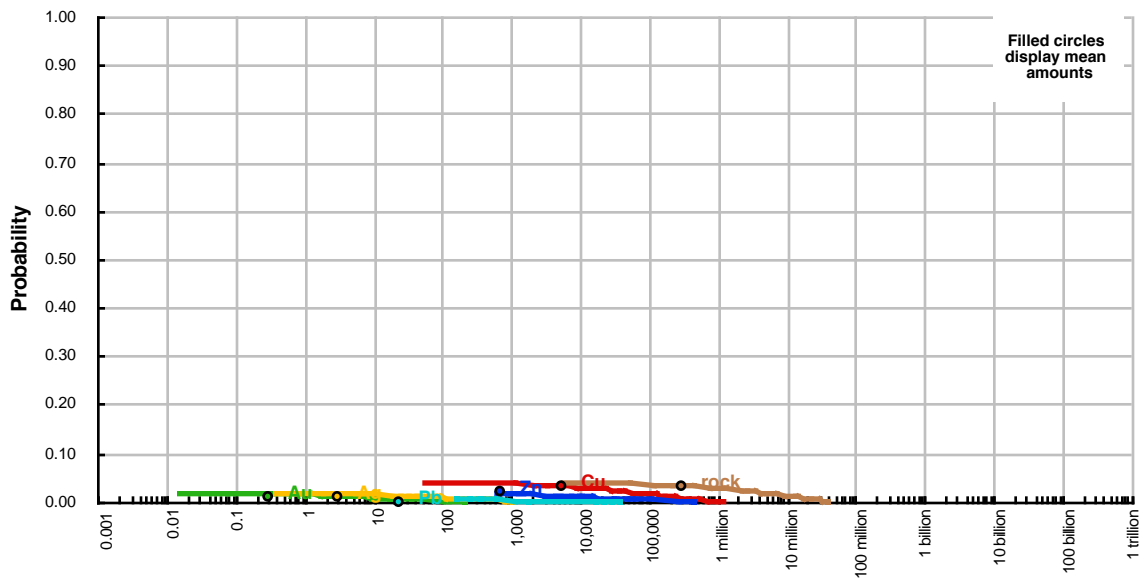
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

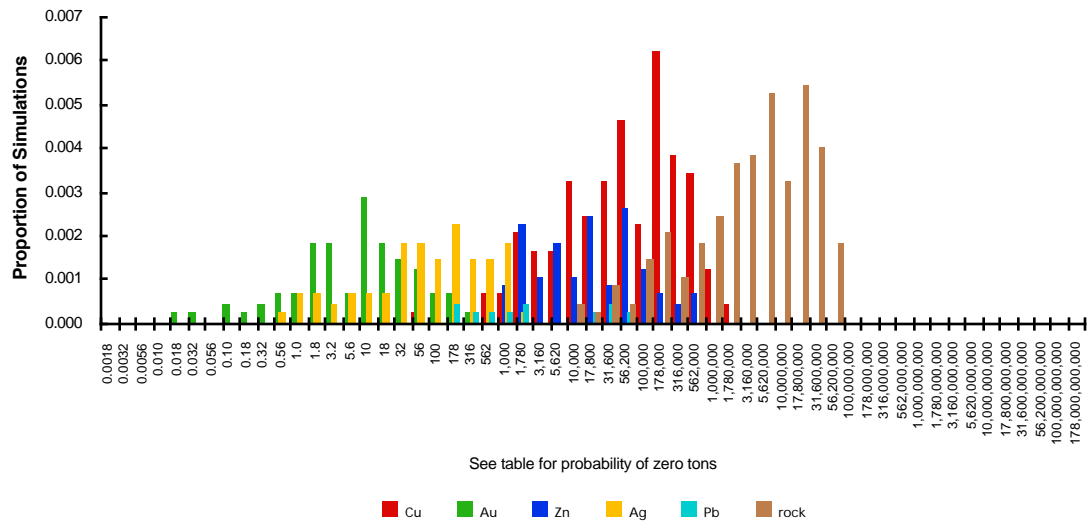
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	5,100	0	700	3	23	300,000
Probability of mean	0.03	0.01	0.02	0.01	0.00	0.03
Probability of zero	0.96	0.98	0.98	0.98	1.00	0.96

The tract ID is AK-SE11

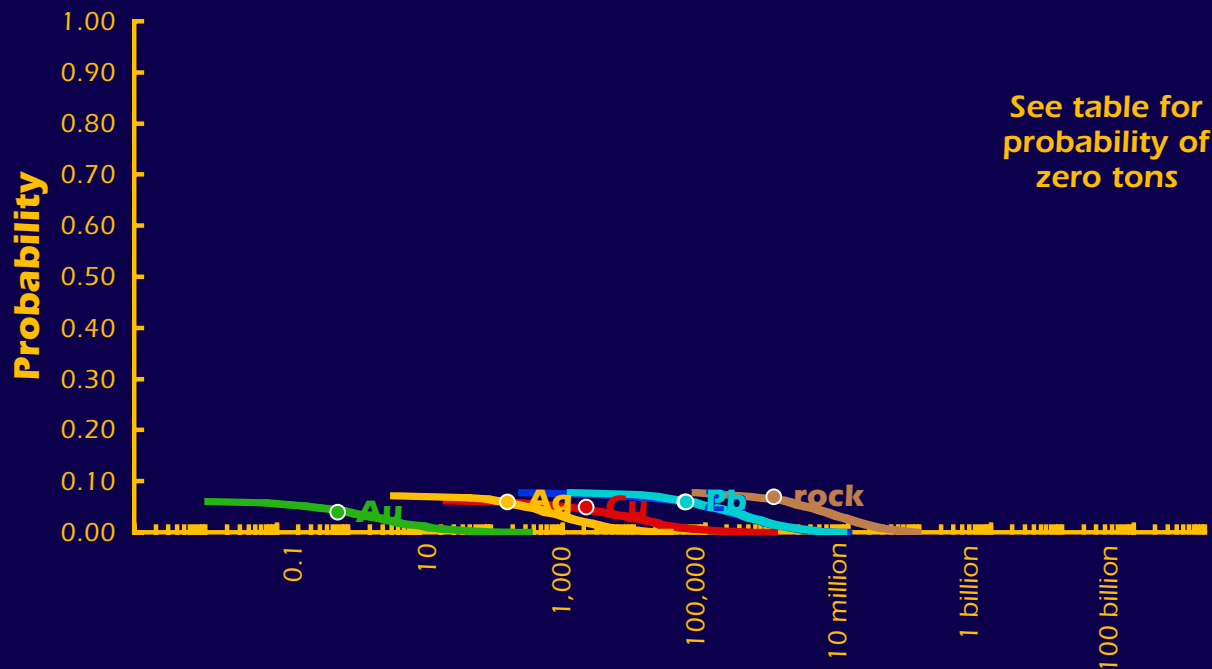
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

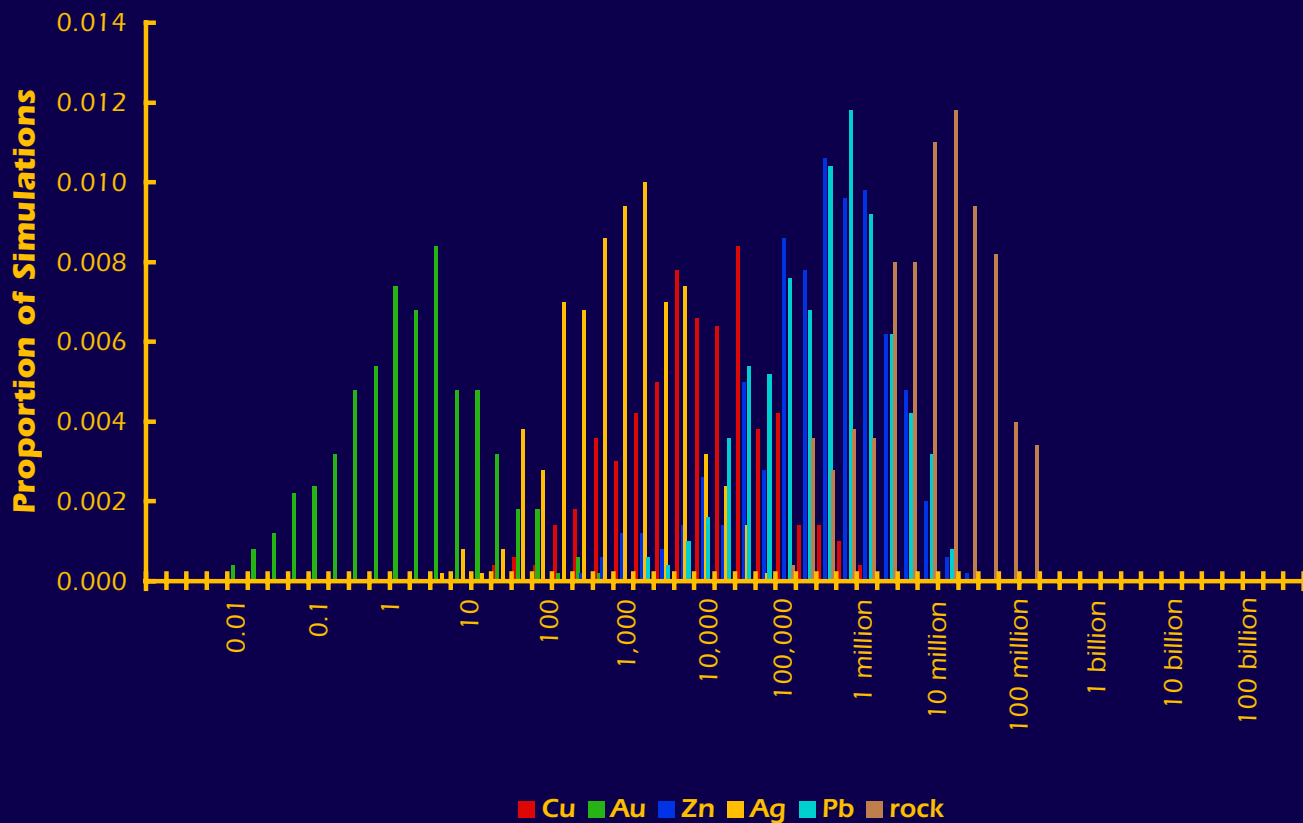


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SE12

The Mark3 Index is 47:

Polymetallic replacement

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	1,100	0	120,000	310	120,000	2,700,000
mean	2,100	1	51,000	160	53,000	900,000
Probability of mean	0.05	0.04	0.06	0.06	0.06	0.07
Probability of zero	0.94	0.94	0.92	0.93	0.92	0.92

The tract ID is AK-SE12The Mark3 Index is 47: **Polymetallic replacement**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

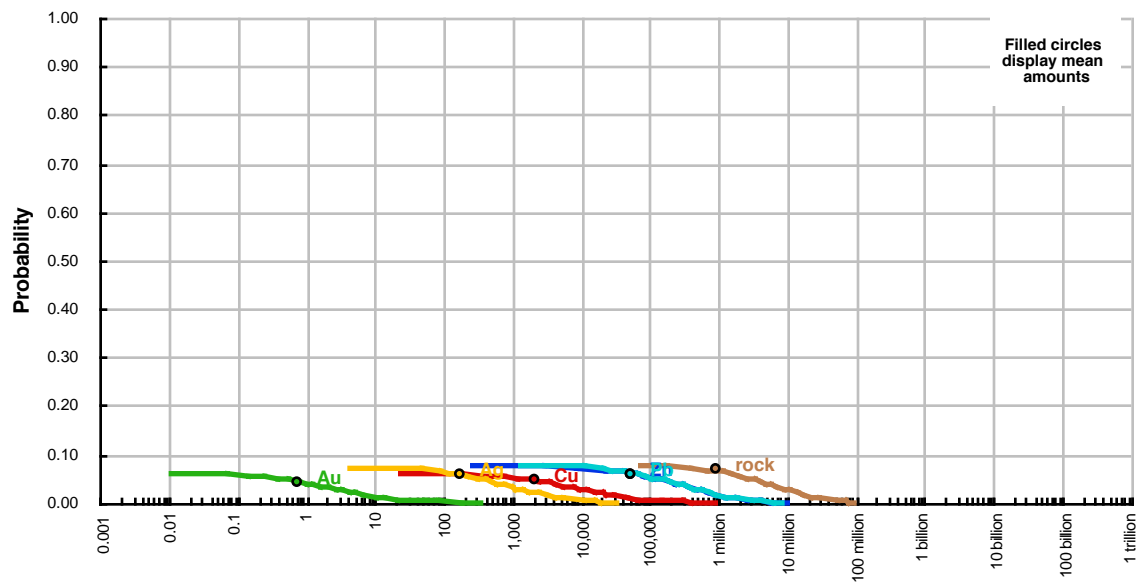
There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

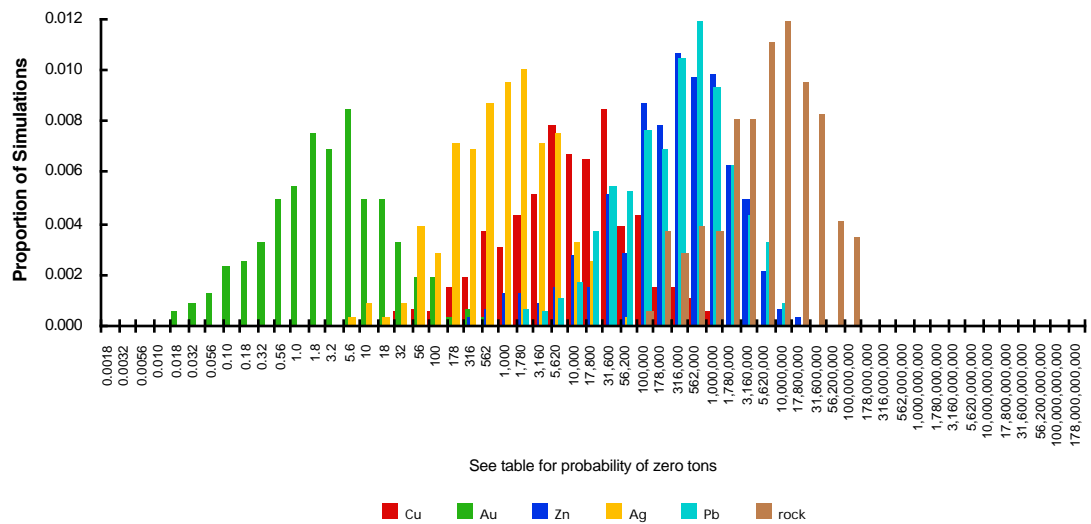
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	1,100	0	120,000	310	120,000	2,700,000
mean	2,100	1	51,000	160	53,000	900,000
Probability of mean	0.05	0.04	0.06	0.06	0.06	0.07
Probability of zero	0.94	0.94	0.92	0.93	0.92	0.92

The tract ID is AK-SE12

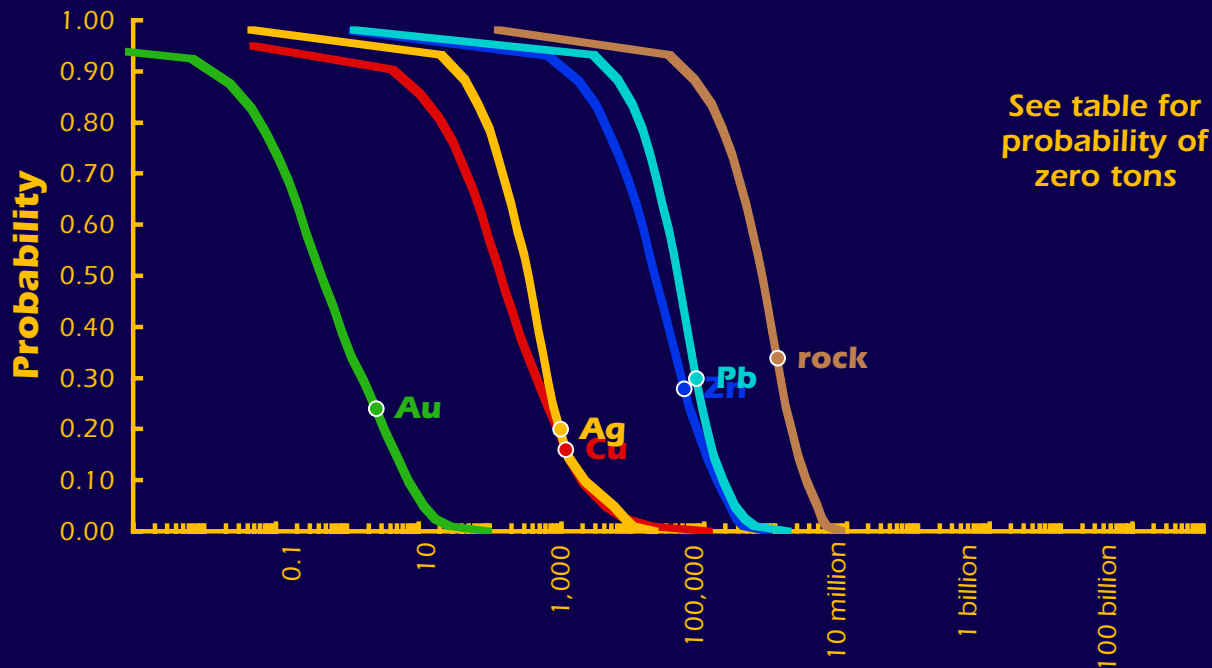
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)



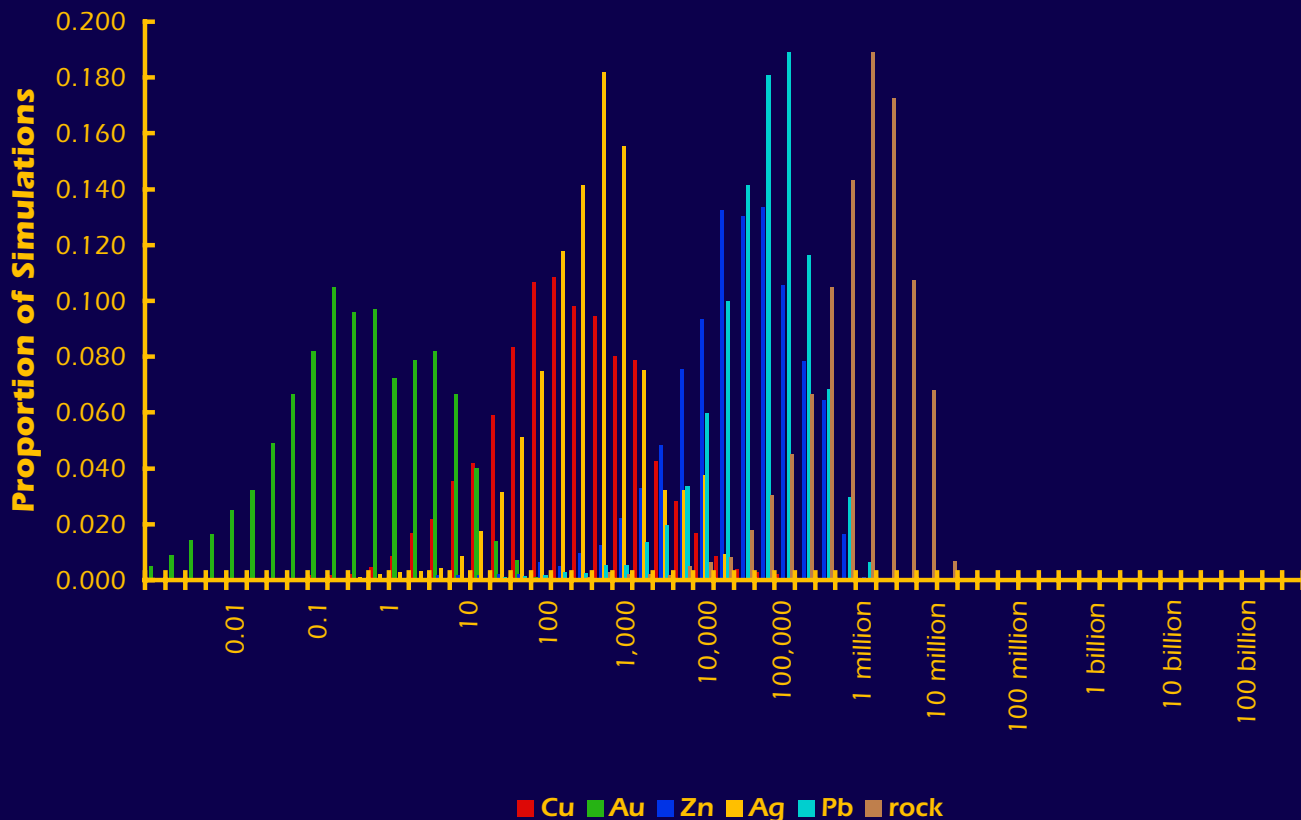
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



See table for
probability of
zero tons

Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SE13

The Mark3 Index is 46:

Polymetallic vein

There is a 90% or greater chance of 5 or more deposits.

There is a 50% or greater chance of 9 or more deposits.

There is a 10% or greater chance of 15 or more deposits.

There is a 5% or greater chance of 17 or more deposits.

There is a 1% or greater chance of 21 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	280	14	1,600	19,000
0.90	5	0	1,300	36	5,200	60,000
0.50	140	0	21,000	340	43,000	650,000
0.10	1,900	7	152,000	2,100	180,000	2,700,000
0.05	4,100	12	230,000	5,500	270,000	3,800,000
mean	1,100	2	52,000	960	76,000	1,100,000
Probability of mean	0.16	0.24	0.28	0.20	0.30	0.34
Probability of zero	0.05	0.03	0.02	0.02	0.02	0.02

The tract ID is AK-SE13The Mark3 Index is 46: **Polymetallic vein**

There is a 90% or greater chance of 5 or more deposits.

There is a 50% or greater chance of 9 or more deposits.

There is a 10% or greater chance of 15 or more deposits.

There is a 5% or greater chance of 17 or more deposits.

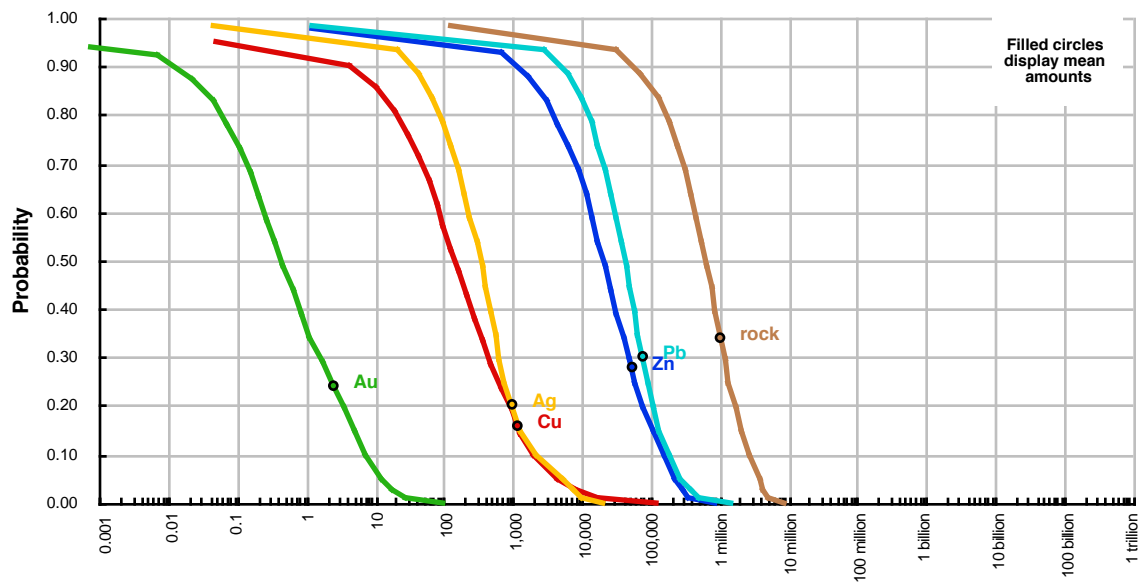
There is a 1% or greater chance of 21 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

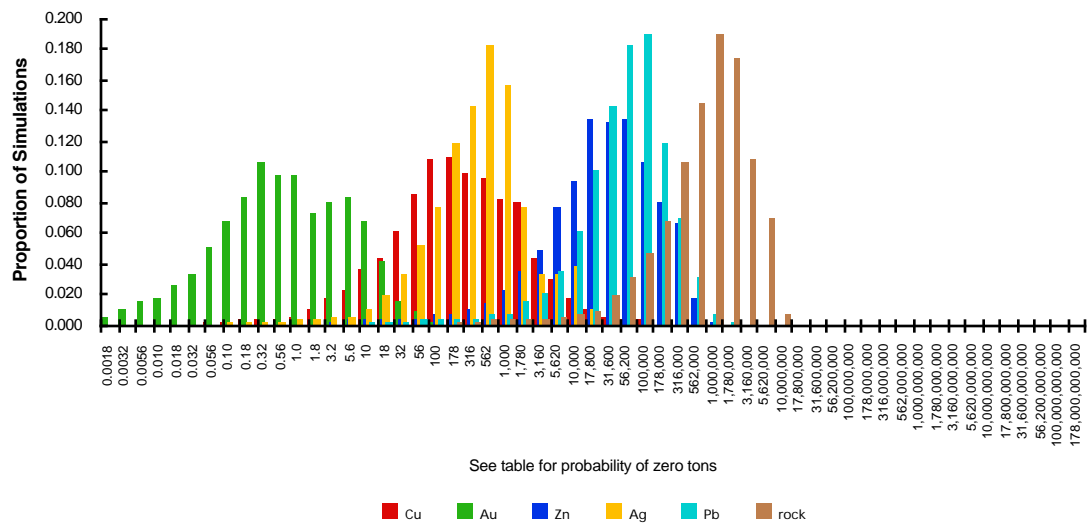
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	280	14	1,600	19,000
0.90	5	0	1,300	36	5,200	60,000
0.50	140	0	21,000	340	43,000	650,000
0.10	1,900	7	152,000	2,100	180,000	2,700,000
0.05	4,100	12	230,000	5,500	270,000	3,800,000
mean	1,100	2	52,000	960	76,000	1,100,000
Probability of mean	0.16	0.24	0.28	0.20	0.30	0.34
Probability of zero	0.05	0.03	0.02	0.02	0.02	0.02

The tract ID is AK-SE13

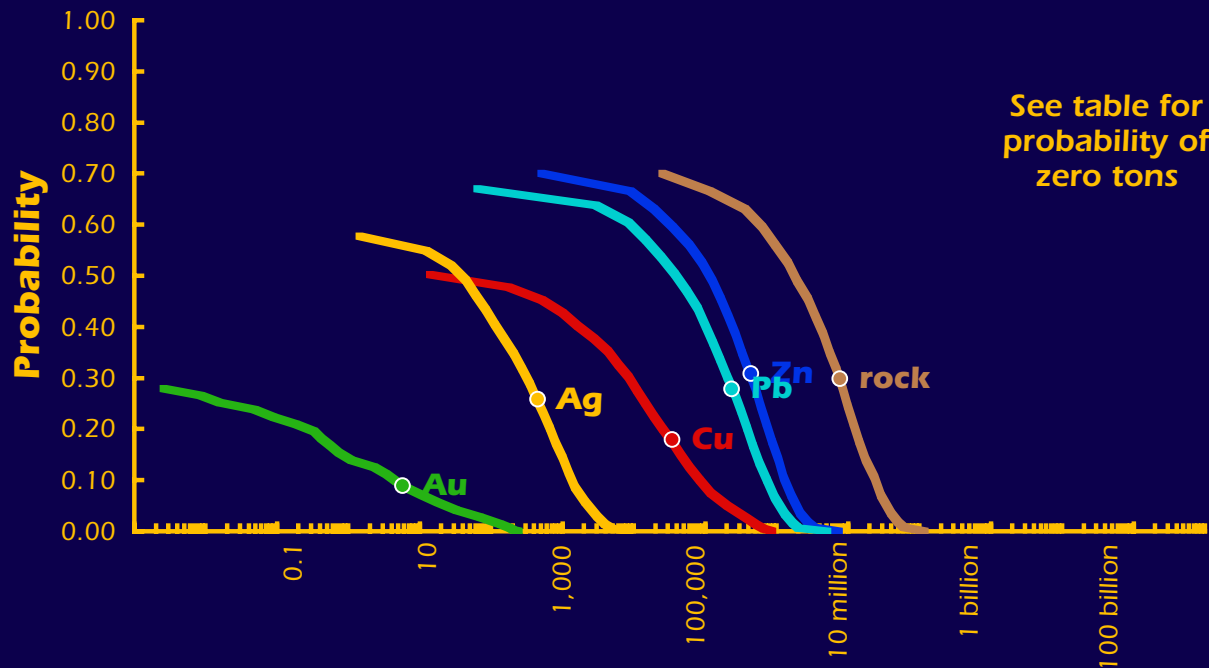
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

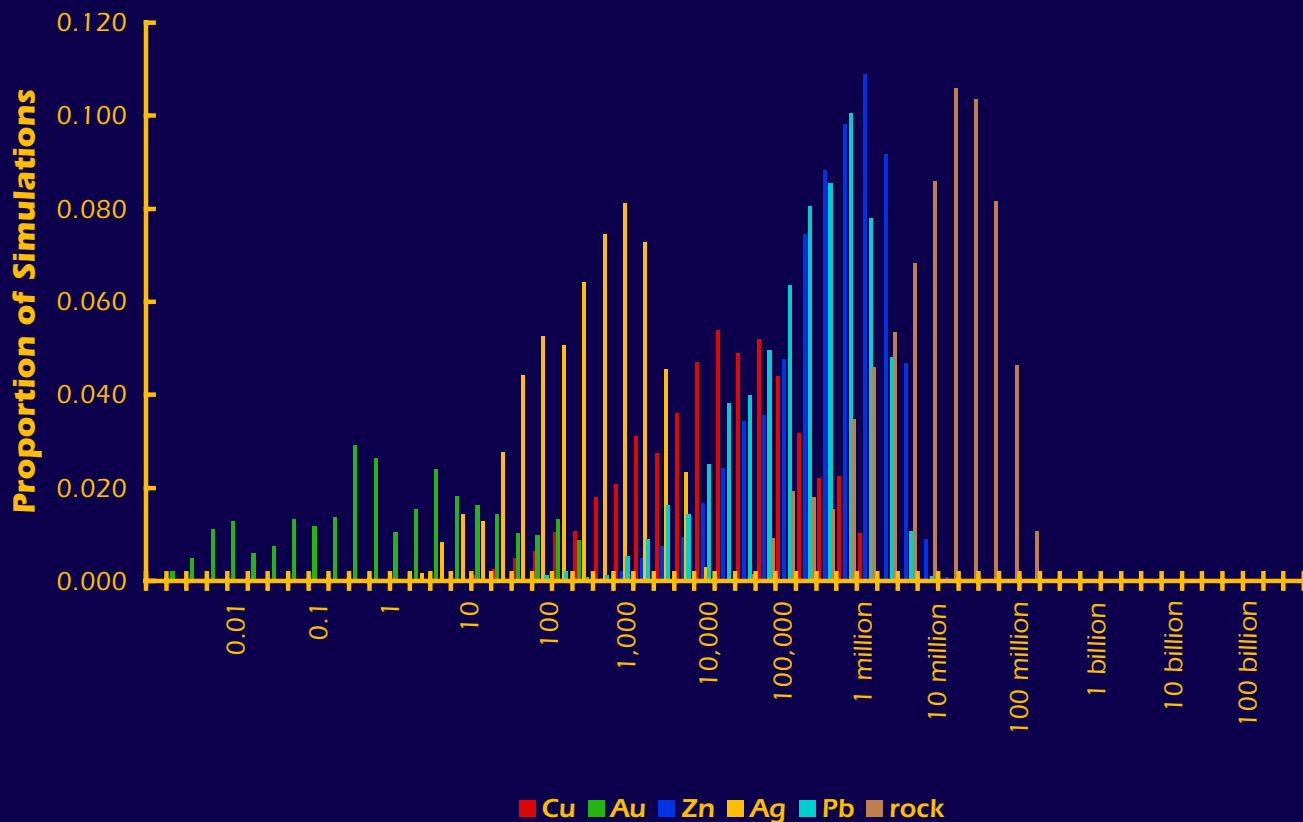


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SE14

The Mark3 Index is 22:

Skarn Zn-Pb

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

There is a 1% or greater chance of 7 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	28	0	120,000	38	39,000	1,800,000
0.10	85,000	5	1,300,000	1,400	730,000	24,000,000
0.05	210,000	23	1,900,000	2,300	1,100,000	34,000,000
mean	34,000	6	430,000	440	230,000	7,500,000
Probability of mean	0.18	0.09	0.31	0.26	0.28	0.30
Probability of zero	0.50	0.72	0.30	0.42	0.33	0.30

The tract ID is AK-SE14The Mark3 Index is 22: **Skarn Zn-Pb**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

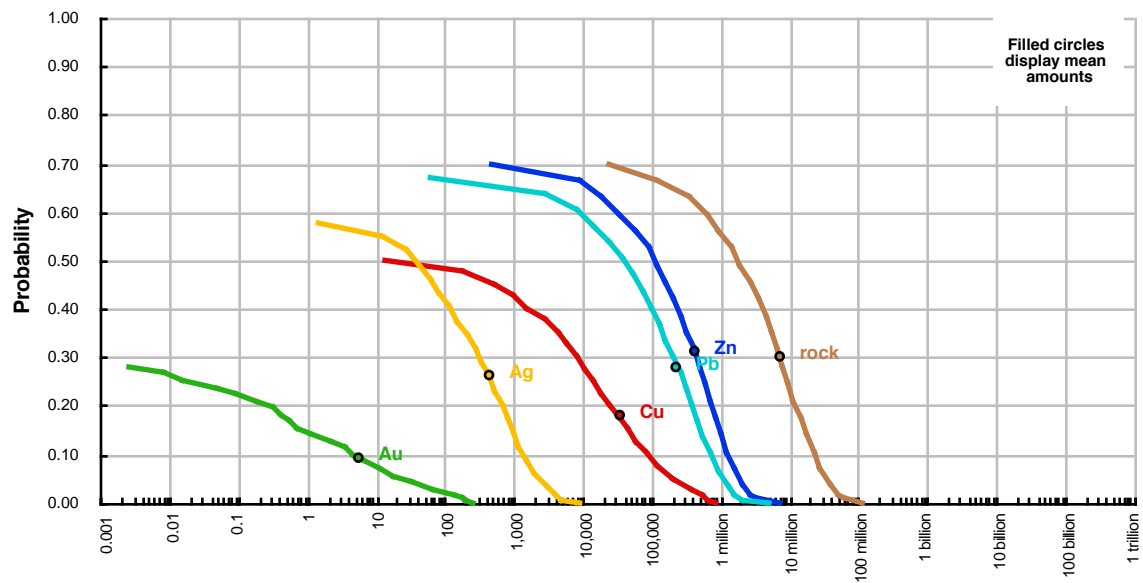
There is a 1% or greater chance of 7 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

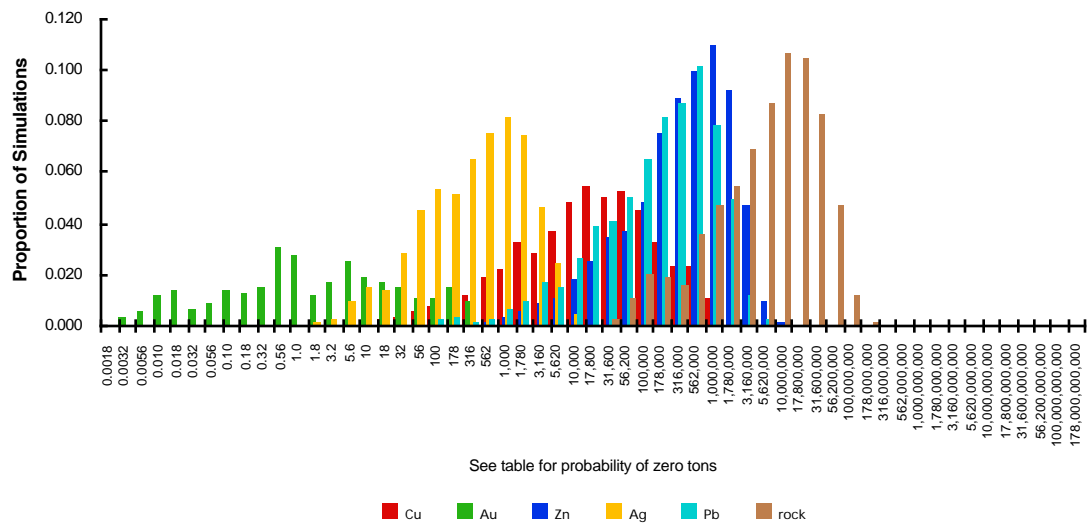
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	28	0	120,000	38	39,000	1,800,000
0.10	85,000	5	1,300,000	1,400	730,000	24,000,000
0.05	210,000	23	1,900,000	2,300	1,100,000	34,000,000
mean	34,000	6	430,000	440	230,000	7,500,000
Probability of mean	0.18	0.09	0.31	0.26	0.28	0.30
Probability of zero	0.50	0.72	0.30	0.42	0.33	0.30

The tract ID is AK-SE14

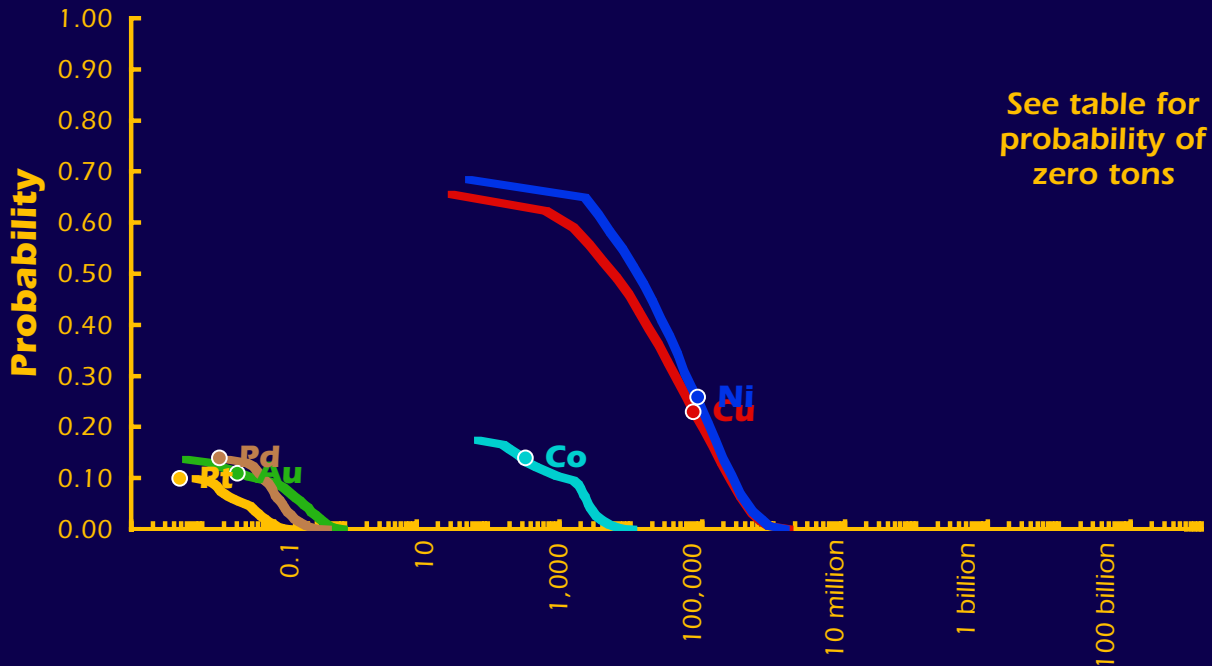
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

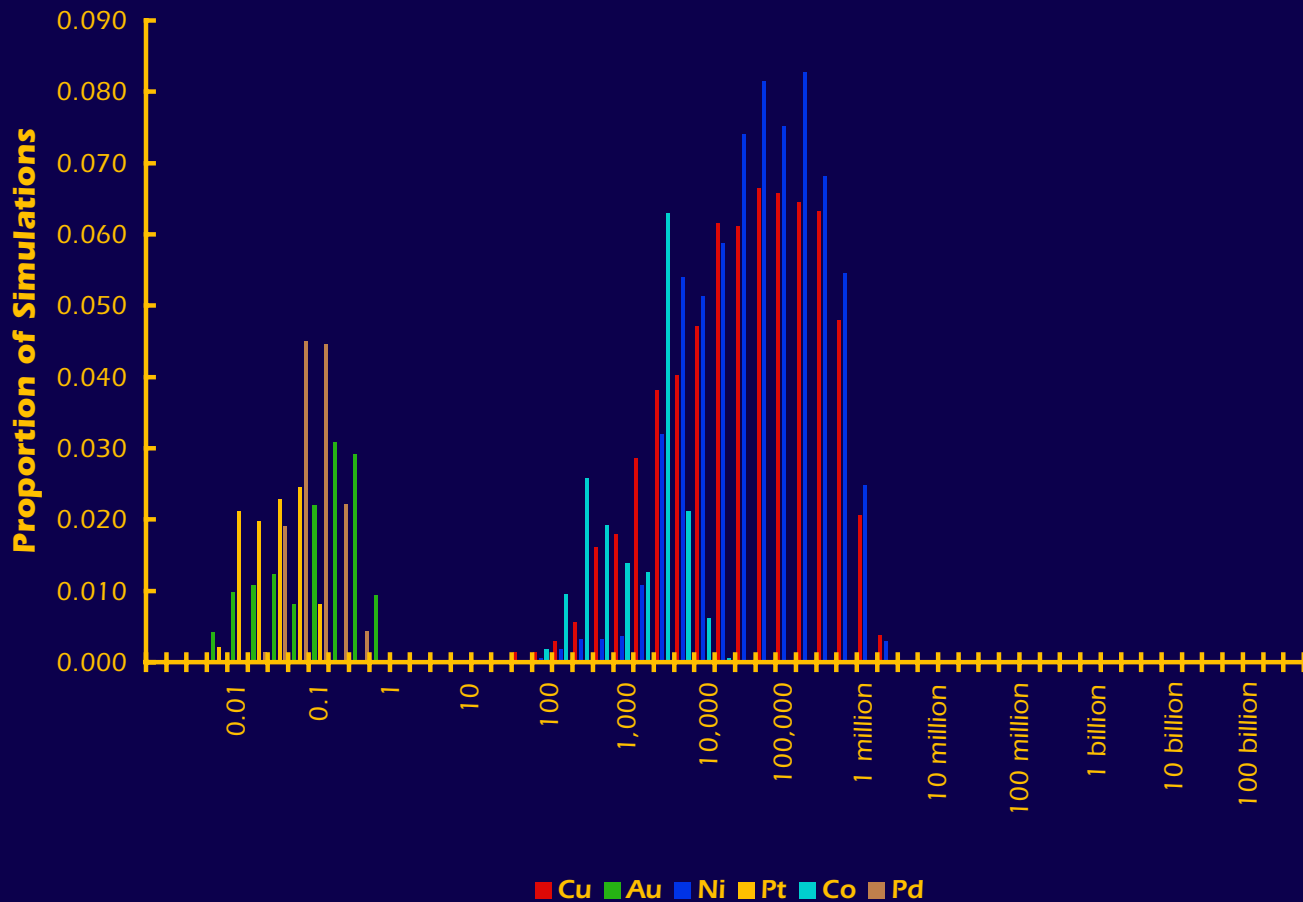


Cumulative Distributions of Contained Metal (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal (metric tons)



The tract ID is AK-SE17

The Mark3 Index is 19:

Synorogenic and synvolcanic Ni-Cu

There is a 90% or greater chance of 0 or more deposits.
There is a 50% or greater chance of 1 or more deposits.
There is a 10% or greater chance of 3 or more deposits.
There is a 5% or greater chance of 8 or more deposits.
There is a 1% or greater chance of 13 or more deposits.

Estimated amounts of contained metal (metric tons)

quantile	Cu	Au	Ni	Pt	Co	Pd
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	5,800	0	13,000	0	0	0
0.10	250,000	0	270,000	0	1,200	0
0.05	400,000	0	430,000	0	2,500	0
mean	74,000	0	84,000	0	330	0
Probability of mean	0.23	0.11	0.26	0.10	0.14	0.14
Probability of zero	0.34	0.86	0.32	0.90	0.83	0.86

The tract ID is AK-SE17The Mark3 Index is 19: **Synorogenic and synvolcanic Ni-Cu**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 8 or more deposits.

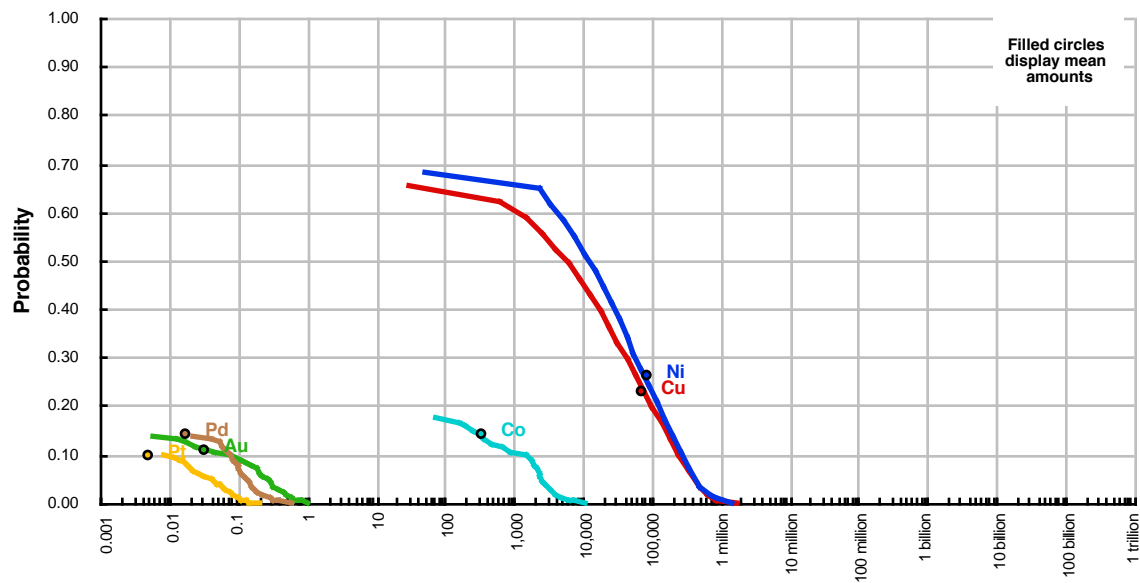
There is a 1% or greater chance of 13 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

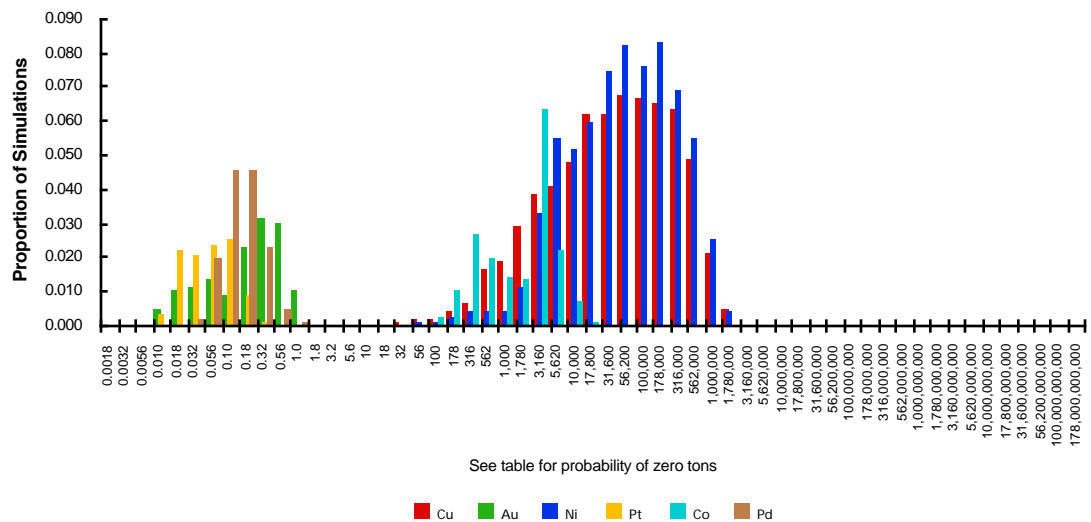
quantile	Cu	Au	Ni	Pt	Co	Pd
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	5,800	0	13,000	0	0	0
0.10	250,000	0	270,000	0	1,200	0
0.05	400,000	0	430,000	0	2,500	0
mean	74,000	0	84,000	0	330	0
Probability of mean	0.23	0.11	0.26	0.10	0.14	0.14
Probability of zero	0.34	0.86	0.32	0.90	0.83	0.86

The tract ID is AK-SE17

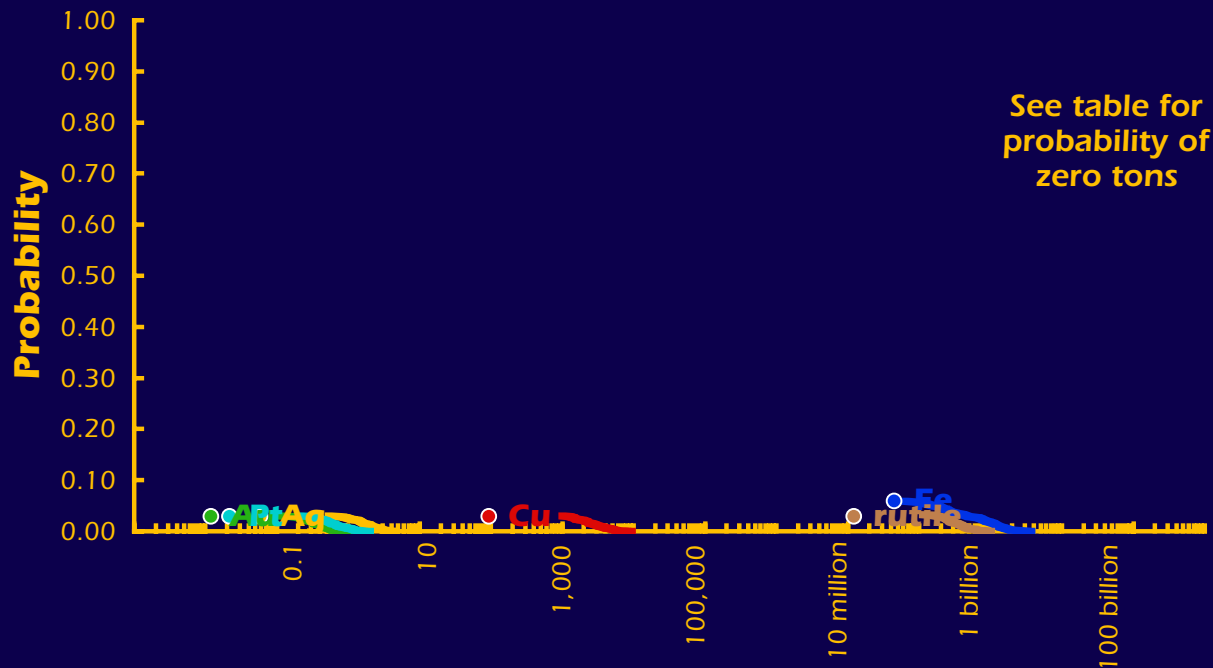
Cumulative Distributions of Contained Metal



Histograms of Contained Metal and Mineralized Rock (metric tons)

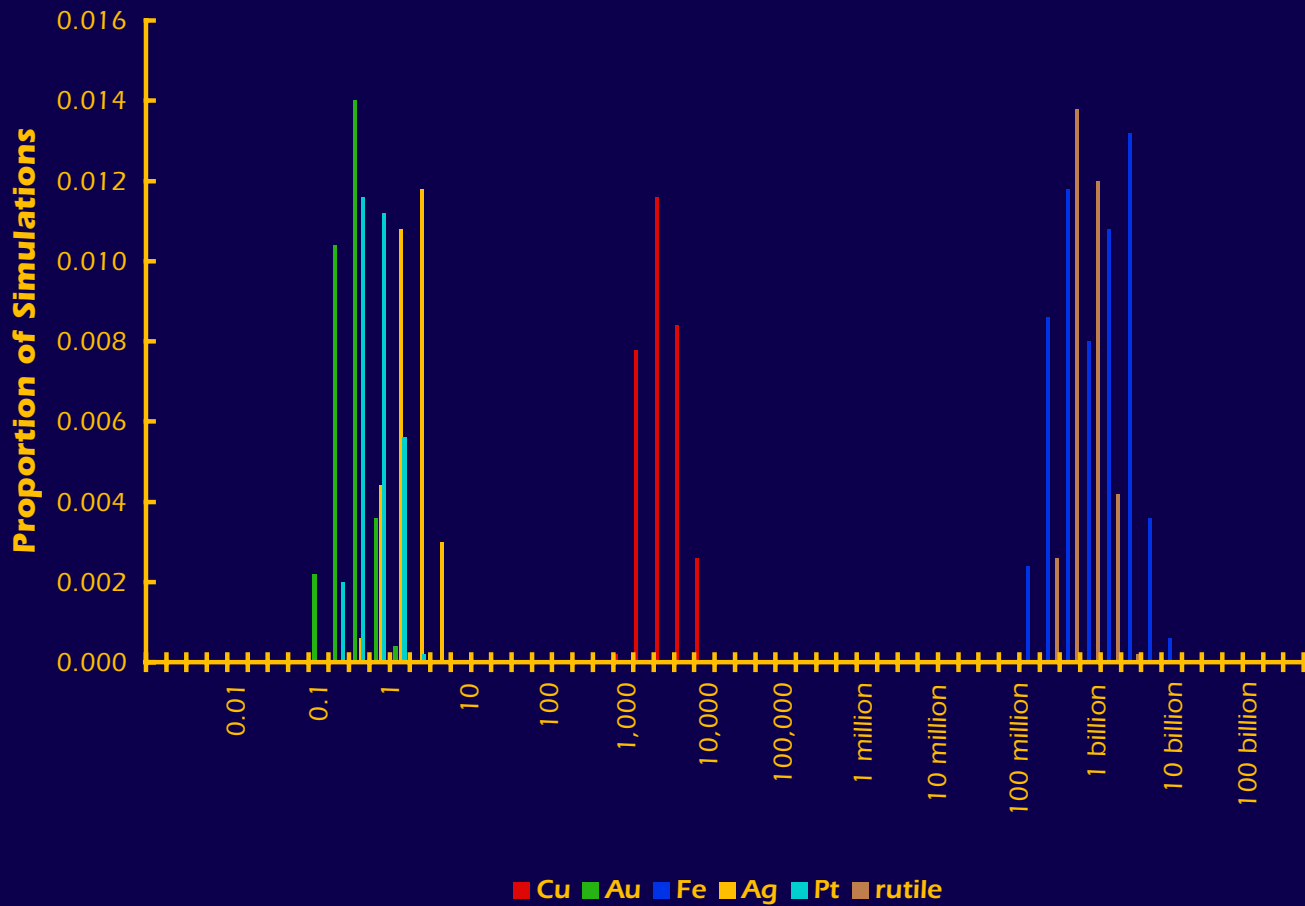


Cumulative Distributions of Contained Metal (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal (metric tons)



The tract ID is AK-SE18

The Mark3 Index is 120:

Alaska PGE

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal (metric tons)

quantile	Cu	Au	Fe	Ag	Pt	rutile
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	160,000,000	0	0	0
mean	92	0	44,000,000	0	0	12,000,000
Probability of mean	0.03	0.03	0.06	0.03	0.03	0.03
Probability of zero	0.97	0.97	0.94	0.97	0.97	0.97

The tract ID is AK-SE18The Mark3 Index is 120: **Alaska PGE**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

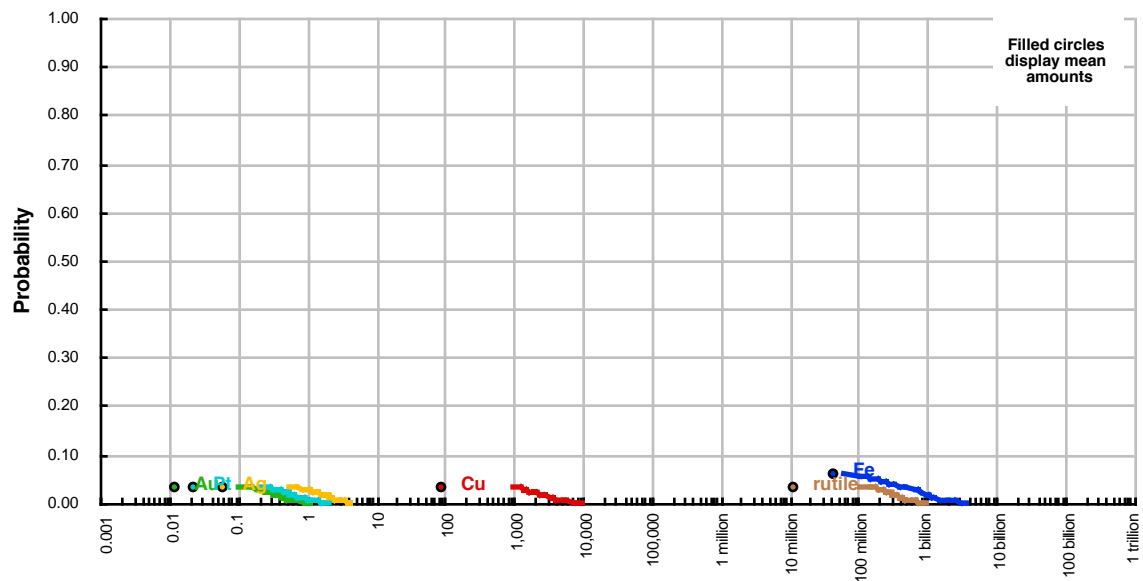
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

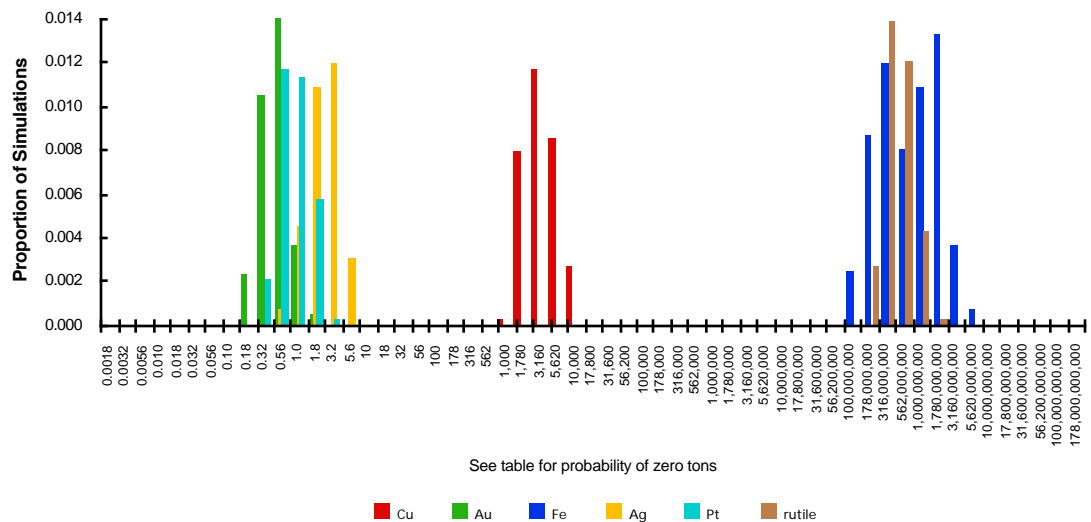
quantile	Cu	Au	Fe	Ag	Pt	rutile
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	160,000,000	0	0	0
mean	92	0	44,000,000	0	0	12,000,000
Probability of mean	0.03	0.03	0.06	0.03	0.03	0.03
Probability of zero	0.97	0.97	0.94	0.97	0.97	0.97

The tract ID is AK-SE18

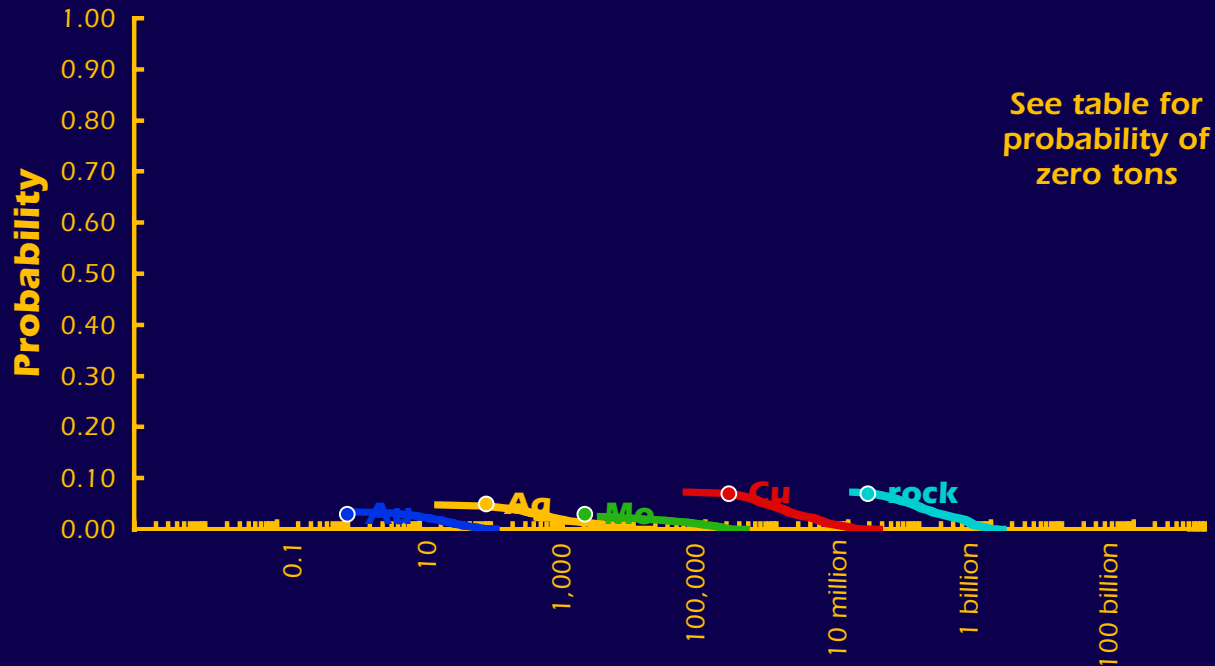
Cumulative Distributions of Contained Metal



Histograms of Contained Metal and Mineralized Rock (metric tons)

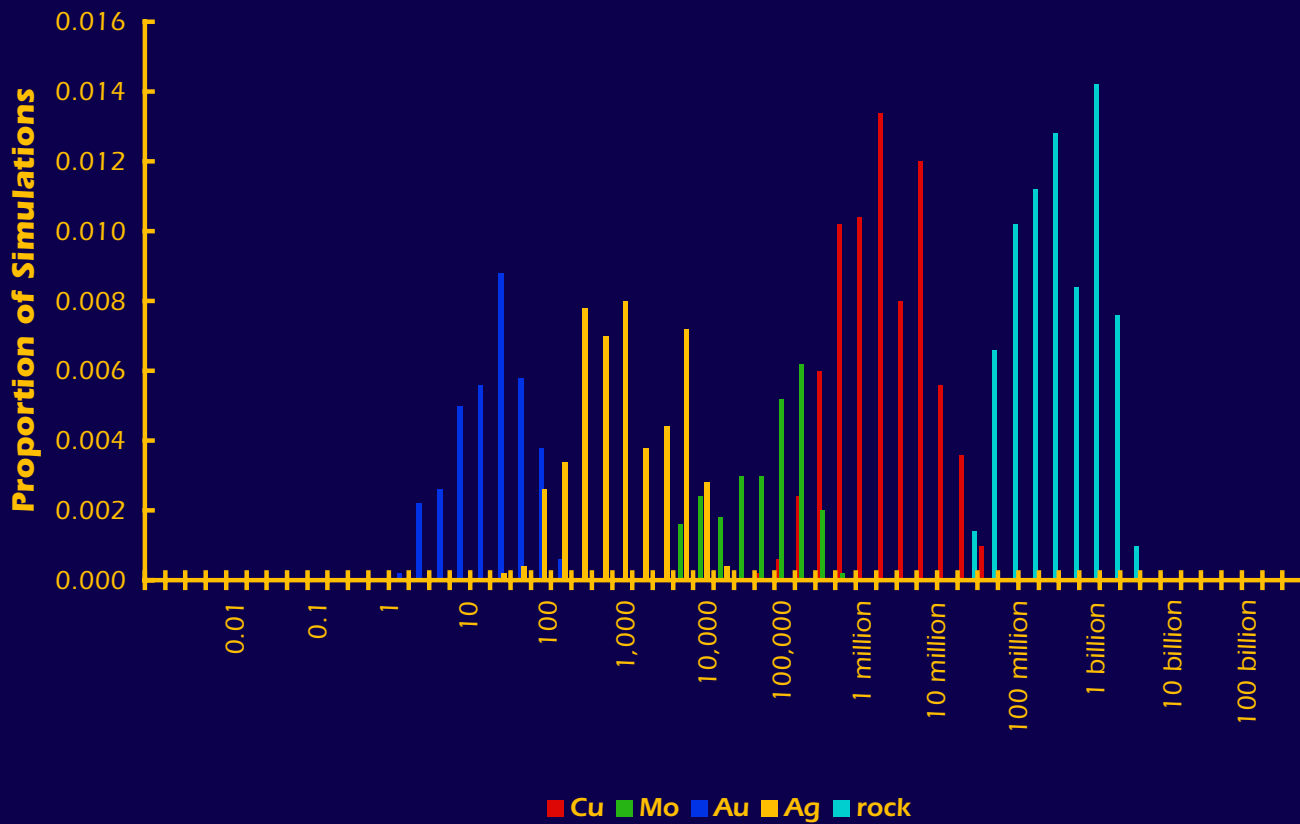


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SE19

The Mark3 Index is 9:

Porphyry Cu, skarn related

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	710,000	0	0	0	79,000,000
mean	210,000	2,000	1	84	19,000,000
Probability of mean	0.07	0.03	0.03	0.05	0.07
Probability of zero	0.93	0.97	0.97	0.95	0.93

The tract ID is AK-SE19The Mark3 Index is 9: **Porphyry Cu, skarn related**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

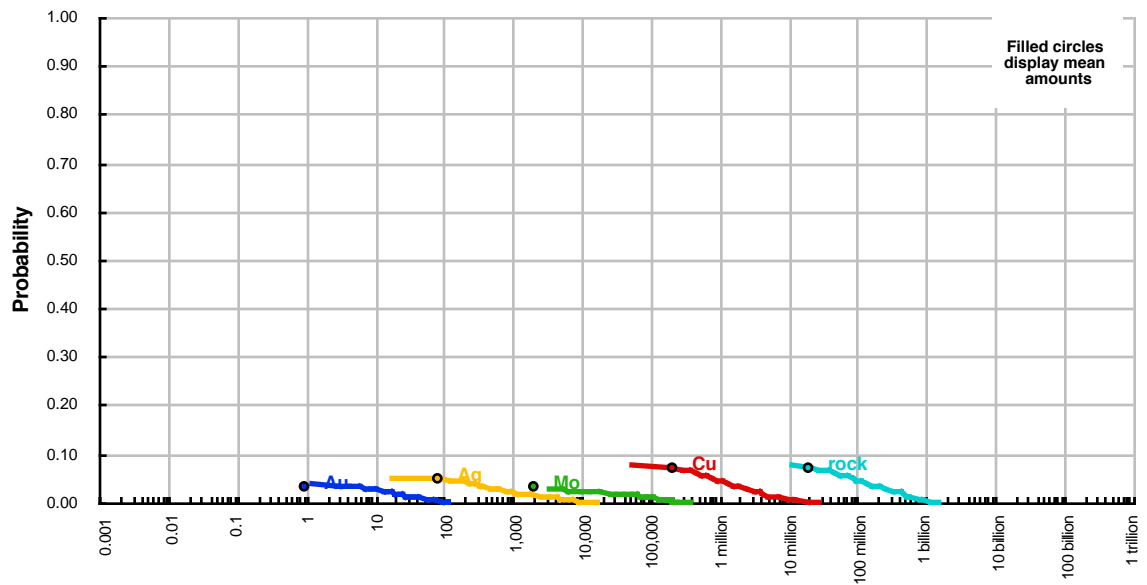
There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

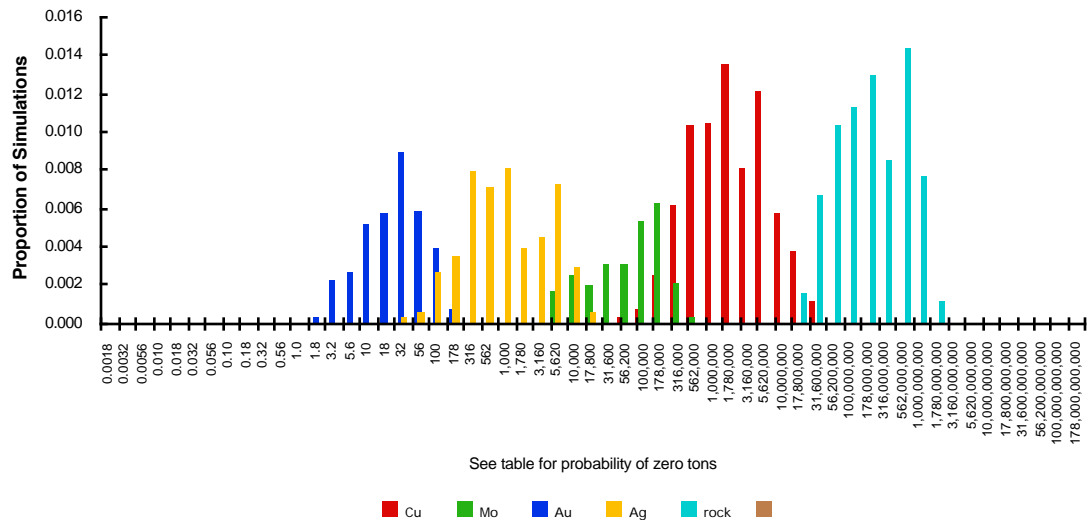
quantile	Cu	Mo	Au	Ag	rock	0
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	710,000	0	0	0	79,000,000	0
mean	210,000	2,000	1	84	19,000,000	0
Probability of mean	0.07	0.03	0.03	0.05	0.07	0.00
Probability of zero	0.93	0.97	0.97	0.95	0.93	0.00

The tract ID is AK-SE19

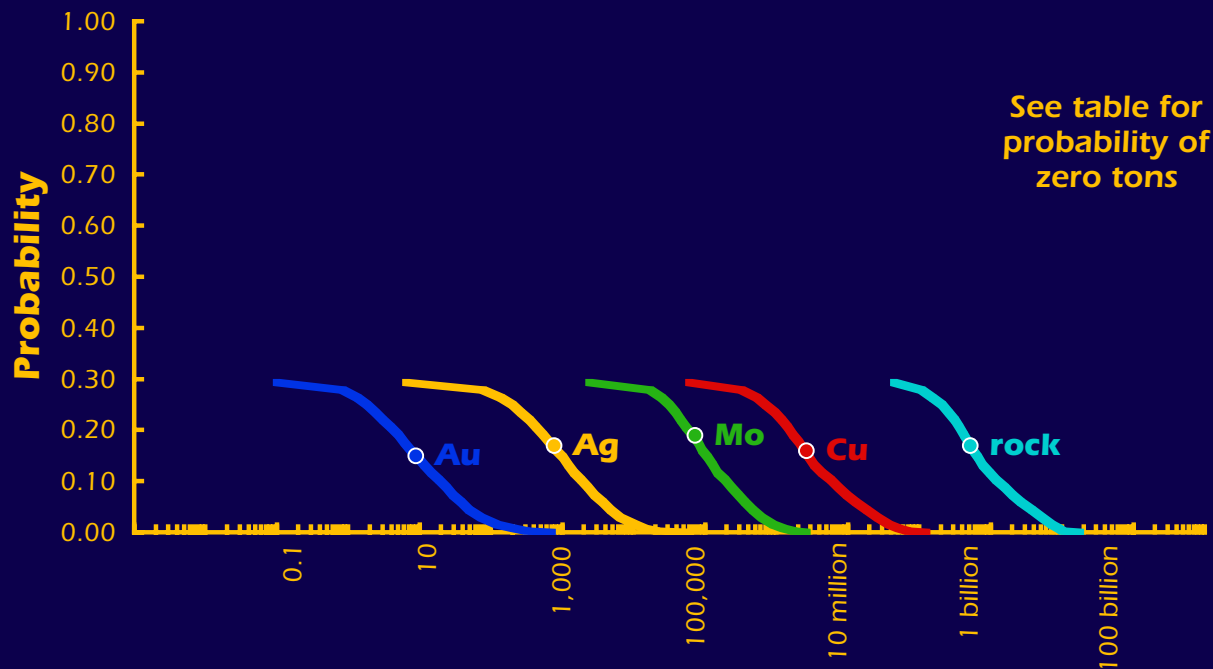
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

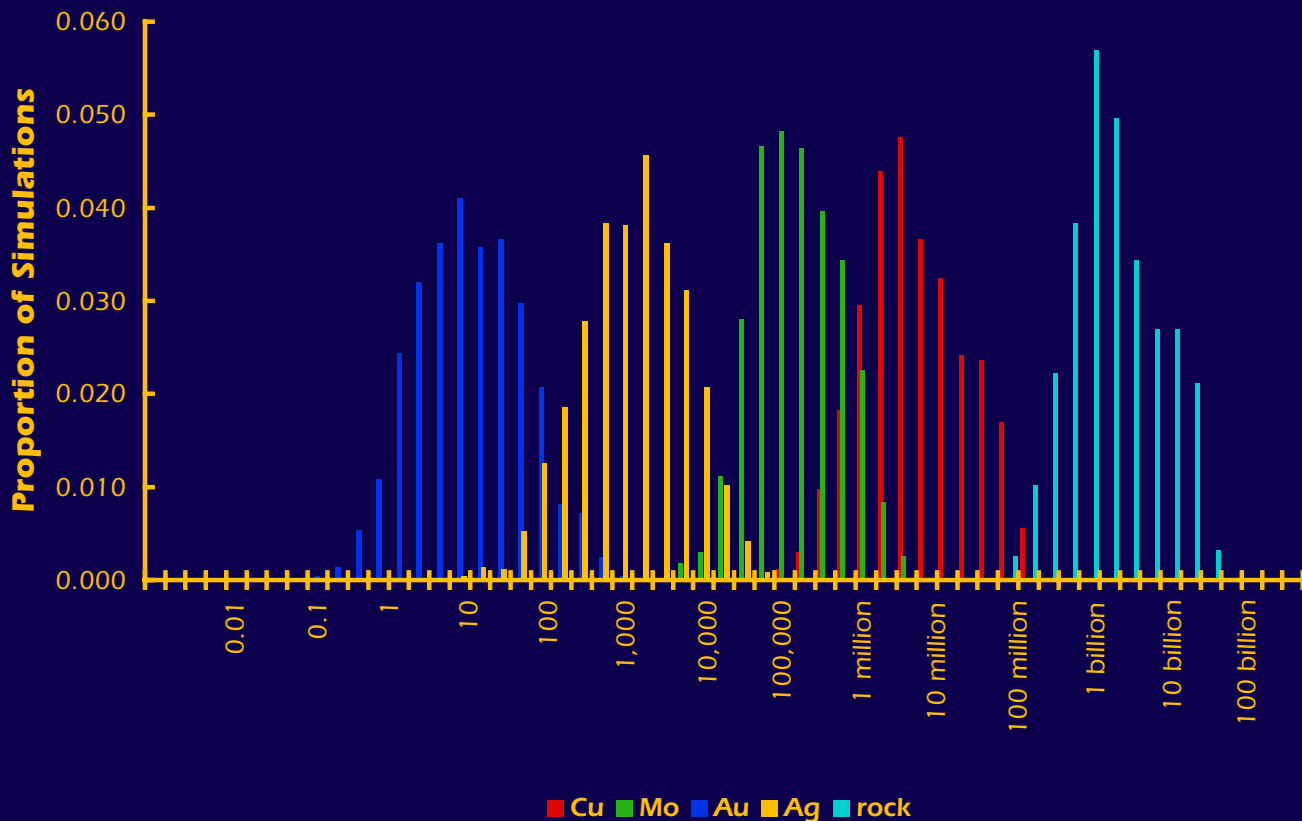


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SE20

The Mark3 Index is 2:

Porphyry Cu-Mo

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	6,100,000	200,000	20	1,900	1,200,000,000
0.05	16,000,000	420,000	45	4,200	3,200,000,000
mean	2,600,000	70,000	9	760	500,000,000
Probability of mean	0.16	0.19	0.15	0.17	0.17
Probability of zero	0.71	0.71	0.71	0.71	0.71

The tract ID is AK-SE20The Mark3 Index is 2: **Porphyry Cu-Mo**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

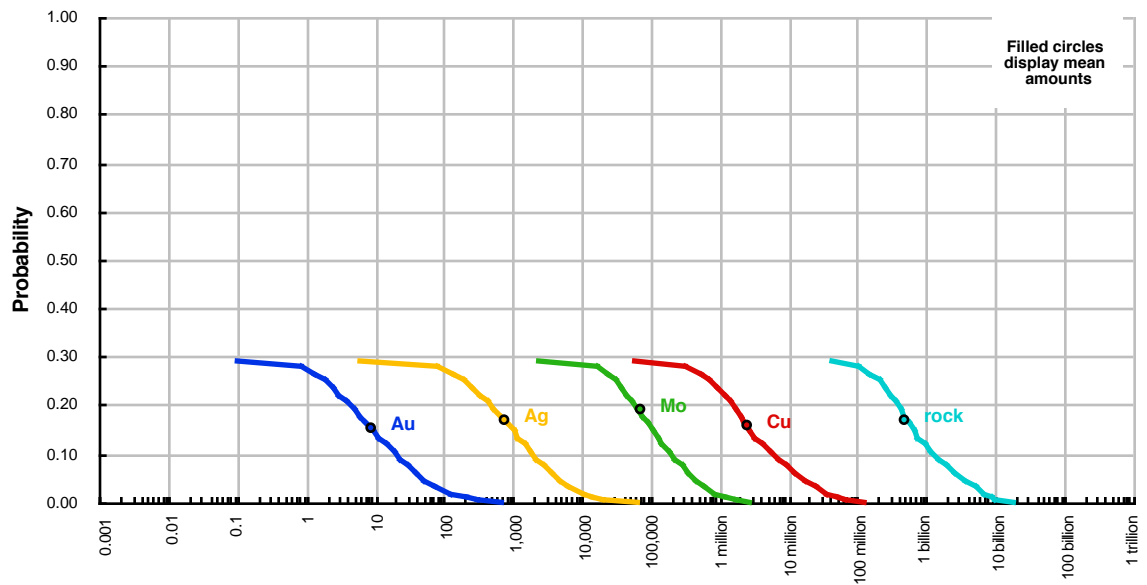
There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

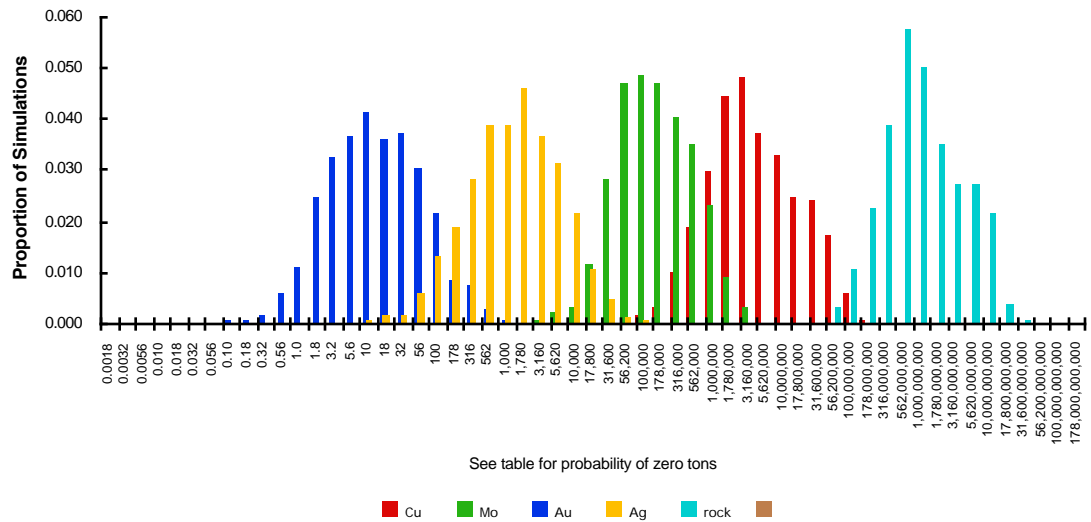
quantile	Cu	Mo	Au	Ag	rock	0
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	6,100,000	200,000	20	1,900	1,200,000,000	0
0.05	16,000,000	420,000	45	4,200	3,200,000,000	0
mean	2,600,000	70,000	9	760	500,000,000	0
Probability of mean	0.16	0.19	0.15	0.17	0.17	0.00
Probability of zero	0.71	0.71	0.71	0.71	0.71	0.00

The tract ID is AK-SE20

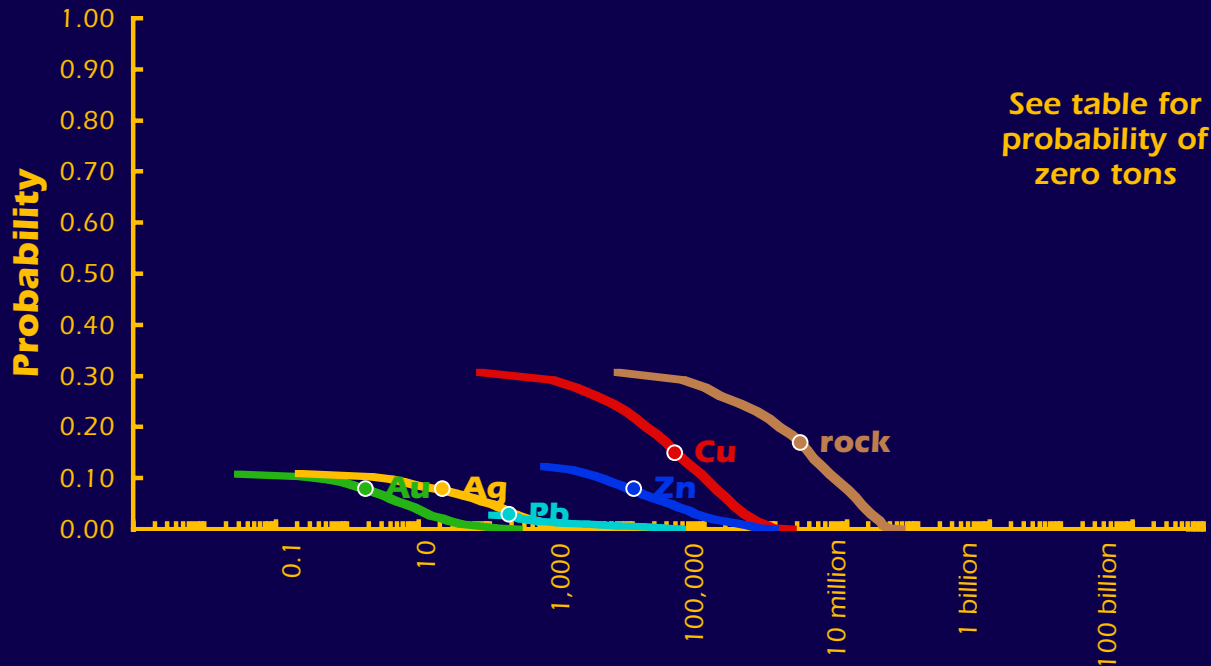
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

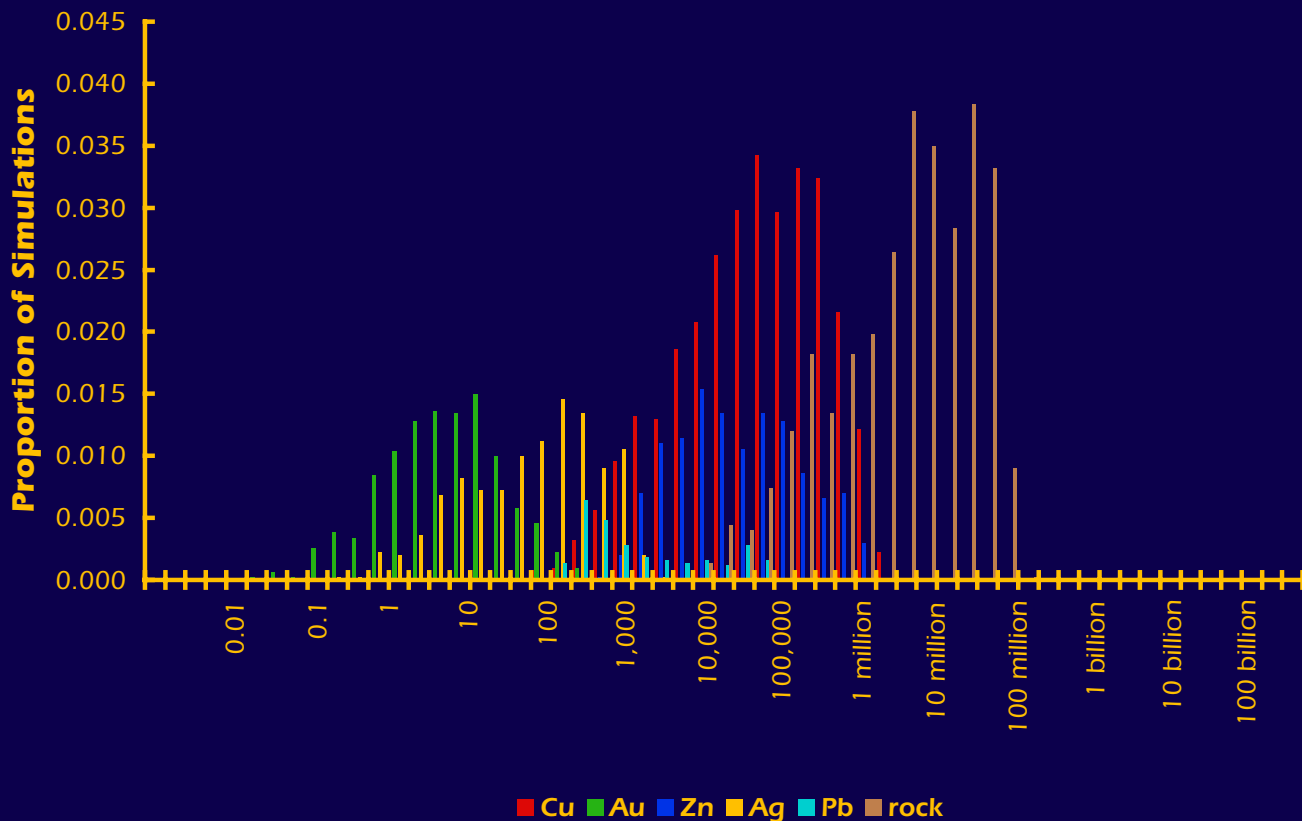


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SW03

The Mark3 Index is 11:

Massive sulfide, Cyprus

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	100,000	0	3,590	4	0	6,500,000
0.05	240,000	6	34,000	100	0	16,000,000
mean	38,000	2	10,000	21	180	2,200,000
Probability of mean	0.15	0.08	0.08	0.08	0.03	0.17
Probability of zero	0.69	0.89	0.88	0.89	0.97	0.69

The tract ID is AK-SW03The Mark3 Index is 11: **Massive sulfide, Cyprus**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

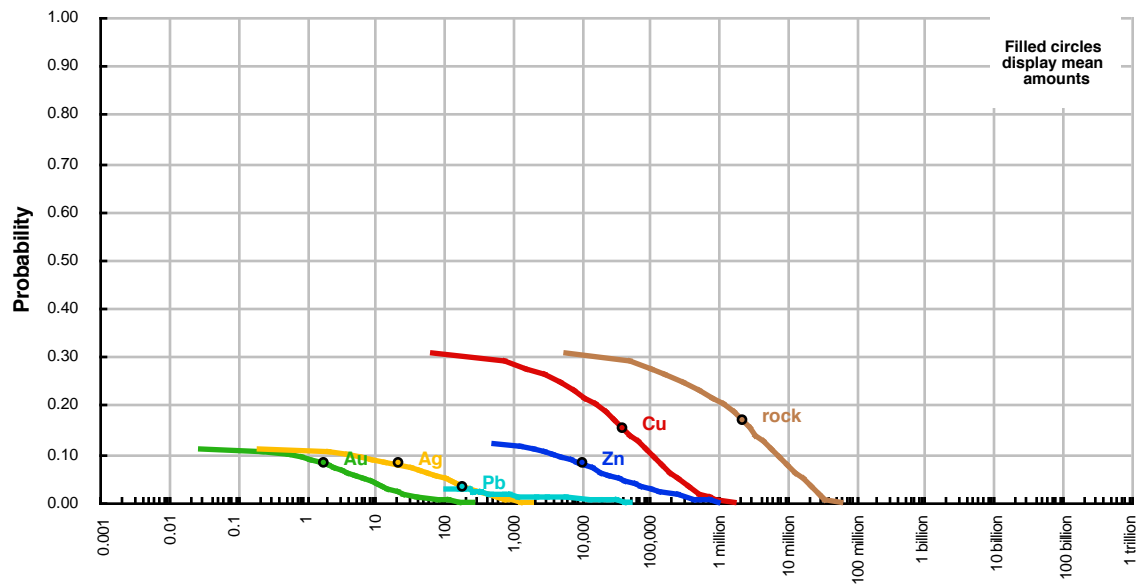
There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

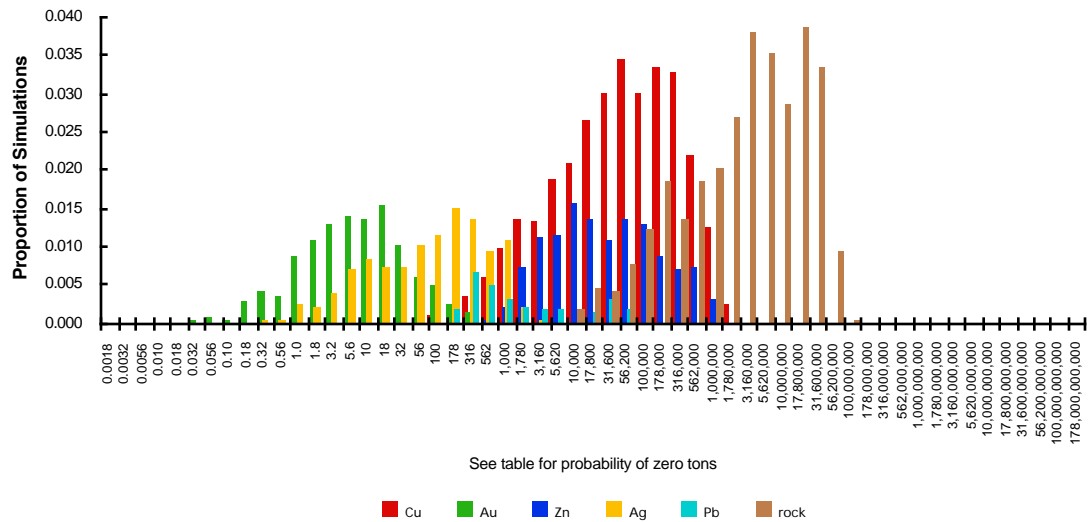
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	100,000	0	3,590	4	0	6,500,000
0.05	240,000	6	34,000	100	0	16,000,000
mean	38,000	2	10,000	21	180	2,200,000
Probability of mean	0.15	0.08	0.08	0.08	0.03	0.17
Probability of zero	0.69	0.89	0.88	0.89	0.97	0.69

The tract ID is AK-SW03

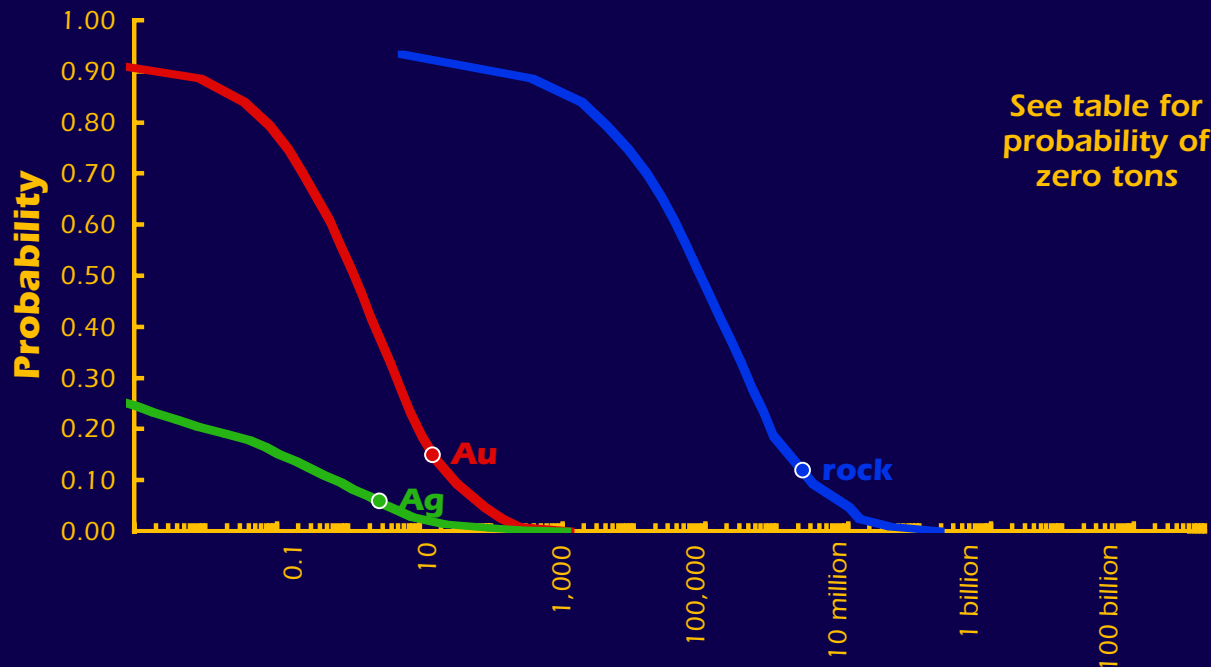
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

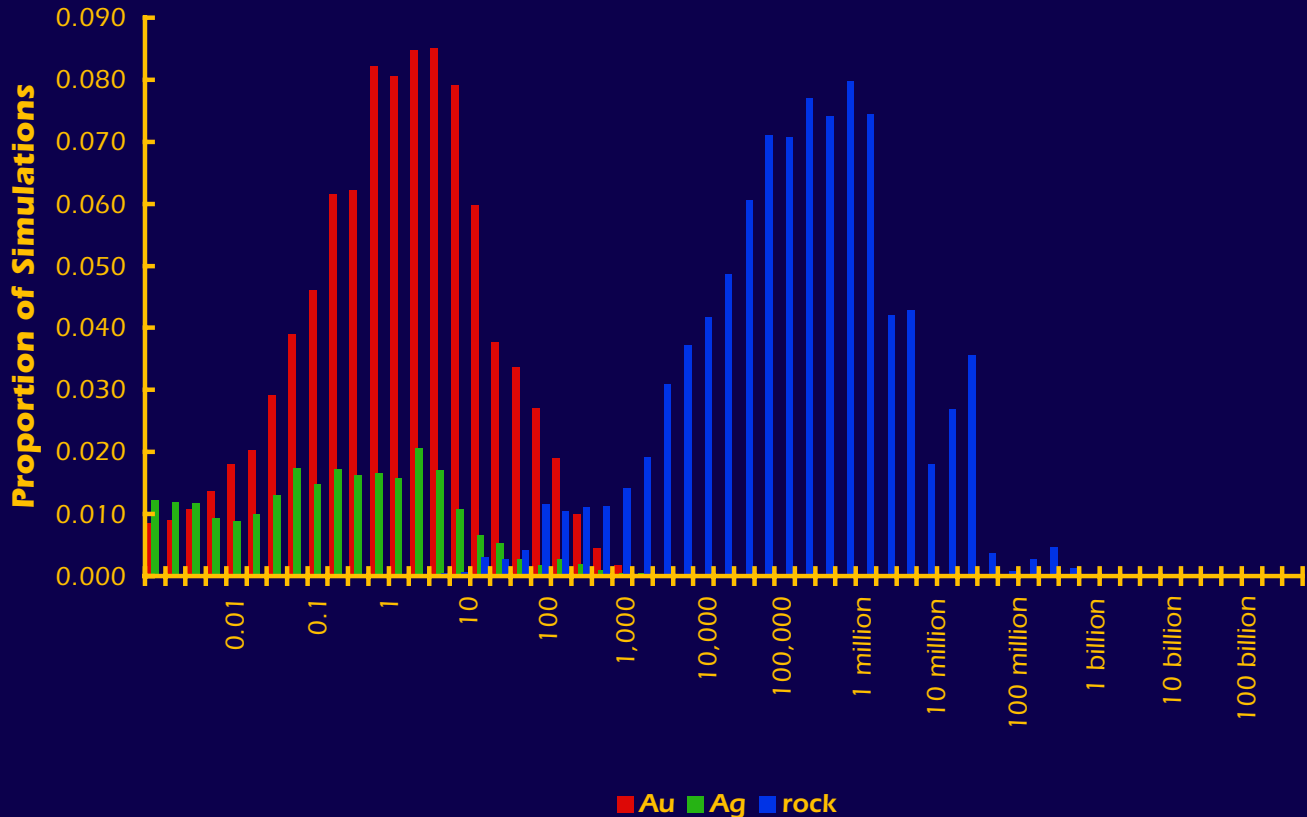


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SW06

The Mark3 Index is 27:

Low sulfide Au-quartz vein

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

There is a 1% or greater chance of 6 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	180
0.50	1	0	85,000
0.10	29	1	2,770,000
0.05	75	3	9,800,000
mean	15	3	2,300,000
Probability of mean	0.15	0.06	0.12
Probability of zero	0.07	0.73	0.07

The tract ID is AK-SW06The Mark3 Index is 27: **Low sulfide Au-quartz vein**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

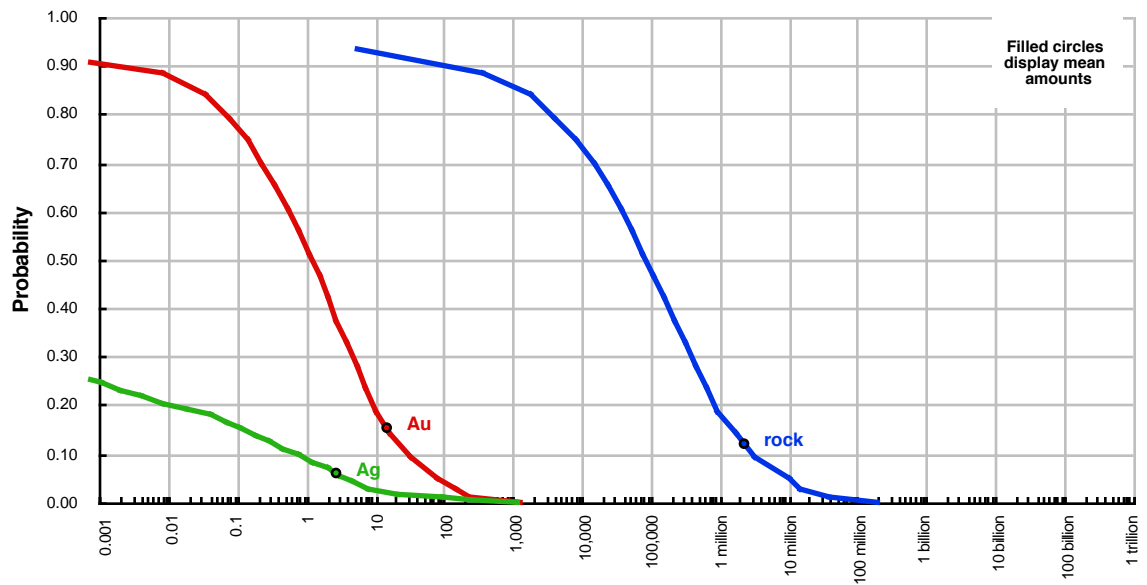
There is a 1% or greater chance of 6 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

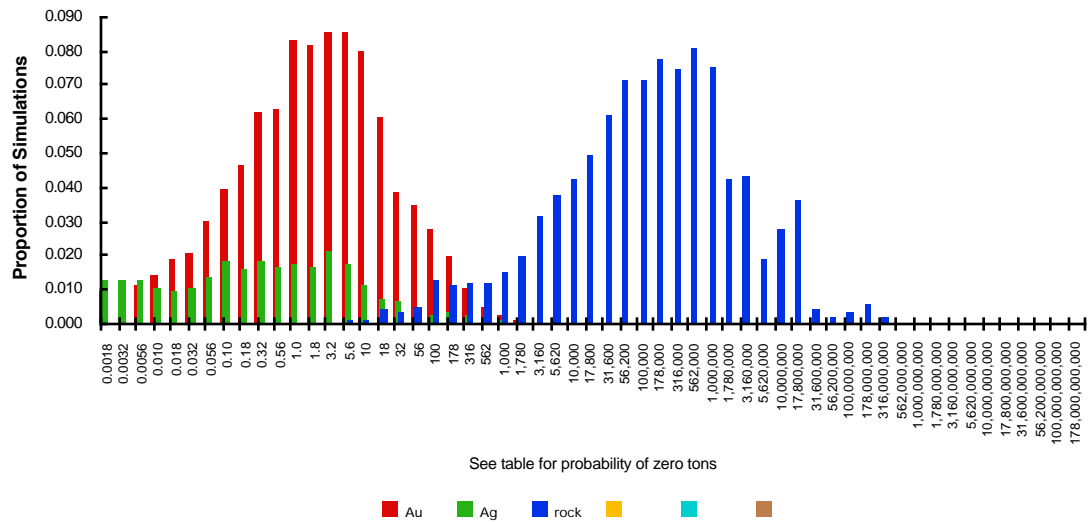
quantile	Au	Ag	rock	0	0	0
0.95	0	0	0	0	0	0
0.90	0	0	180	0	0	0
0.50	1	0	85,000	0	0	0
0.10	29	1	2,770,000	0	0	0
0.05	75	3	9,800,000	0	0	0
mean	15	3	2,300,000	0	0	0
Probability of mean	0.15	0.06	0.12	0.00	0.00	0.00
Probability of zero	0.07	0.73	0.07	0.00	0.00	0.00

The tract ID is AK-SW06

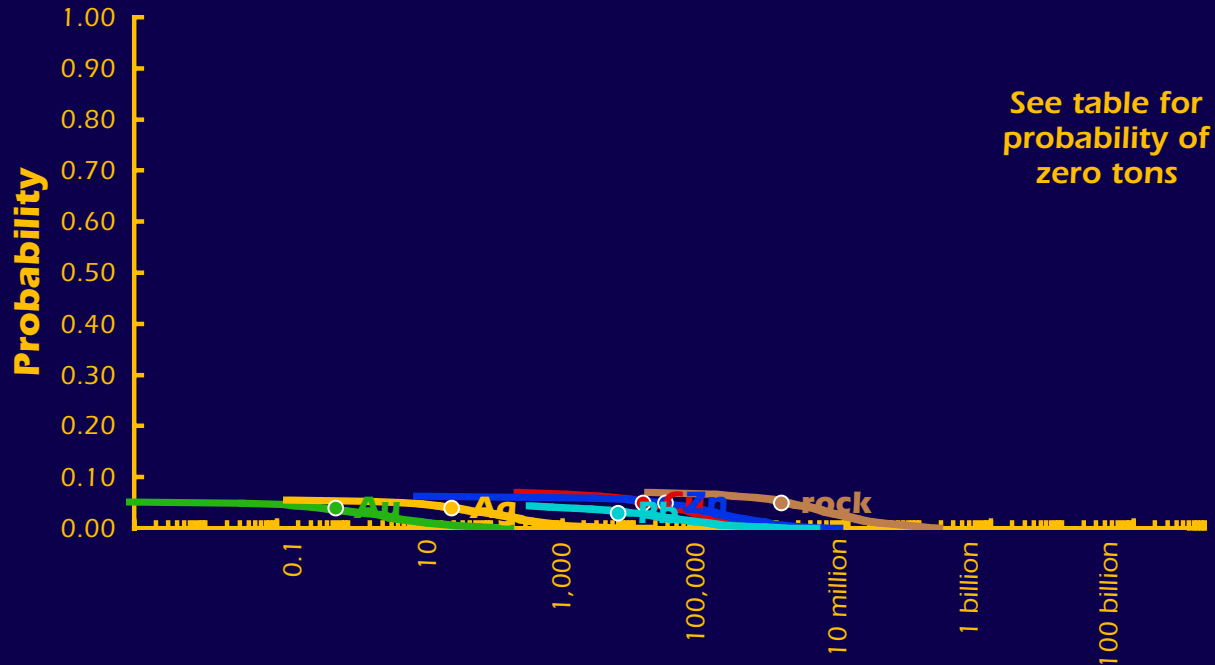
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

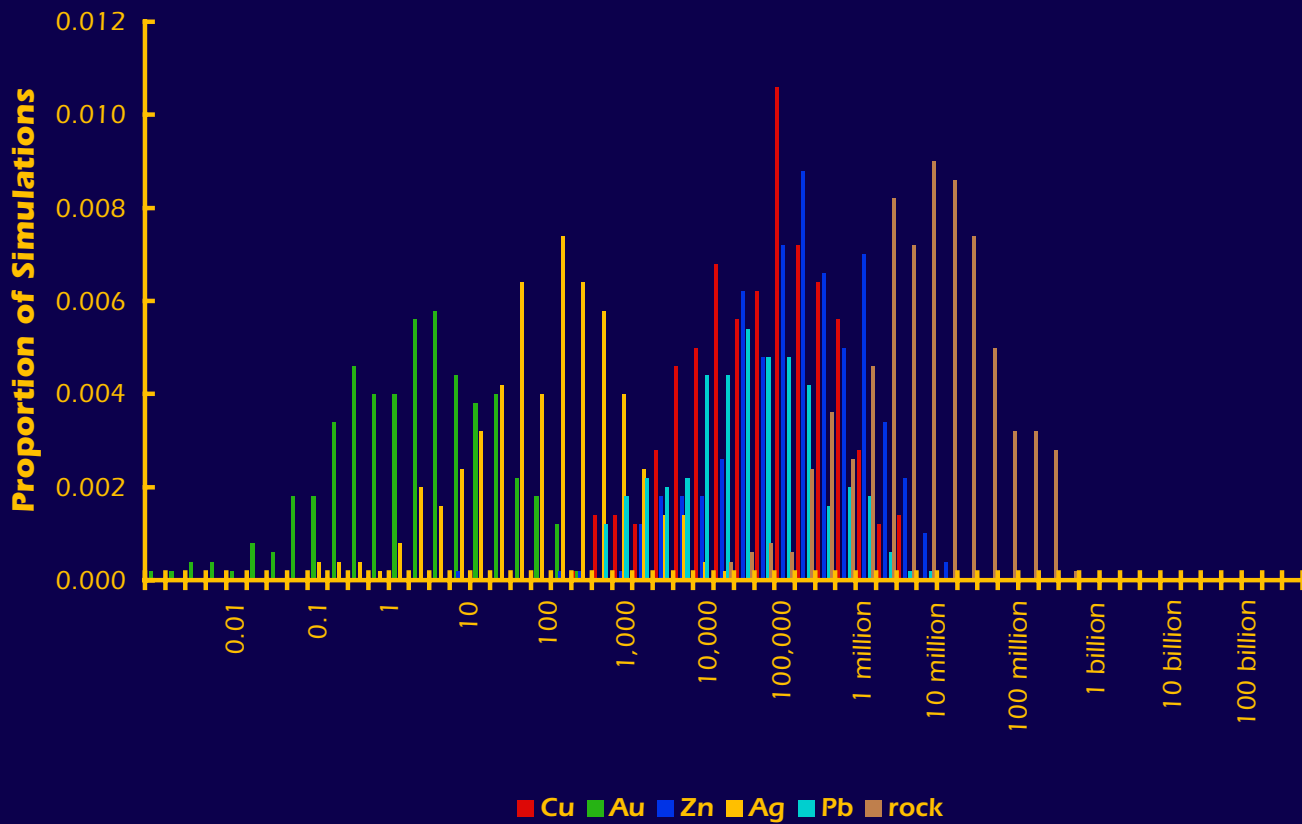


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SW08

The Mark3 Index is 93:

Massive sulfide, kuroko

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	15,000	0	25,000	5	0	1,500,000
mean	13,000	1	28,000	27	6,000	1,100,000
Probability of mean	0.05	0.04	0.05	0.04	0.03	0.05
Probability of zero	0.93	0.95	0.94	0.94	0.96	0.93

The tract ID is AK-SW08The Mark3 Index is 93: **Massive sulfide, kuroko**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

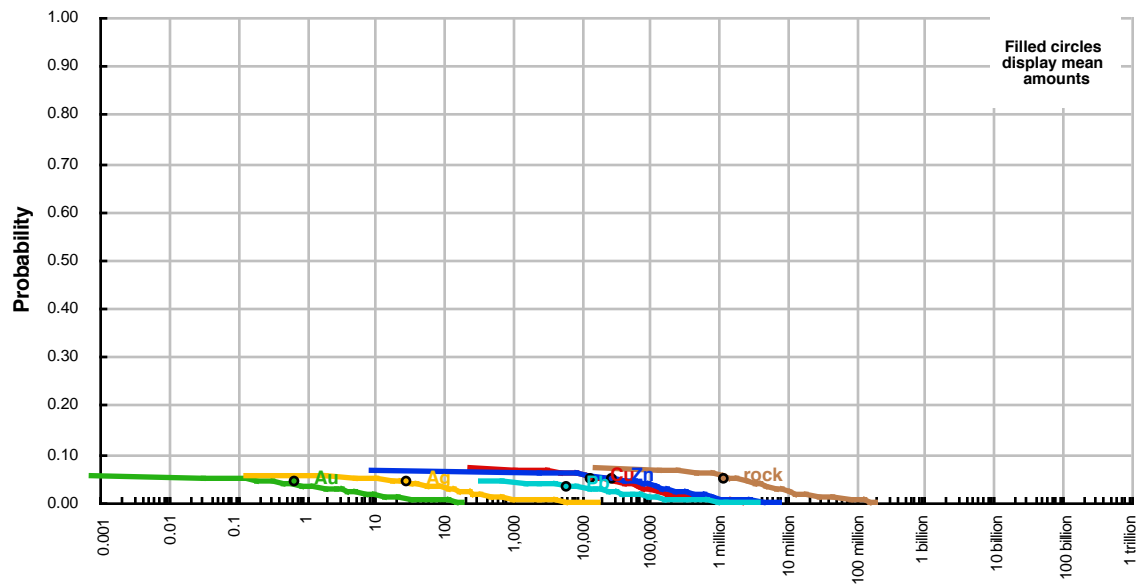
There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

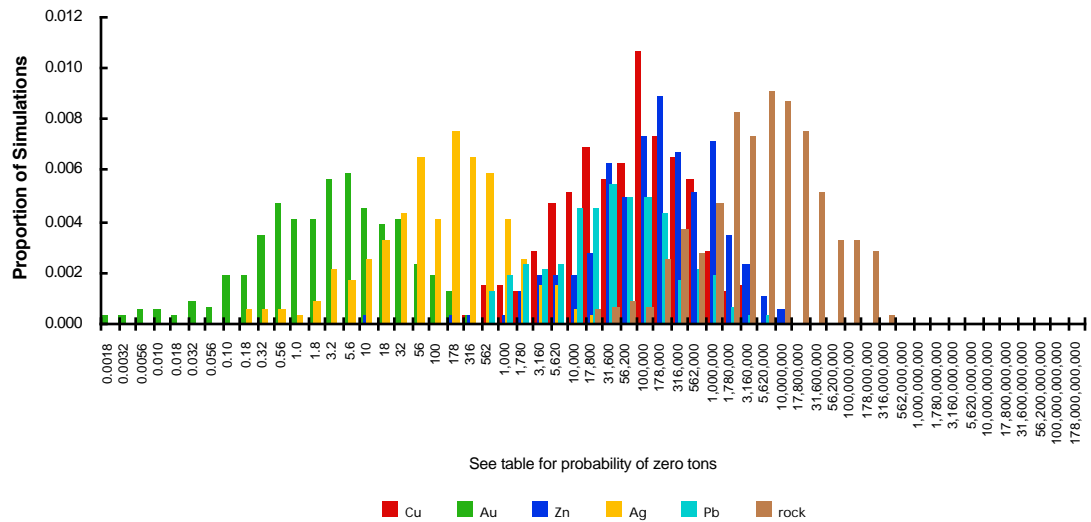
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	15,000	0	25,000	5	0	1,500,000
mean	13,000	1	28,000	27	6,000	1,100,000
Probability of mean	0.05	0.04	0.05	0.04	0.03	0.05
Probability of zero	0.93	0.95	0.94	0.94	0.96	0.93

The tract ID is AK-SW08

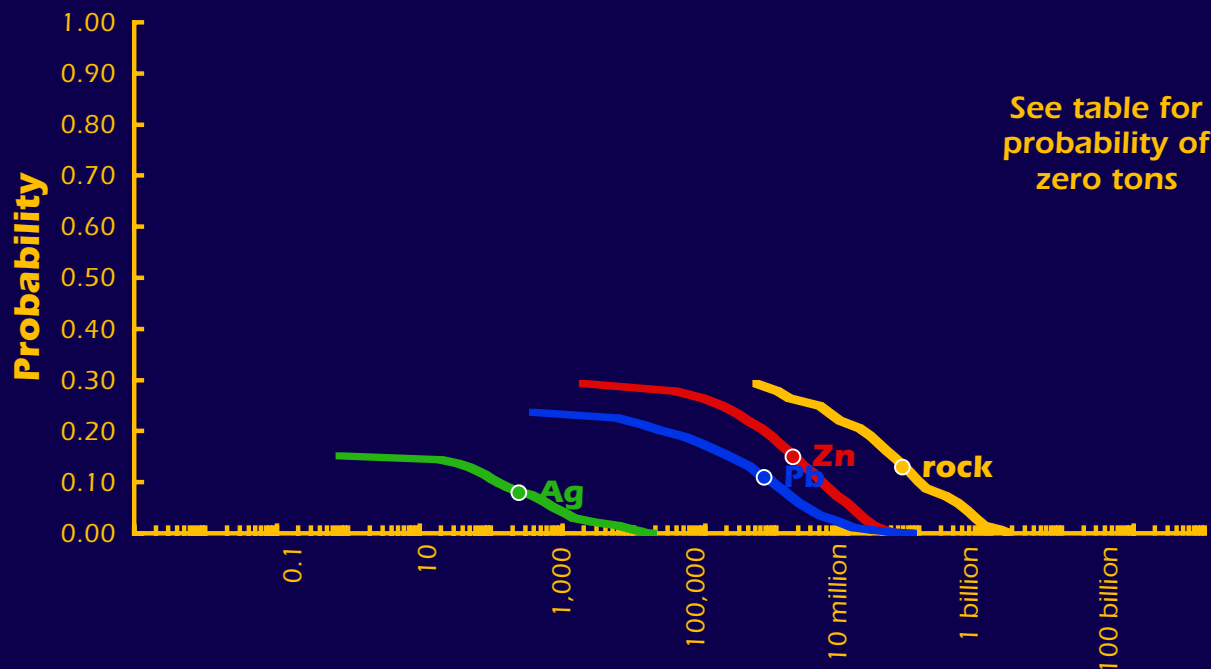
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)



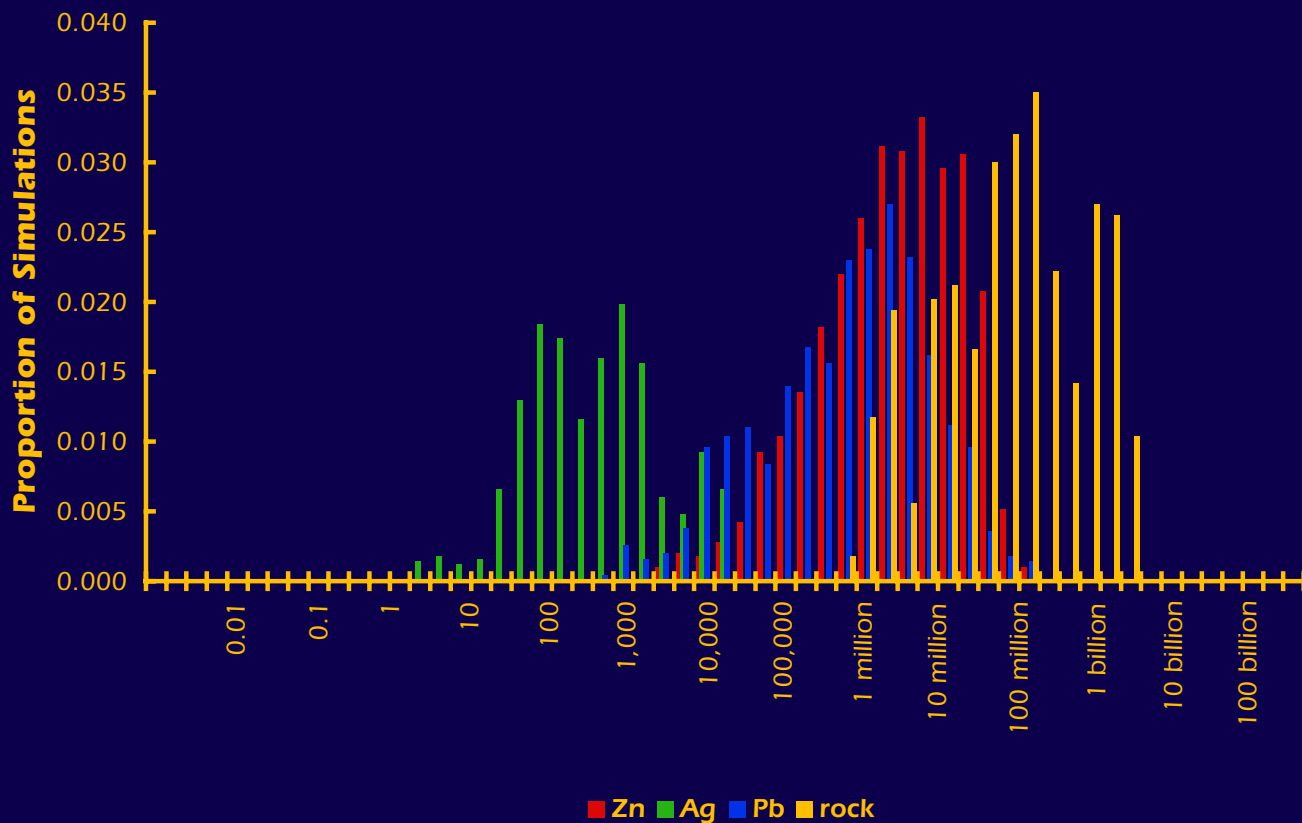
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



See table for
probability of
zero tons

Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SW10

The Mark3 Index is 108:

Mississippi Valley

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Zn	Ag	Pb	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	4,400,000	120	892,000	100,000,000
0.05	12,000,000	820	2,700,000	410,000,000
mean	1,700,000	240	660,000	57,000,000
Probability of mean	0.15	0.08	0.11	0.13
Probability of zero	0.71	0.85	0.76	0.71

The tract ID is AK-SW10The Mark3 Index is 108: **Mississippi Valley**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

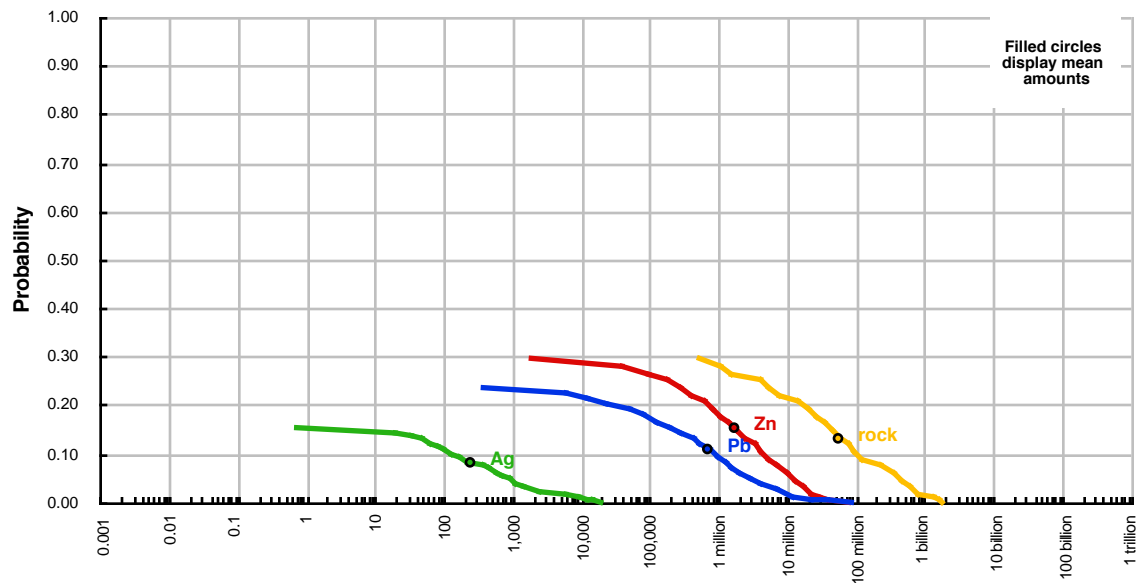
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

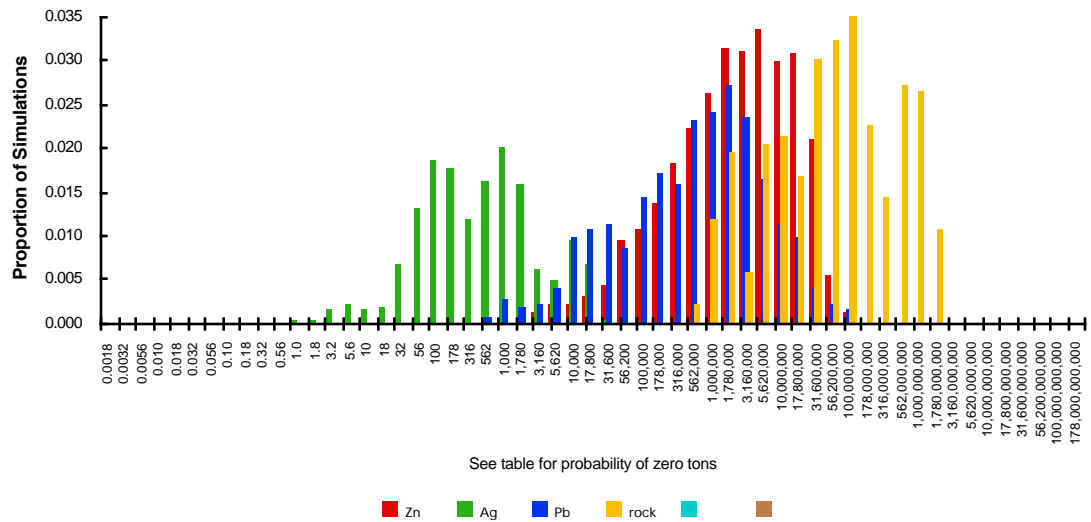
quantile	Zn	Ag	Pb	rock	0	0
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	4,400,000	120	892,000	100,000,000	0	0
0.05	12,000,000	820	2,700,000	410,000,000	0	0
mean	1,700,000	240	660,000	57,000,000	0	0
Probability of mean	0.15	0.08	0.11	0.13	0.00	0.00
Probability of zero	0.71	0.85	0.76	0.71	0.00	0.00

The tract ID is AK-SW10

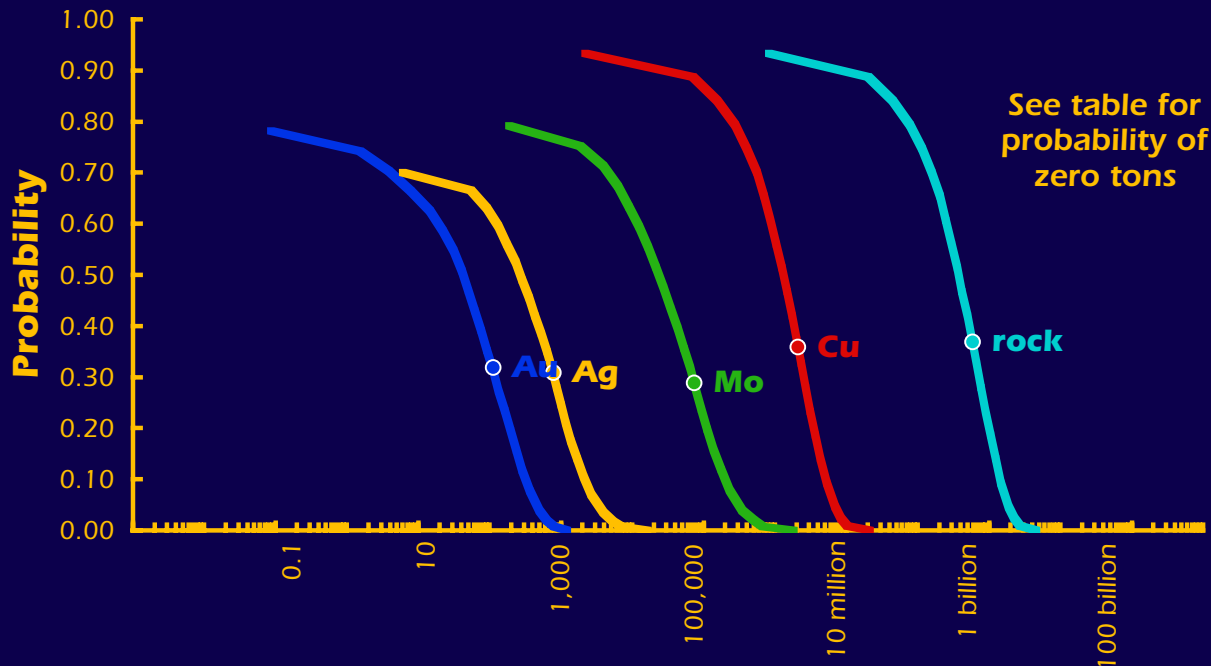
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

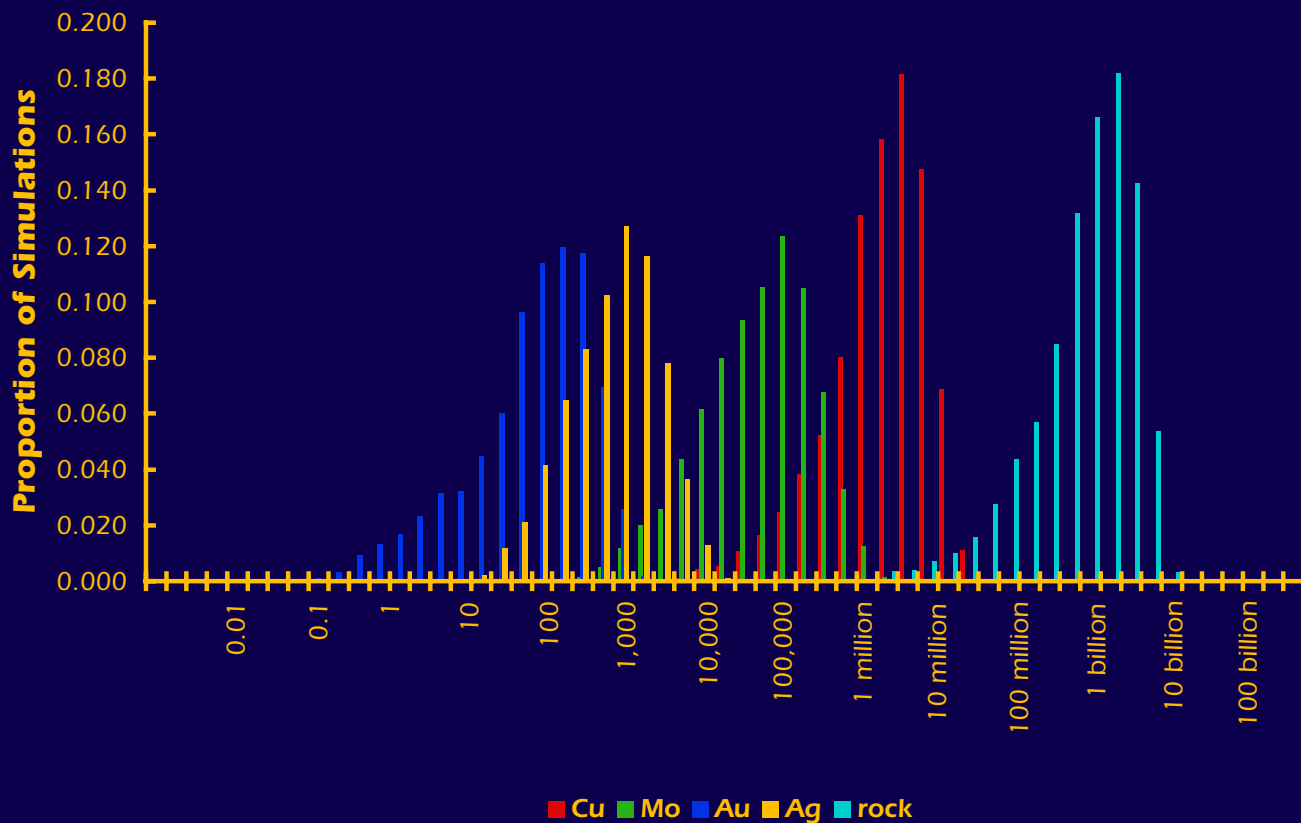


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SW12

The Mark3 Index is 89:

Porphyry Cu (BC-AK)

There is a 90% or greater chance of 1 or more deposits.
There is a 50% or greater chance of 2 or more deposits.
There is a 10% or greater chance of 6 or more deposits.
There is a 5% or greater chance of 8 or more deposits.
There is a 1% or greater chance of 10 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	49,000	0	0	0	14,000,000
0.50	1,300,000	24,000	42	270	380,000,000
0.10	5,100,000	200,000	312	2,200	1,400,000,000
0.05	6,800,000	310,000	460	3,200	1,800,000,000
mean	2,100,000	73,000	110	770	580,000,000
Probability of mean	0.36	0.29	0.32	0.31	0.37
Probability of zero	0.07	0.21	0.22	0.30	0.07

The tract ID is AK-SW12The Mark3 Index is 89: **Porphyry Cu (BC-AK)**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 8 or more deposits.

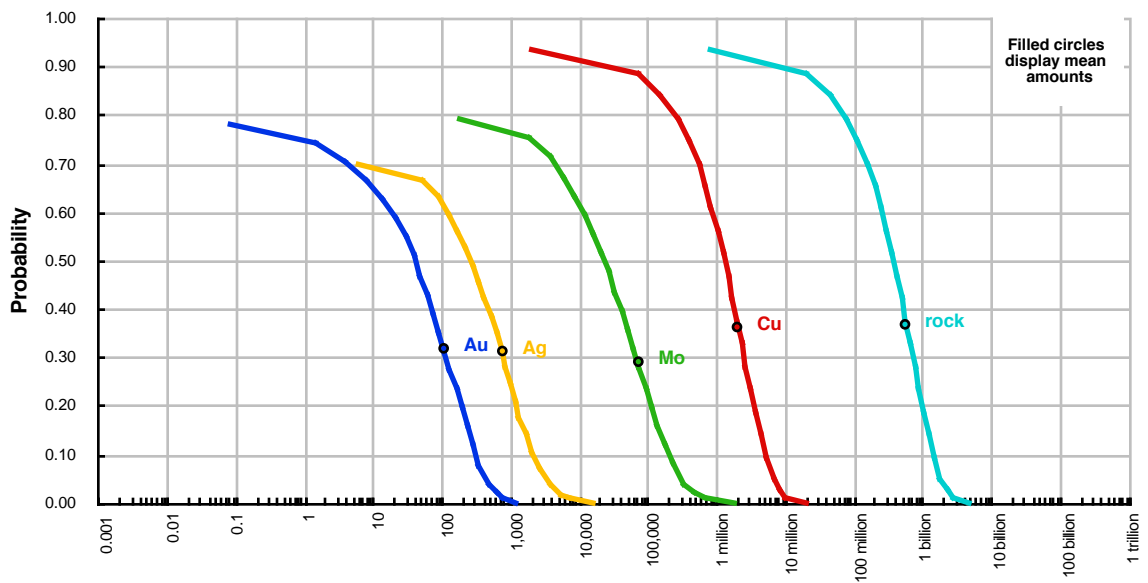
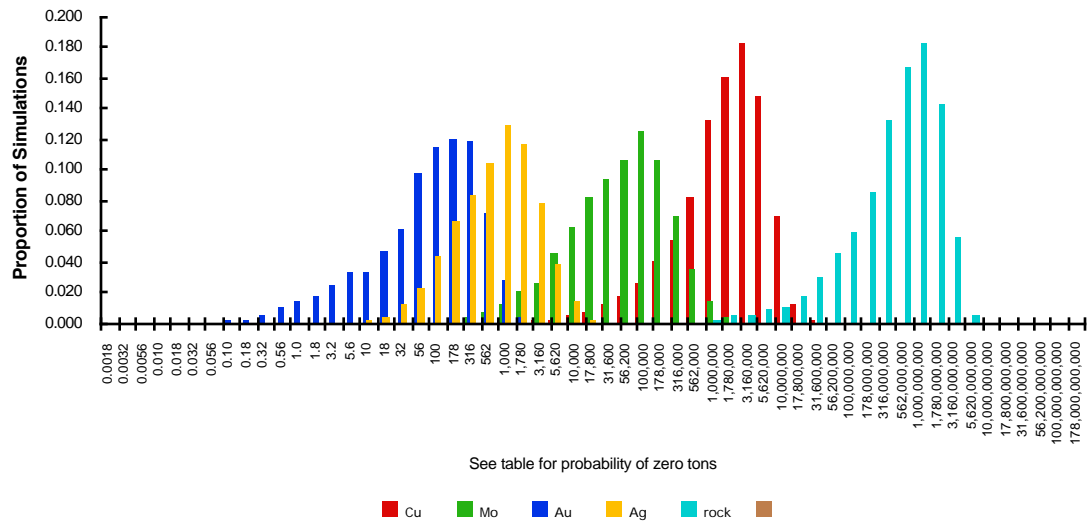
There is a 1% or greater chance of 10 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

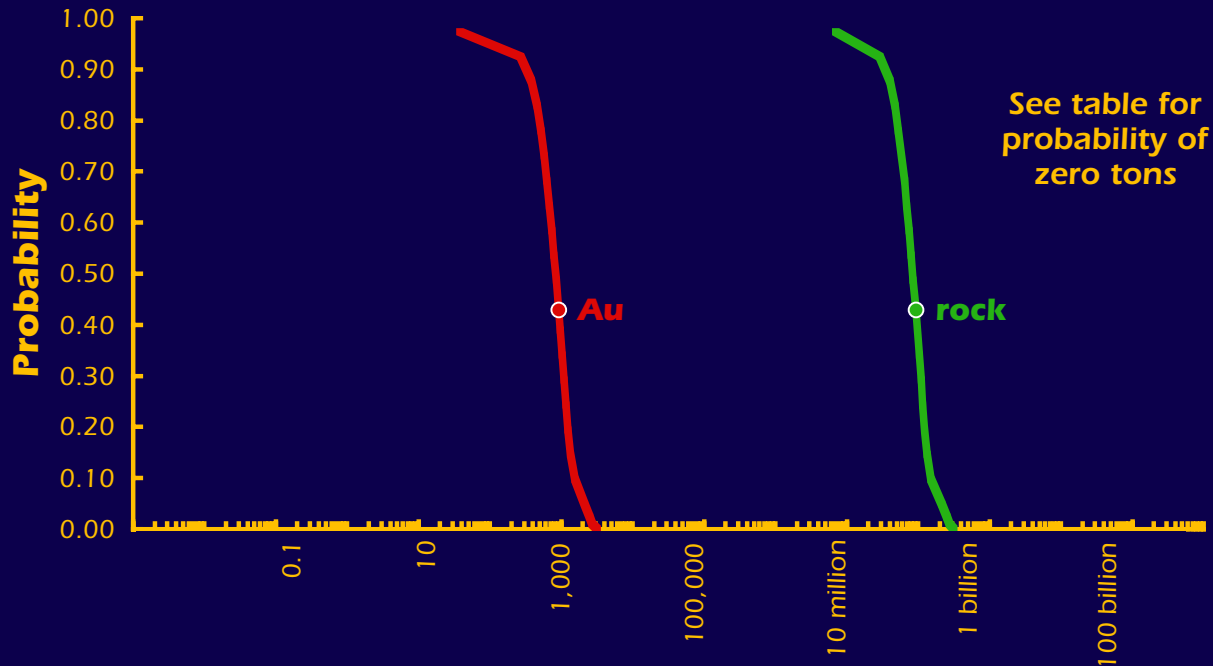
quantile	Cu	Mo	Au	Ag	rock	0
0.95	0	0	0	0	0	0
0.90	49,000	0	0	0	14,000,000	0
0.50	1,300,000	24,000	42	270	380,000,000	0
0.10	5,100,000	200,000	312	2,200	1,400,000,000	0
0.05	6,800,000	310,000	460	3,200	1,800,000,000	0
mean	2,100,000	73,000	110	770	580,000,000	0
Probability of mean	0.36	0.29	0.32	0.31	0.37	0.00
Probability of zero	0.07	0.21	0.22	0.30	0.07	0.00

The tract ID is AK-SW12

Cumulative Distributions of Contained Metal and Mineralized Rock

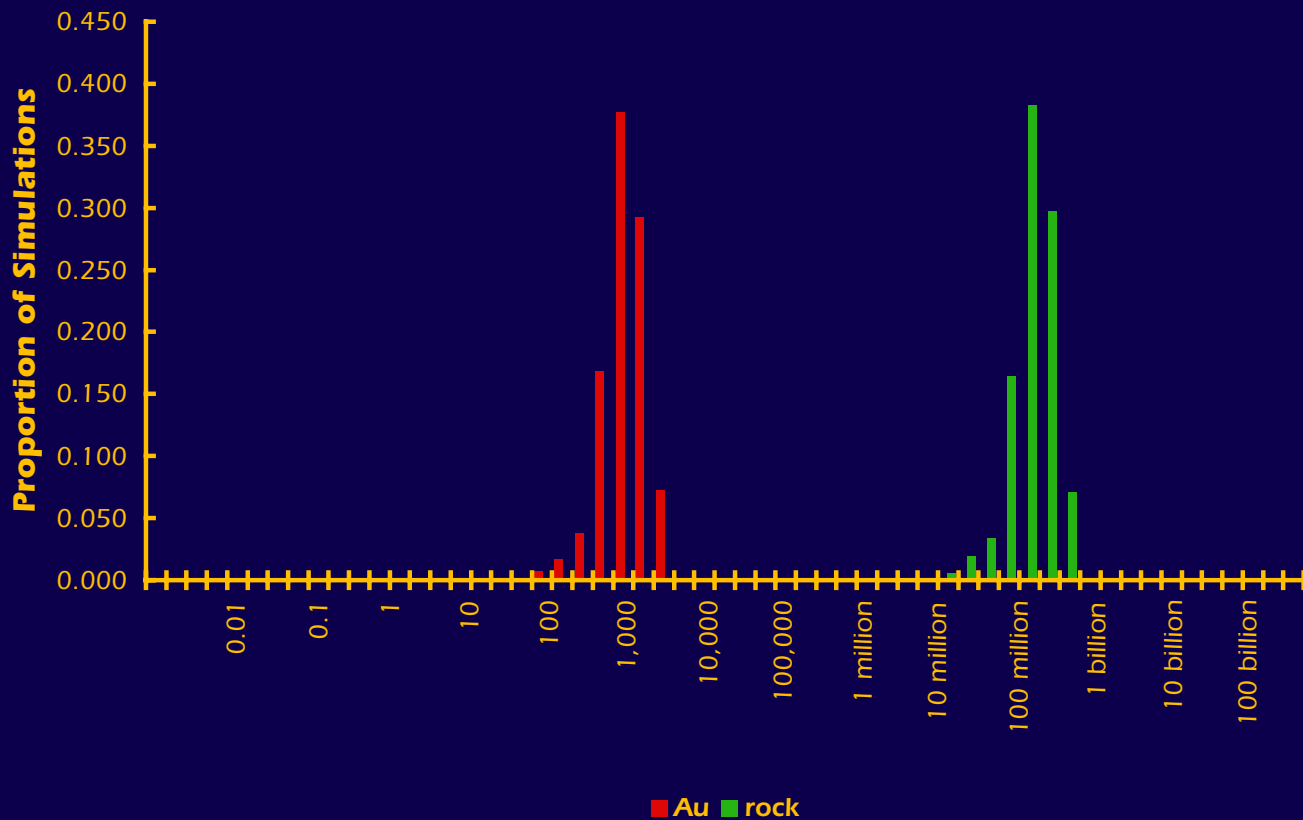
Histograms of Contained Metal and Mineralized Rock
(metric tons)

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SW13

The Mark3 Index is 121:

Plutonic porphyry gold-Chicken Mountain

There is a 90% or greater chance of 3 or more deposits.

There is a 50% or greater chance of 6 or more deposits.

There is a 10% or greater chance of 10 or more deposits.

There is a 5% or greater chance of 15 or more deposits.

There is a 1% or greater chance of 20 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	rock
0.95	170	18,000,000
0.90	340	35,000,000
0.50	830	84,000,000
0.10	1,500	150,000,000
0.05	2,100	210,000,000
mean	910	92,000,000
Probability of mean	0.43	0.43
Probability of zero	0.03	0.03

The tract ID is AK-SW13The Mark3 Index is 121: **Plutonic porphyry gold-Chicken Mountain**

There is a 90% or greater chance of 3 or more deposits.

There is a 50% or greater chance of 6 or more deposits.

There is a 10% or greater chance of 10 or more deposits.

There is a 5% or greater chance of 15 or more deposits.

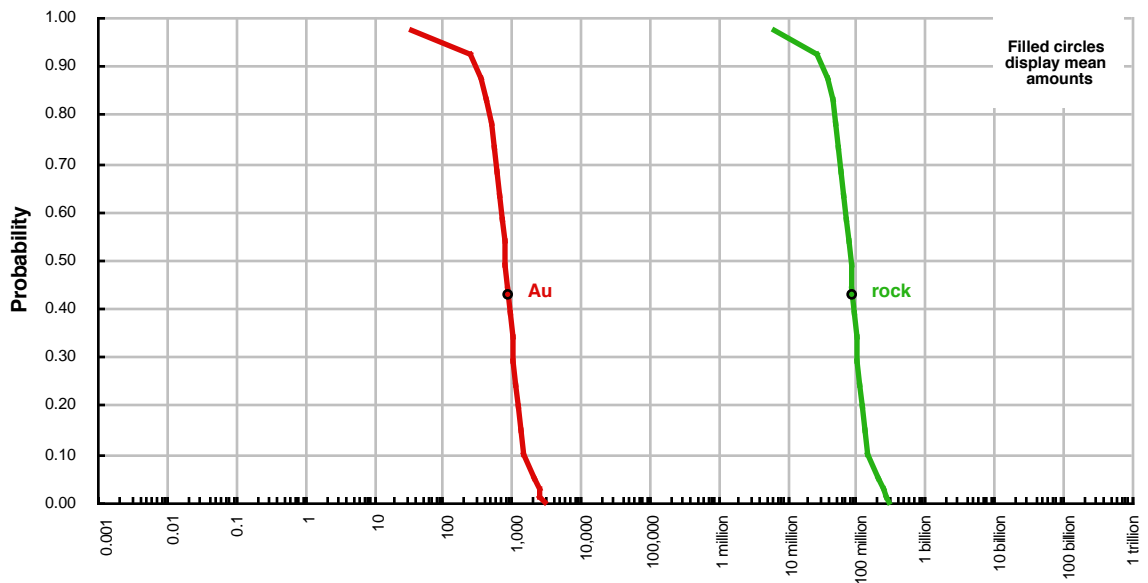
There is a 1% or greater chance of 20 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

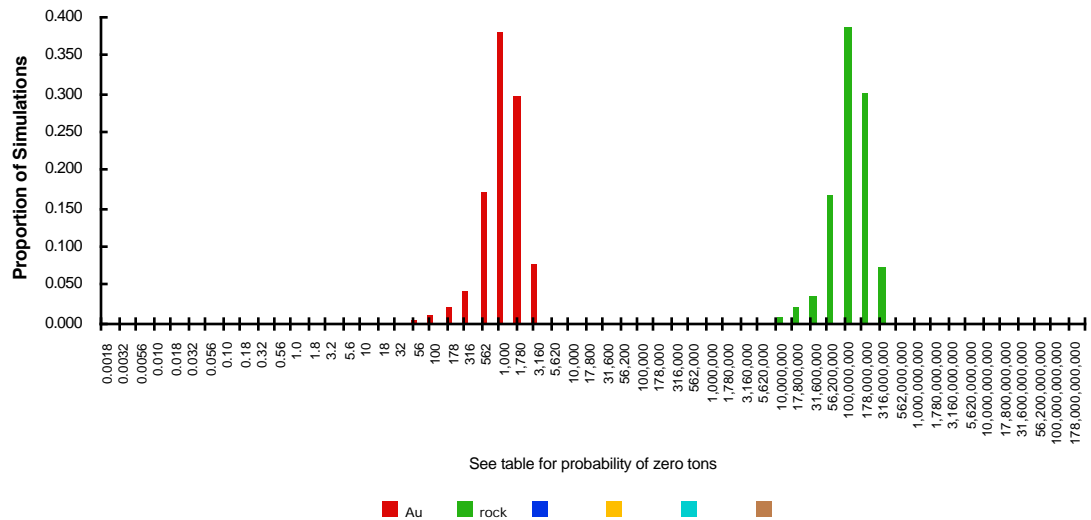
quantile	Au	rock	0	0	0	0
0.95	170	18,000,000	0	0	0	0
0.90	340	35,000,000	0	0	0	0
0.50	830	84,000,000	0	0	0	0
0.10	1,500	150,000,000	0	0	0	0
0.05	2,100	210,000,000	0	0	0	0
mean	910	92,000,000	0	0	0	0
Probability of mean	0.43	0.43	0.00	0.00	0.00	0.00
Probability of zero	0.03	0.03	0.00	0.00	0.00	0.00

The tract ID is AK-SW13

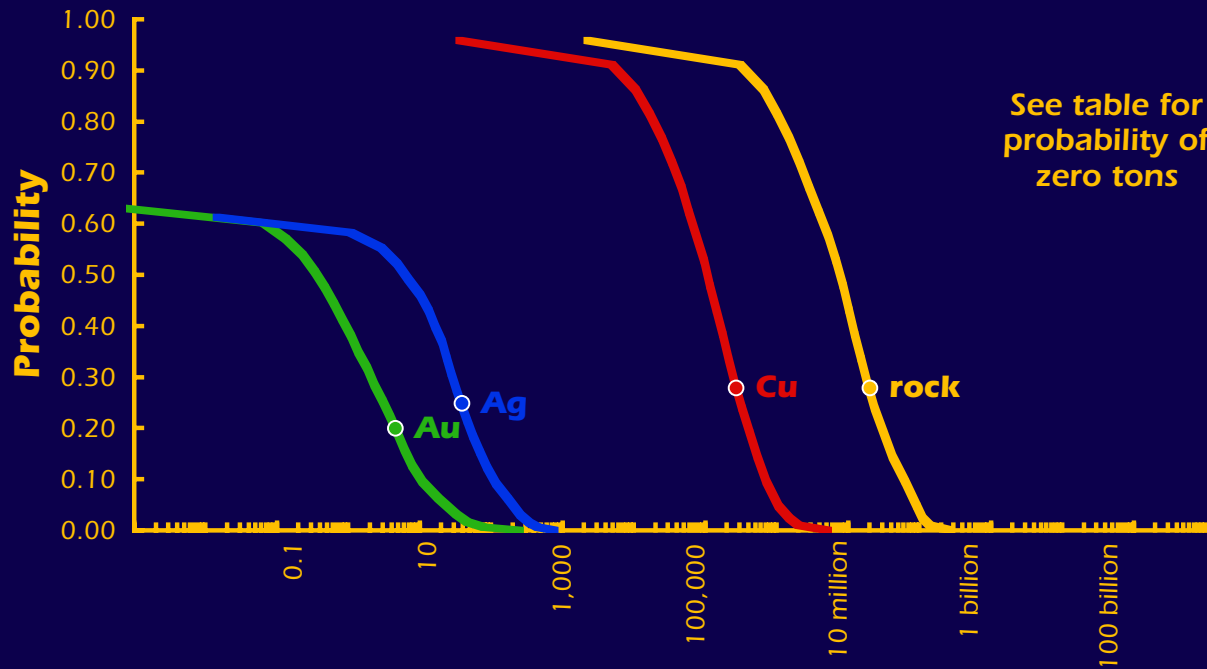
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

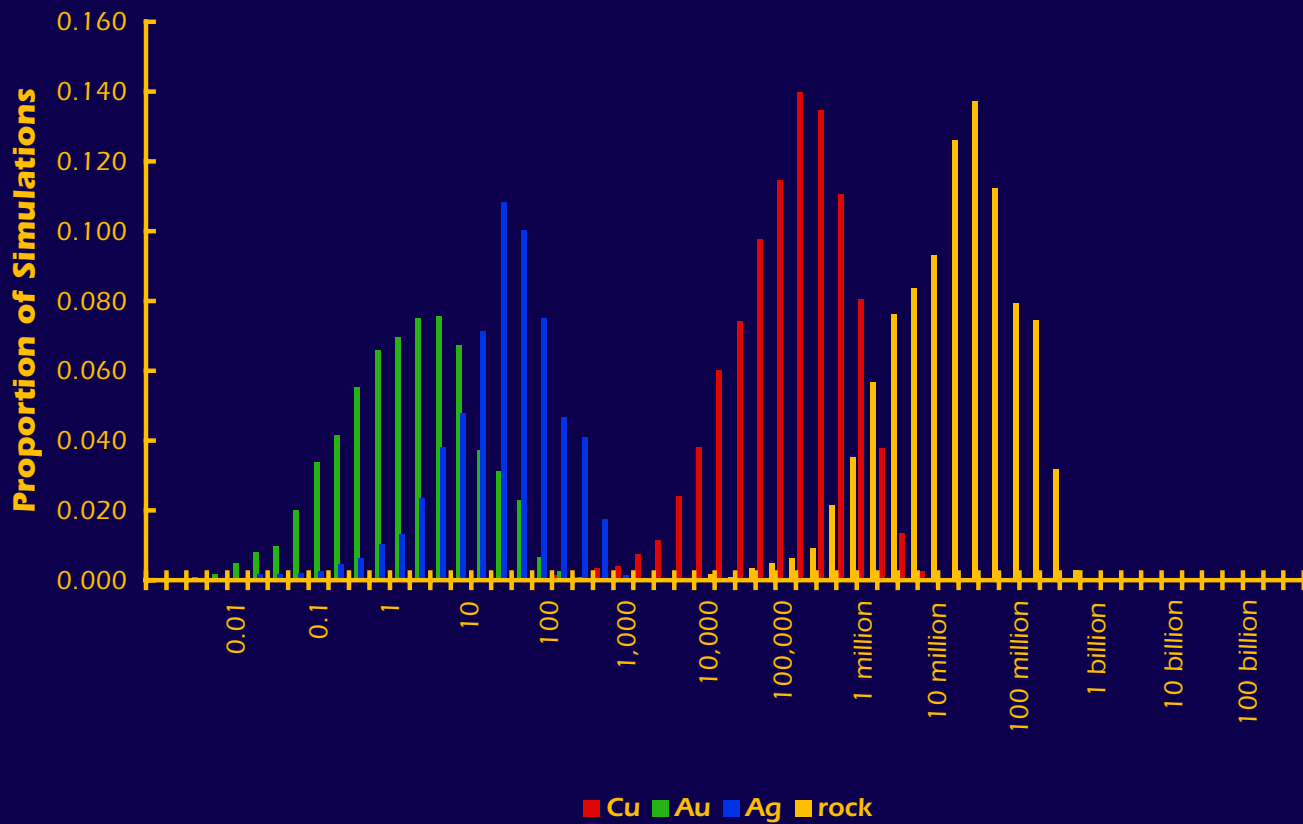


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SW17

The Mark3 Index is 8:

Skarn Cu

There is a 90% or greater chance of 2 or more deposits.
There is a 50% or greater chance of 3 or more deposits.
There is a 10% or greater chance of 8 or more deposits.
There is a 5% or greater chance of 12 or more deposits.
There is a 1% or greater chance of 24 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Ag	rock
0.95	790	0	0	39,000
0.90	6,100	0	0	380,000
0.50	110,000	0	6	7,700,000
0.10	700,000	10	107	62,000,000
0.05	1,100,000	23	200	90,000,000
mean	260,000	4	38	20,000,000
Probability of mean	0.28	0.20	0.25	0.28
Probability of zero	0.04	0.37	0.39	0.04

The tract ID is AK-SW17The Mark3 Index is 8: **Skarn Cu**

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 8 or more deposits.

There is a 5% or greater chance of 12 or more deposits.

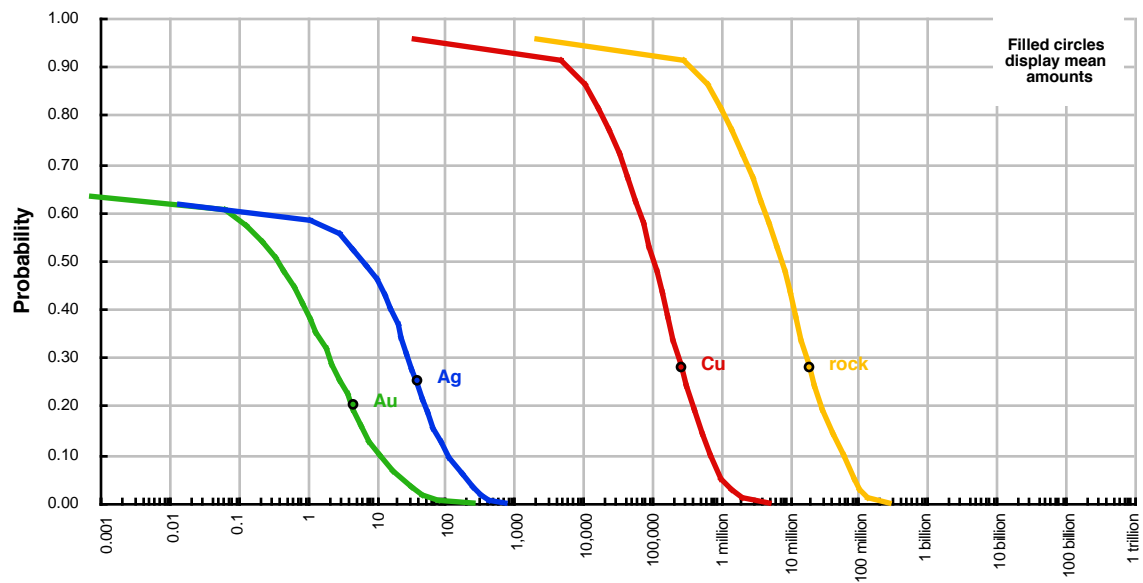
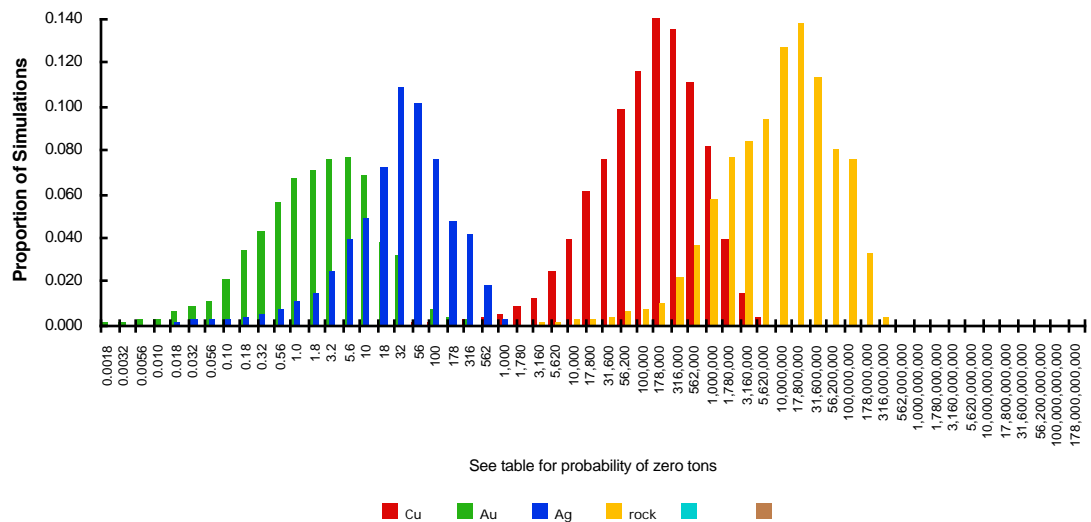
There is a 1% or greater chance of 24 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

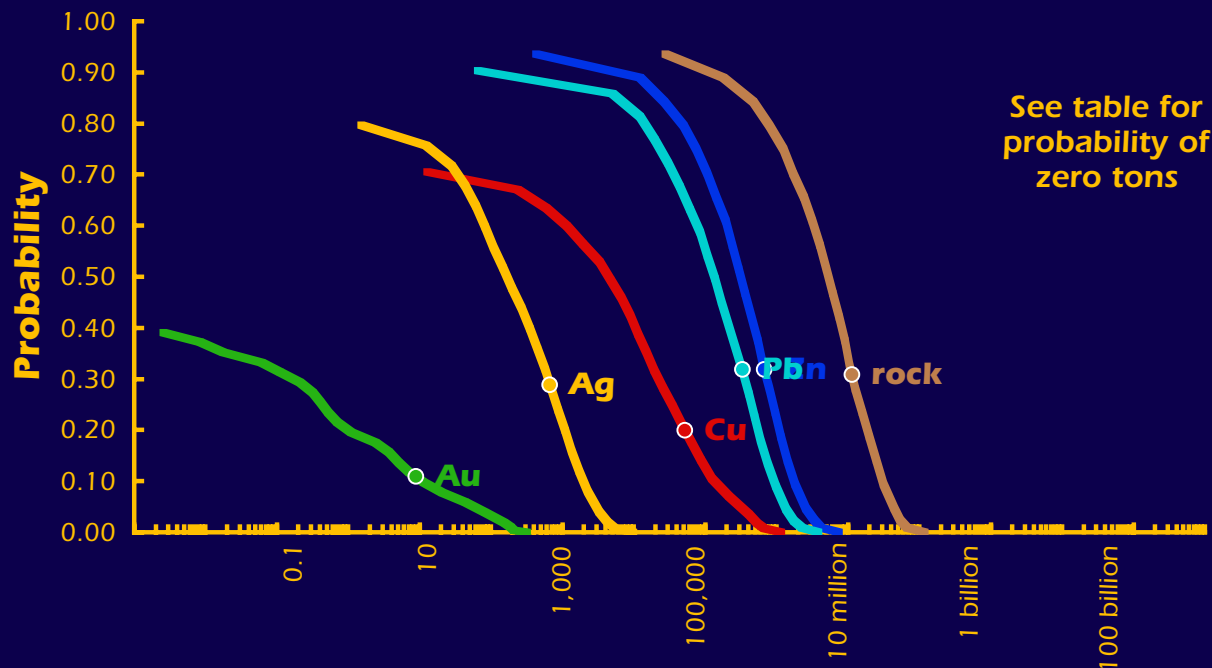
quantile	Cu	Au	Ag	rock	0	0
0.95	790	0	0	39,000	0	0
0.90	6,100	0	0	380,000	0	0
0.50	110,000	0	6	7,700,000	0	0
0.10	700,000	10	107	62,000,000	0	0
0.05	1,100,000	23	200	90,000,000	0	0
mean	260,000	4	38	20,000,000	0	0
Probability of mean	0.28	0.20	0.25	0.28	0.00	0.00
Probability of zero	0.04	0.37	0.39	0.04	0.00	0.00

The tract ID is AK-SW17

Cumulative Distributions of Contained Metal and Mineralized Rock

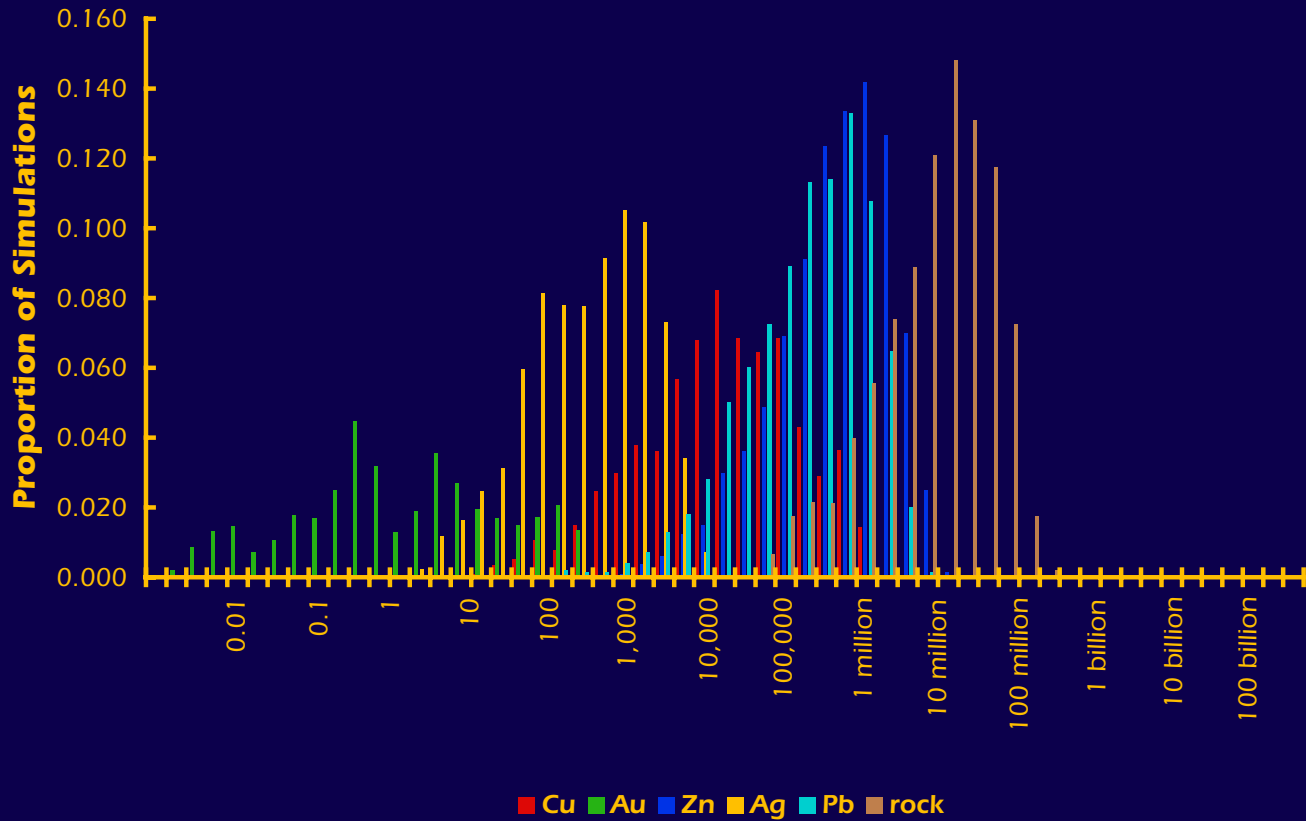
Histograms of Contained Metal and Mineralized Rock
(metric tons)

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SW18

The Mark3 Index is 22:

Skarn Zn-Pb

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

There is a 1% or greater chance of 12 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	9,400	0	270	140,000
0.50	4,500	0	320,000	170	140,000	5,300,000
0.10	130,000	11	1,740,000	1,900	920,000	30,000,000
0.05	330,000	60	2,400,000	2,900	1,300,000	44,000,000
mean	51,000	9	660,000	660	330,000	11,000,000
Probability of mean	0.20	0.11	0.32	0.29	0.32	0.31
Probability of zero	0.29	0.61	0.06	0.20	0.10	0.06

The tract ID is AK-SW18The Mark3 Index is 22: **Skarn Zn-Pb**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

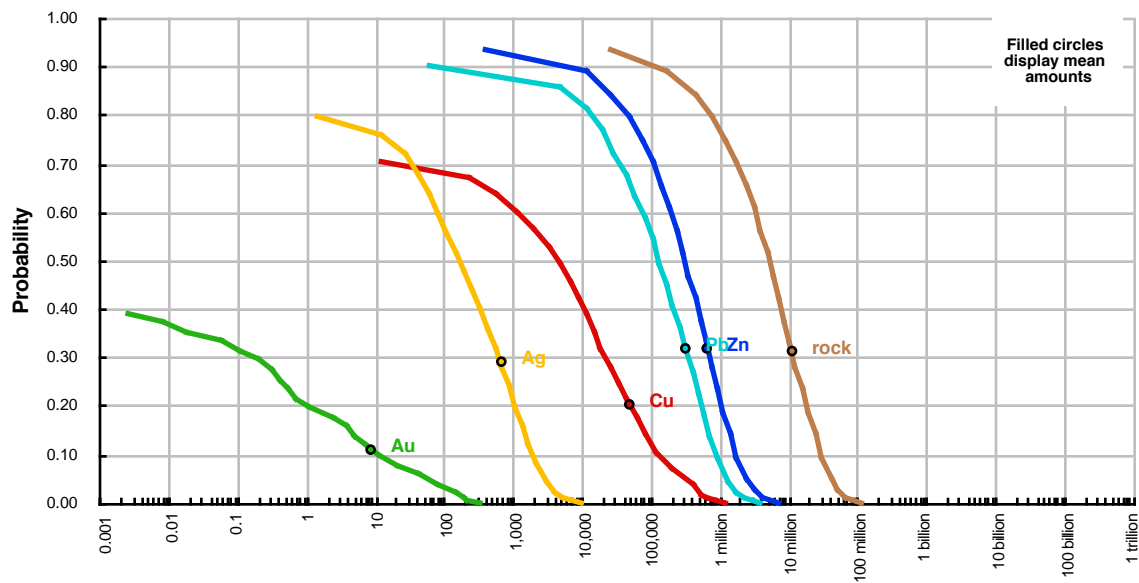
There is a 1% or greater chance of 12 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

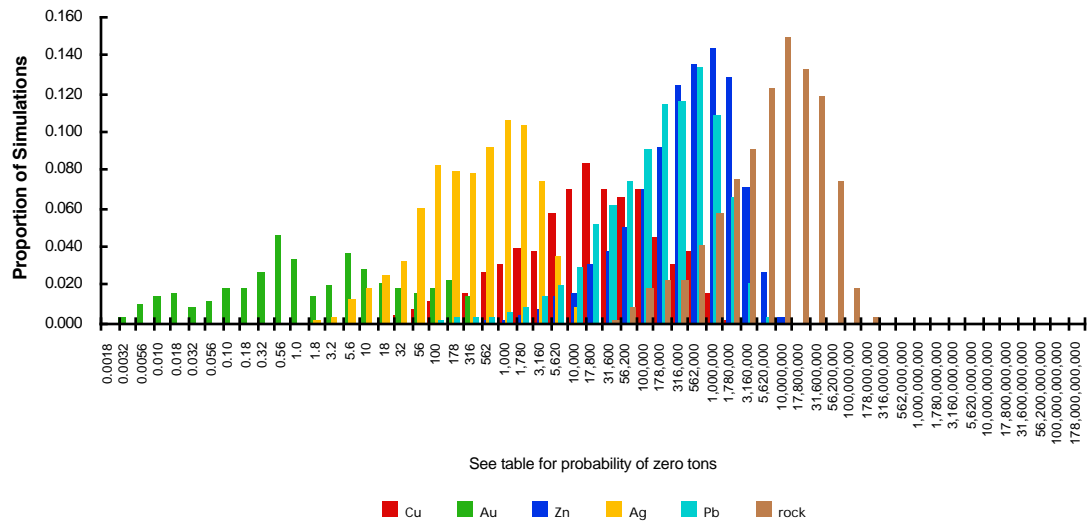
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	9,400	0	270	140,000
0.50	4,500	0	320,000	170	140,000	5,300,000
0.10	130,000	11	1,740,000	1,900	920,000	30,000,000
0.05	330,000	60	2,400,000	2,900	1,300,000	44,000,000
mean	51,000	9	660,000	660	330,000	11,000,000
Probability of mean	0.20	0.11	0.32	0.29	0.32	0.31
Probability of zero	0.29	0.61	0.06	0.20	0.10	0.06

The tract ID is AK-SW18

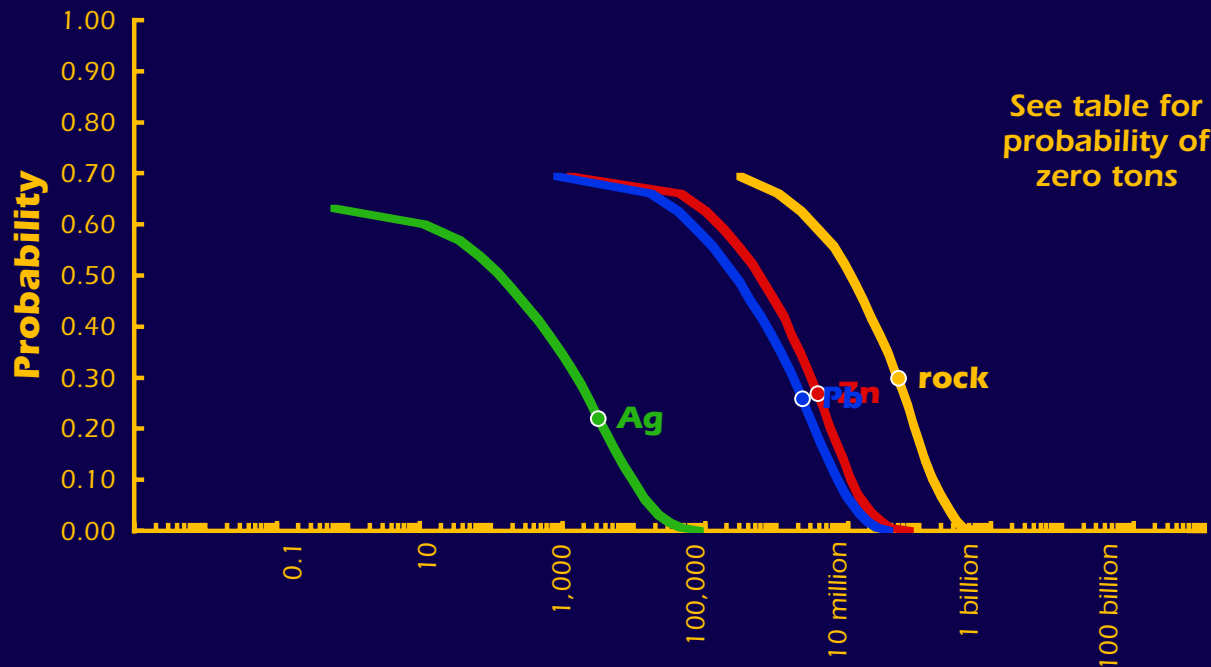
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)



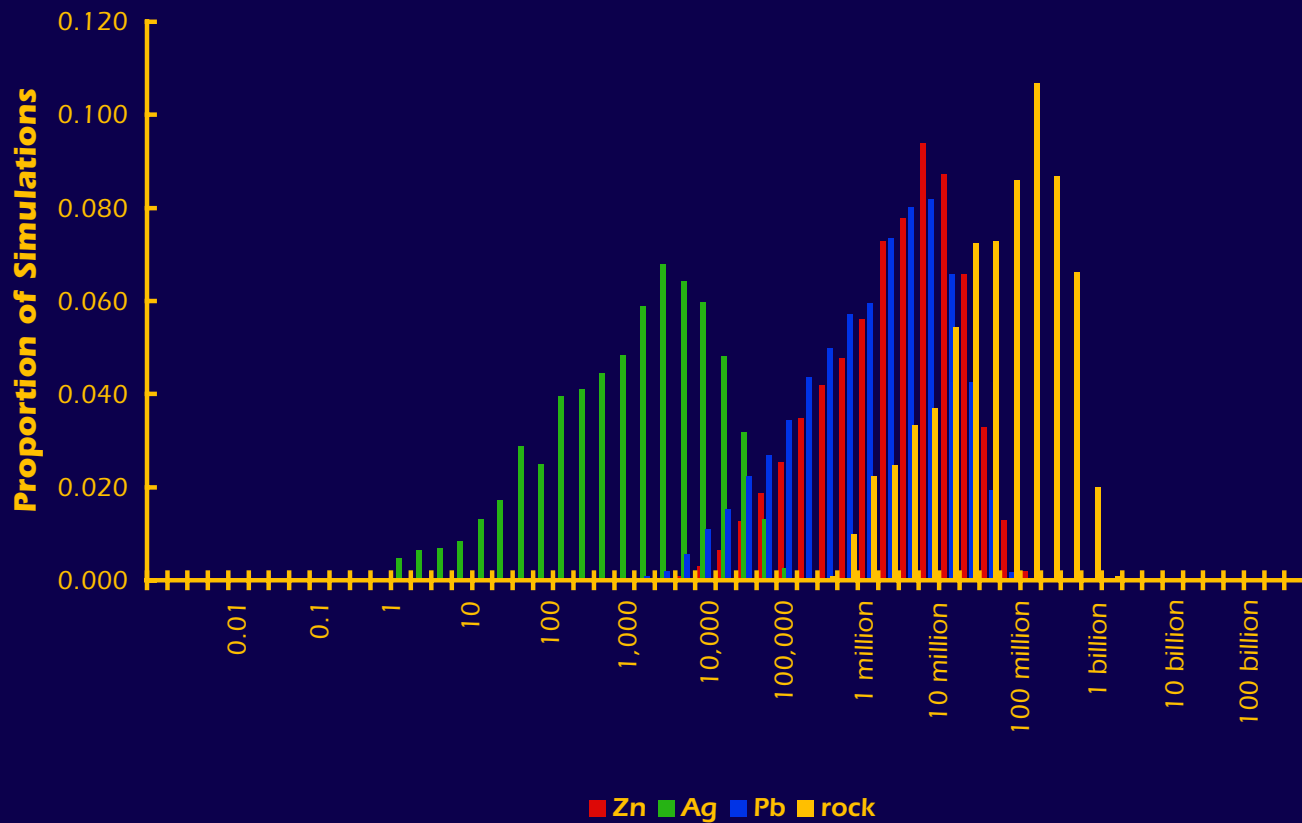
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



See table for
probability of
zero tons

Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SW19

The Mark3 Index is 13:

Sedimentary exhalative Zn-Pb

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Zn	Ag	Pb	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	570,000	140	260,000	11,000,000
0.10	11,000,000	9,500	7,210,000	160,000,000
0.05	17,000,000	17,000	11,000,000	250,000,000
mean	3,700,000	3,100	2,300,000	51,000,000
Probability of mean	0.27	0.22	0.26	0.30
Probability of zero	0.31	0.37	0.31	0.31

The tract ID is AK-SW19The Mark3 Index is 13: **Sedimentary exhalative Zn-Pb**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

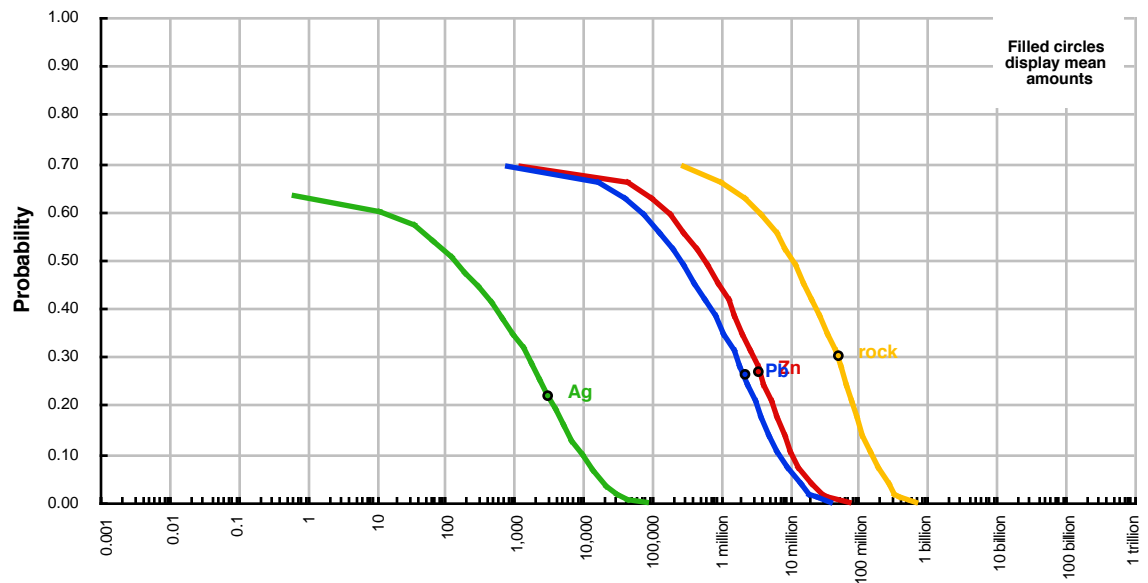
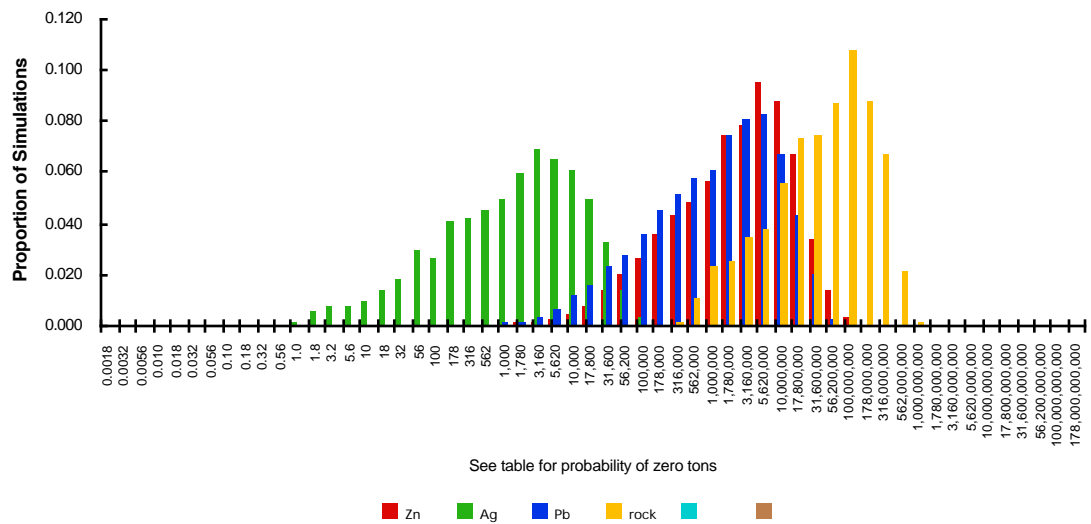
There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

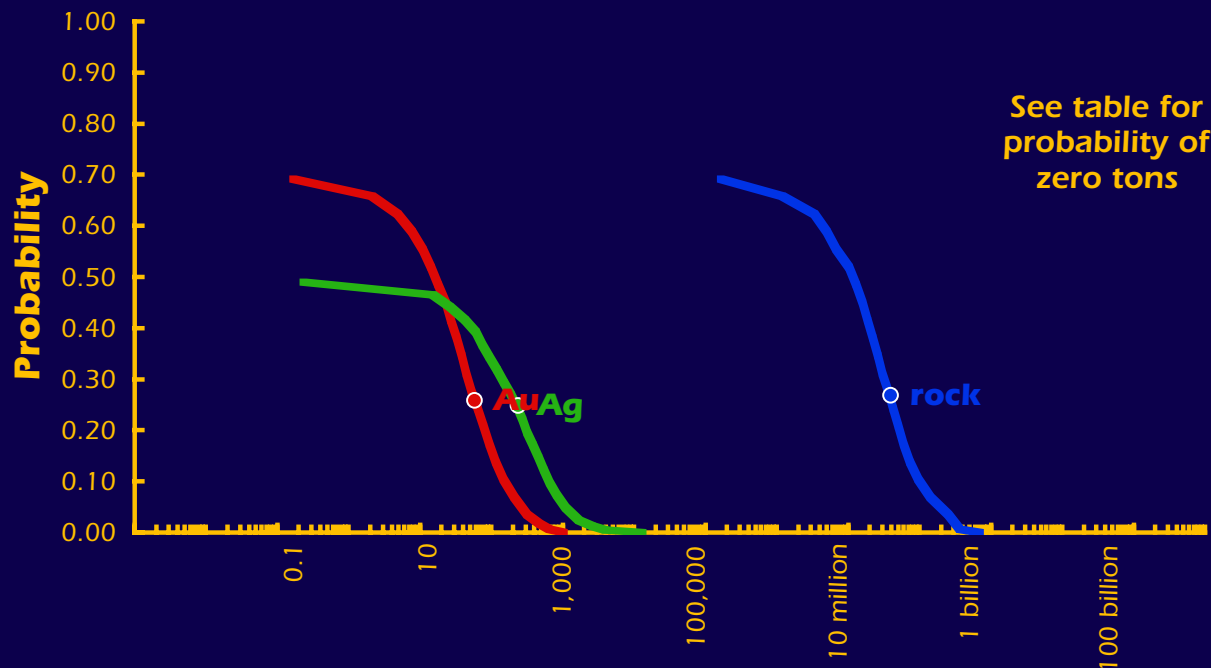
There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Zn	Ag	Pb	rock	0	0
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	570,000	140	260,000	11,000,000	0	0
0.10	11,000,000	9,500	7,210,000	160,000,000	0	0
0.05	17,000,000	17,000	11,000,000	250,000,000	0	0
mean	3,700,000	3,100	2,300,000	51,000,000	0	0
Probability of mean	0.27	0.22	0.26	0.30	0.00	0.00
Probability of zero	0.31	0.37	0.31	0.31	0.00	0.00

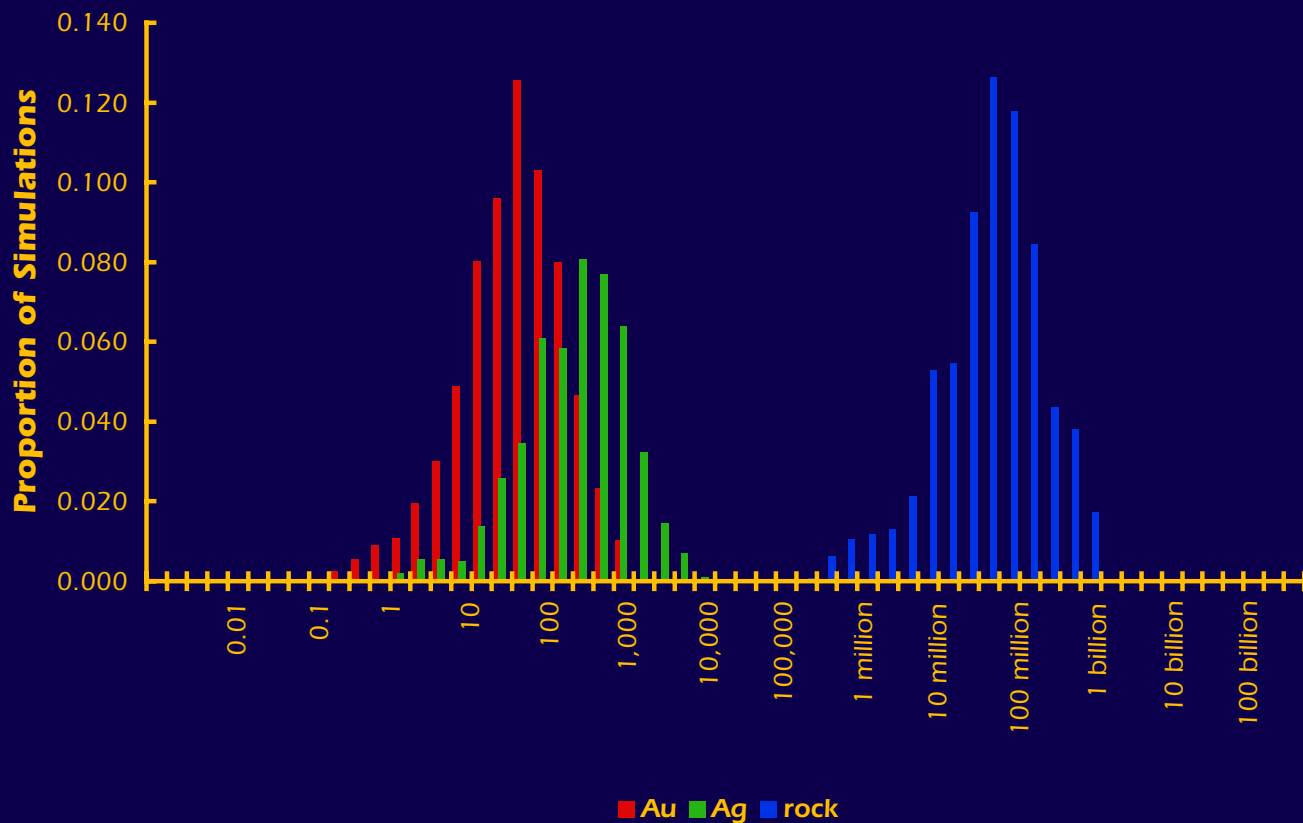
The tract ID is AK-SW19**Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-SW20

The Mark3 Index is 45:

Hot spring Au-Ag

There is a 90% or greater chance of 0 or more deposits.
There is a 50% or greater chance of 1 or more deposits.
There is a 10% or greater chance of 2 or more deposits.
There is a 5% or greater chance of 3 or more deposits.
There is a 1% or greater chance of 6 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	16	0	12,000,000
0.10	150	650	99,700,000
0.05	260	1,100	200,000,000
mean	56	230	38,000,000
Probability of mean	0.26	0.25	0.27
Probability of zero	0.31	0.51	0.31

The tract ID is AK-SW20The Mark3 Index is 45: **Hot spring Au-Ag**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

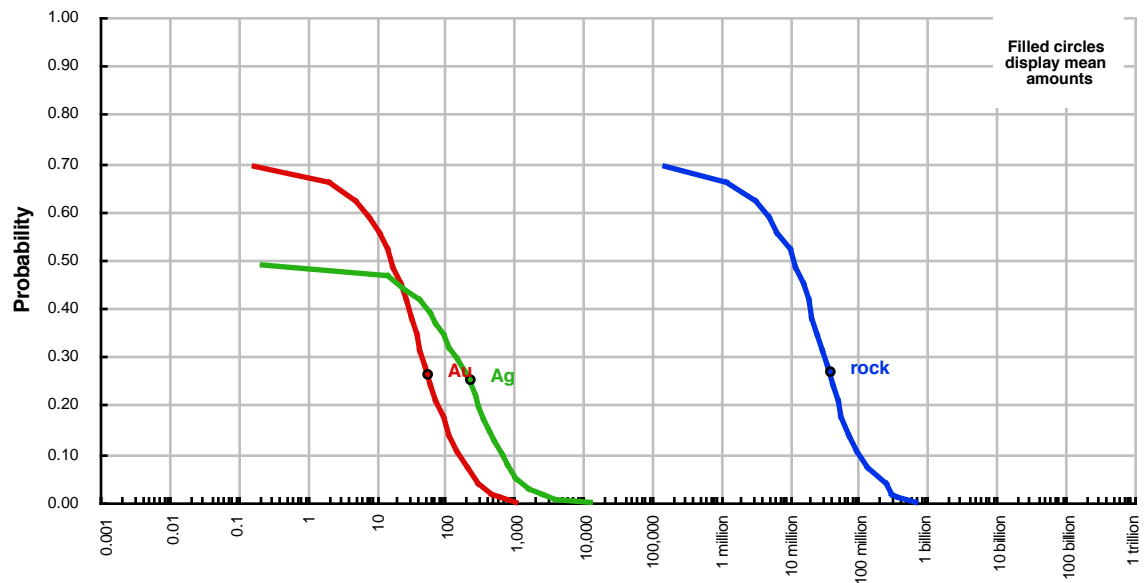
There is a 1% or greater chance of 6 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

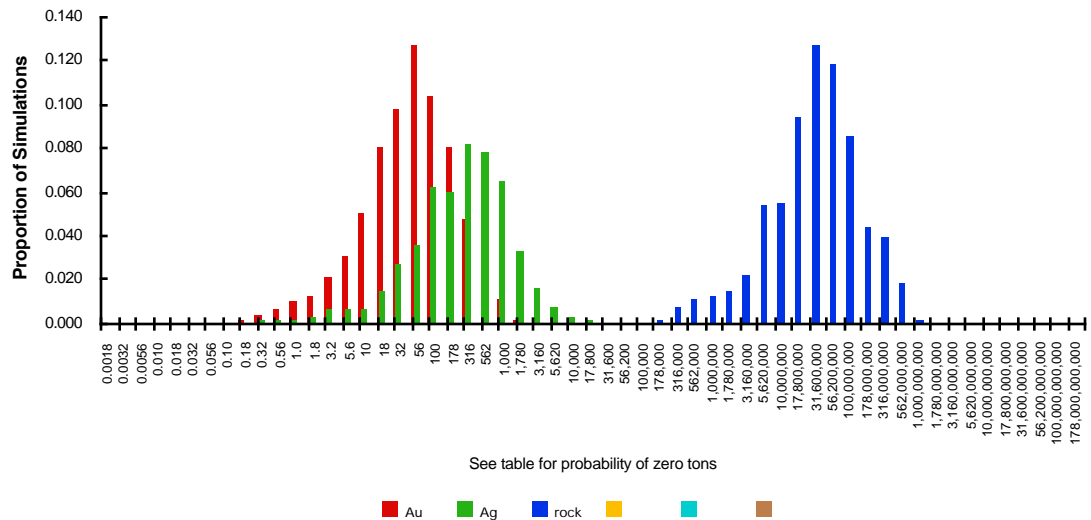
quantile	Au	Ag	rock	0	0	0
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	16	0	12,000,000	0	0	0
0.10	150	650	99,700,000	0	0	0
0.05	260	1,100	200,000,000	0	0	0
mean	56	230	38,000,000	0	0	0
Probability of mean	0.26	0.25	0.27	0.00	0.00	0.00
Probability of zero	0.31	0.51	0.31	0.00	0.00	0.00

The tract ID is AK-SW20

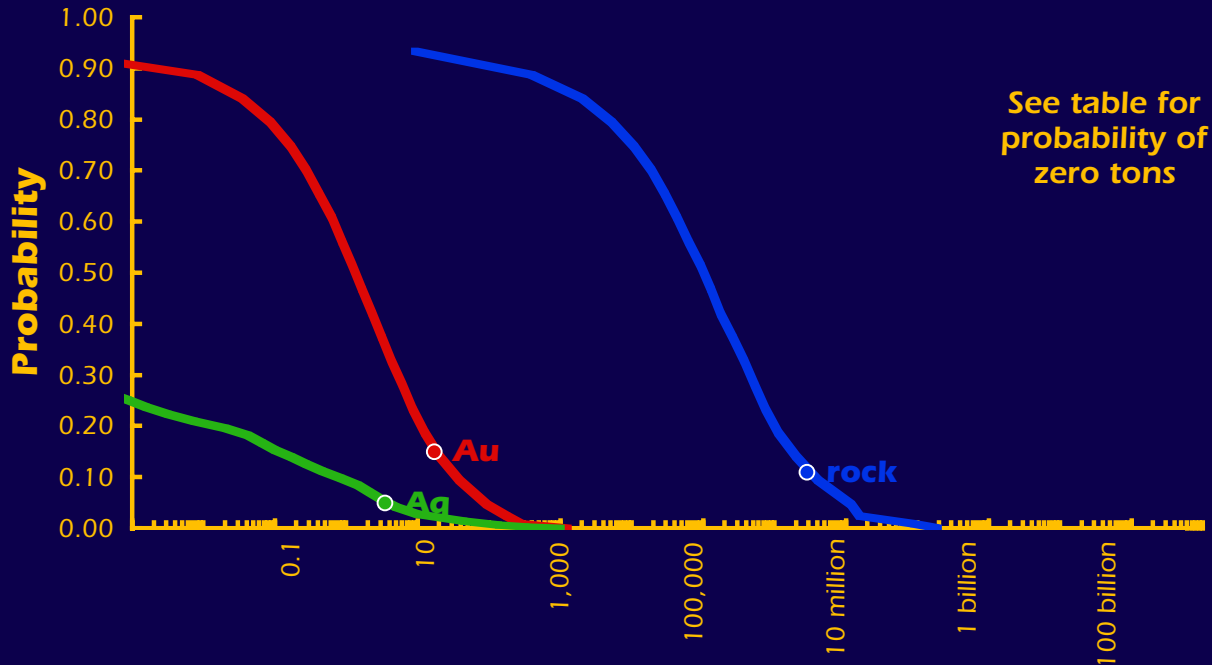
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

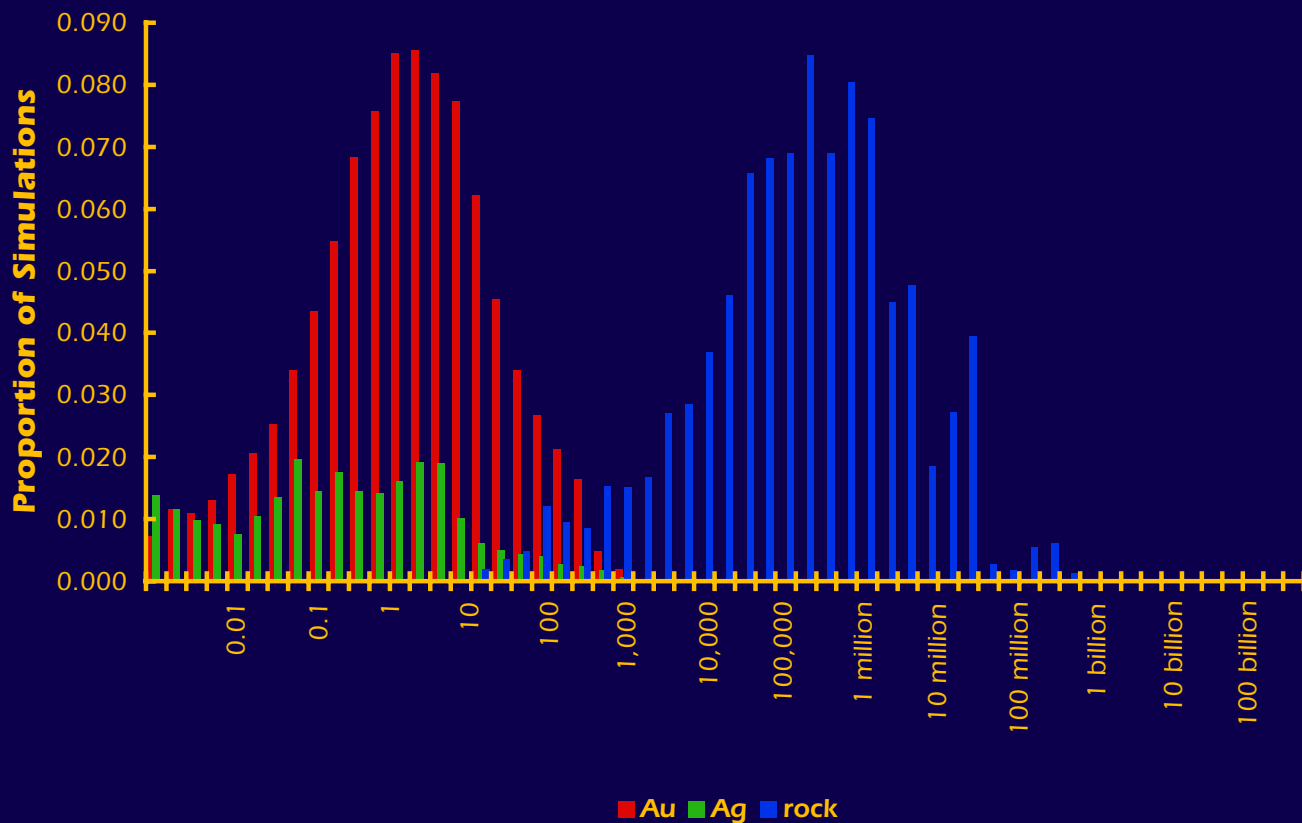


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AK-WC09

The Mark3 Index is 27:

Low sulfide Au-quartz vein

There is a 90% or greater chance of 1 or more deposits.
There is a 50% or greater chance of 2 or more deposits.
There is a 10% or greater chance of 3 or more deposits.
There is a 5% or greater chance of 5 or more deposits.
There is a 1% or greater chance of 10 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	190
0.50	1	0	100,000
0.10	35	1	3,430,000
0.05	87	4	11,000,000
mean	17	3	2,800,000
Probability of mean	0.15	0.05	0.11
Probability of zero	0.07	0.72	0.07

The tract ID is AK-WC09The Mark3 Index is 27: **Low sulfide Au-quartz vein**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

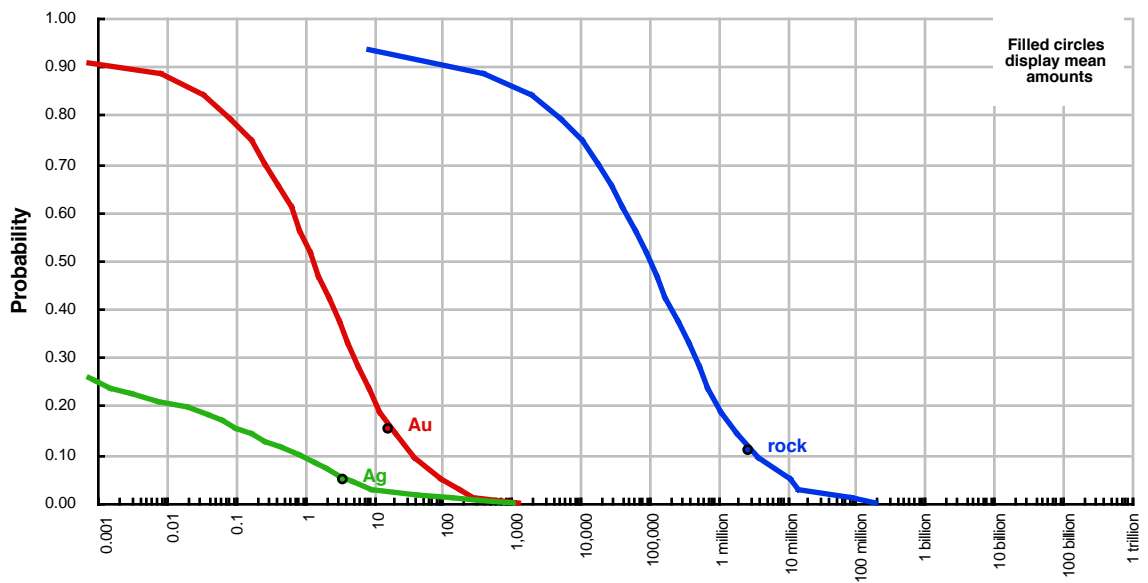
There is a 1% or greater chance of 10 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

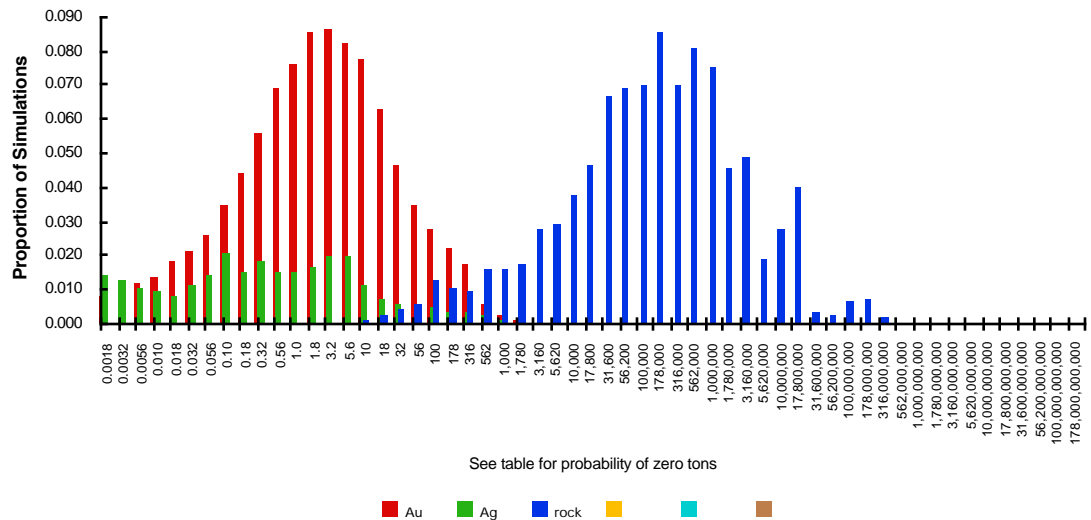
quantile	Au	Ag	rock	0	0	0
0.95	0	0	0	0	0	0
0.90	0	0	190	0	0	0
0.50	1	0	100,000	0	0	0
0.10	35	1	3,430,000	0	0	0
0.05	87	4	11,000,000	0	0	0
mean	17	3	2,800,000	0	0	0
Probability of mean	0.15	0.05	0.11	0.00	0.00	0.00
Probability of zero	0.07	0.72	0.07	0.00	0.00	0.00

The tract ID is AK-WC09

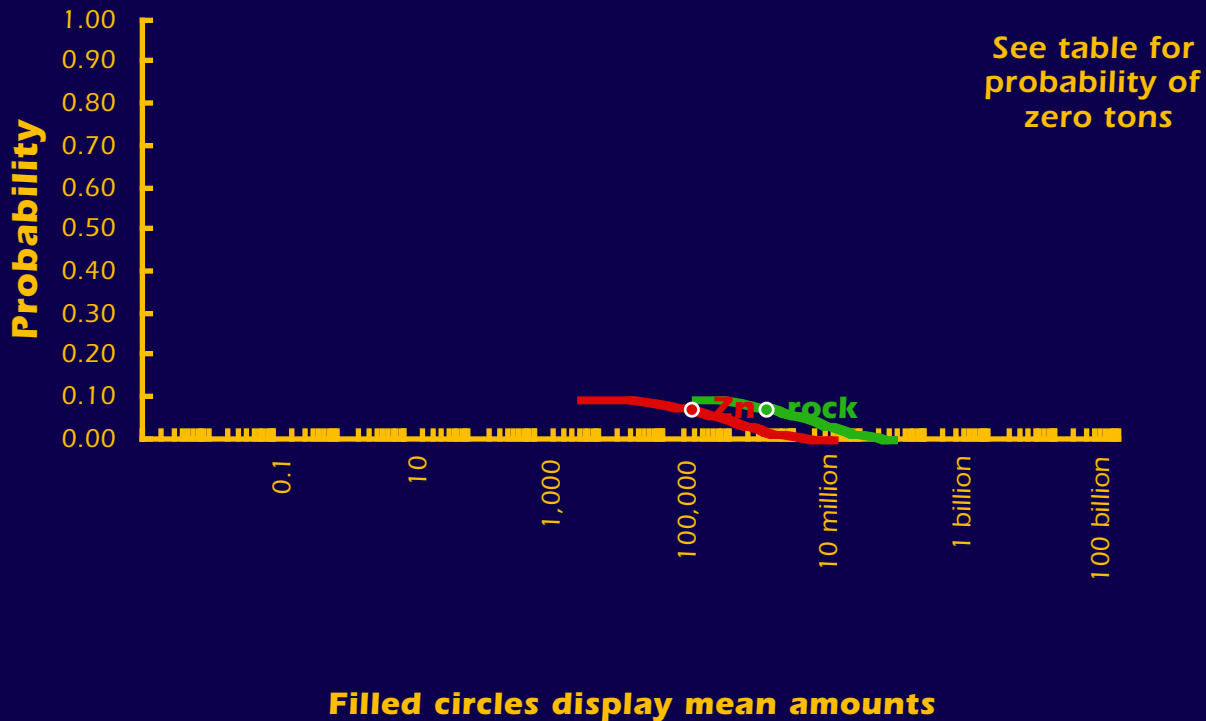
Cumulative Distributions of Contained Metal and Mineralized Rock



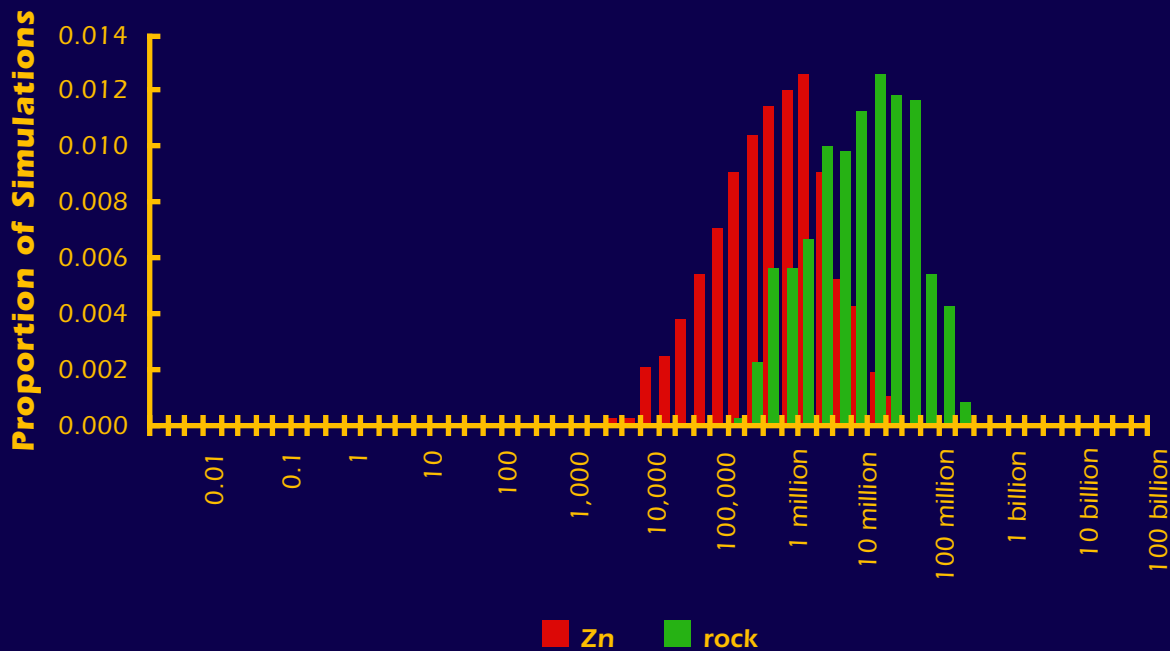
Histograms of Contained Metal and Mineralized Rock (metric tons)



Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AD02

The Mark3 Index is 106:

Sedimentary exhalative Zn

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Zn	rock
0.95	0	0
0.90	0	0
0.50	0	0
0.10	0	0
0.05	770,000	14,000,000
mean	270,000	3,900,000
Probability of mean	0.07	0.07
Probability of zero	0.90	0.90

The tract ID is AD02The Mark3 Index is 106: **Sedimentary exhalative Zn**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

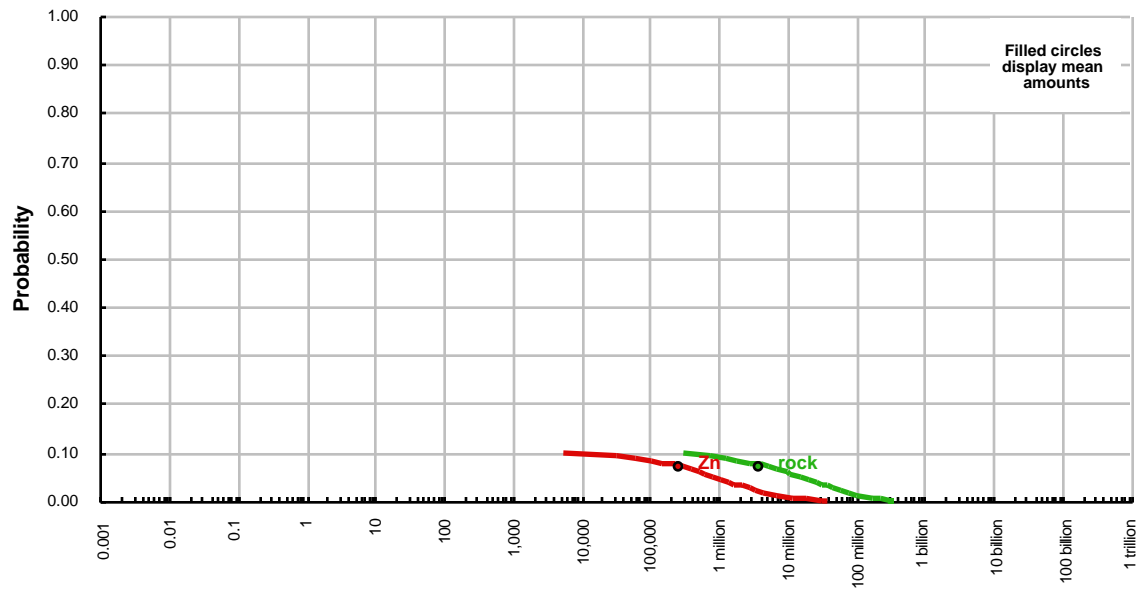
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

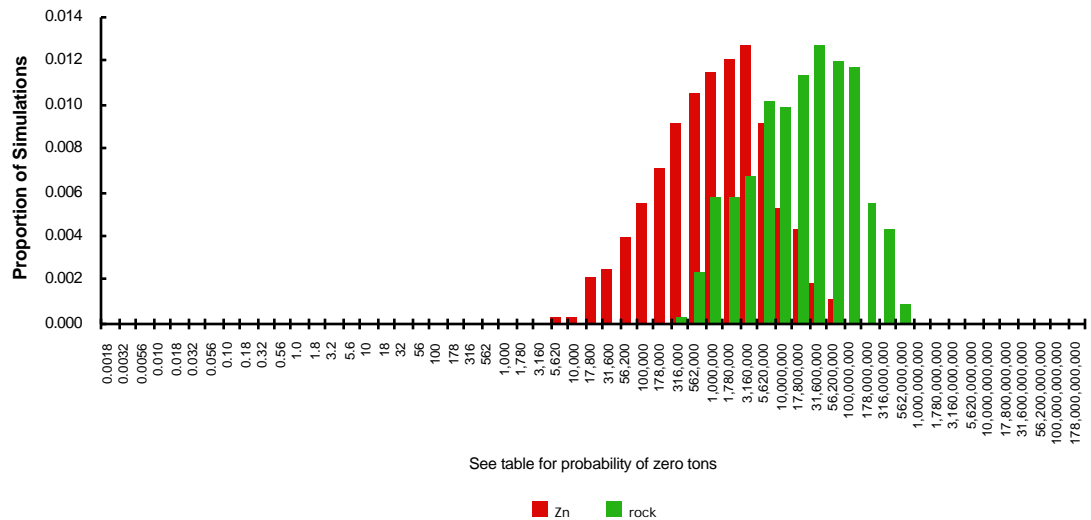
quantile	Zn	rock
0.95	0	0
0.90	0	0
0.50	0	0
0.10	0	0
0.05	770,000	14,000,000
mean	270,000	3,900,000
Probability of mean	0.07	0.07
Probability of zero	0.90	0.90

The tract ID is AD02

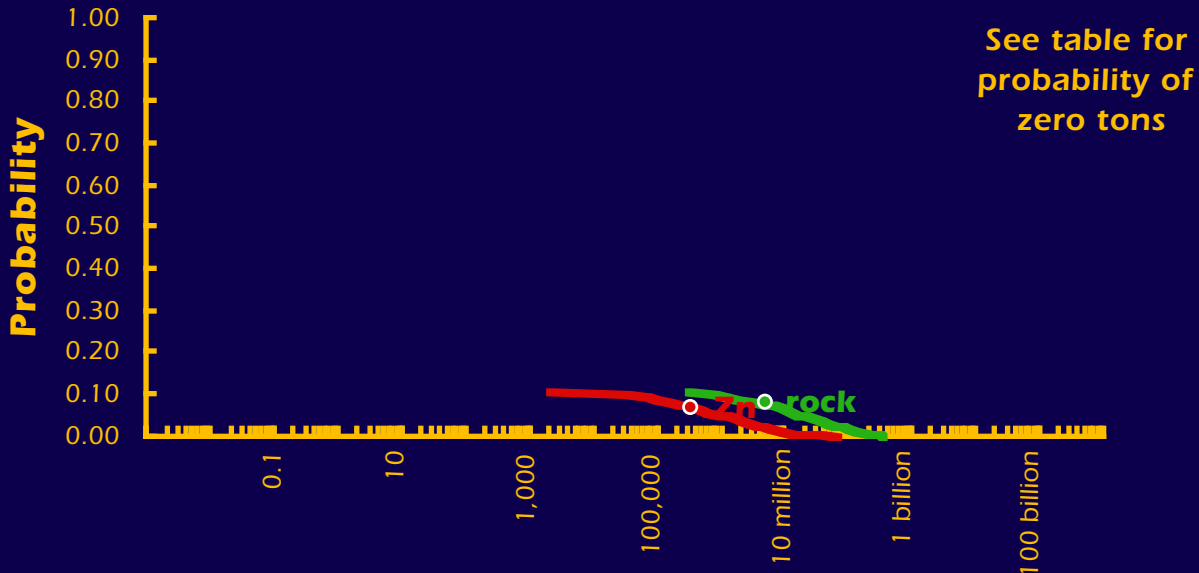
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

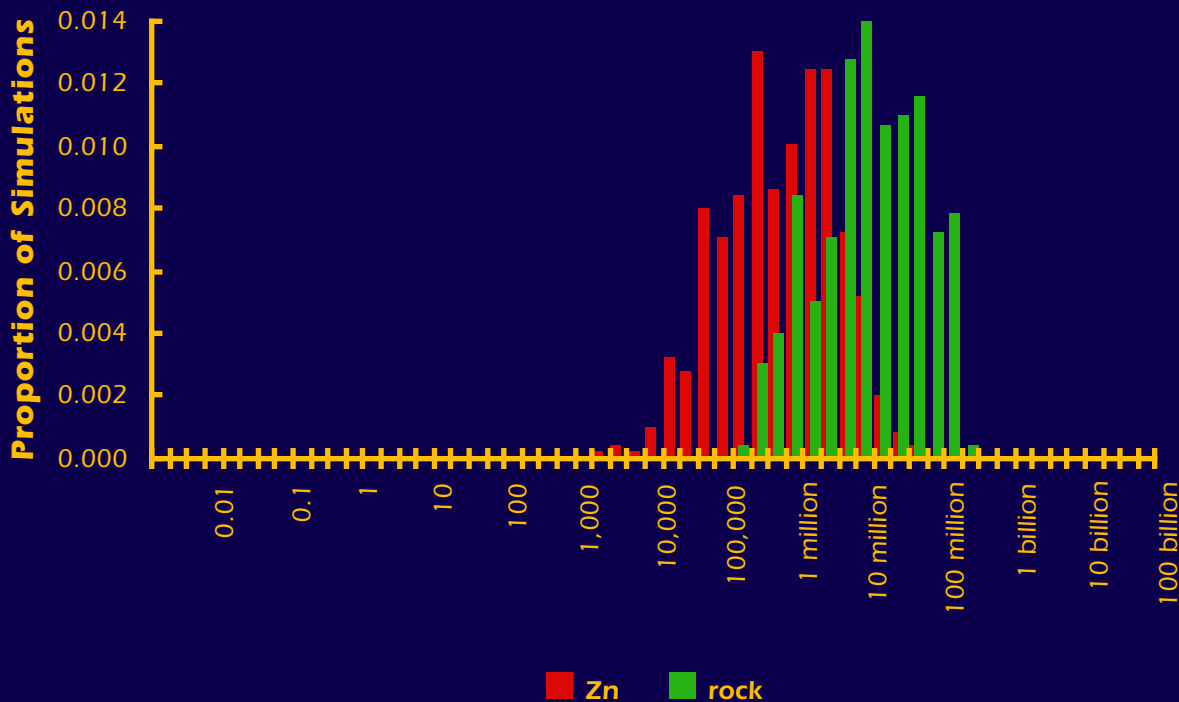


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is AD03

The Mark3 Index is 106:

Sedimentary exhalative Zn

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Zn	rock
0.95	0	0
0.90	0	0
0.50	0	0
0.10	26,000	560,000
0.05	1,100,000	17,000,000
mean	340,000	4,900,000
Probability of mean	0.00	0.00
Probability of zero	0.90	0.90

The tract ID is AD03

The Mark3 Index is 106: **Sedimentary exhalative Zn**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

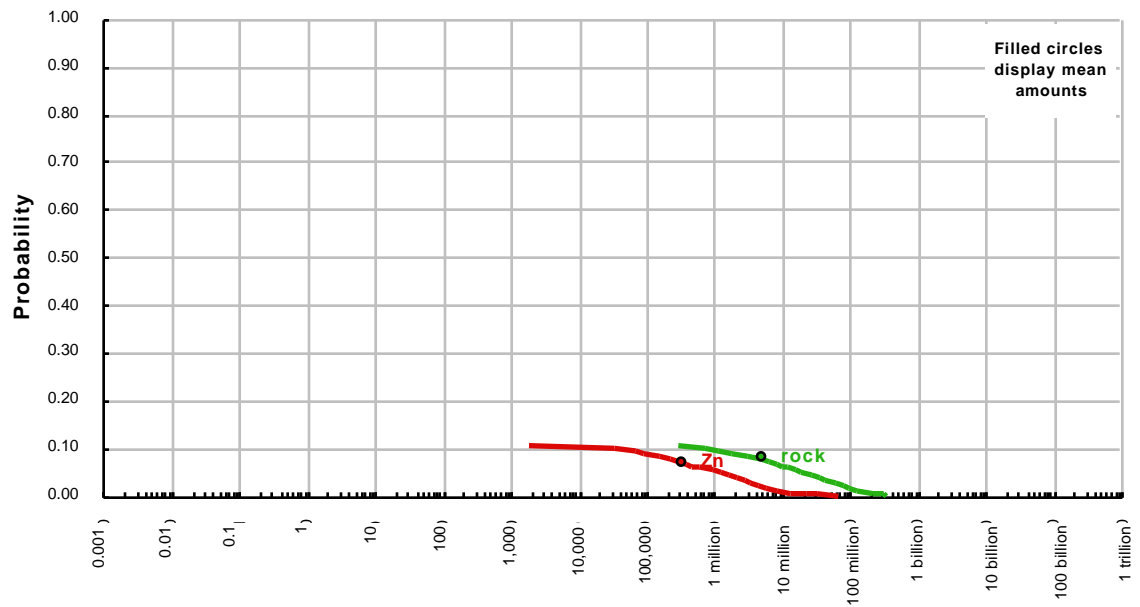
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

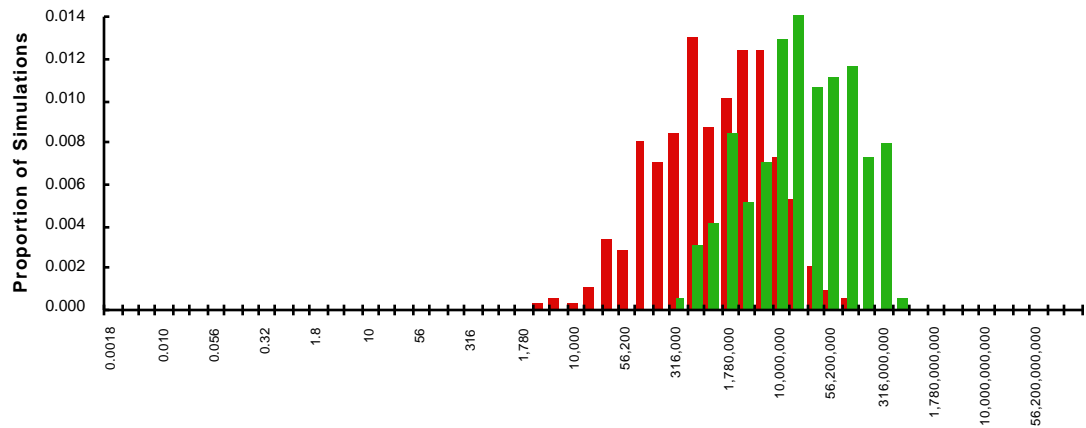
quantile	Zn	rock
0.95	0	0
0.90	0	0
0.50	0	0
0.10	26,000	560,000
0.05	1,100,000	17,000,000
mean	340,000	4,900,000
Probability of mean	0.07	0.08
Probability of zero	0.90	0.90

The tract ID is AD03

Cumulative Distributions of Contained Metal and Mineralized Rock



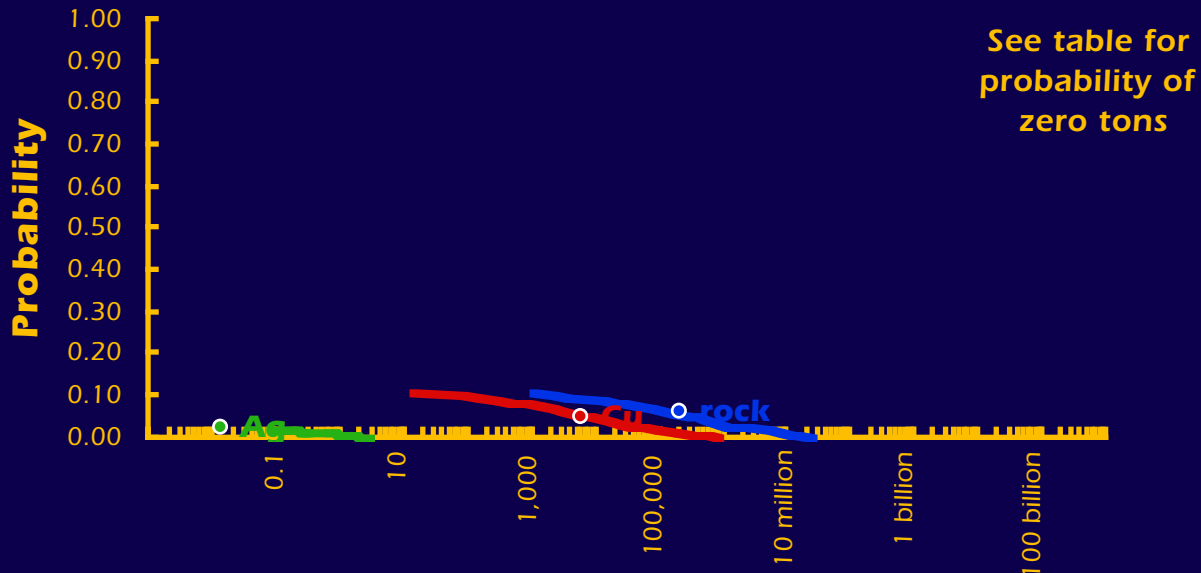
Histograms of Contained Metal and Mineralized Rock (metric tons)



See table for probability of zero tons

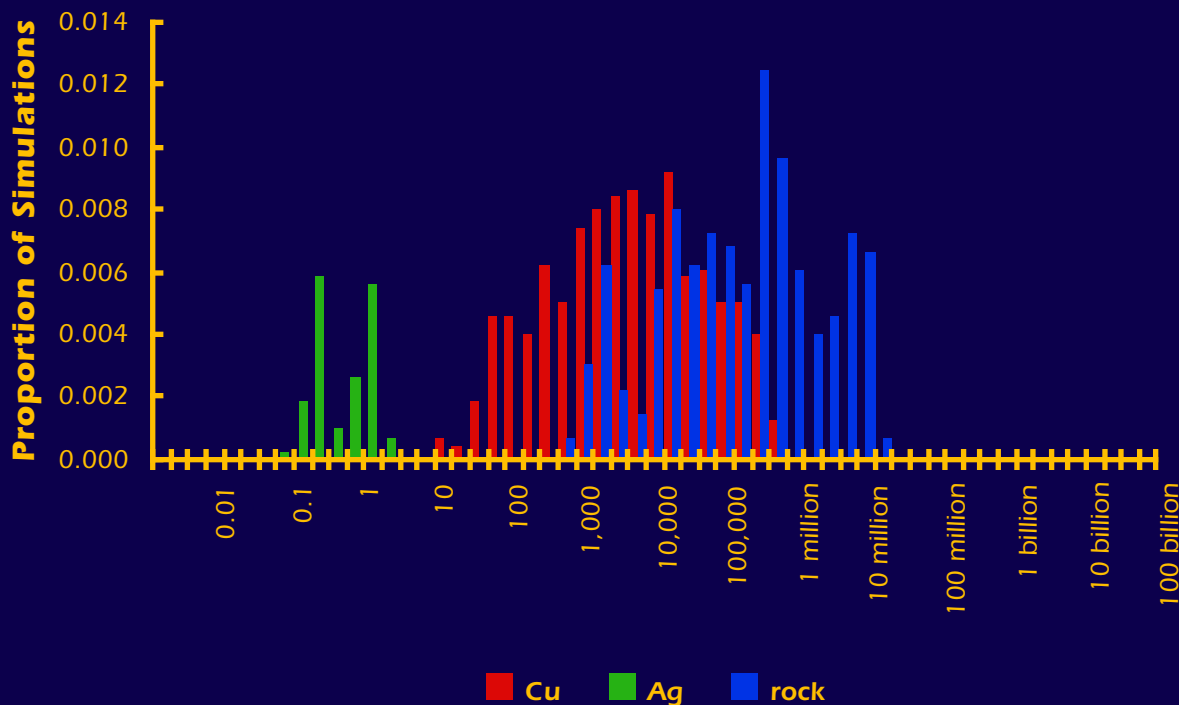
■ Zn ■ rock

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CP01

The Mark3 Index is 97:

Sediment-hosted Cu, red-bed

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	65	0	1,940
0.05	6,900	0	340,000
mean	5,500	0	200,000
Probability of mean	0.05	0.02	0.06
Probability of zero	0.90	0.98	0.90

The tract ID is CP01

The Mark3 Index is 97: **Sediment-hosted Cu, red-bed**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

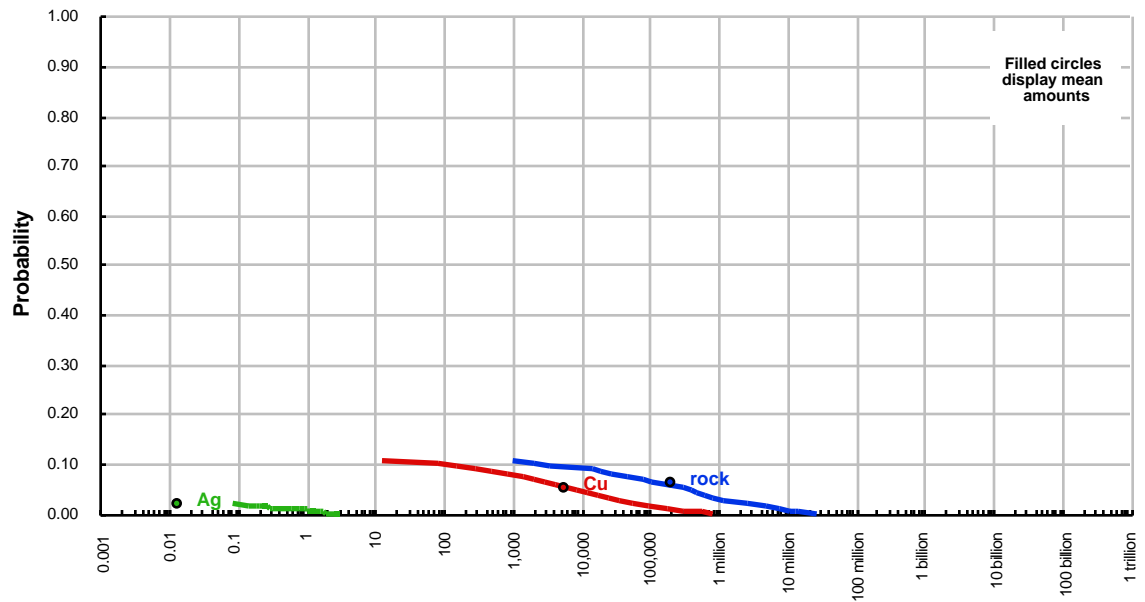
There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

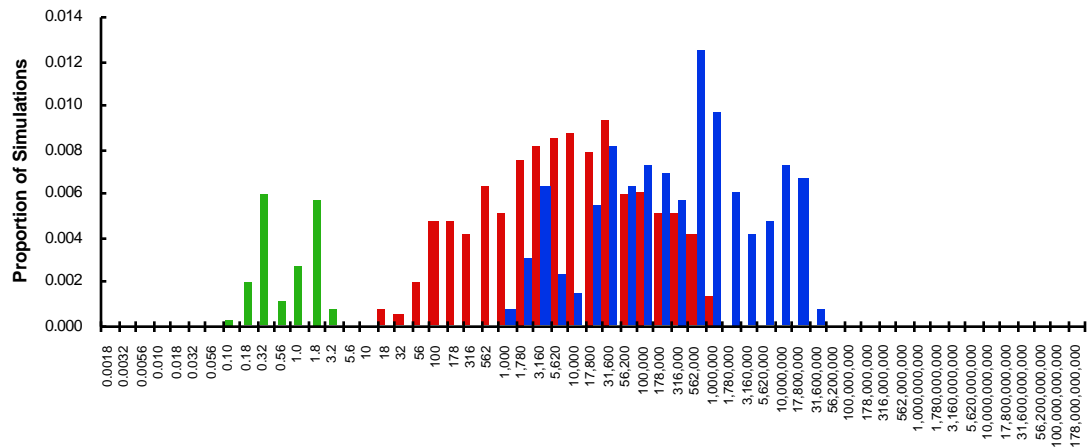
quantile	Cu	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	65	0	1,940
0.05	6,900	0	340,000
mean	5,500	0	200,000
Probability of mean	0.05	0.02	0.06
Probability of zero	0.90	0.98	0.90

The tract ID is CP01

Cumulative Distributions of Contained Metal and Mineralized Rock



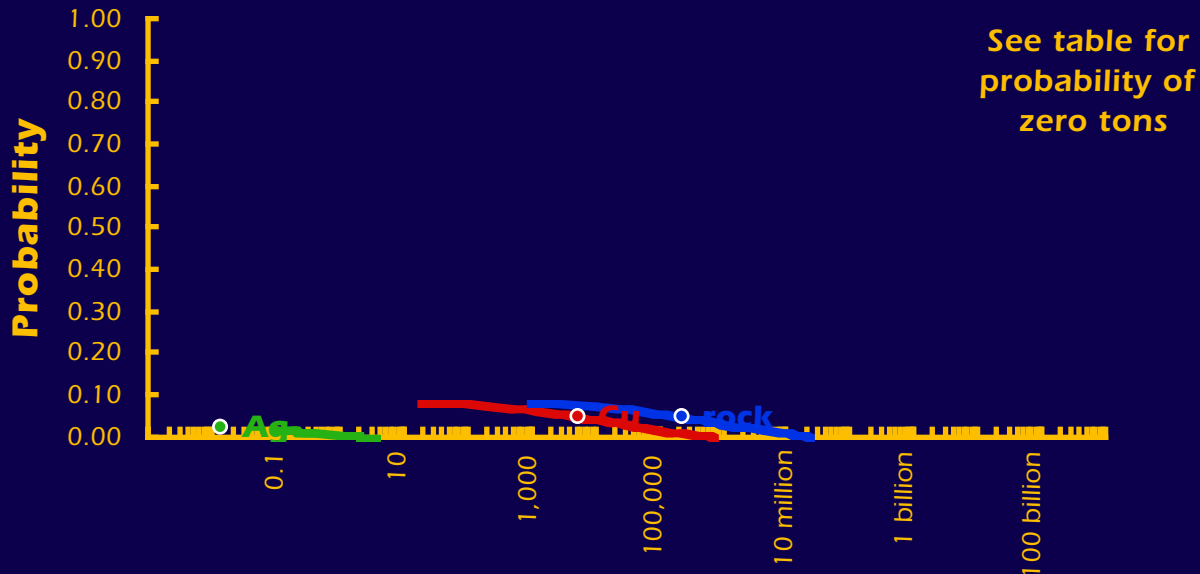
Histograms of Contained Metal and Mineralized Rock (metric tons)



See table for probability of zero tons

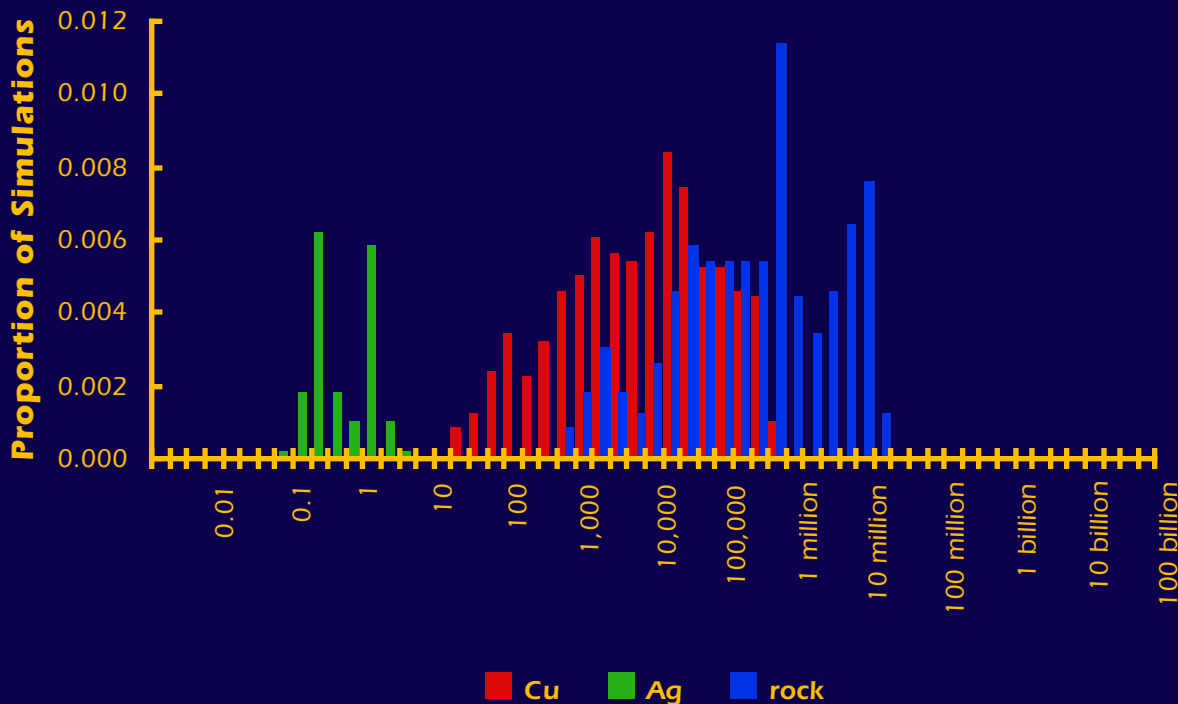
Cu Ag rock

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CPO2

The Mark3 Index is 97:

Sediment-hosted Cu, red-bed

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	0	0
0.05	4,500	0	180,000
mean	5,300	0	220,000
Probability of mean	0.05	0.02	0.05
Probability of zero	0.92	0.98	0.92

The tract ID is CP02The Mark3 Index is 97: **Sediment-hosted Cu, red-bed**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

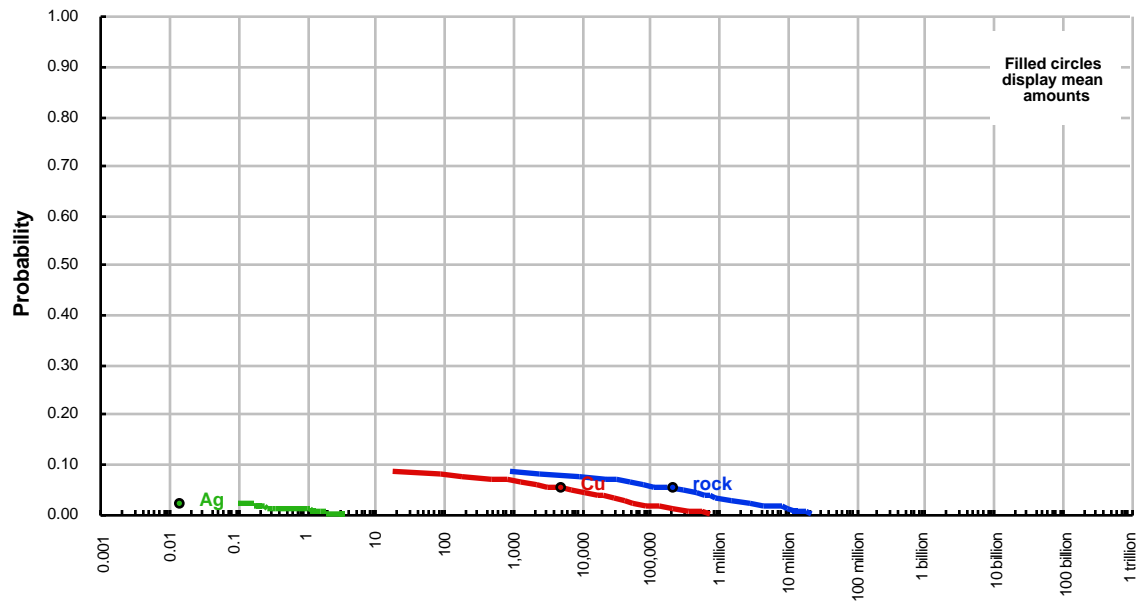
There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

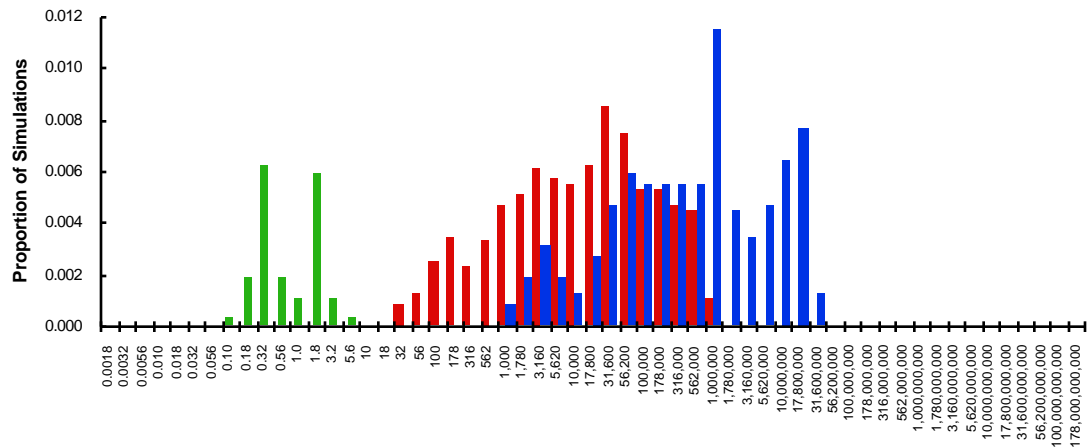
quantile	Cu	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	0	0
0.05	4,500	0	180,000
mean	5,300	0	220,000
Probability of mean	0.05	0.02	0.05
Probability of zero	0.92	0.98	0.92

The tract ID is CP02

Cumulative Distributions of Contained Metal and Mineralized Rock



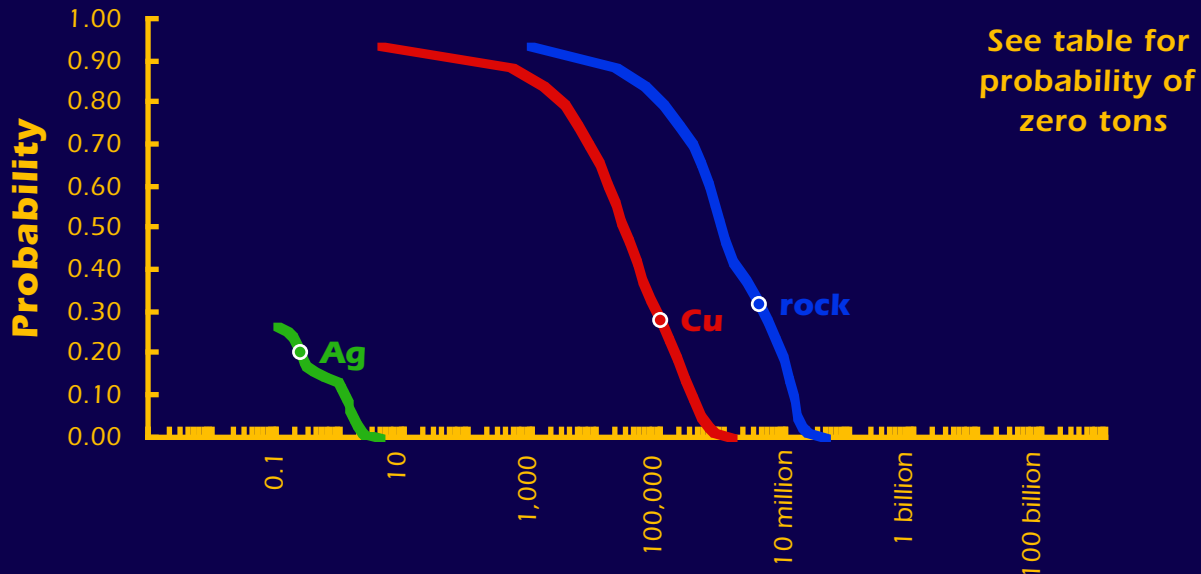
Histograms of Contained Metal and Mineralized Rock (metric tons)



See table for probability of zero tons

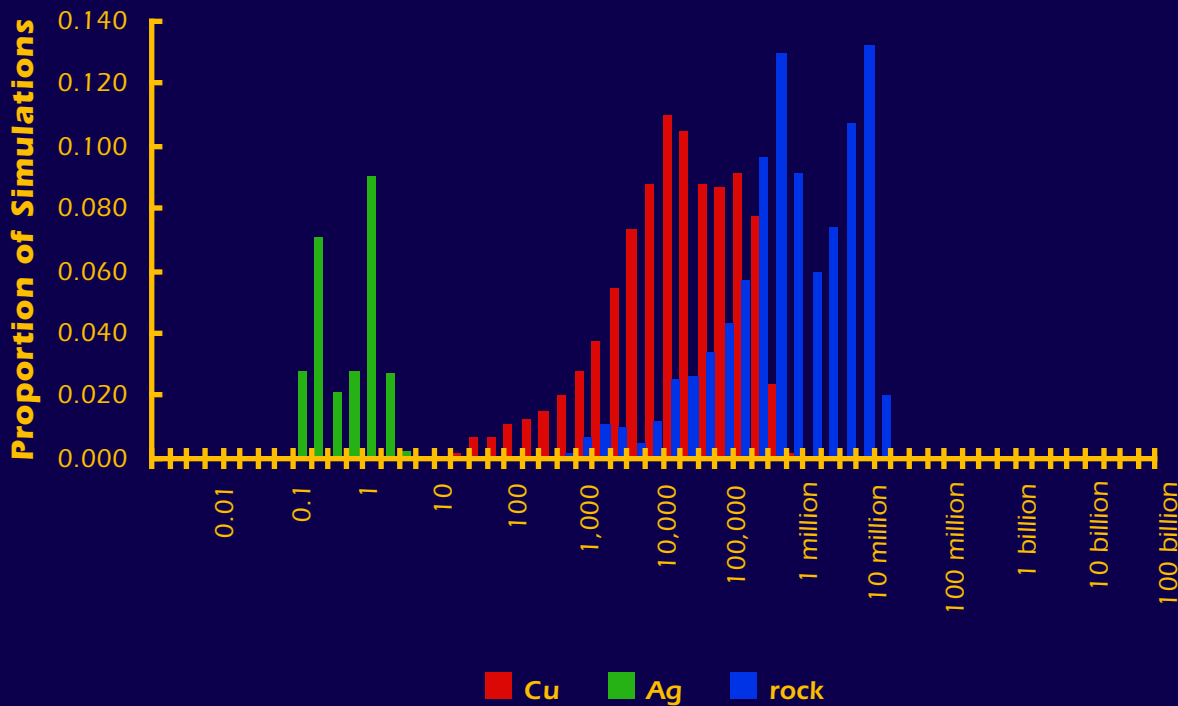
Cu Ag rock

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CPO3

The Mark3 Index is 97:

Sediment-hosted Cu, red-bed

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Ag	rock
0.95	0	0	0
0.90	280	0	13,000
0.50	27,000	0	930,000
0.10	320,000	1	11,900,000
0.05	440,000	2	14,000,000
mean	99,000	0	3,700,000
Probability of mean	0.28	0.20	0.32
Probability of zero	0.06	0.73	0.06

The tract ID is CP03The Mark3 Index is 97: **Sediment-hosted Cu, red-bed**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

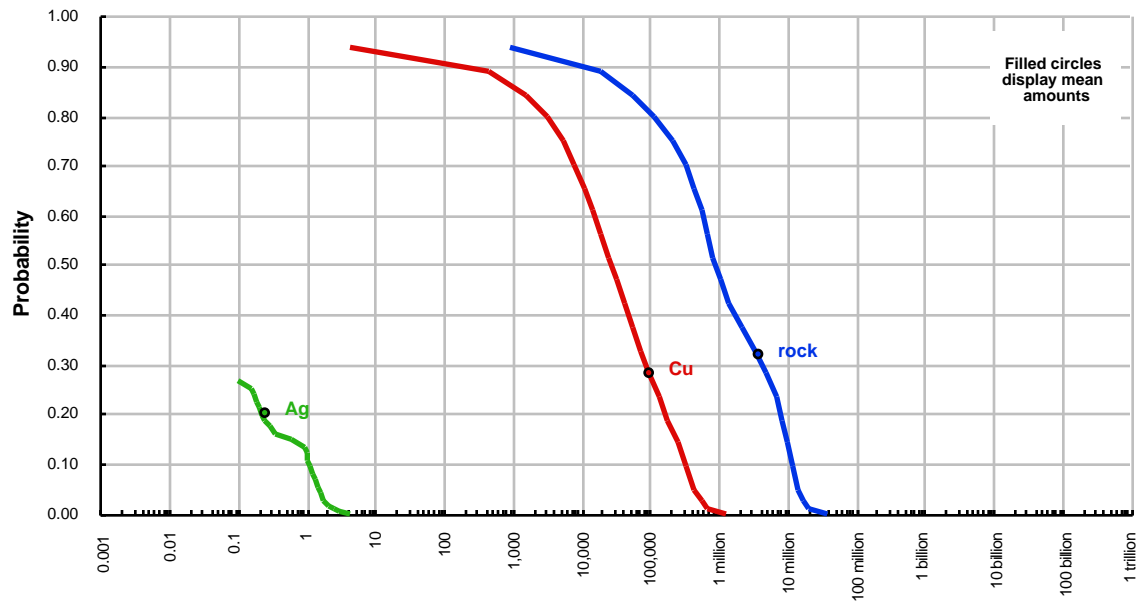
There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

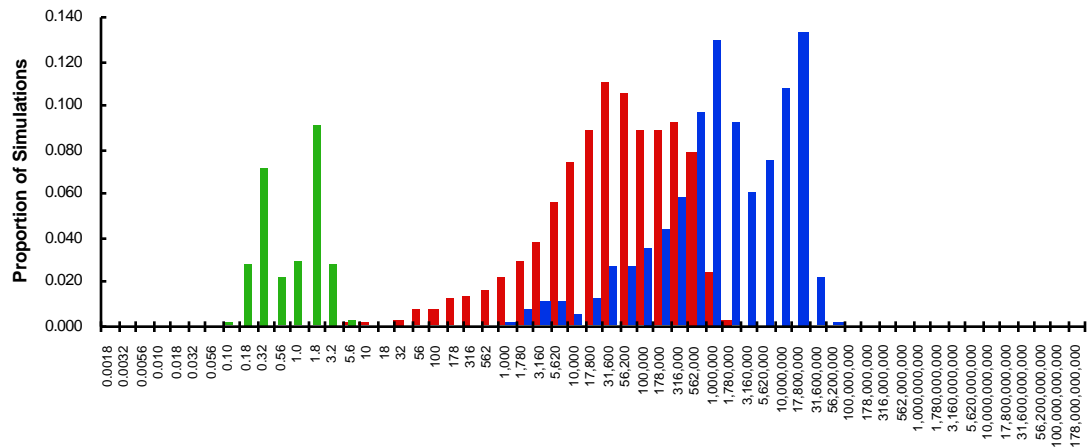
quantile	Cu	Ag	rock
0.95	0	0	0
0.90	280	0	13,000
0.50	27,000	0	930,000
0.10	320,000	1	11,900,000
0.05	440,000	2	14,000,000
mean	99,000	0	3,700,000
Probability of mean	0.28	0.20	0.32
Probability of zero	0.06	0.73	0.06

The tract ID is CP03

Cumulative Distributions of Contained Metal and Mineralized Rock



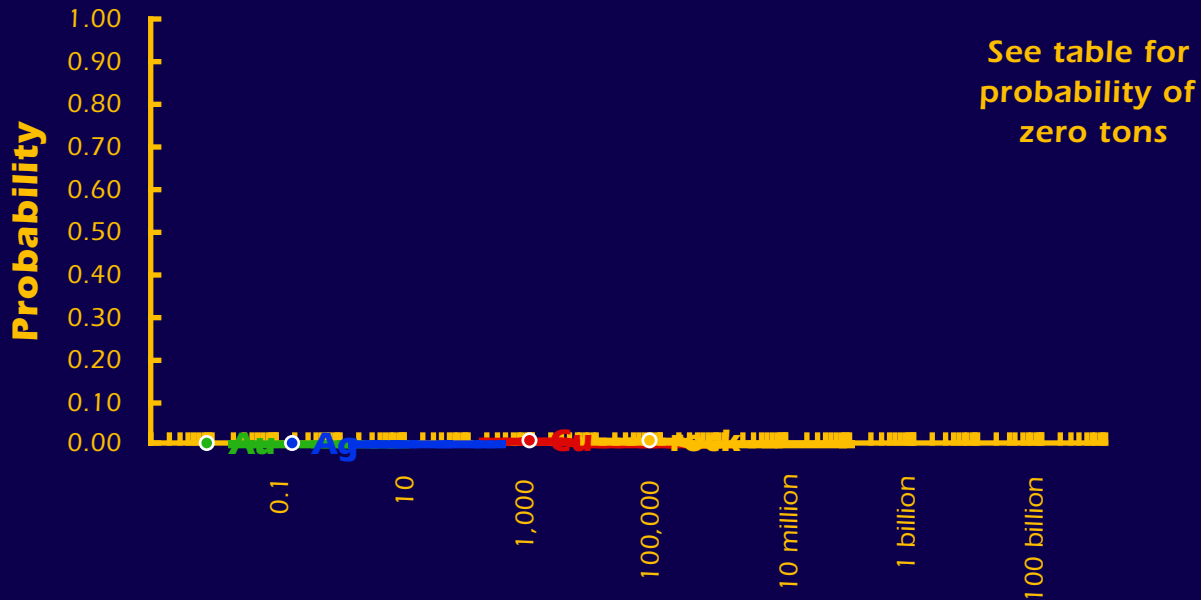
Histograms of Contained Metal and Mineralized Rock (metric tons)



See table for probability of zero tons

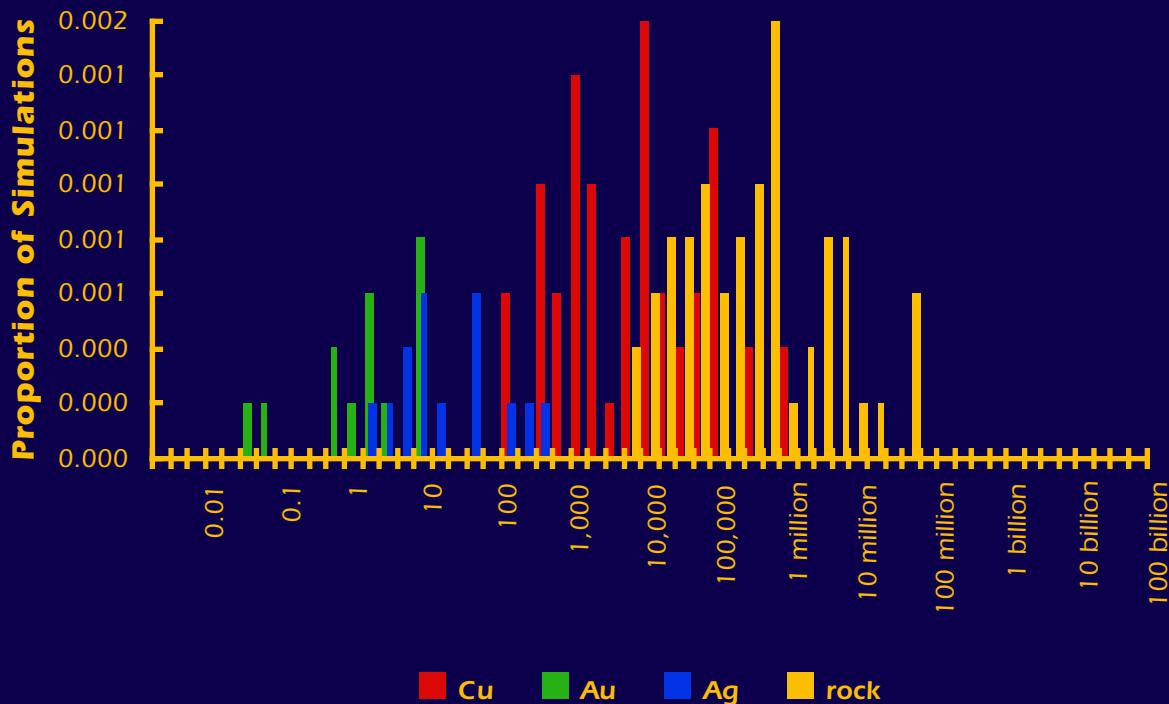
Cu Ag rock

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR01

The Mark3 Index is 8:

Skorn Cu

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	0	0	0	0
mean	920	0	0	72,000
Probability of mean	0.01	0.00	0.00	0.01
Probability of zero	0.99	1.00	1.00	0.99

The tract ID is CR01The Mark3 Index is 8: **Skarn Cu**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

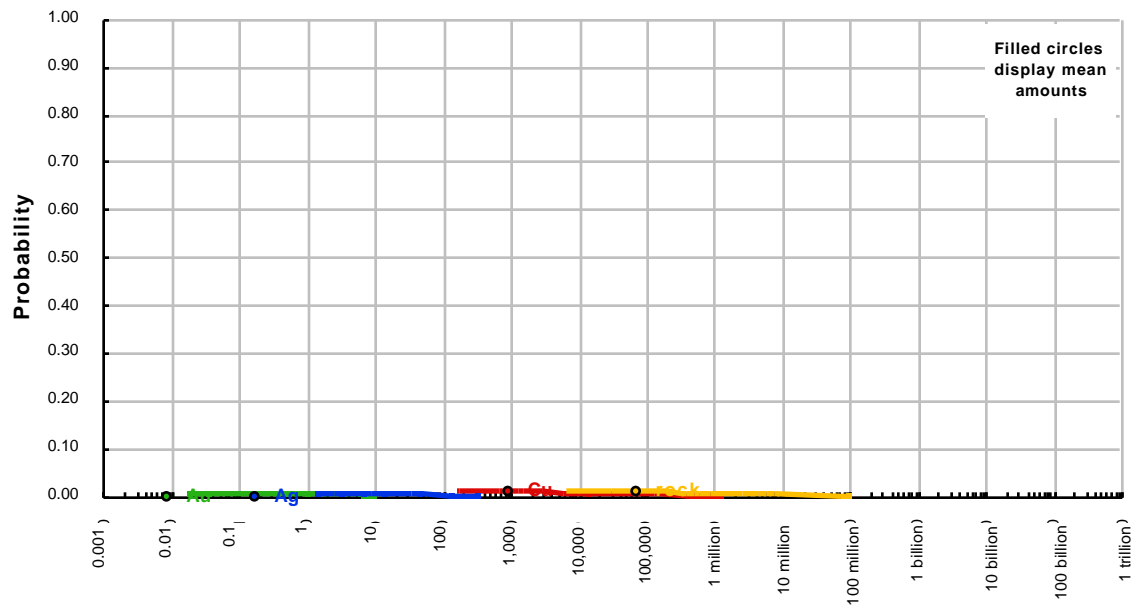
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

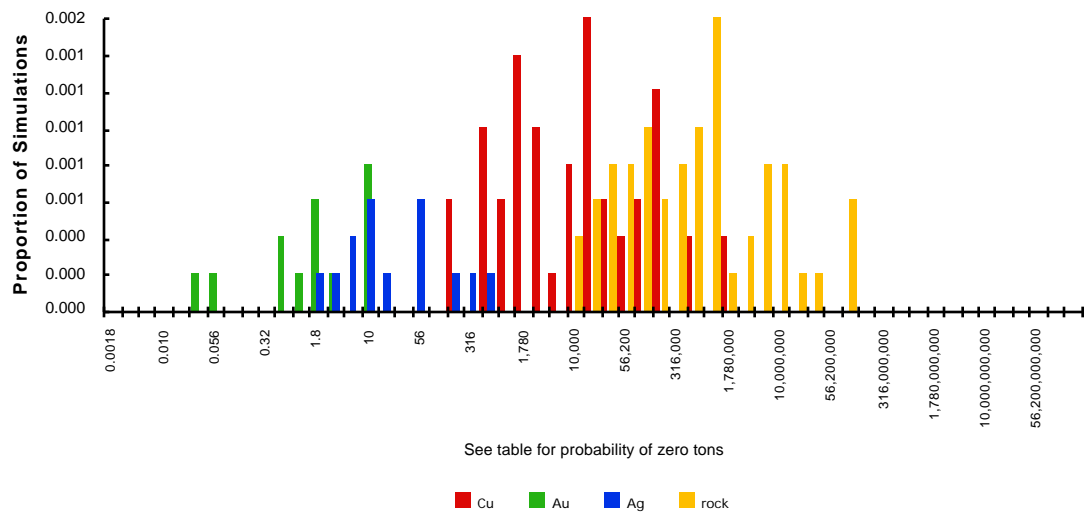
quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	0	0	0	0
mean	920	0	0	72,000
Probability of mean	0.01	0.00	0.00	0.01
Probability of zero	0.99	1.00	1.00	0.99

The tract ID is CR01

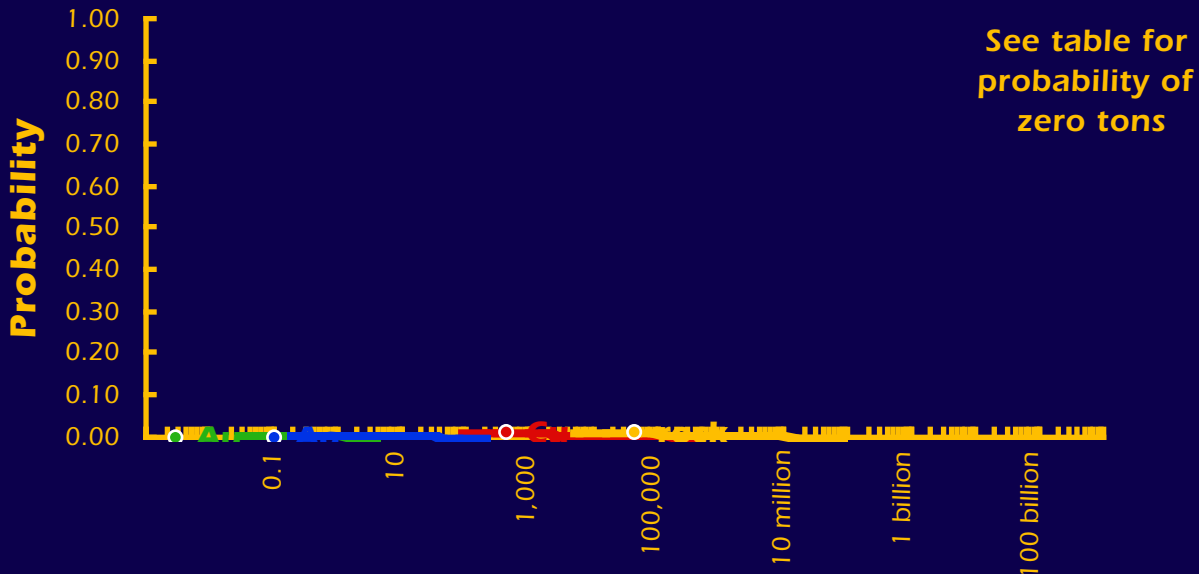
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

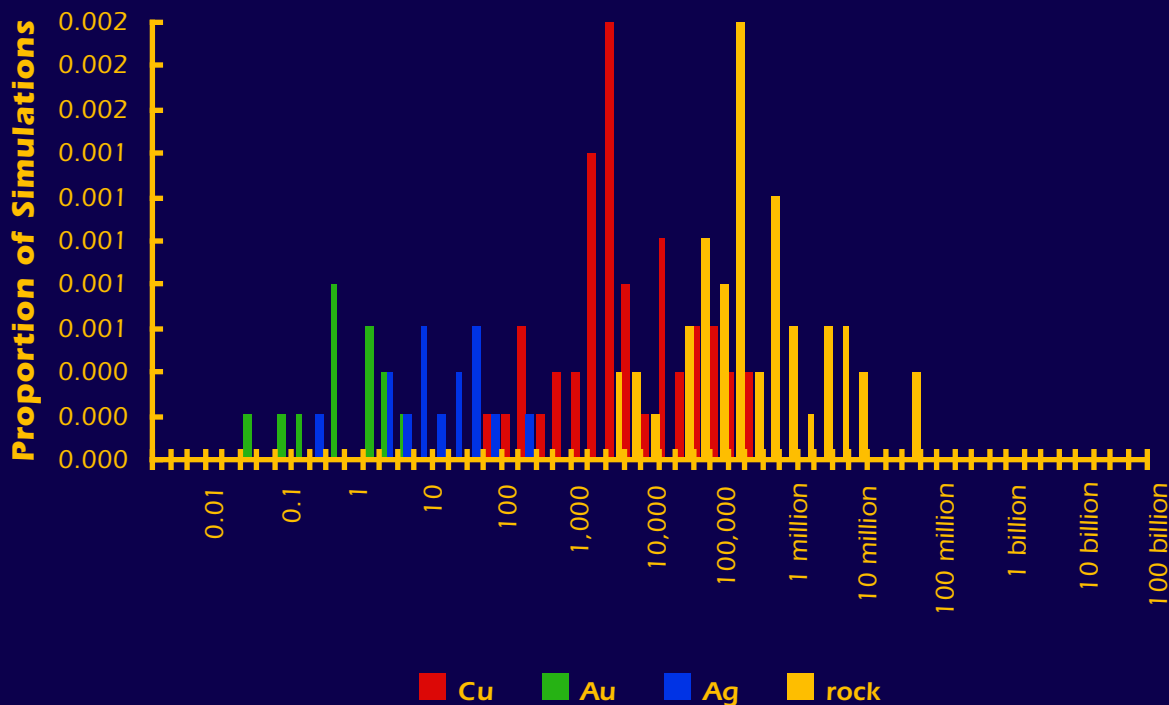


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR02

The Mark3 Index is 8:

Skarn Cu

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	0	0	0	0
mean	420	0	0	45,000
Probability of mean	0.01	0.00	0.00	0.01
Probability of zero	0.99	1.00	1.00	0.99

The tract ID is CR02The Mark3 Index is 8: **Skarn Cu**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

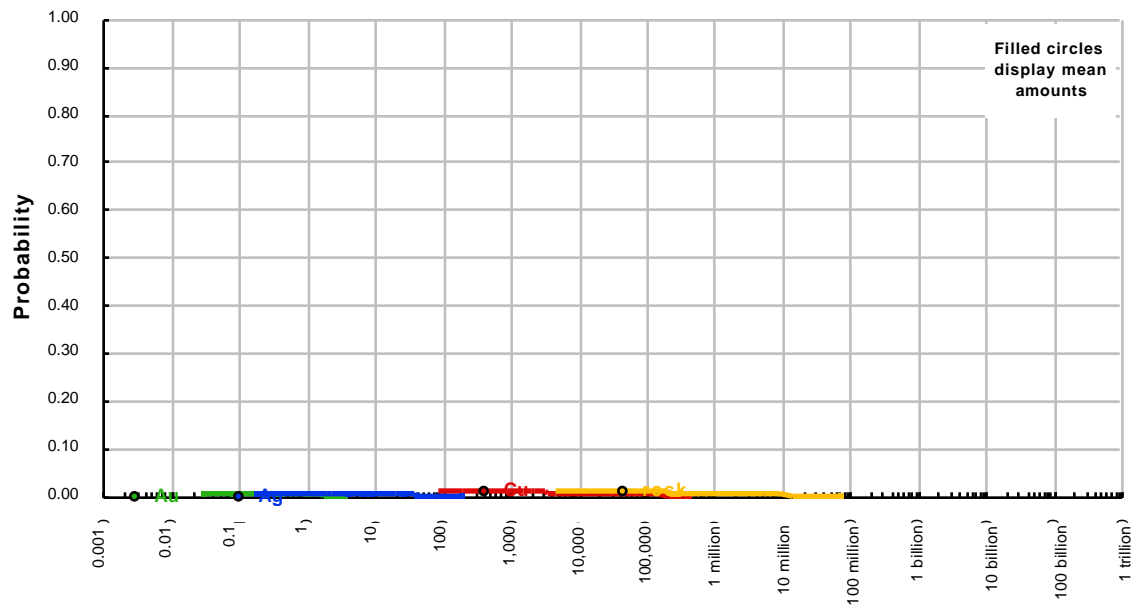
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

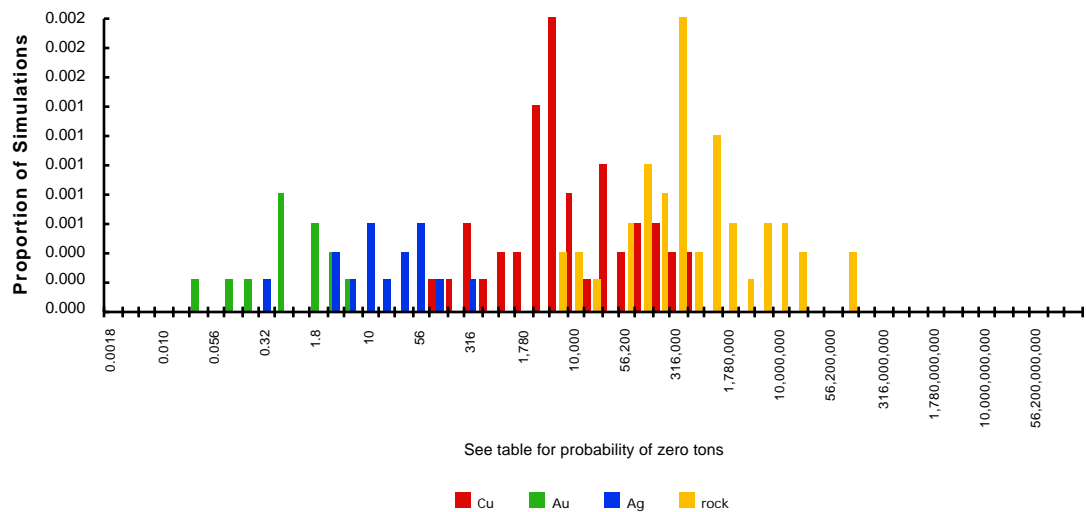
quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	0	0	0	0
mean	420	0	0	45,000
Probability of mean	0.01	0.00	0.00	0.01
Probability of zero	0.99	1.00	1.00	0.99

The tract ID is CR02

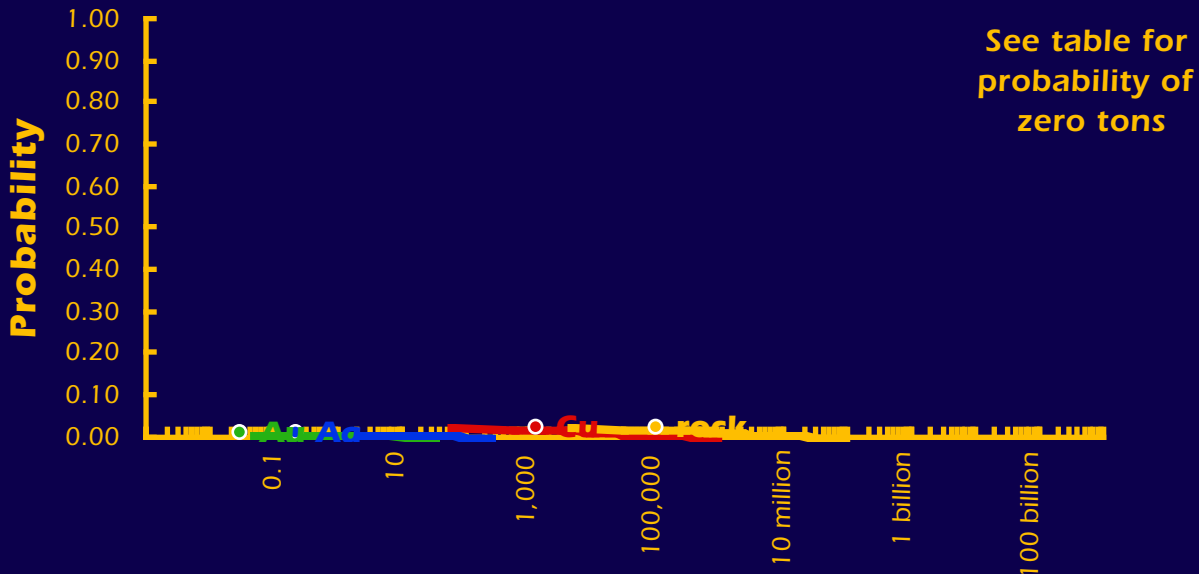
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

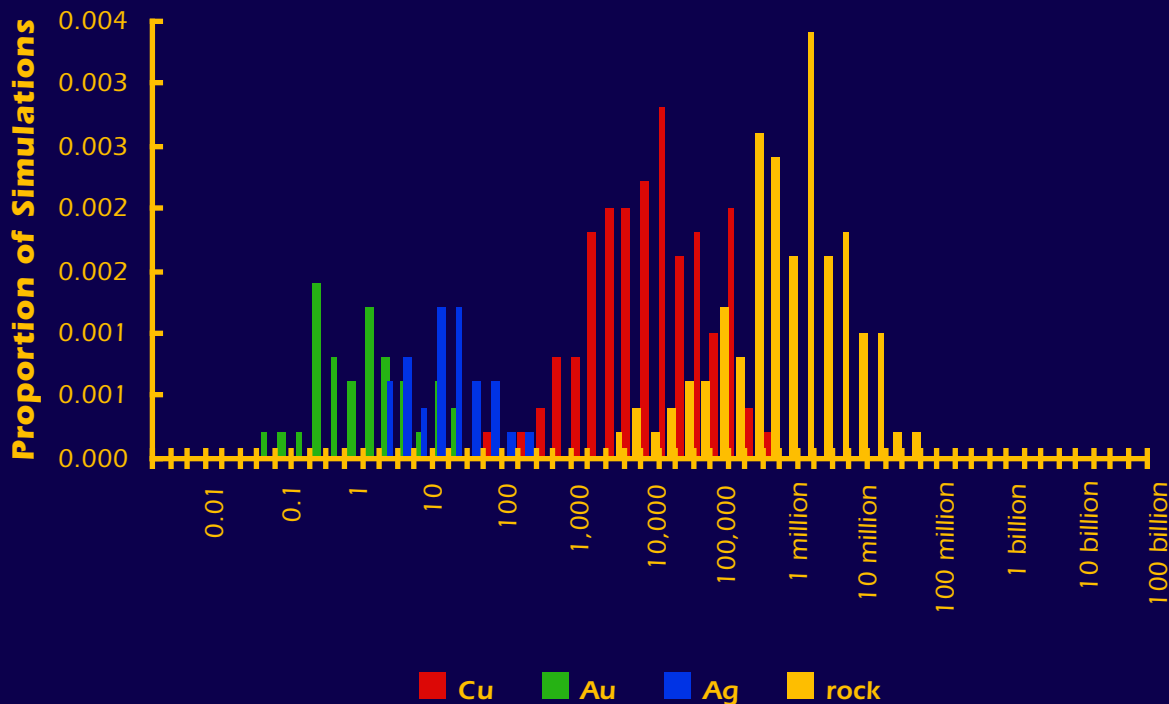


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CRO3

The Mark3 Index is 8:

Skarn Cu

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	0	0	0	0
mean	1,300	0	0	93,000
Probability of mean	0.02	0.01	0.01	0.02
Probability of zero	0.98	0.99	0.99	0.98

The tract ID is CR03The Mark3 Index is 8: **Skarn Cu**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

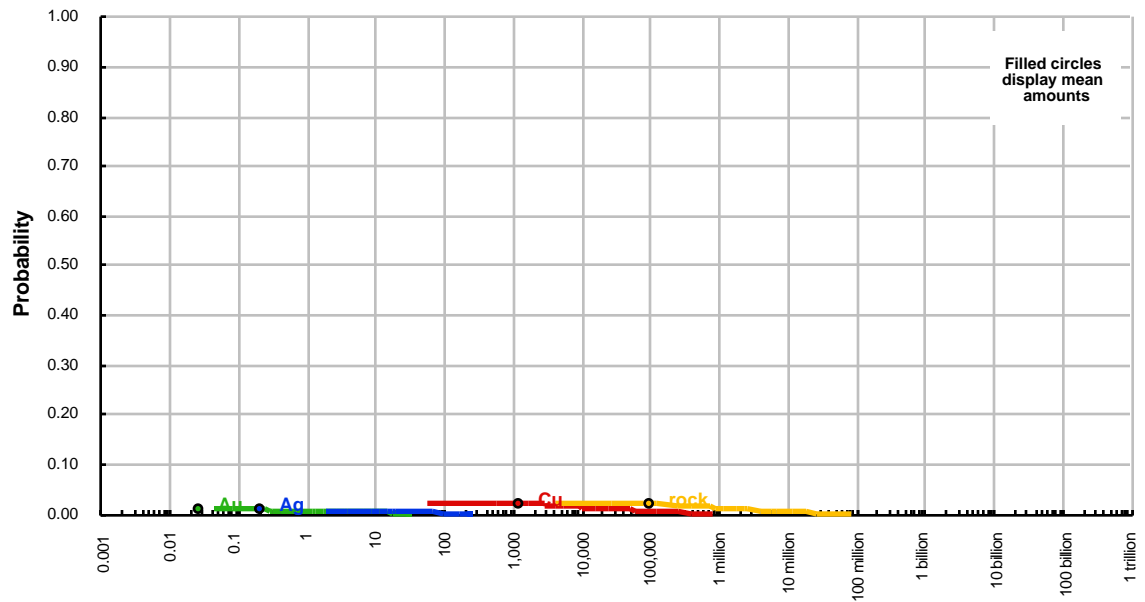
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

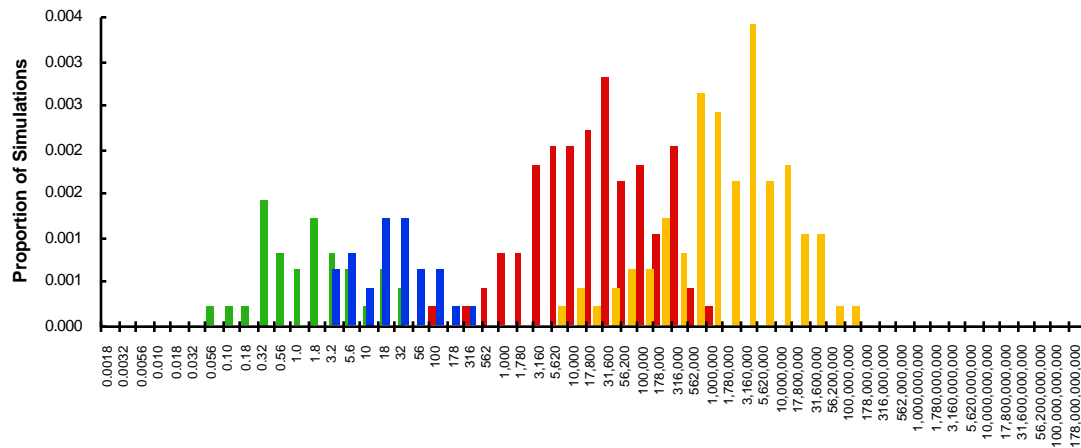
quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	0	0	0	0
mean	1,300	0	0	93,000
Probability of mean	0.02	0.01	0.01	0.02
Probability of zero	0.98	0.99	0.99	0.98

The tract ID is CR03

Cumulative Distributions of Contained Metal and Mineralized Rock



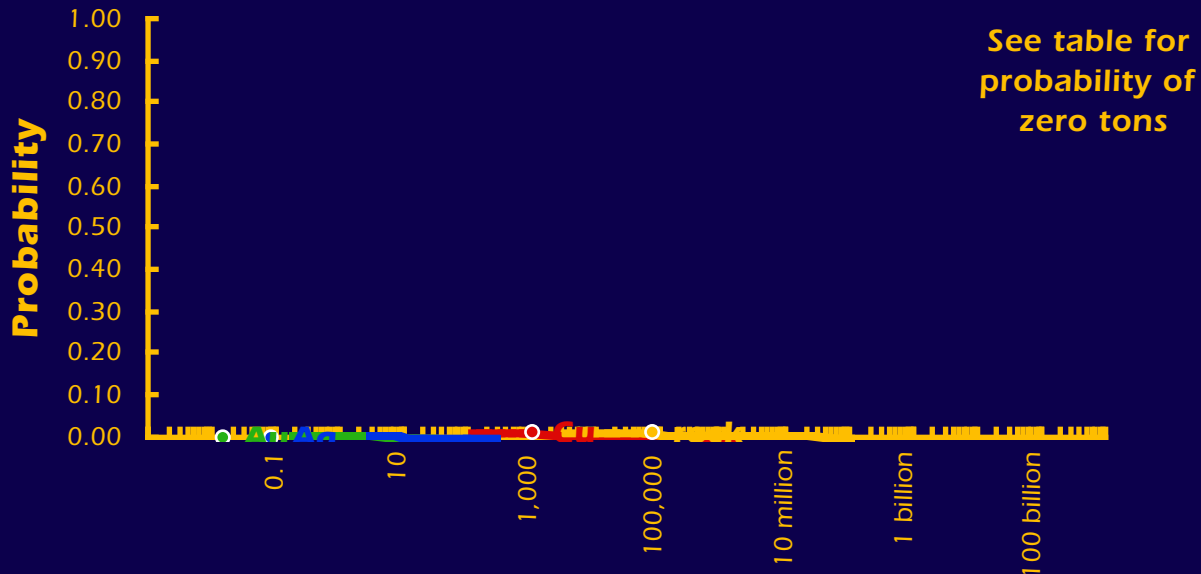
Histograms of Contained Metal and Mineralized Rock (metric tons)



See table for probability of zero tons

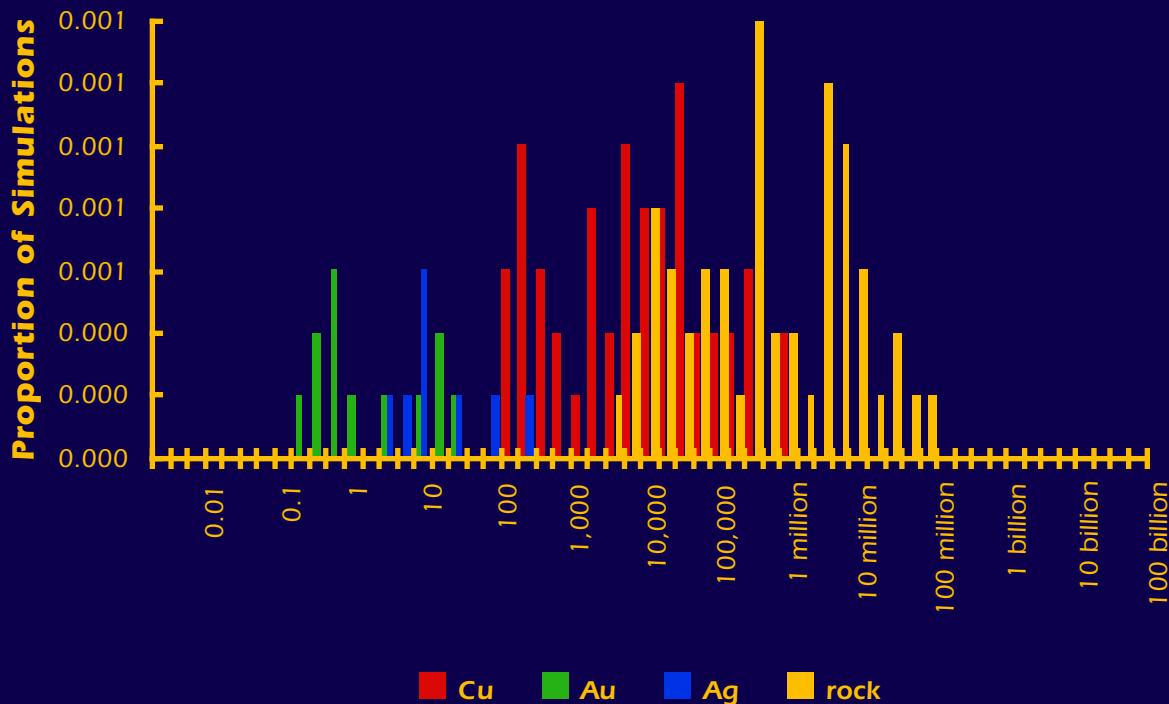
Cu Au Ag rock

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CRO4

The Mark3 Index is 8:

Skarn Cu

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	0	0	0	0
mean	1,000	0	0	79,000
Probability of mean	0.01	0.00	0.00	0.01
Probability of zero	0.99	1.00	1.00	0.99

The tract ID is CR04The Mark3 Index is 8: **Skarn Cu**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

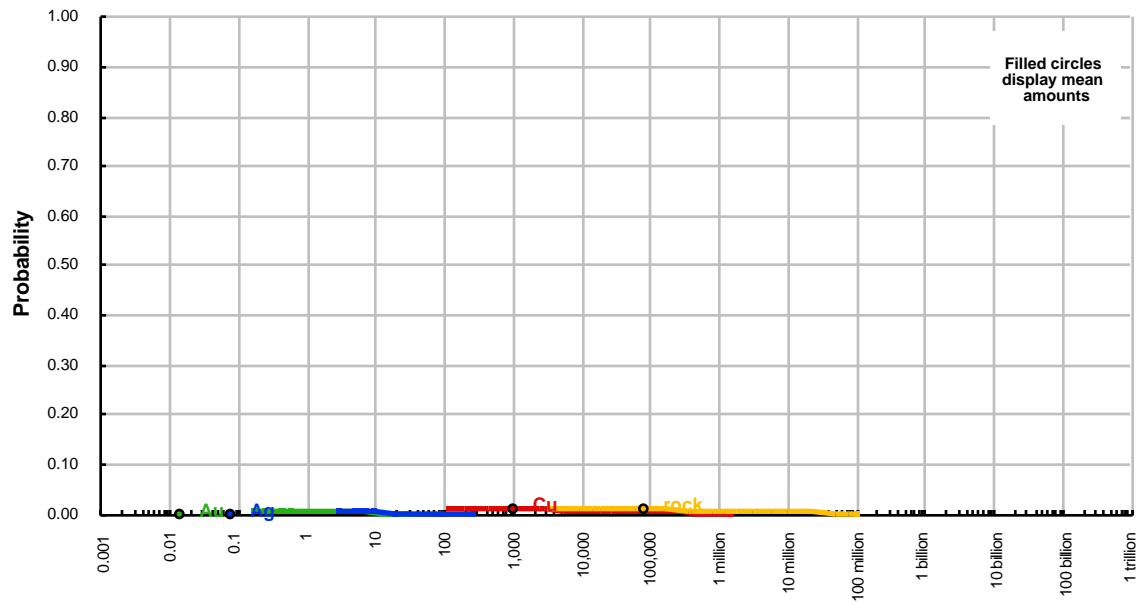
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

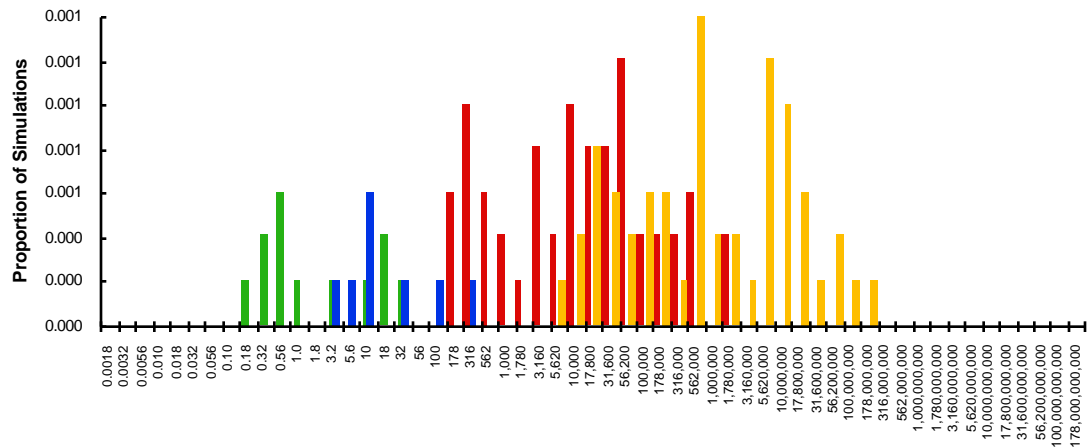
quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	0	0	0	0
mean	1,000	0	0	79,000
Probability of mean	0.01	0.00	0.00	0.01
Probability of zero	0.99	1.00	1.00	0.99

The tract ID is CR04

Cumulative Distributions of Contained Metal and Mineralized Rock



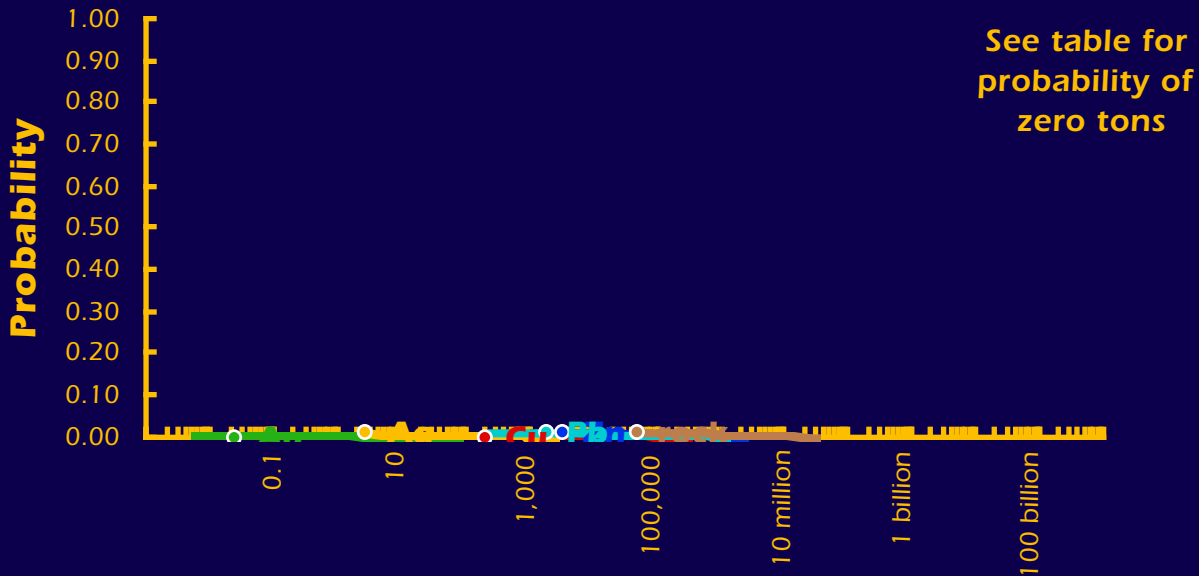
Histograms of Contained Metal and Mineralized Rock (metric tons)



See table for probability of zero tons

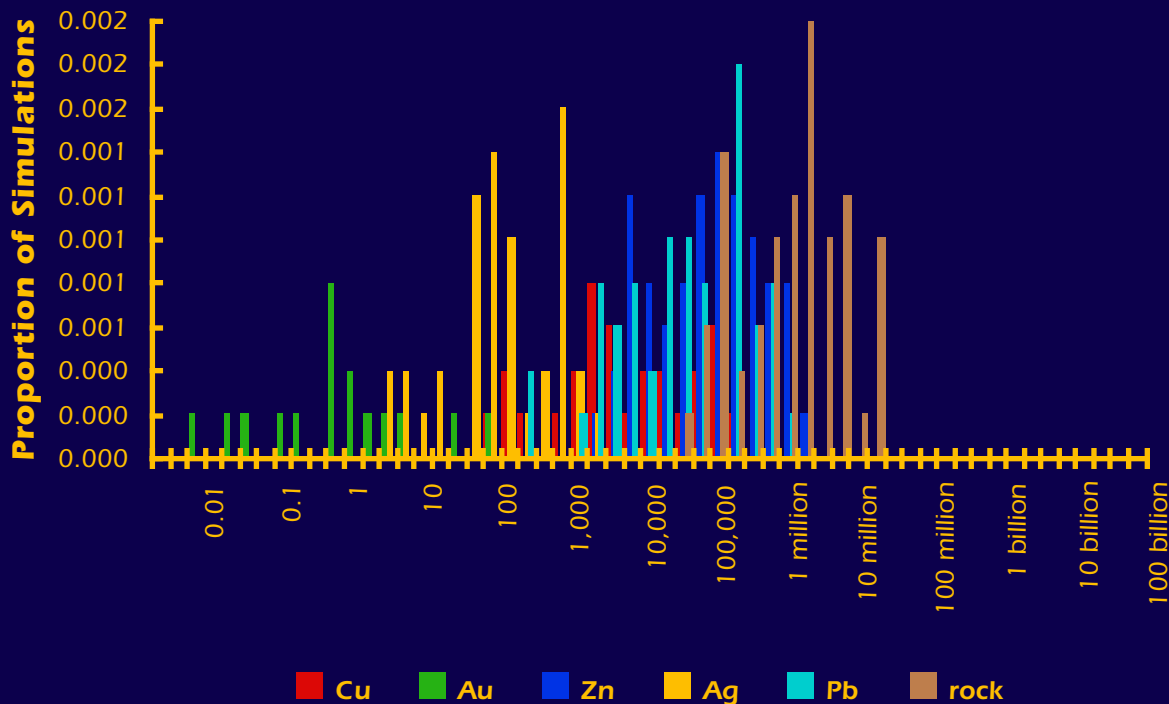
Cu Au Ag rock

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR05

The Mark3 Index is 22:

Skarn Zn-Pb

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	200	0	3,200	3	1,800	47,000
Probability of mean	0.00	0.00	0.01	0.01	0.01	0.01
Probability of zero	0.99	1.00	0.99	0.99	0.99	0.99

The tract ID is CR05The Mark3 Index is 22: **Skarn Zn-Pb**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

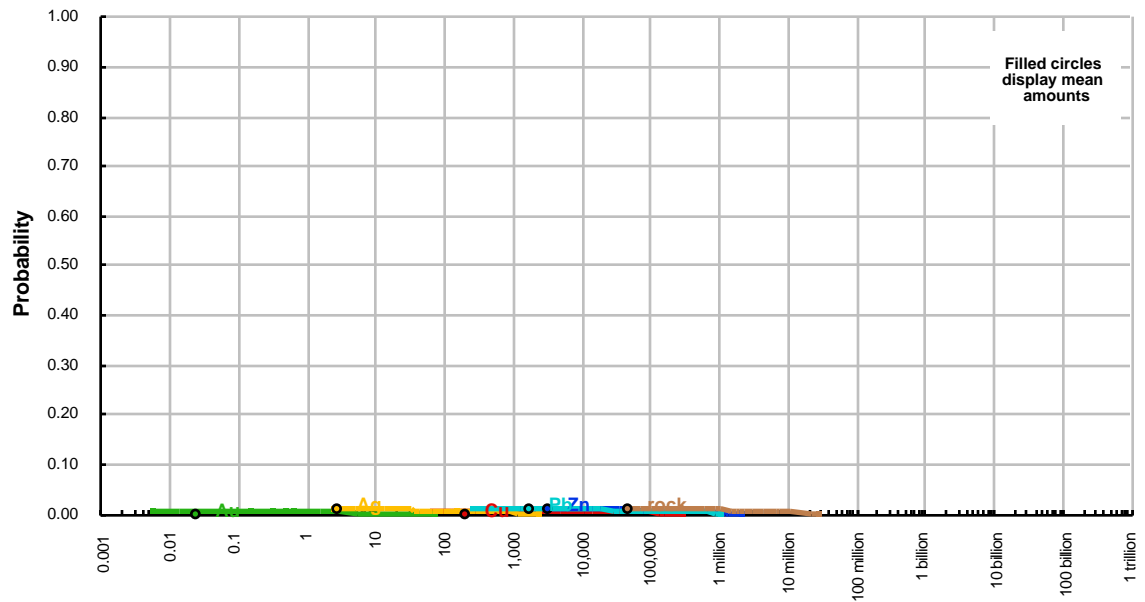
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

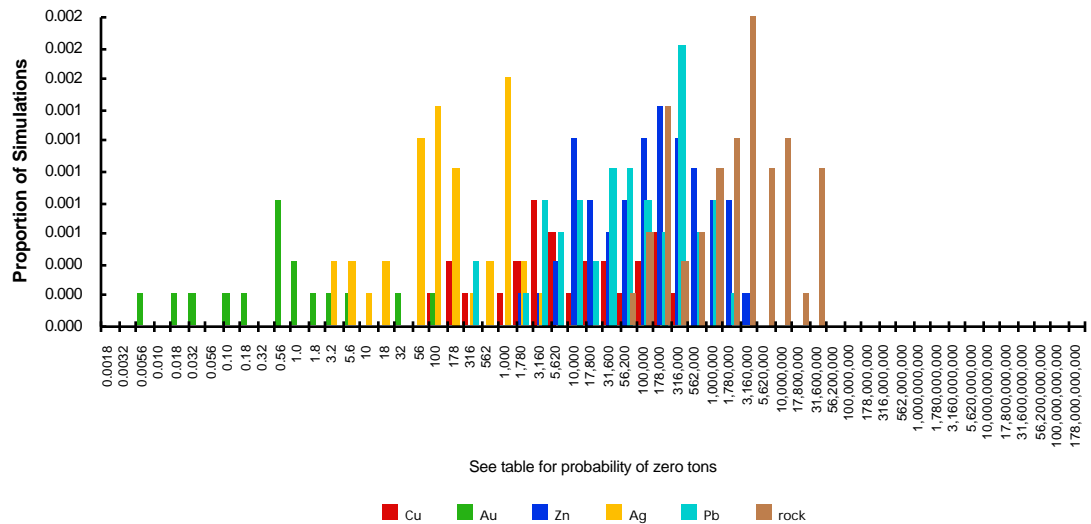
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	200	0	3,200	3	1,800	47,000
Probability of mean	0.00	0.00	0.01	0.01	0.01	0.01
Probability of zero	0.99	1.00	0.99	0.99	0.99	0.99

The tract ID is CR05

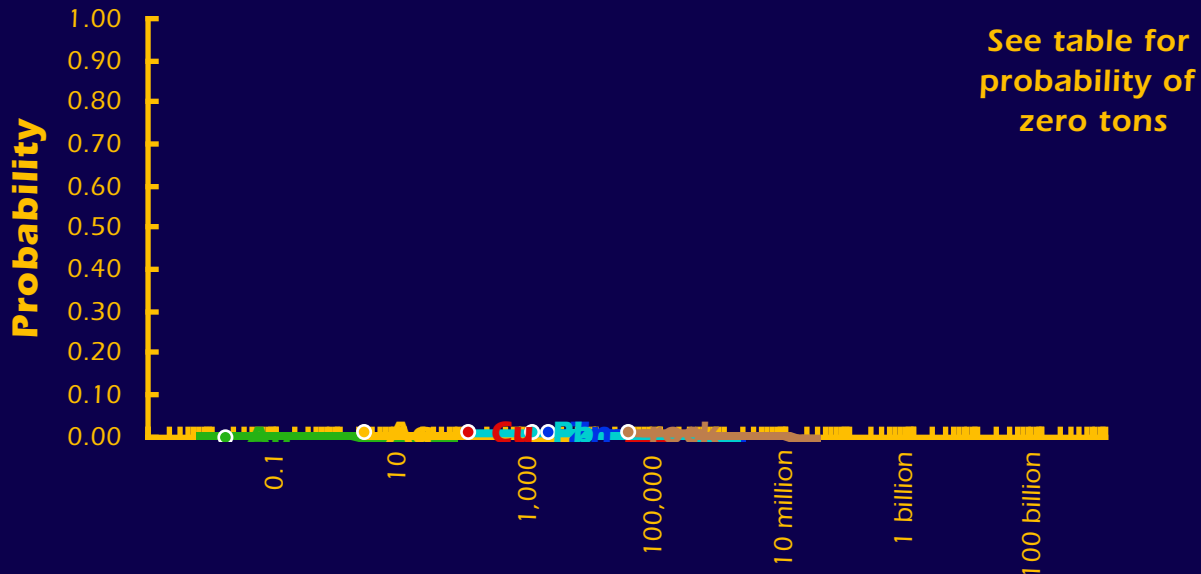
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

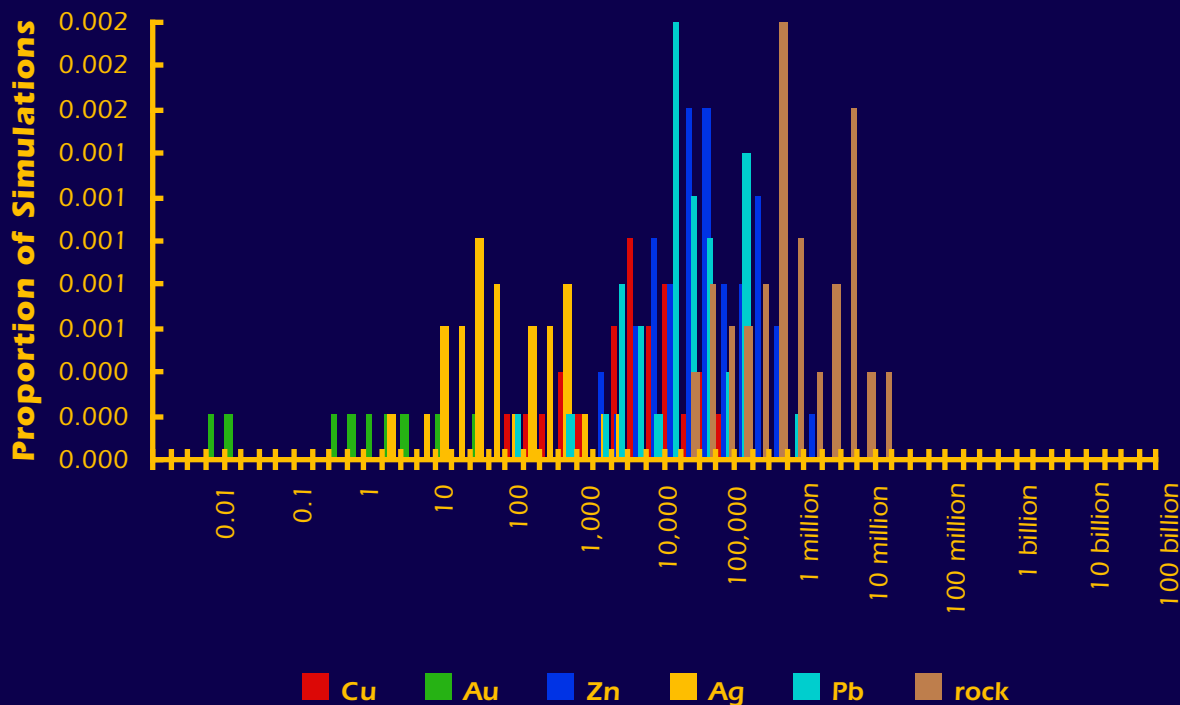


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR06

The Mark3 Index is 22:

Skarn Zn-Pb

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	100	0	1,900	2	1,000	33,000
Probability of mean	0.01	0.00	0.01	0.01	0.01	0.01
Probability of zero	1.00	1.00	0.99	0.99	0.99	0.99

The tract ID is CR06The Mark3 Index is 22: **Skarn Zn-Pb**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

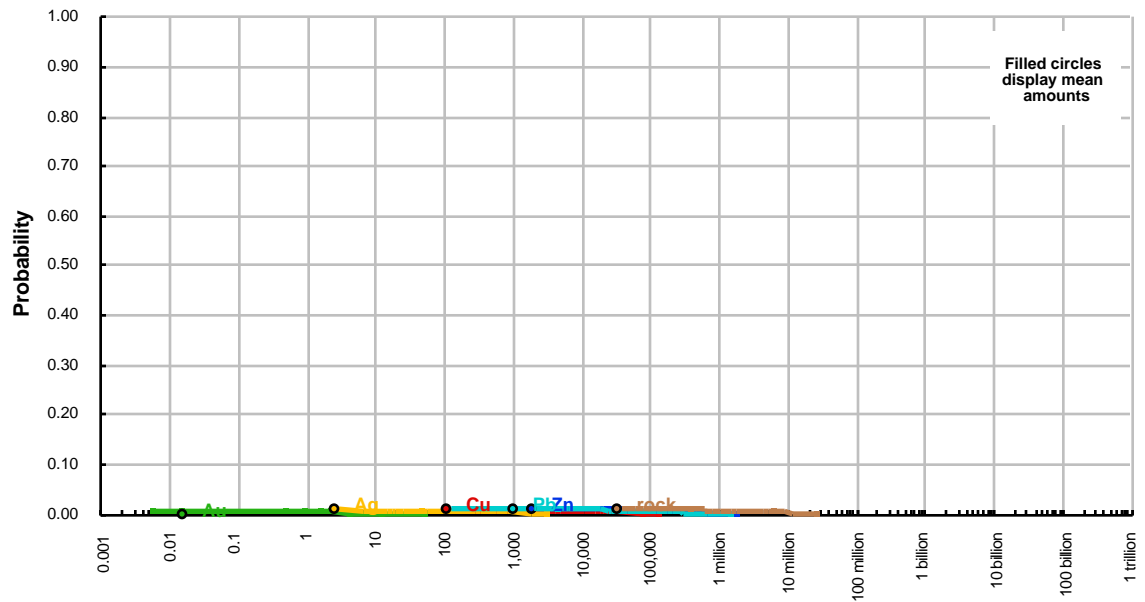
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

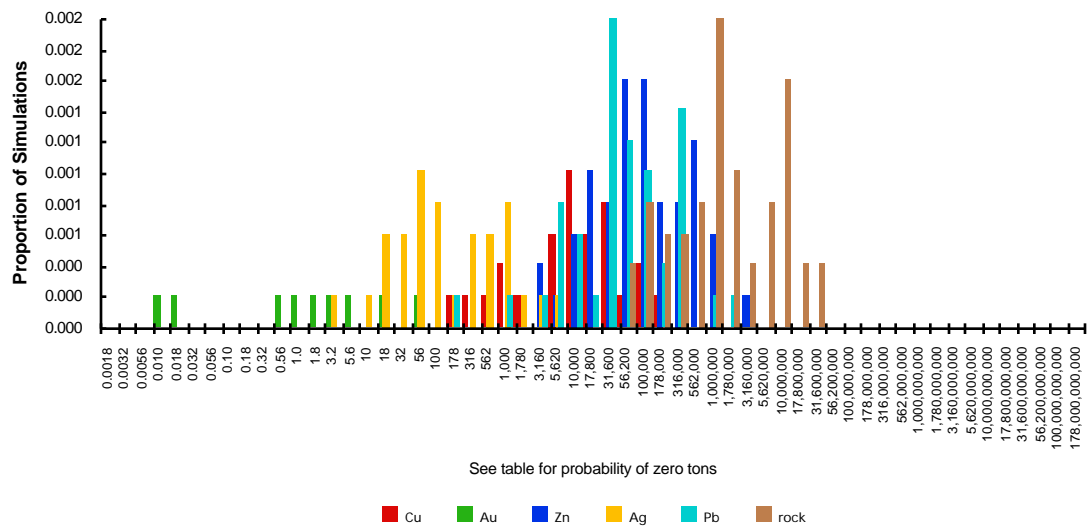
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	100	0	1,900	2	1,000	33,000
Probability of mean	0.01	0.00	0.01	0.01	0.01	0.01
Probability of zero	1.00	1.00	0.99	0.99	0.99	0.99

The tract ID is CR06

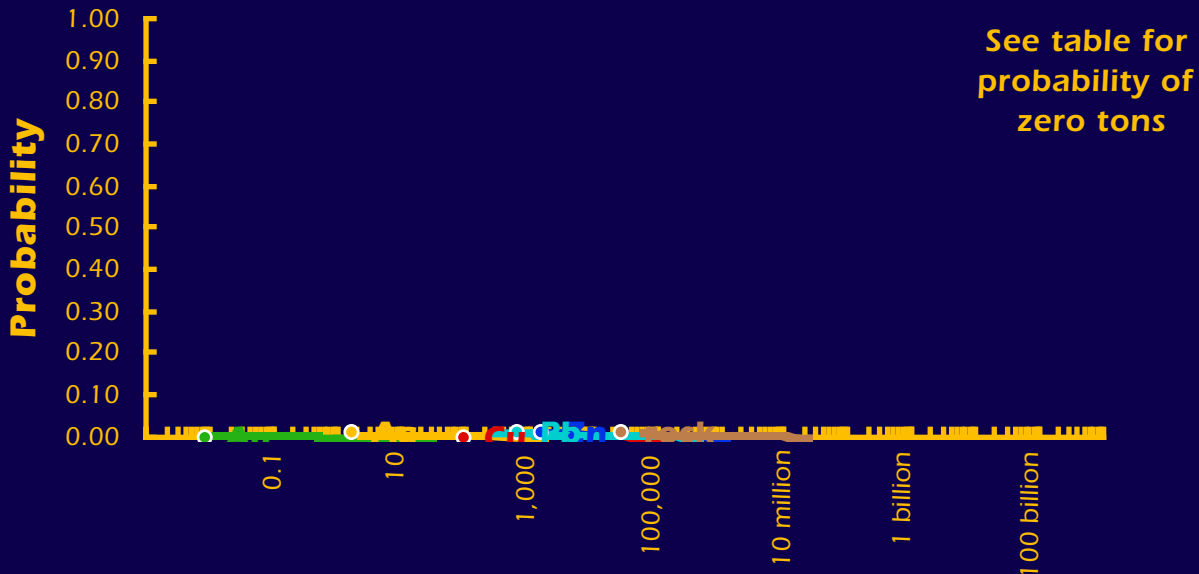
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

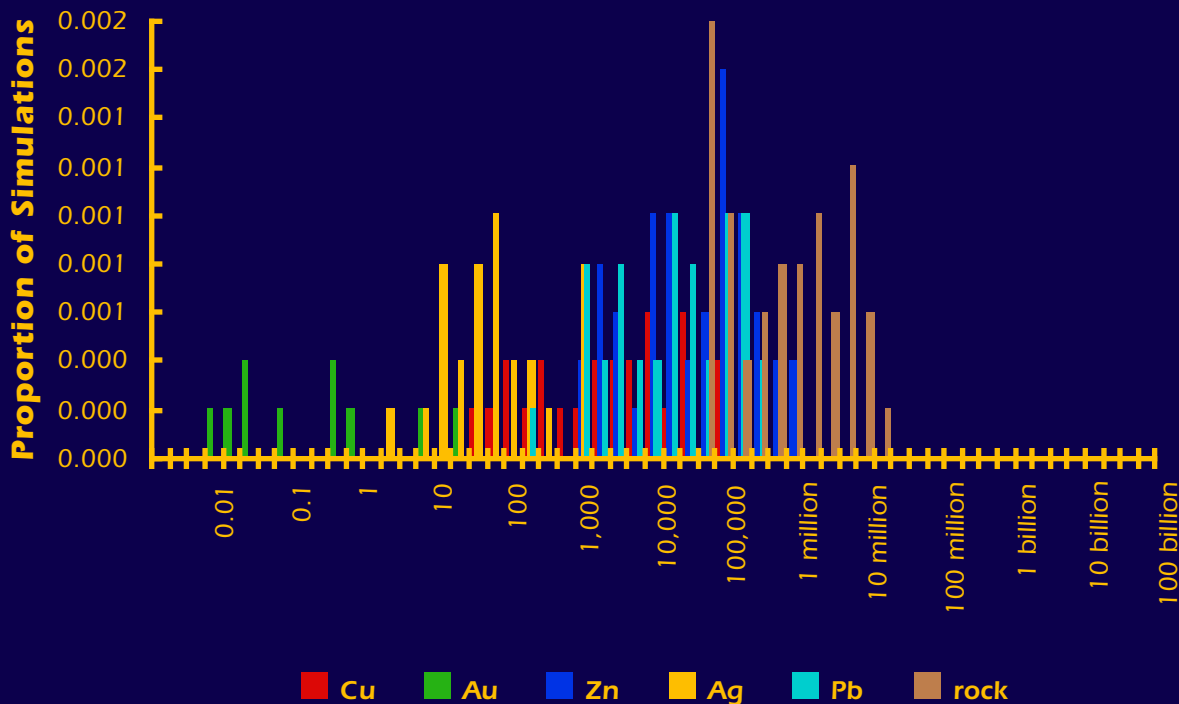


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR07

The Mark3 Index is 22:

Skarn Zn-Pb

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	89	0	1,500	2	650	28,000
Probability of mean	0.00	0.00	0.01	0.01	0.01	0.01
Probability of zero	1.00	1.00	0.99	0.99	0.99	0.99

The tract ID is CR07The Mark3 Index is 22: **Skarn Zn-Pb**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

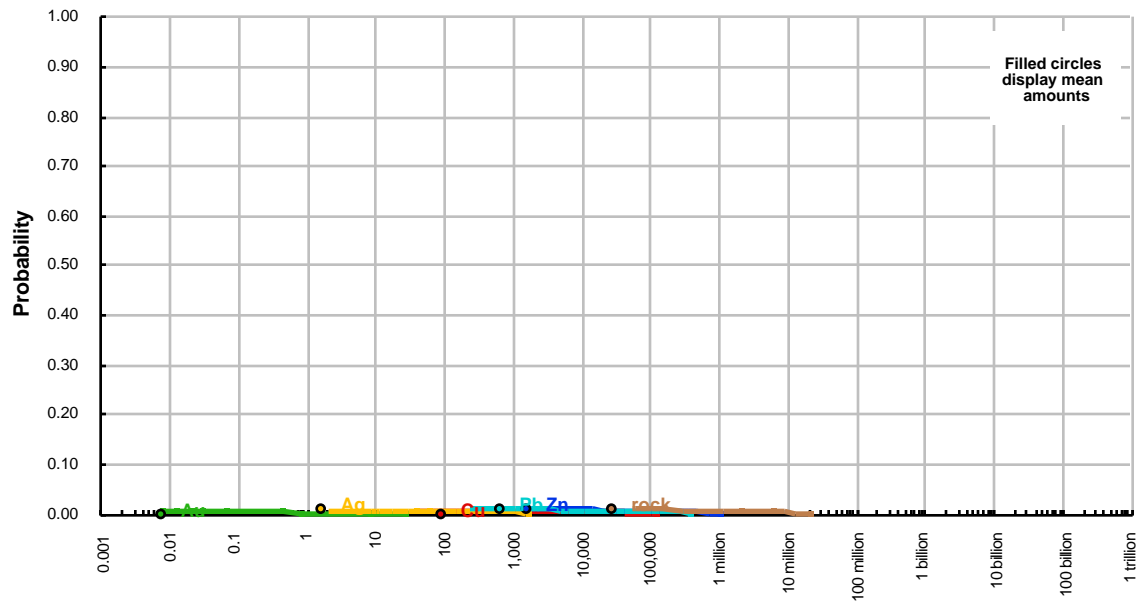
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

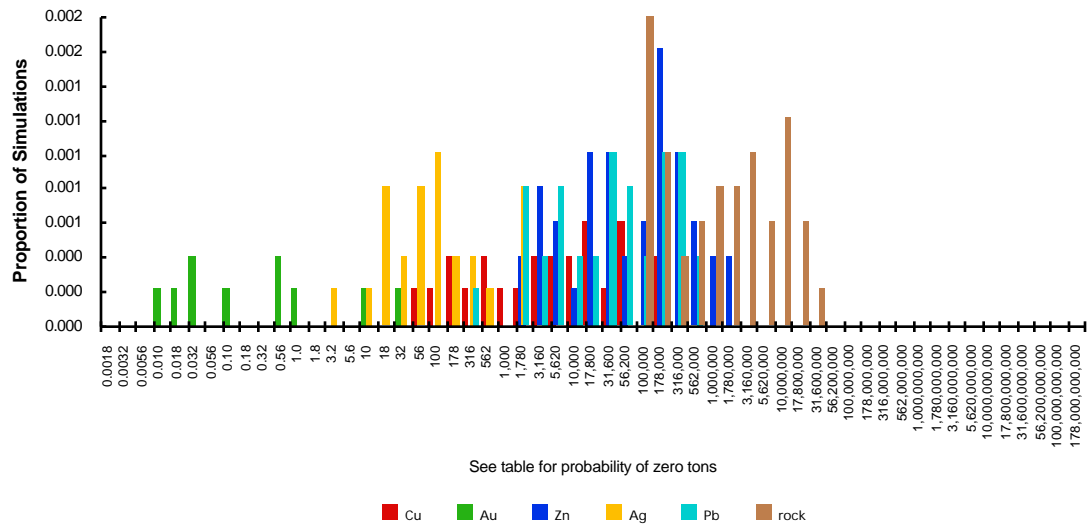
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	89	0	1,500	2	650	28,000
Probability of mean	0.00	0.00	0.01	0.01	0.01	0.01
Probability of zero	1.00	1.00	0.99	0.99	0.99	0.99

The tract ID is CR07

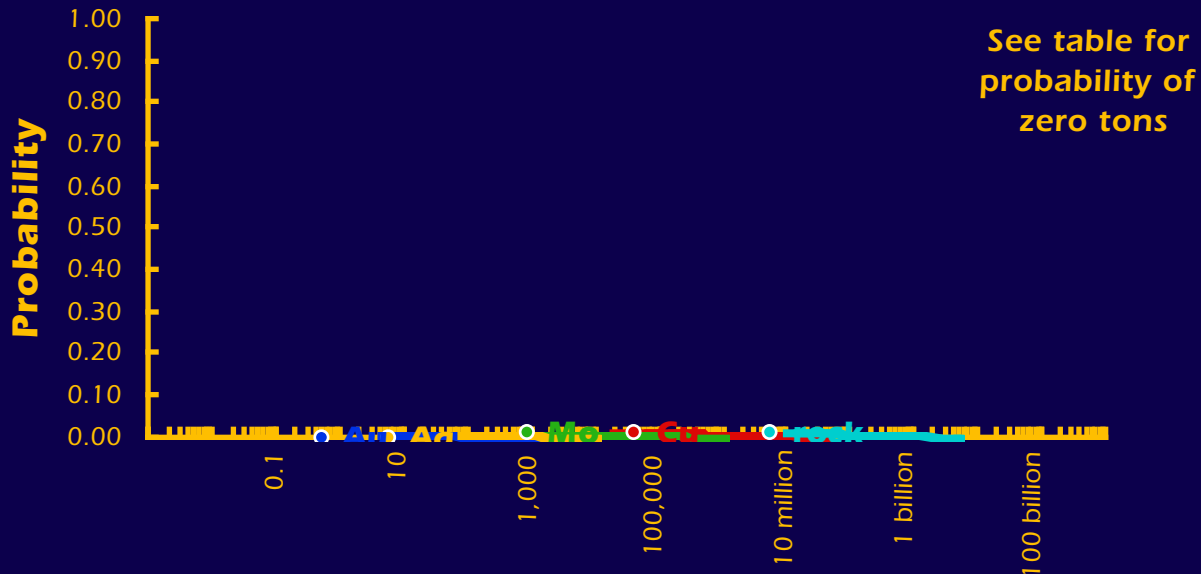
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

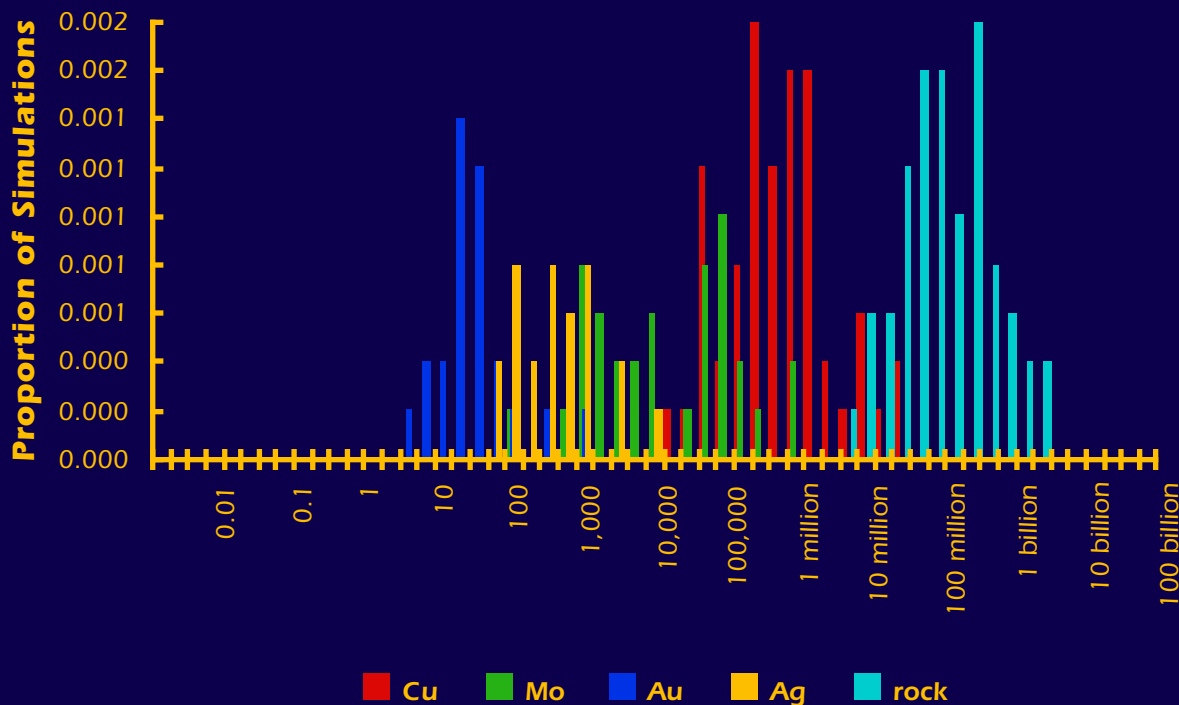


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR08

The Mark3 Index is 4:

Porphyry Cu

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	0	0	0	0	0
mean	41,000	830	1	6	5,600,000
Probability of mean	0.01	0.01	0.00	0.00	0.01
Probability of zero	0.99	0.99	1.00	1.00	0.99

The tract ID is CR08The Mark3 Index is 4: **Porphyry Cu**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

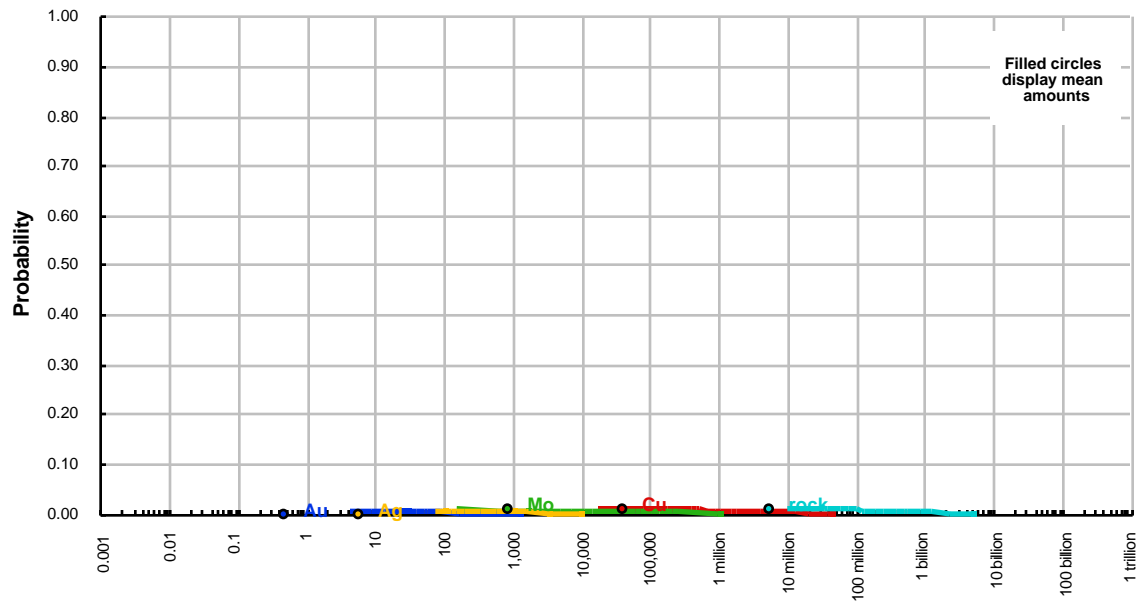
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

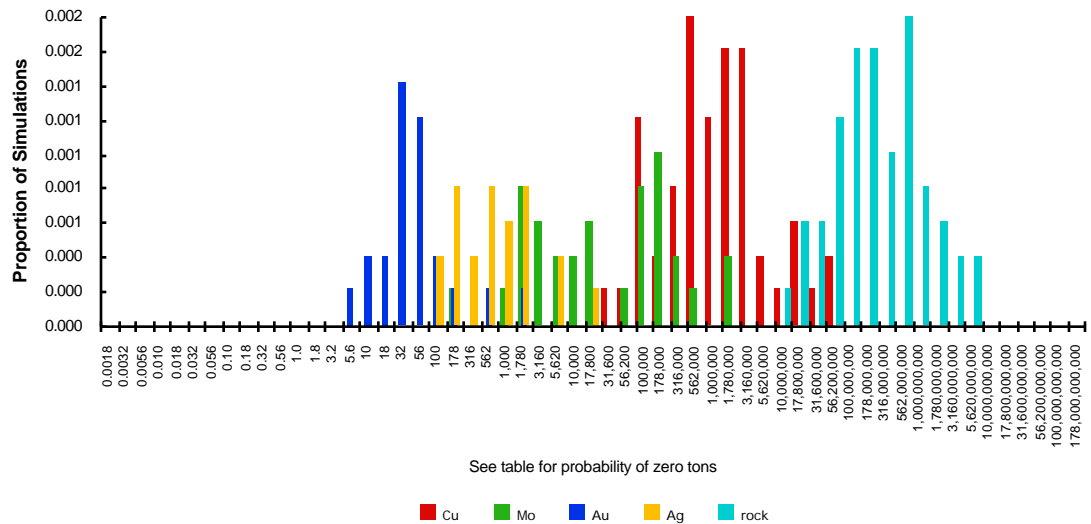
quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	0	0	0	0	0
mean	41,000	830	1	6	5,600,000
Probability of mean	0.01	0.01	0.00	0.00	0.01
Probability of zero	0.99	0.99	1.00	1.00	0.99

The tract ID is CR08

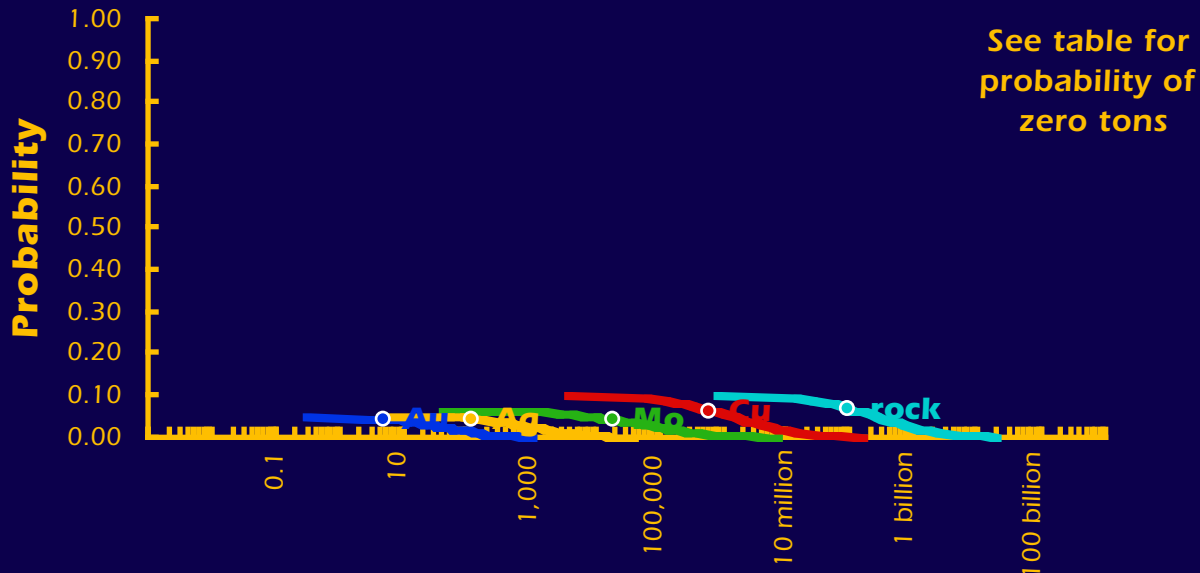
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

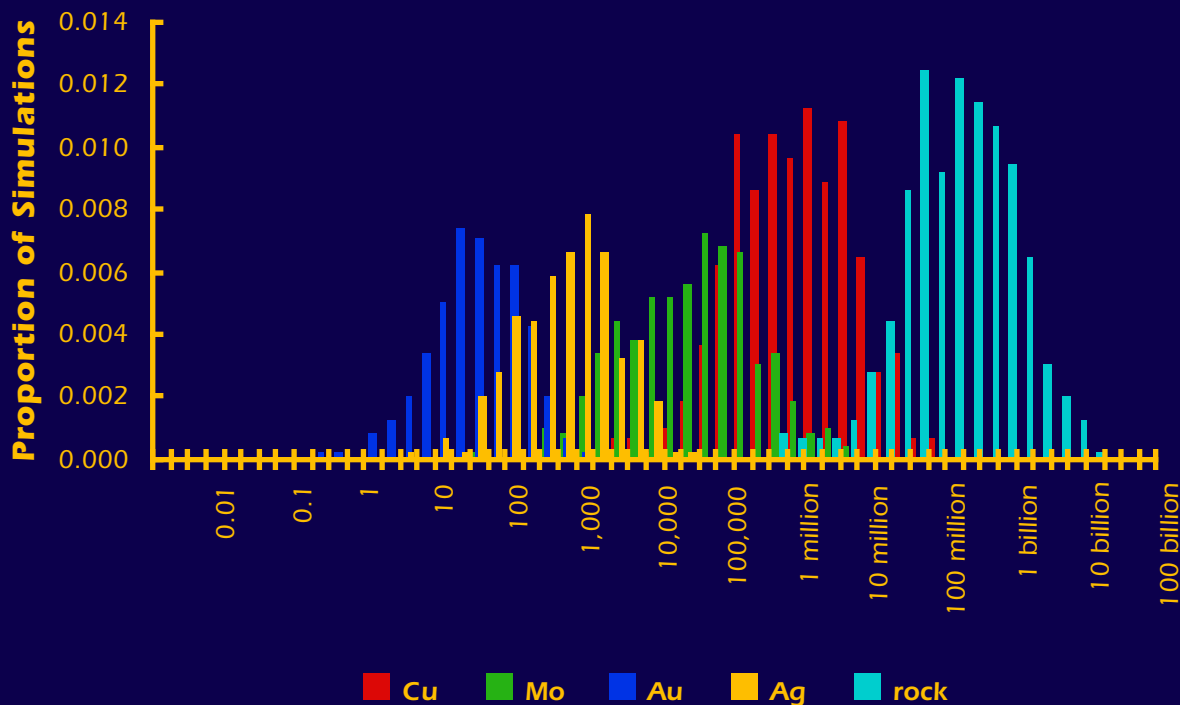


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR09

The Mark3 Index is 4:

Porphyry Cu

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	1,500,000	6,200	0	26	240,000,000
mean	590,000	19,000	4	120	91,000,000
Probability of mean	0.06	0.04	0.04	0.04	0.07
Probability of zero	0.90	0.94	0.95	0.95	0.90

The tract ID is CR09The Mark3 Index is 4: **Porphyry Cu**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

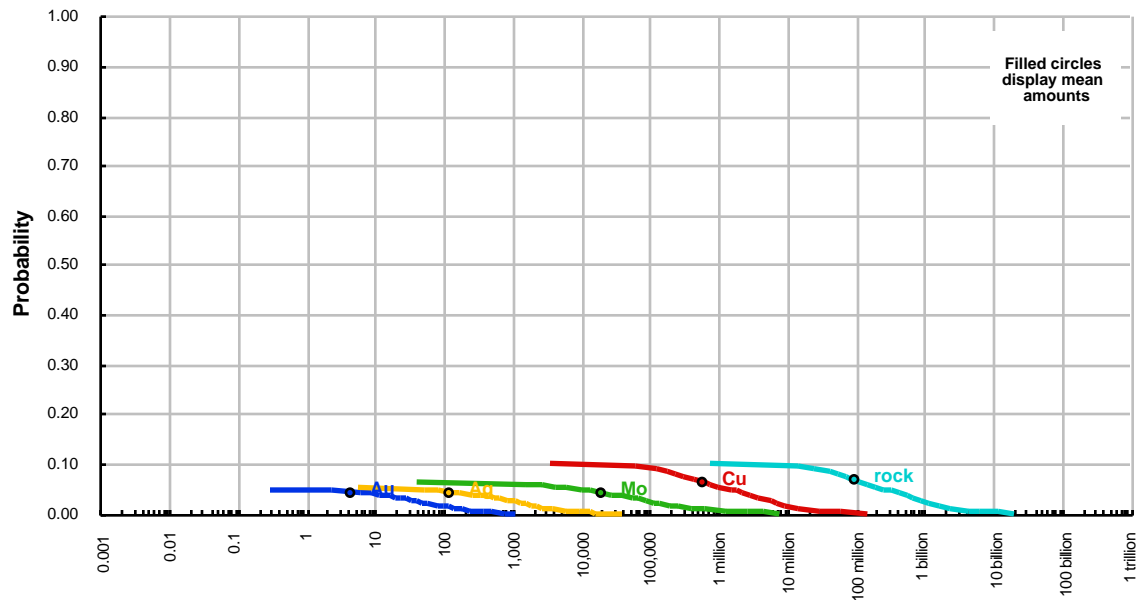
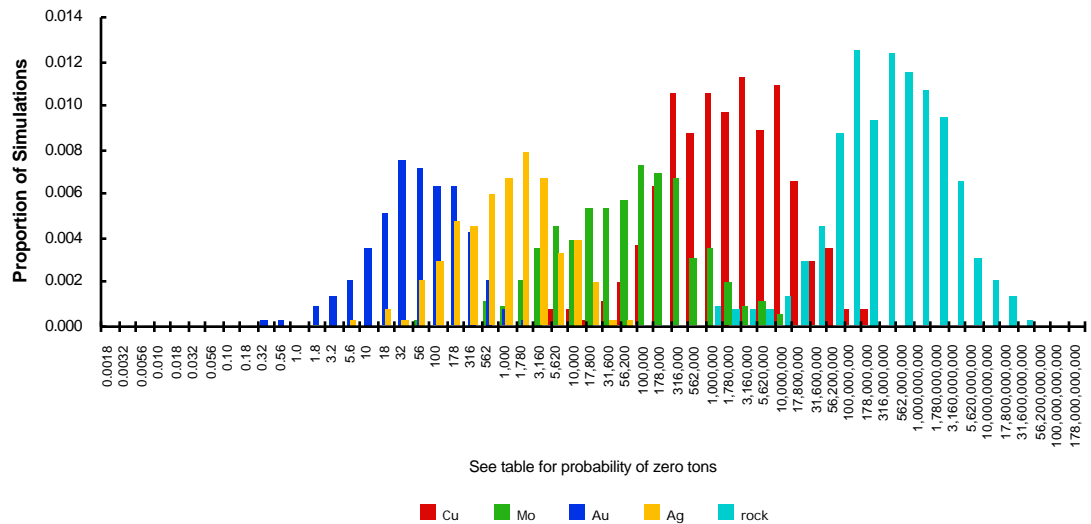
There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

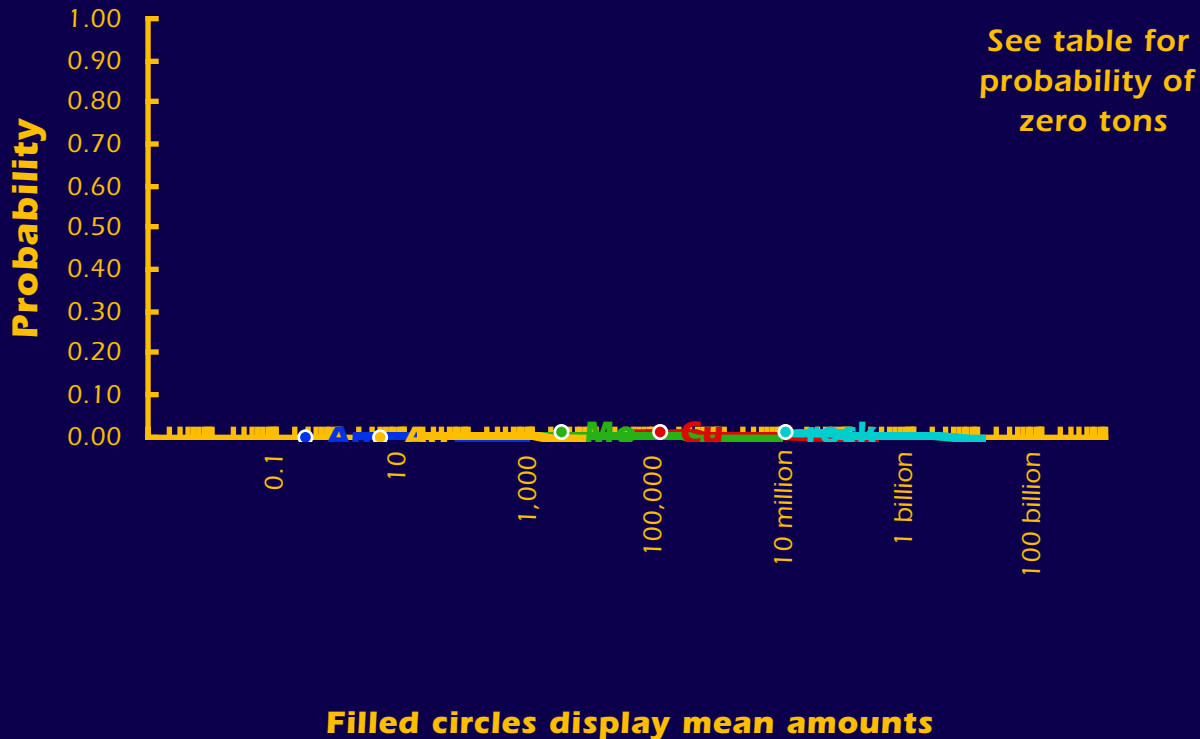
quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	1,500,000	6,200	0	26	240,000,000
mean	590,000	19,000	4	120	91,000,000
Probability of mean	0.06	0.04	0.04	0.04	0.07
Probability of zero	0.90	0.94	0.95	0.95	0.90

The tract ID is CR09

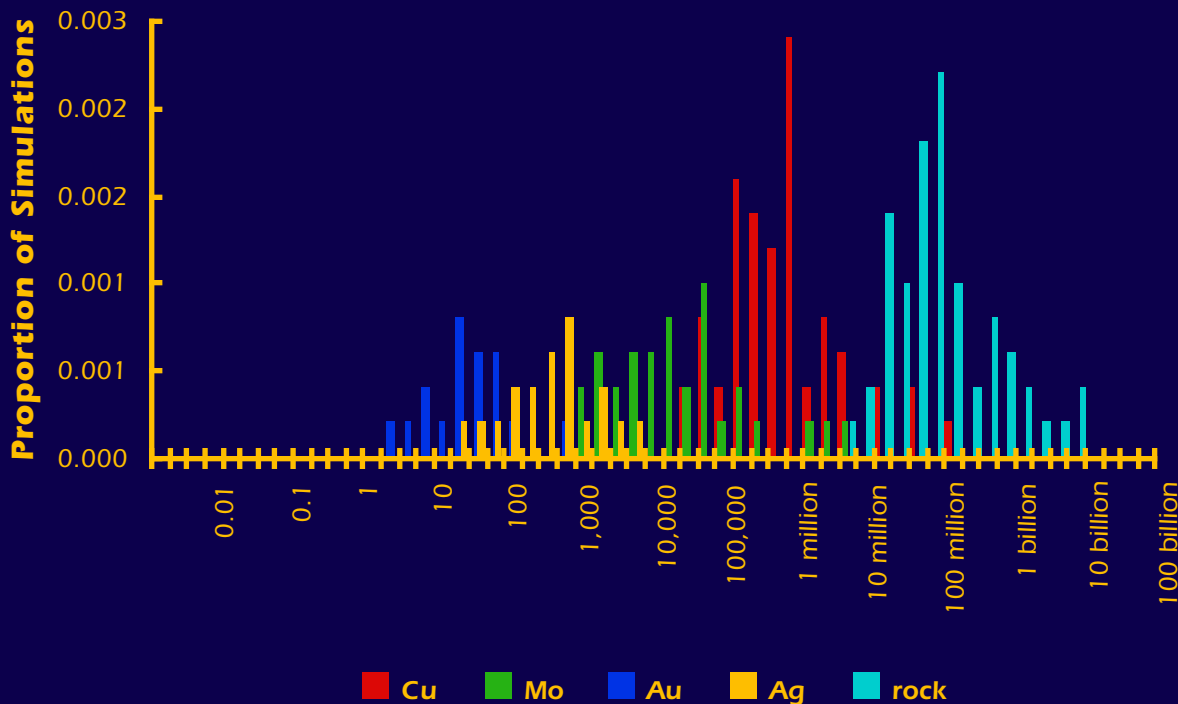
Cumulative Distributions of Contained Metal and Mineralized Rock

Histograms of Contained Metal and Mineralized Rock
(metric tons)

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR10

The Mark3 Index is 4:

Porphyry Cu

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	0	0	0	0	0
mean	100,000	3,100	0	4	9,800,000
Probability of mean	0.01	0.01	0.00	0.00	0.01
Probability of zero	0.99	0.99	1.00	1.00	0.99

The tract ID is CR10The Mark3 Index is 4: **Porphyry Cu**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

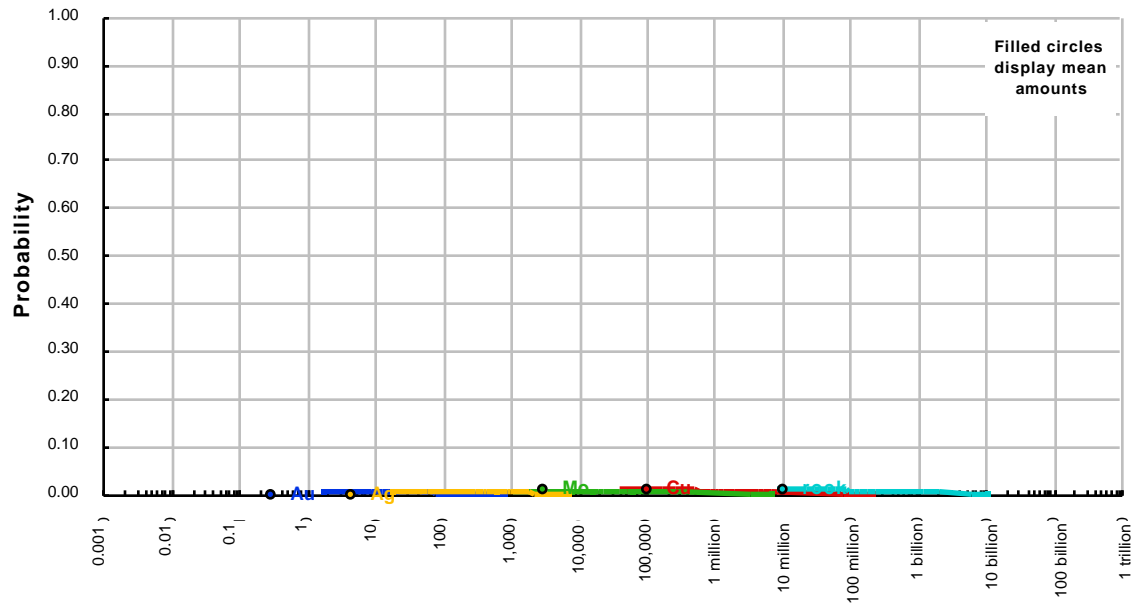
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

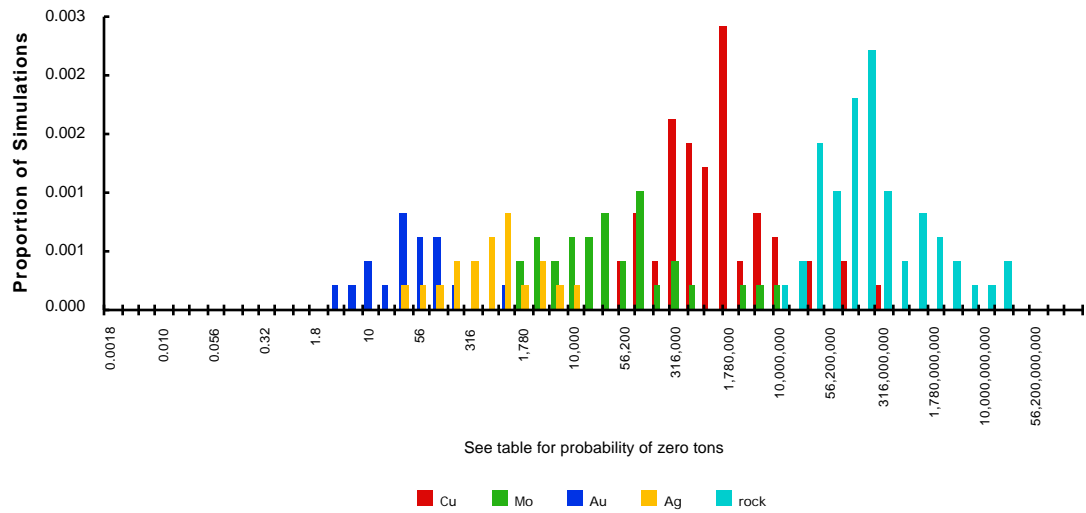
quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	0	0	0	0	0
mean	100,000	3,100	0	4	9,800,000
Probability of mean	0.01	0.01	0.00	0.00	0.01
Probability of zero	0.99	0.99	1.00	1.00	0.99

The tract ID is CR10

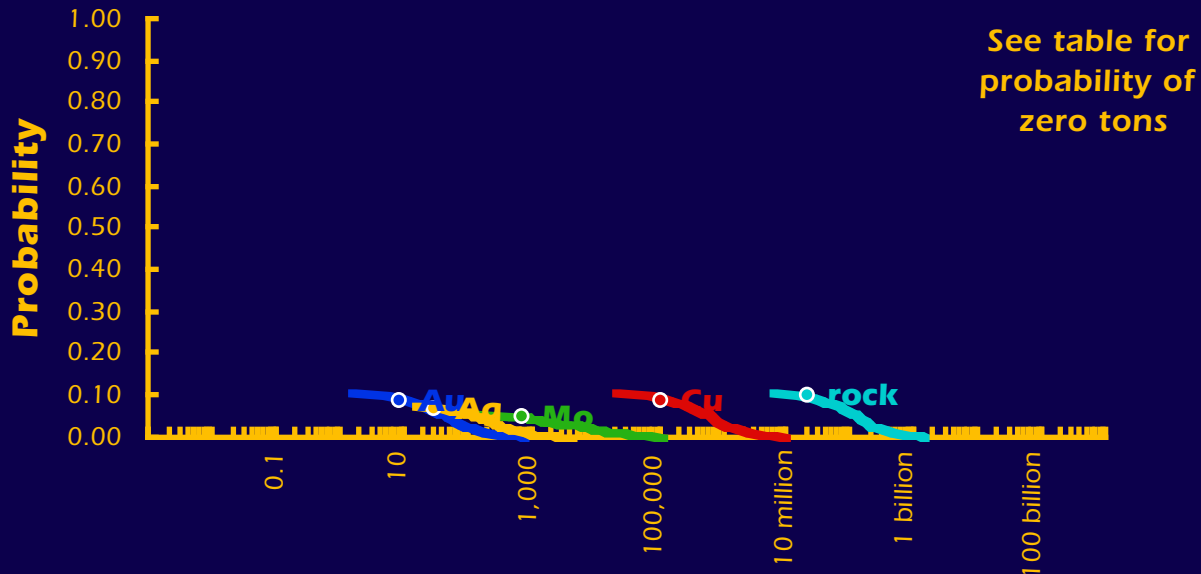
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

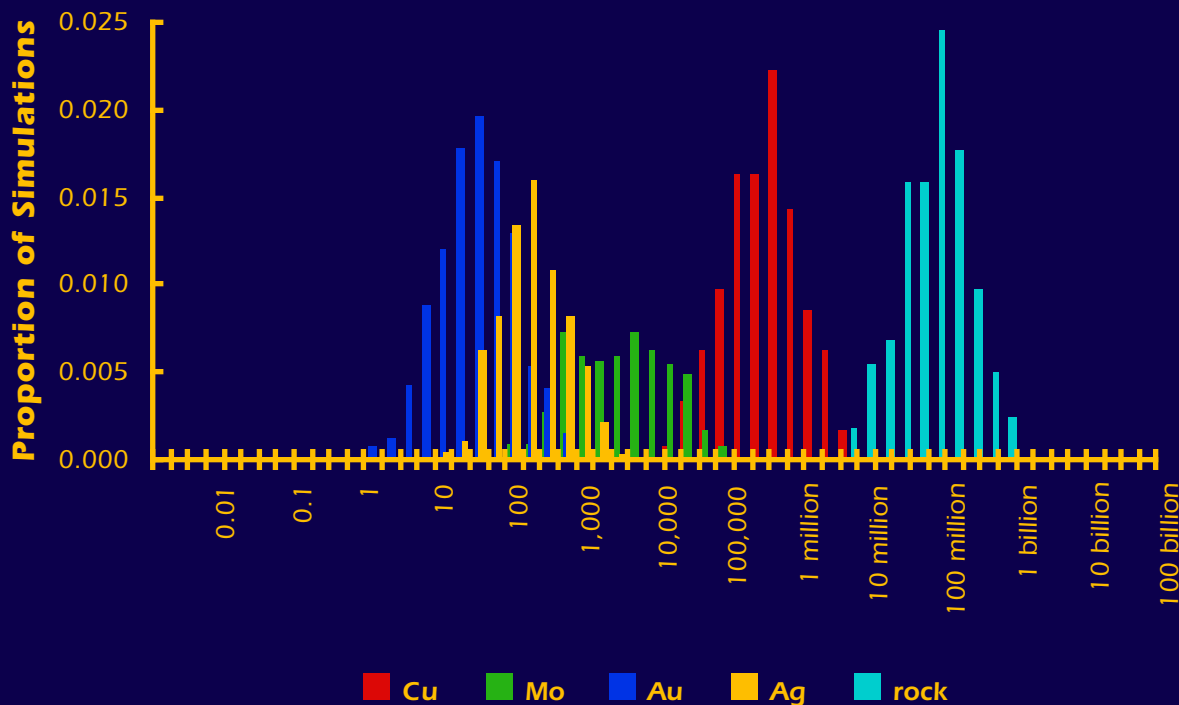


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR11

The Mark3 Index is 34:

Porphyry Cu-Au

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	64,000	0	5	0	14,000,000
0.05	600,000	590	45	130	130,000,000
mean	100,000	680	8	30	20,000,000
Probability of mean	0.09	0.05	0.09	0.07	0.10
Probability of zero	0.90	0.95	0.90	0.93	0.90

The tract ID is CR11The Mark3 Index is 34: **Porphyry Cu-Au**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

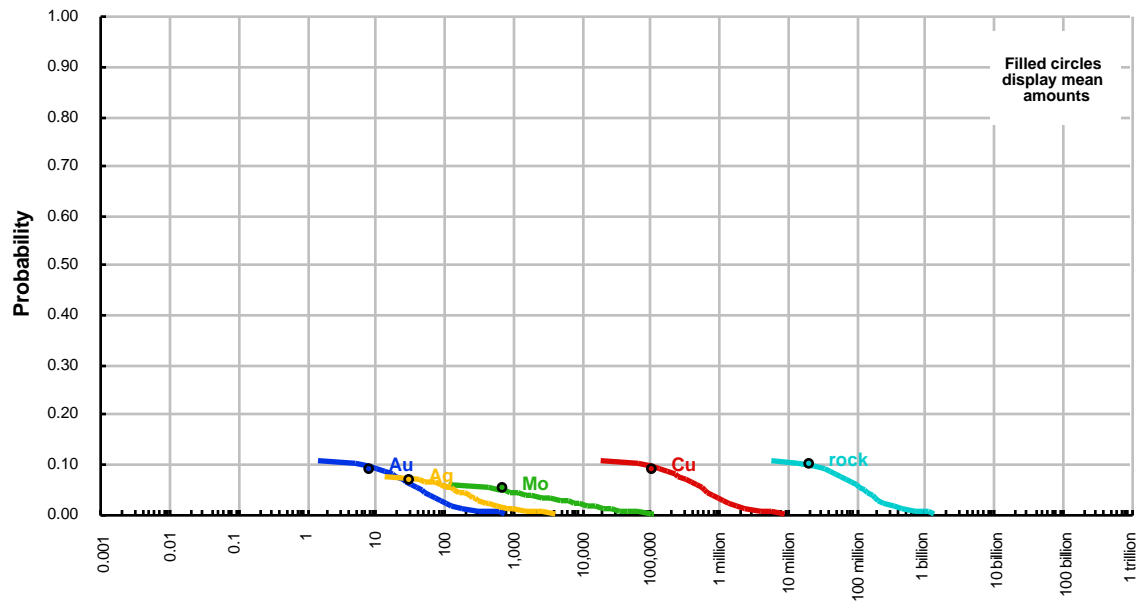
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

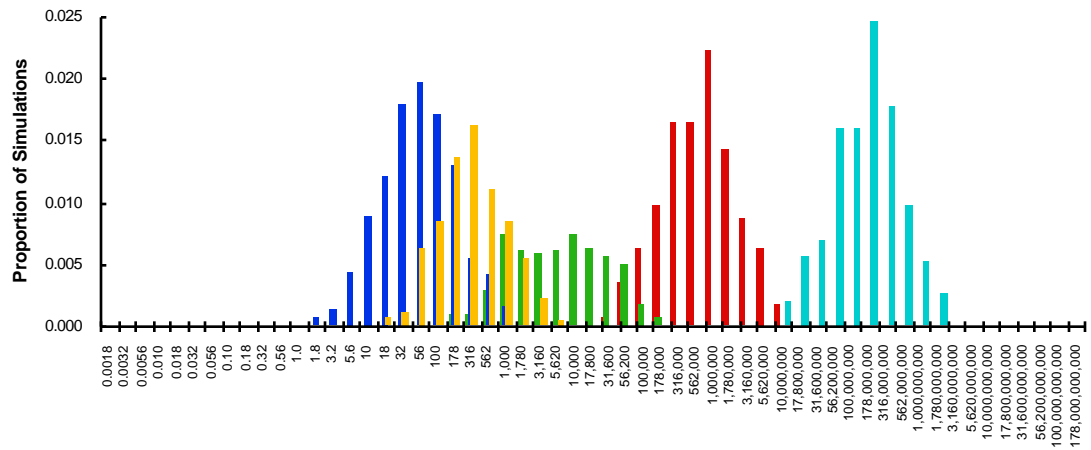
quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	64,000	0	5	0	14,000,000
0.05	600,000	590	45	130	130,000,000
mean	100,000	680	8	30	20,000,000
Probability of mean	0.09	0.05	0.09	0.07	0.10
Probability of zero	0.90	0.95	0.90	0.93	0.90

The tract ID is CR11

Cumulative Distributions of Contained Metal and Mineralized Rock



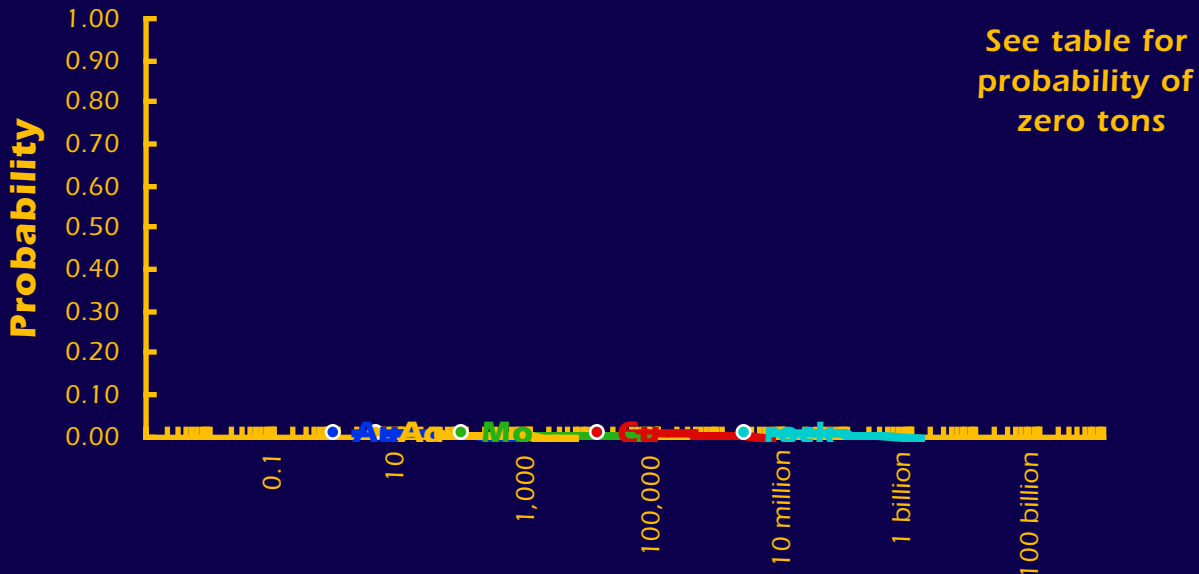
Histograms of Contained Metal and Mineralized Rock (metric tons)



See table for probability of zero tons

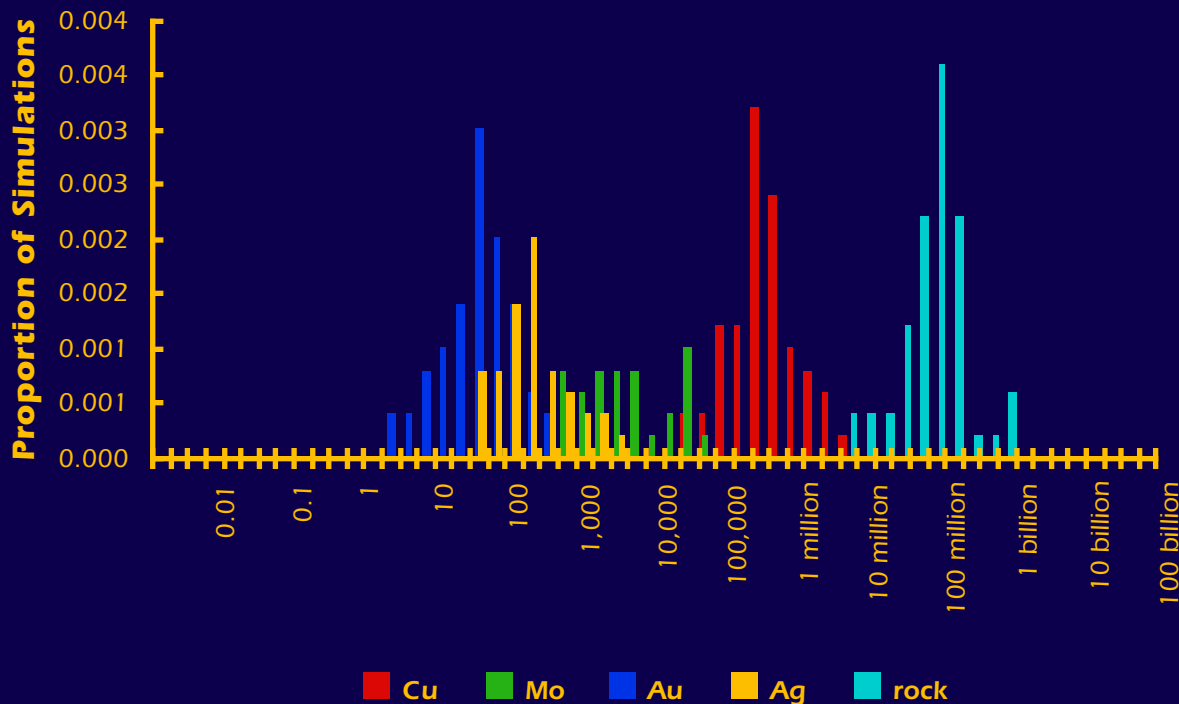
■ Cu ■ Mo ■ Au ■ Ag ■ rock

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR12

The Mark3 Index is 34:

Porphry Cu-Au

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	0	0	0	0	0
mean	11,000	84	1	4	2,200,000
Probability of mean	0.01	0.01	0.01	0.01	0.01
Probability of zero	0.99	0.99	0.99	0.99	0.99

The tract ID is CR12The Mark3 Index is 34: **Porphyry Cu-Au**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

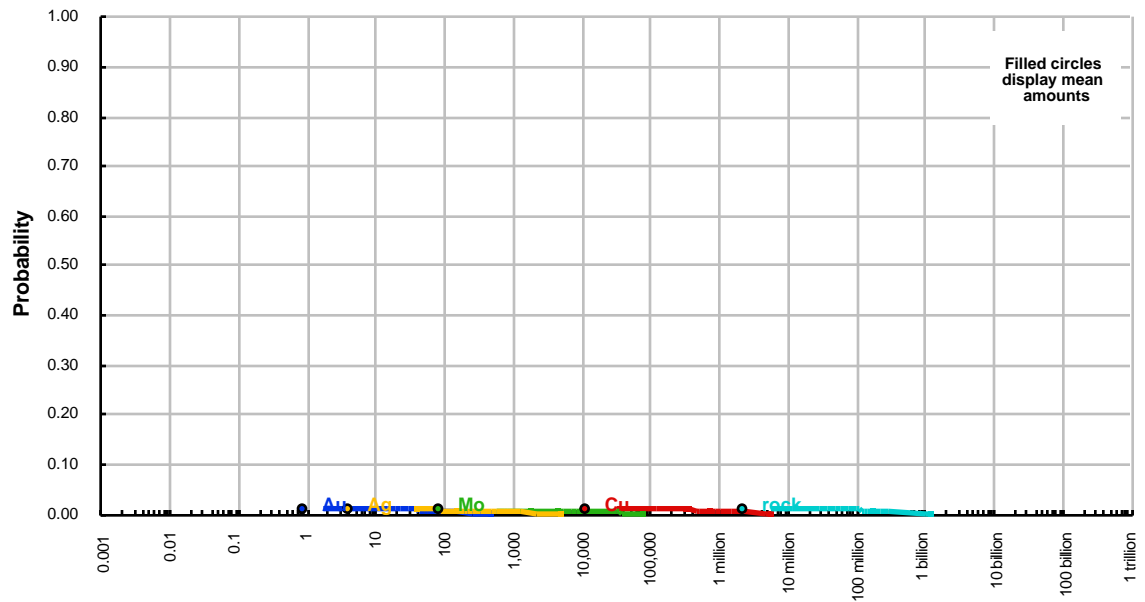
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

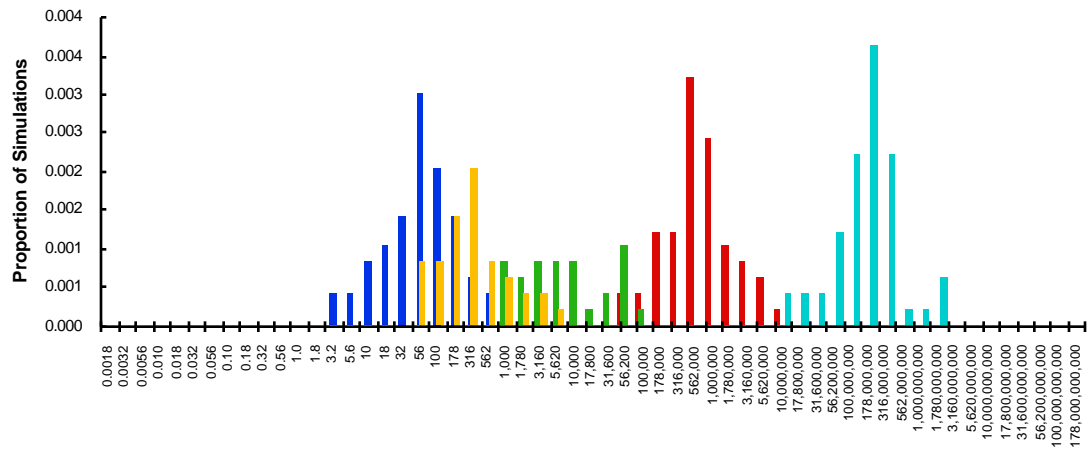
quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	0	0	0	0	0
mean	11,000	84	1	4	2,200,000
Probability of mean	0.01	0.01	0.01	0.01	0.01
Probability of zero	0.99	0.99	0.99	0.99	0.99

The tract ID is CR12

Cumulative Distributions of Contained Metal and Mineralized Rock



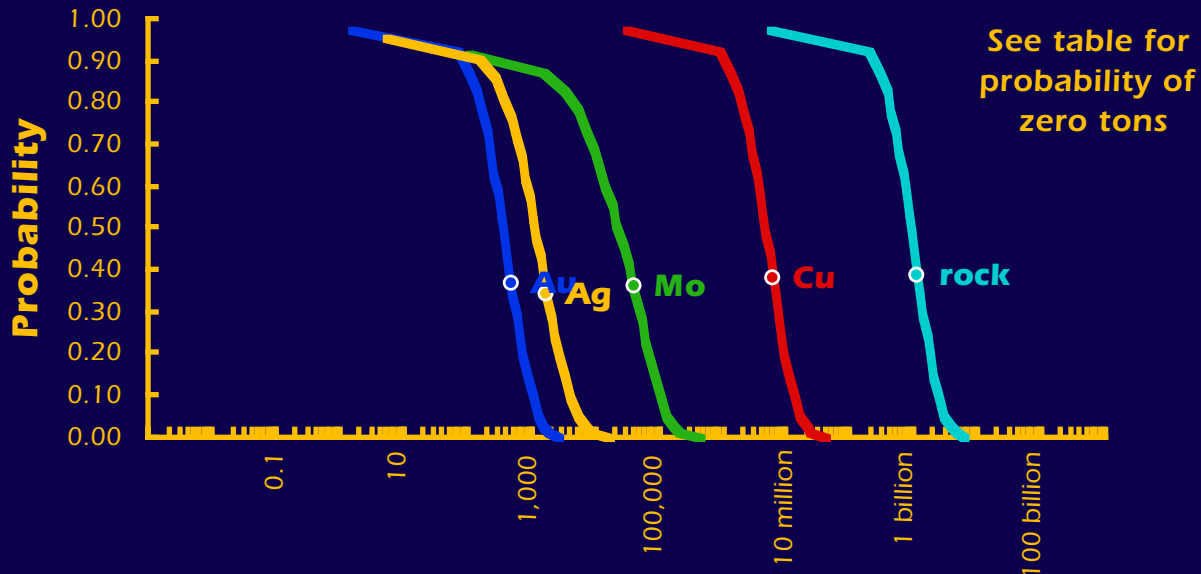
Histograms of Contained Metal and Mineralized Rock (metric tons)



See table for probability of zero tons

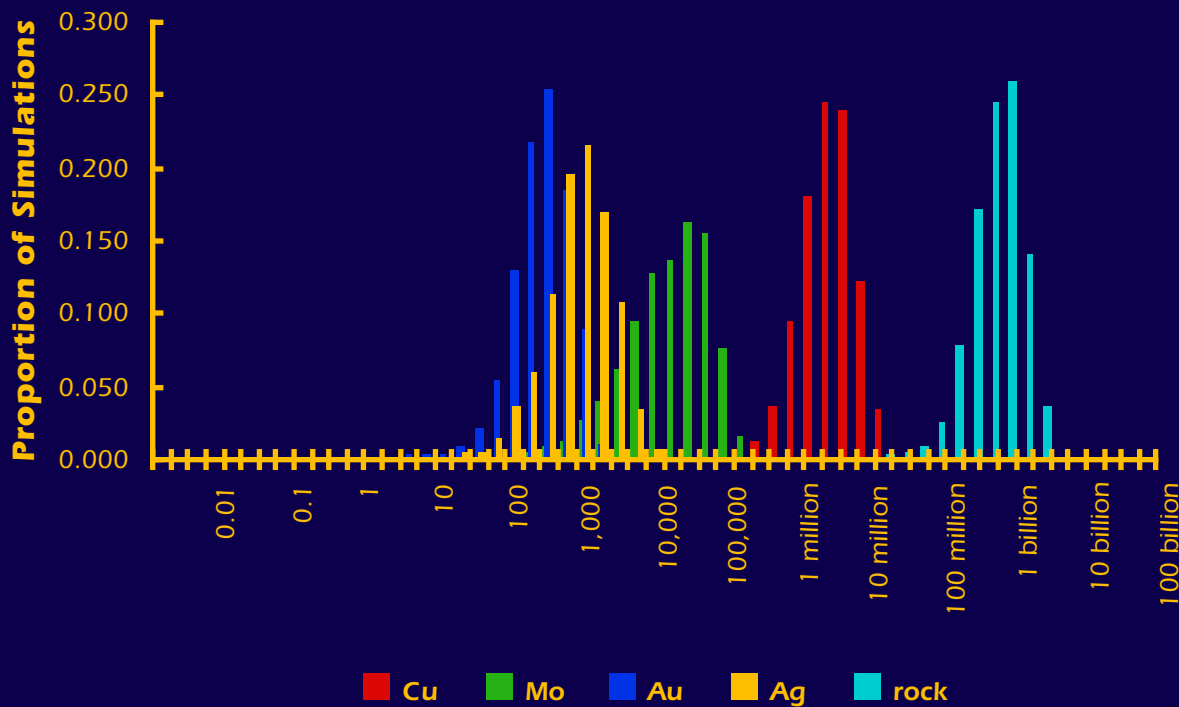
■ Cu ■ Mo ■ Au ■ Ag ■ rock

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR13

The Mark3 Index is 34:

Porphyry Cu-Au

There is a 90% or greater chance of 3 or more deposits.

There is a 50% or greater chance of 5 or more deposits.

There is a 10% or greater chance of 9 or more deposits.

There is a 5% or greater chance of 15 or more deposits.

There is a 1% or greater chance of 20 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	540,000	0	42	30	120,000,000
0.90	1,100,000	770	85	170	230,000,000
0.50	4,400,000	22,000	350	1,100	850,000,000
0.10	12,000,000	97,000	991	3,900	2,300,000,000
0.05	16,000,000	130,000	1,300	5,100	2,900,000,000
mean	5,800,000	38,000	450	1,700	1,100,000,000
Probability of mean	0.38	0.36	0.37	0.34	0.39
Probability of zero	0.03	0.08	0.03	0.05	0.03

The tract ID is CR13The Mark3 Index is 34: **Porphyry Cu-Au**

There is a 90% or greater chance of 3 or more deposits.

There is a 50% or greater chance of 5 or more deposits.

There is a 10% or greater chance of 9 or more deposits.

There is a 5% or greater chance of 15 or more deposits.

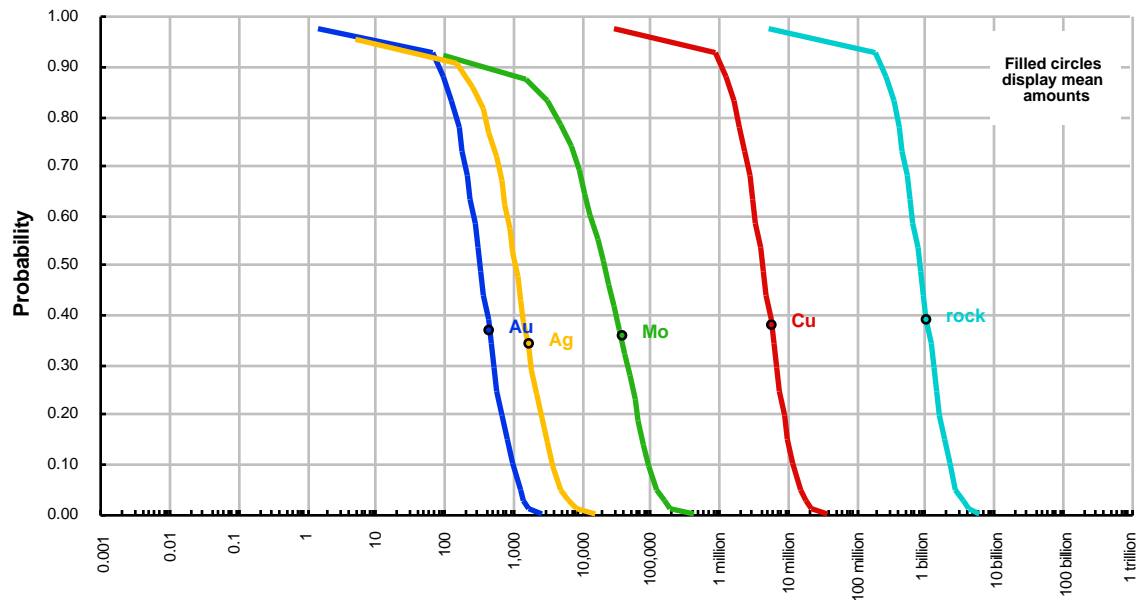
There is a 1% or greater chance of 20 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

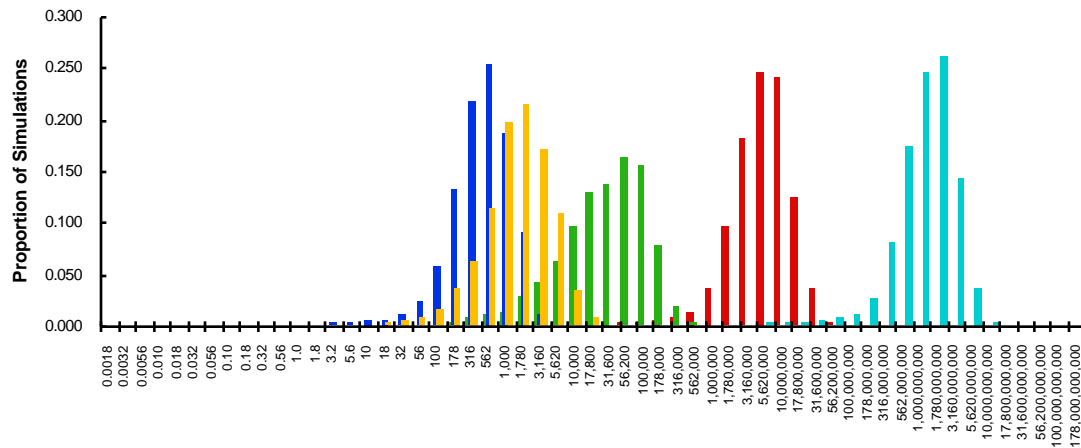
quantile	Cu	Mo	Au	Ag	rock
0.95	540,000	0	42	30	120,000,000
0.90	1,100,000	770	85	170	230,000,000
0.50	4,400,000	22,000	350	1,100	850,000,000
0.10	12,000,000	97,000	991	3,900	2,300,000,000
0.05	16,000,000	130,000	1,300	5,100	2,900,000,000
mean	5,800,000	38,000	450	1,700	1,100,000,000
Probability of mean	0.38	0.36	0.37	0.34	0.39
Probability of zero	0.03	0.08	0.03	0.05	0.03

The tract ID is CR13

Cumulative Distributions of Contained Metal and Mineralized Rock



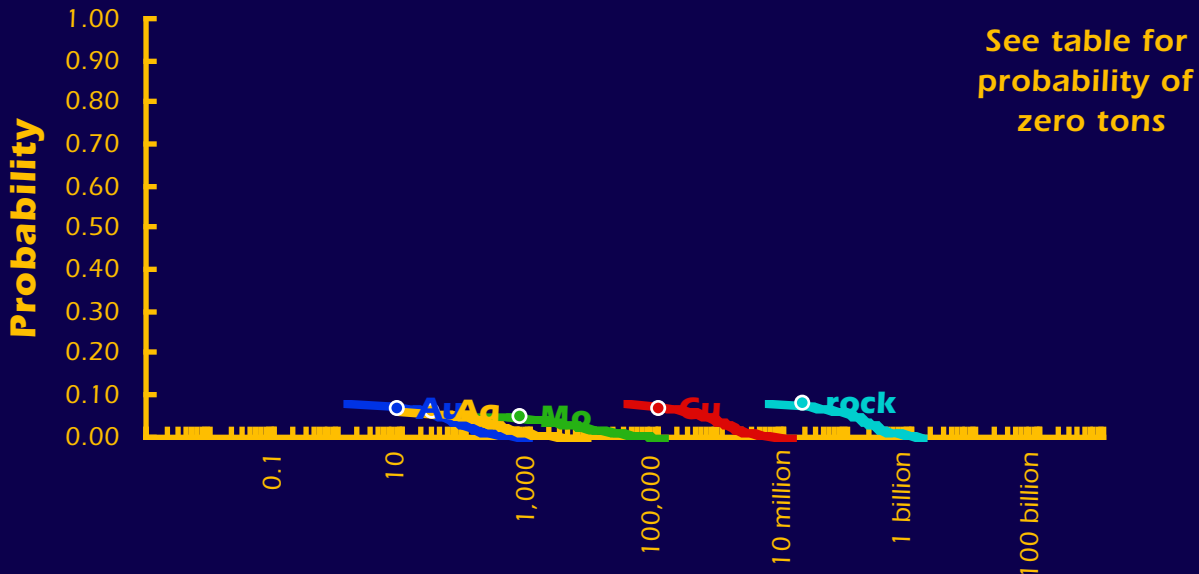
Histograms of Contained Metal and Mineralized Rock (metric tons)



See table for probability of zero tons

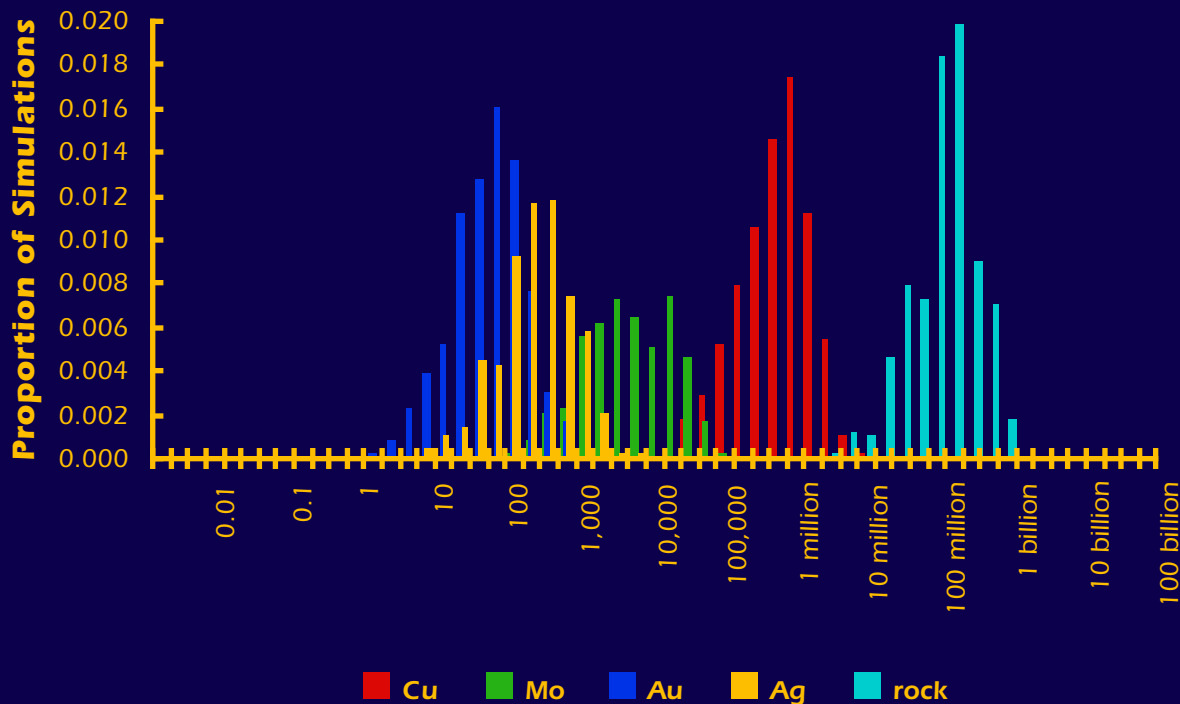
Cu Mo Au Ag rock

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR14

The Mark3 Index is 34:

Porphyry Cu-Au

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	560,000	0	42	82	120,000,000
mean	100,000	670	8	30	19,000,000
Probability of mean	0.07	0.05	0.07	0.06	0.08
Probability of zero	0.92	0.95	0.92	0.94	0.92

The tract ID is CR14The Mark3 Index is 34: **Porphyry Cu-Au**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

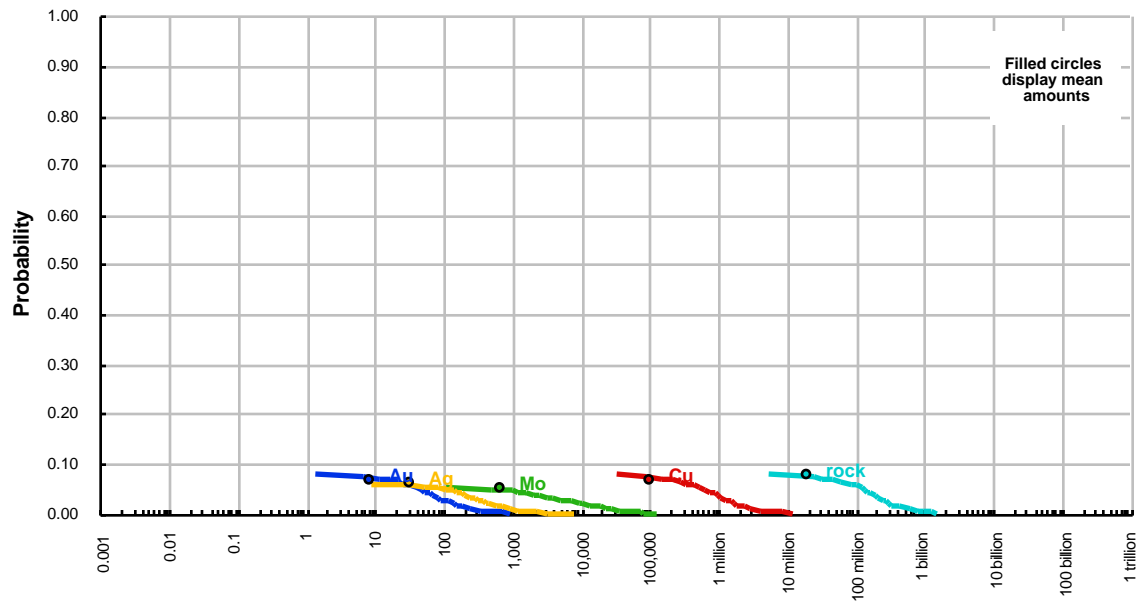
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

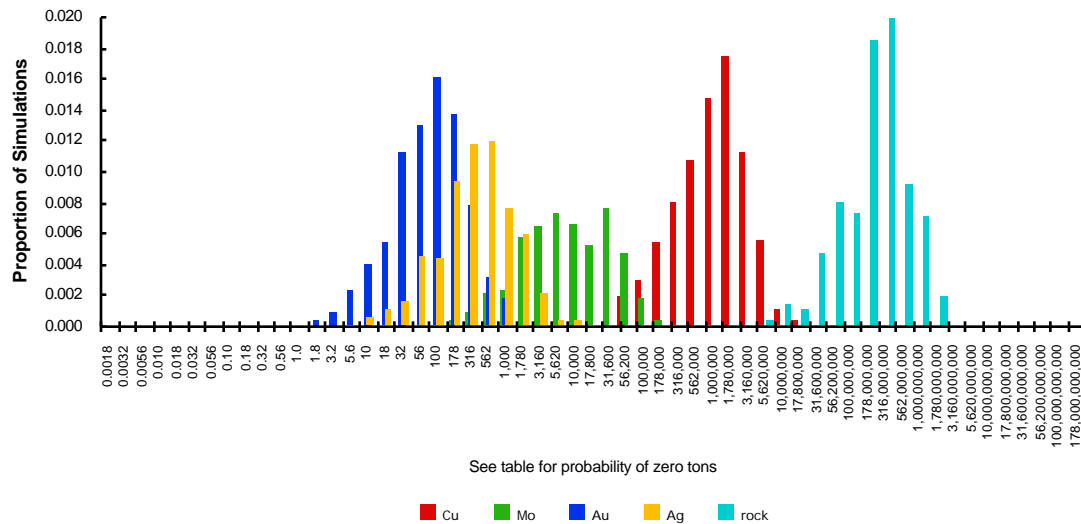
quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	560,000	0	42	82	120,000,000
mean	100,000	670	8	30	19,000,000
Probability of mean	0.07	0.05	0.07	0.06	0.08
Probability of zero	0.92	0.95	0.92	0.94	0.92

The tract ID is CR14

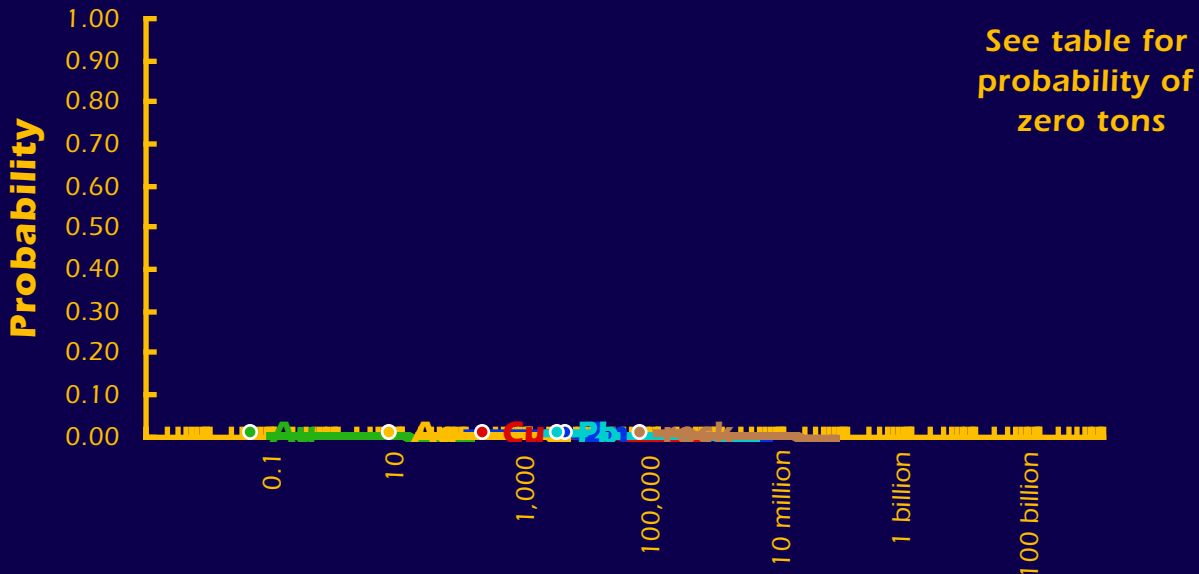
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

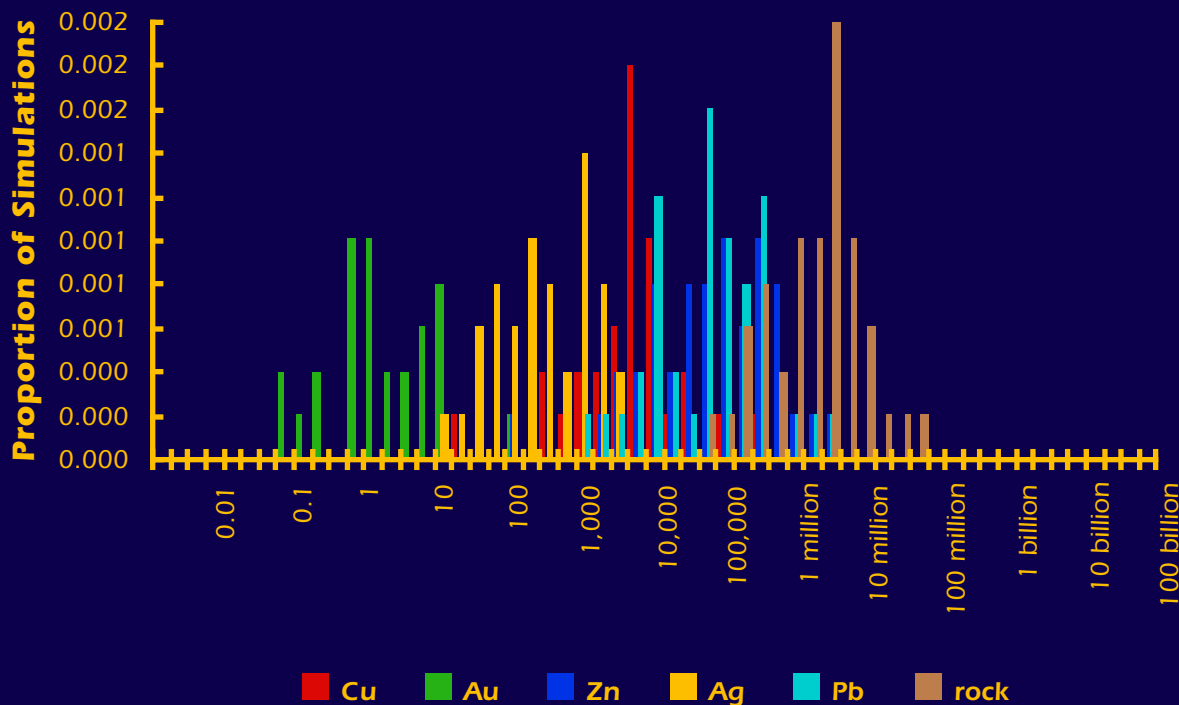


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR15

The Mark3 Index is 47:

Polymetallic replacement

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	180	0	3,400	6	2,700	55,000
Probability of mean	0.01	0.01	0.01	0.01	0.01	0.01
Probability of zero	0.99	0.99	0.99	0.99	0.99	0.99

The tract ID is CR15The Mark3 Index is 47: **Polymetallic replacement**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

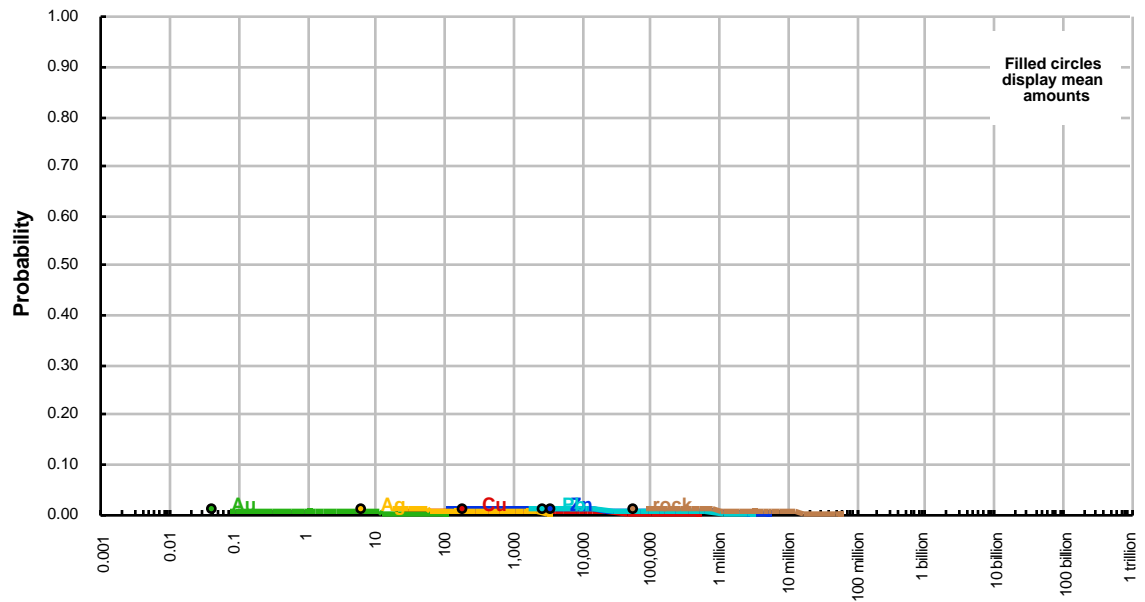
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

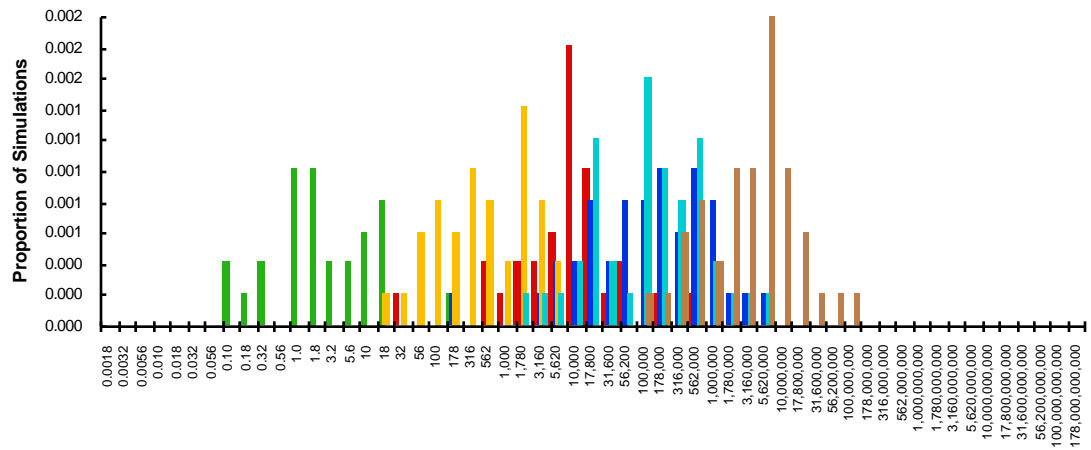
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	180	0	3,400	6	2,700	55,000
Probability of mean	0.01	0.01	0.01	0.01	0.01	0.01
Probability of zero	0.99	0.99	0.99	0.99	0.99	0.99

The tract ID is CR15

Cumulative Distributions of Contained Metal and Mineralized Rock



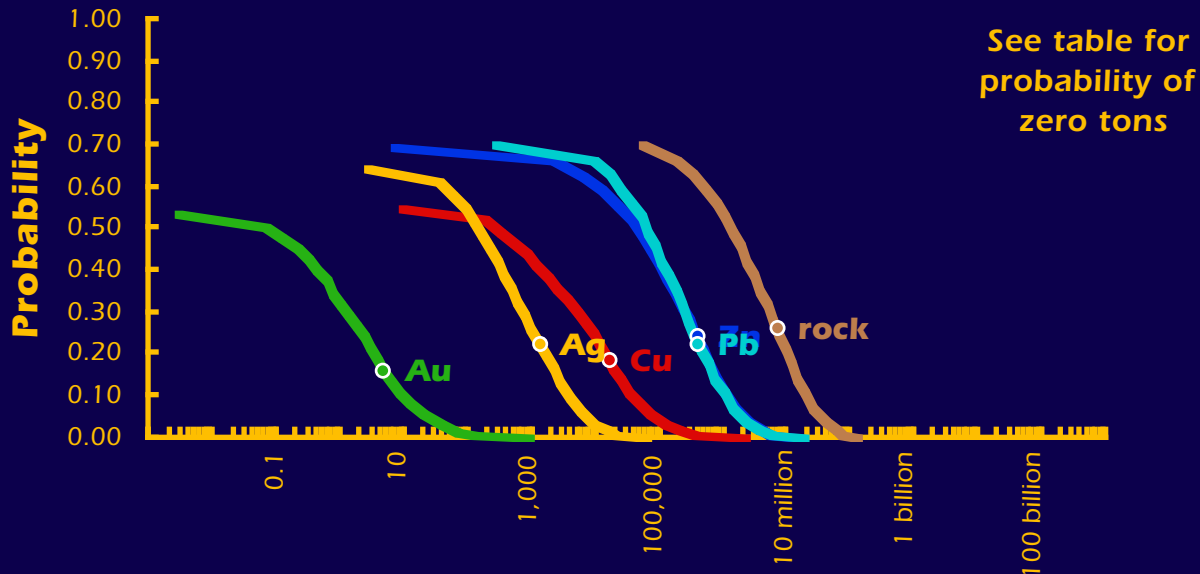
Histograms of Contained Metal and Mineralized Rock (metric tons)



See table for probability of zero tons

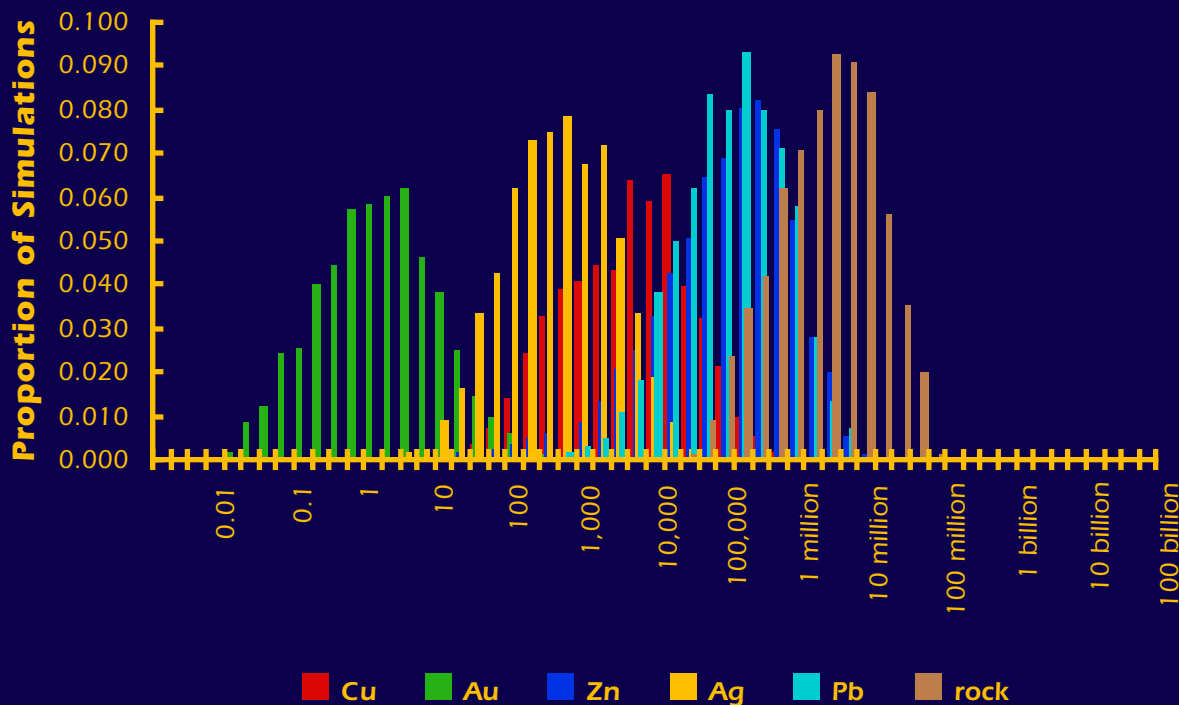
Cu Au Zn Ag Pb rock

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR16

The Mark3 Index is 47:

Polymetallic replacement

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	280	0	46,000	150	62,000	1,300,000
0.10	35,000	9	1,080,000	3,700	1,100,000	20,000,000
0.05	76,000	20	1,900,000	6,900	1,700,000	34,000,000
mean	16,000	5	400,000	1,400	390,000	6,900,000
Probability of mean	0.18	0.16	0.24	0.22	0.22	0.26
Probability of zero	0.45	0.47	0.31	0.36	0.30	0.30

The tract ID is CR16The Mark3 Index is 47: **Polymetallic replacement**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

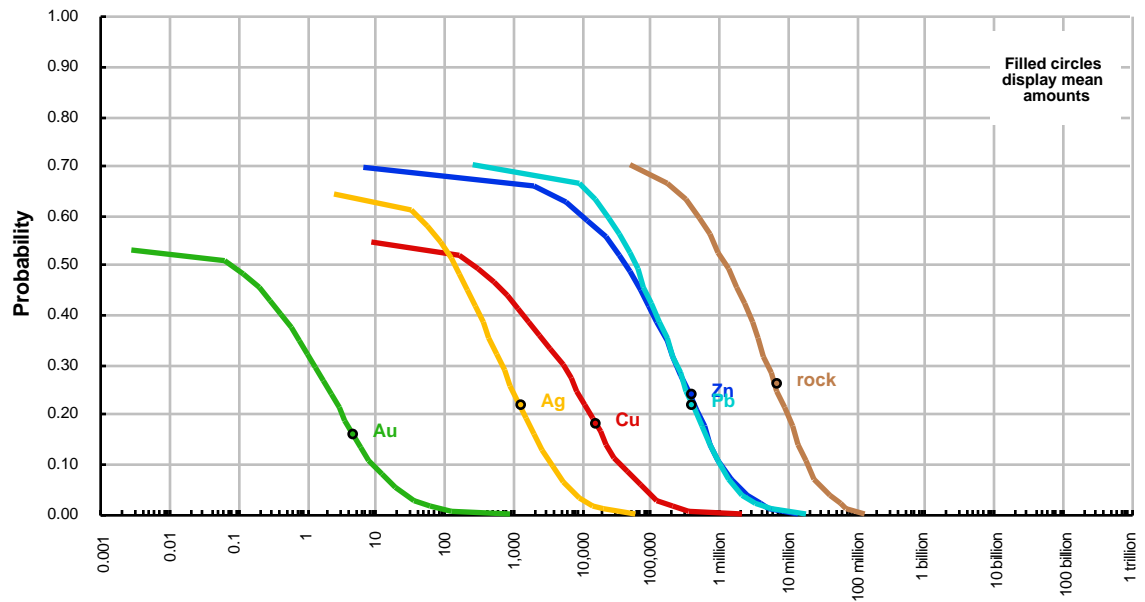
There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

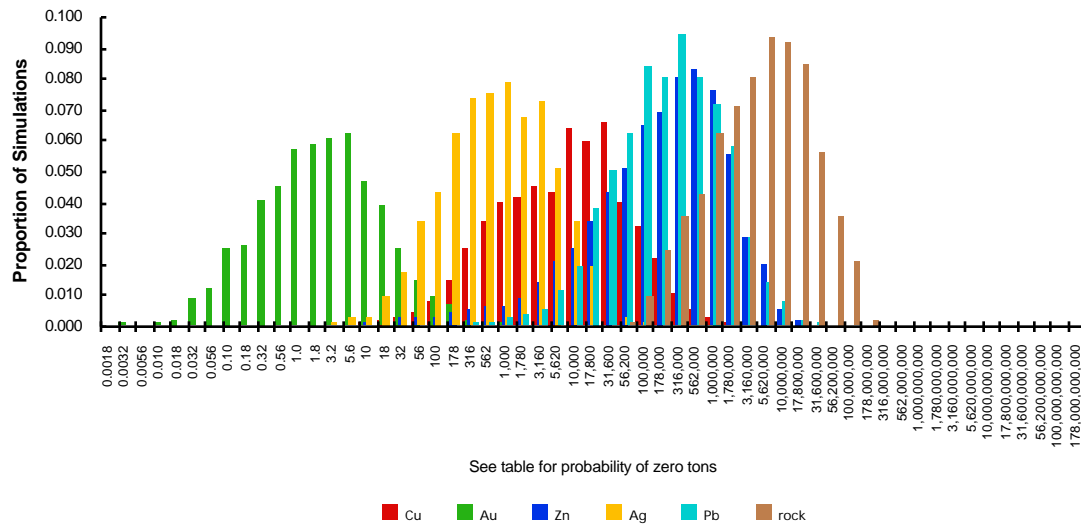
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	280	0	46,000	150	62,000	1,300,000
0.10	35,000	9	1,080,000	3,700	1,100,000	20,000,000
0.05	76,000	20	1,900,000	6,900	1,700,000	34,000,000
mean	16,000	5	400,000	1,400	390,000	6,900,000
Probability of mean	0.18	0.16	0.24	0.22	0.22	0.26
Probability of zero	0.45	0.47	0.31	0.36	0.30	0.30

The tract ID is CR16

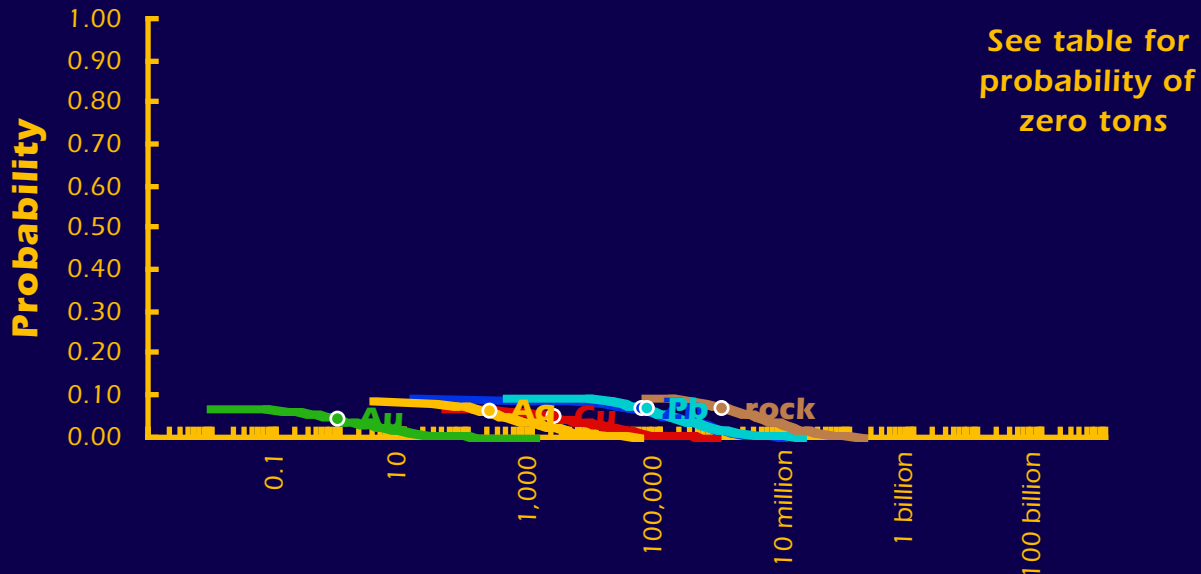
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

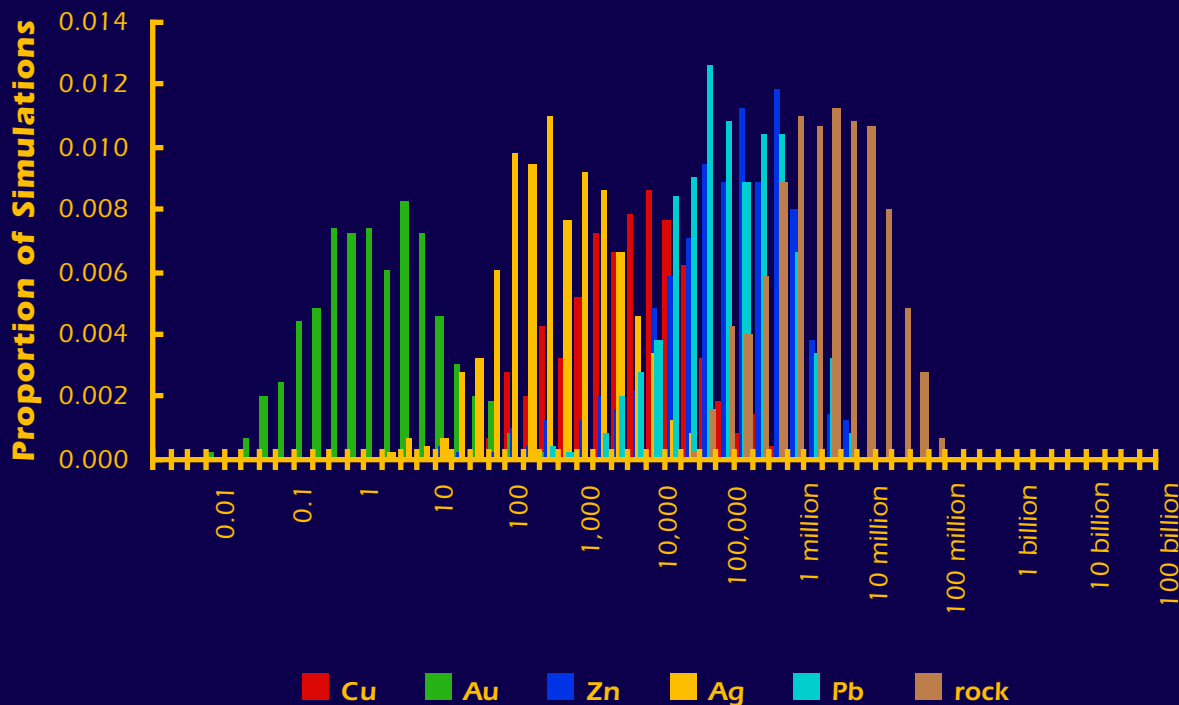


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR17

The Mark3 Index is 47:

Polymetallic replacement

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	2,000	1	140,000	350	130,000	3,000,000
mean	2,200	1	52,000	220	63,000	980,000
Probability of mean	0.05	0.04	0.07	0.06	0.07	0.07
Probability of zero	0.93	0.93	0.91	0.91	0.91	0.91

The tract ID is CR17The Mark3 Index is 47: **Polymetallic replacement**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

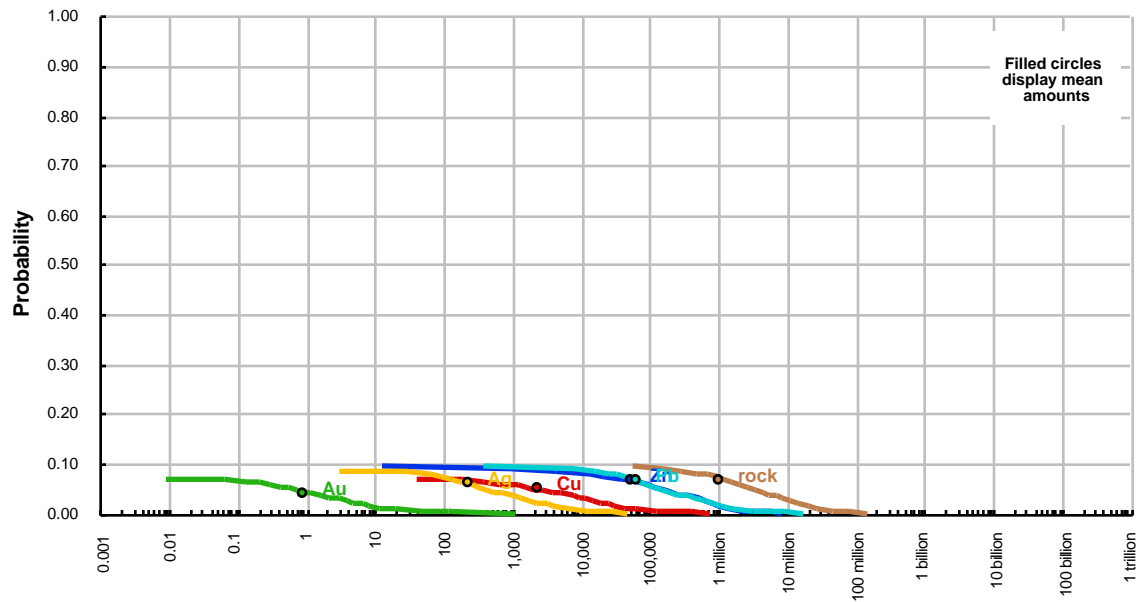
There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

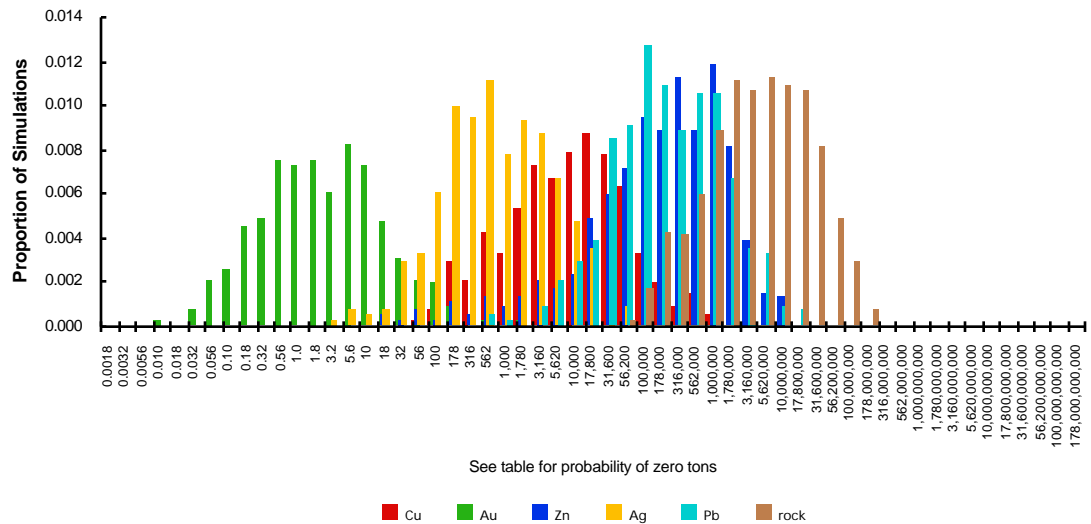
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	2,000	1	140,000	350	130,000	3,000,000
mean	2,200	1	52,000	220	63,000	980,000
Probability of mean	0.05	0.04	0.07	0.06	0.07	0.07
Probability of zero	0.93	0.93	0.91	0.91	0.91	0.91

The tract ID is CR17

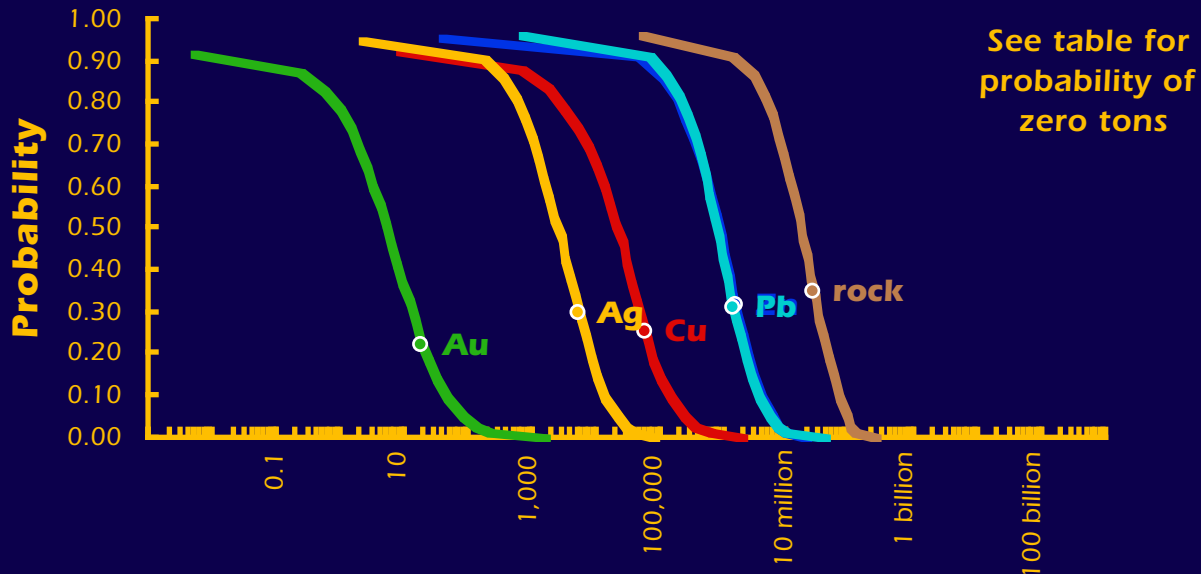
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

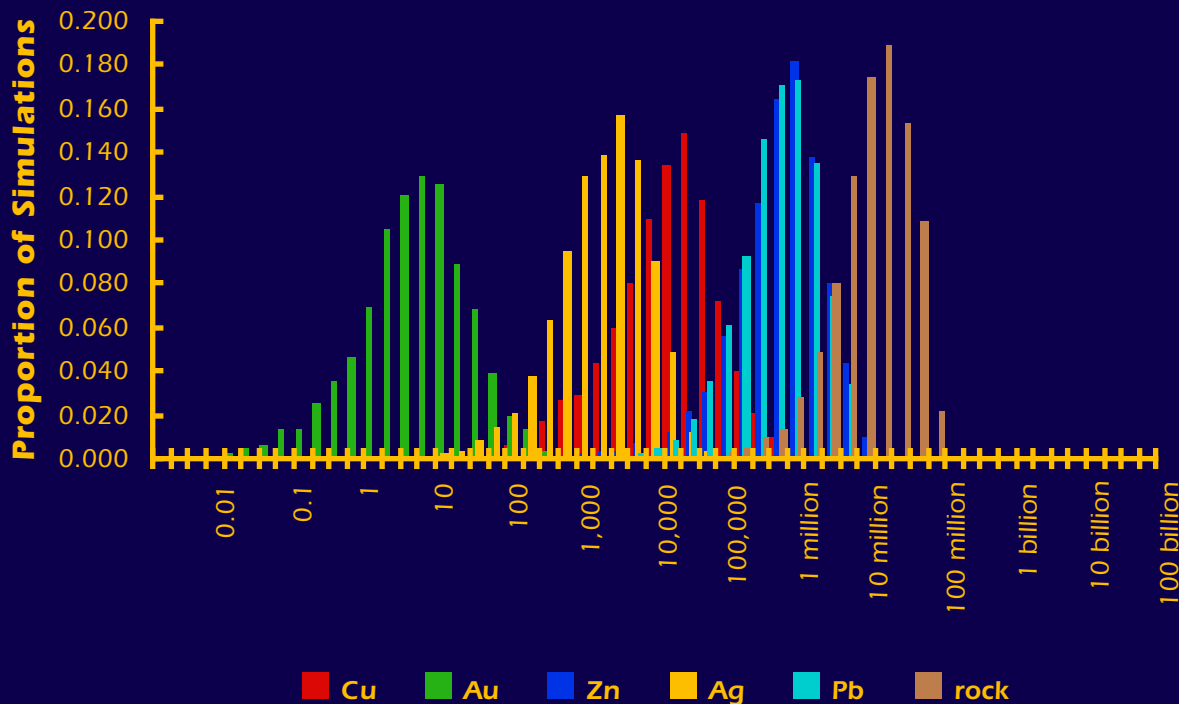


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR18

The Mark3 Index is 47:

Polymetallic replacement

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 4 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 8 or more deposits.

There is a 1% or greater chance of 11 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	4,700	22	19,000	380,000
0.90	350	0	60,000	200	86,000	1,900,000
0.50	22,000	5	860,000	2,600	770,000	16,000,000
0.10	140,000	43	3,880,000	14,000	3,500,000	65,000,000
0.05	230,000	78	5,700,000	20,000	5,100,000	83,000,000
mean	58,000	19	1,500,000	5,300	1,400,000	26,000,000
Probability of mean	0.25	0.22	0.32	0.30	0.31	0.35
Probability of zero	0.07	0.08	0.04	0.05	0.04	0.04

The tract ID is CR18The Mark3 Index is 47: **Polymetallic replacement**

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 4 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 8 or more deposits.

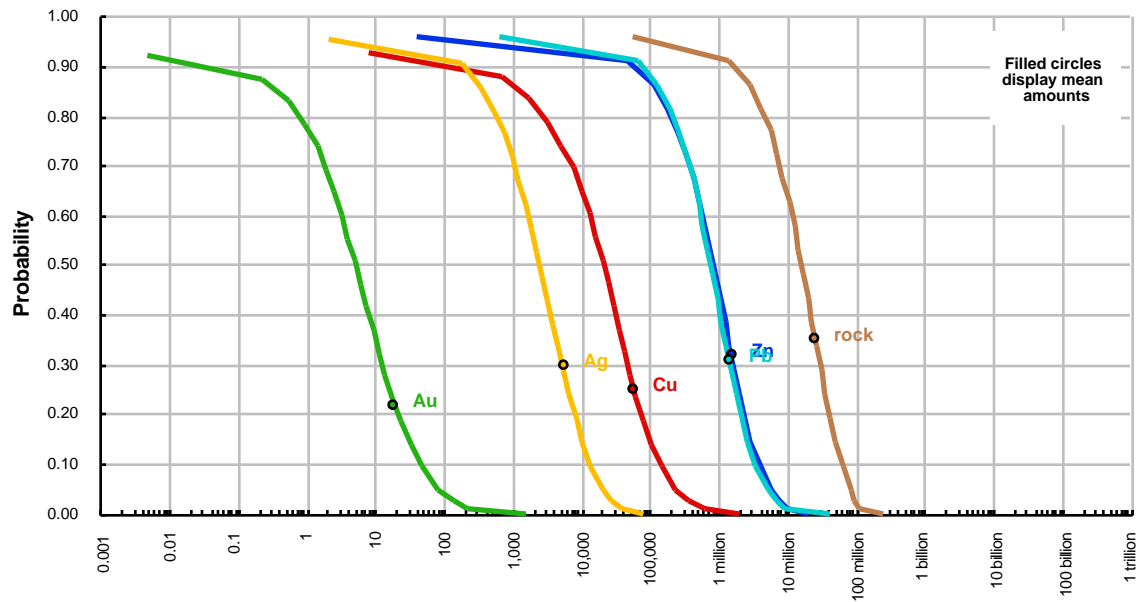
There is a 1% or greater chance of 11 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

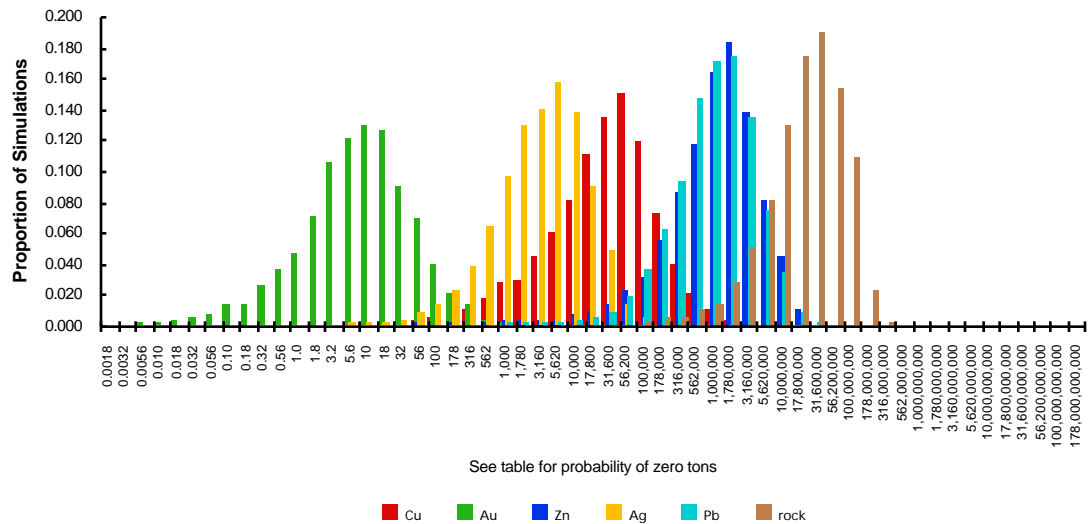
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	4,700	22	19,000	380,000
0.90	350	0	60,000	200	86,000	1,900,000
0.50	22,000	5	860,000	2,600	770,000	16,000,000
0.10	140,000	43	3,880,000	14,000	3,500,000	65,000,000
0.05	230,000	78	5,700,000	20,000	5,100,000	83,000,000
mean	58,000	19	1,500,000	5,300	1,400,000	26,000,000
Probability of mean	0.25	0.22	0.32	0.30	0.31	0.35
Probability of zero	0.07	0.08	0.04	0.05	0.04	0.04

The tract ID is CR18

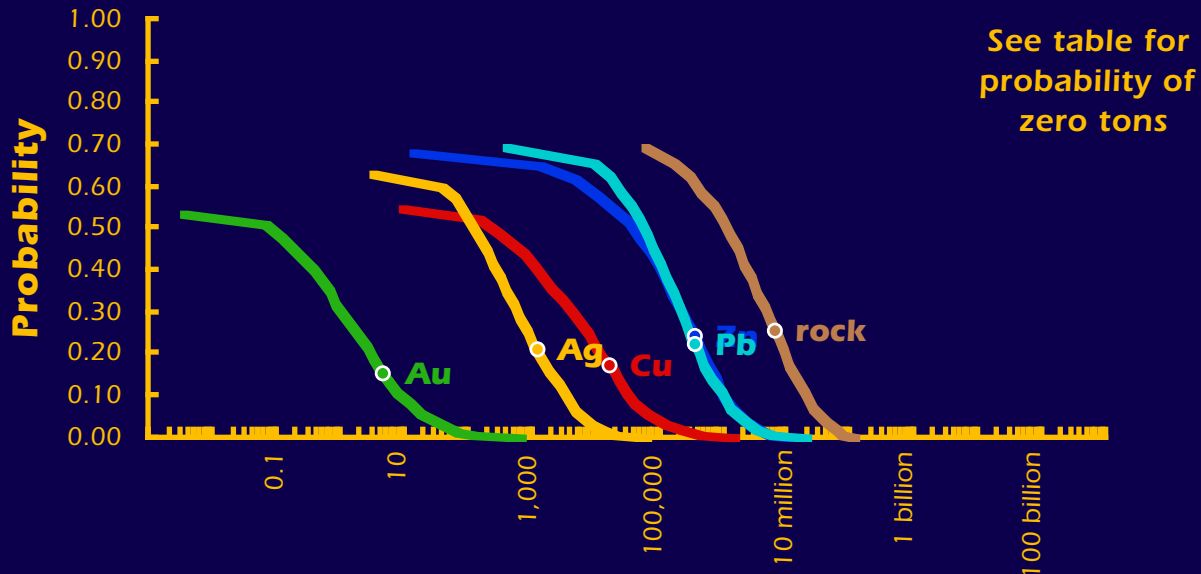
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

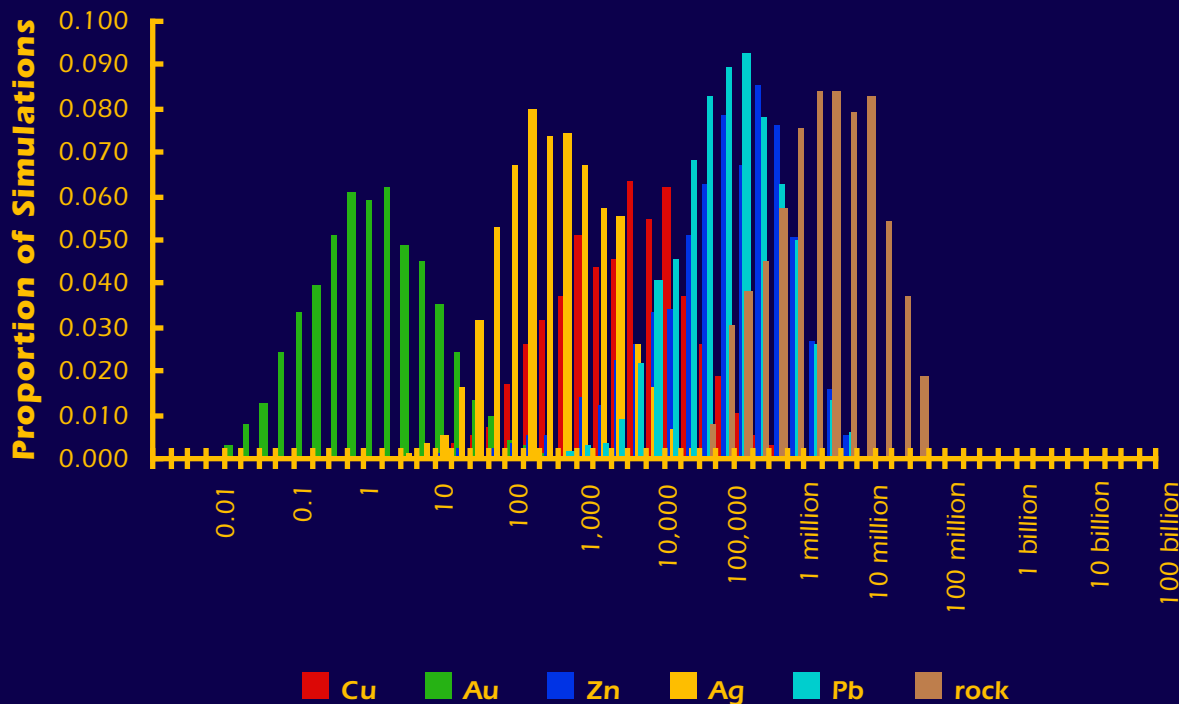


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR19

The Mark3 Index is 47:

Polymetallic replacement

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	260	0	39,000	120	56,000	1,100,000
0.10	32,000	9	984,000	3,400	950,000	19,000,000
0.05	73,000	20	1,700,000	5,800	1,700,000	35,000,000
mean	17,000	5	360,000	1,200	370,000	6,500,000
Probability of mean	0.17	0.15	0.24	0.21	0.22	0.25
Probability of zero	0.45	0.47	0.32	0.37	0.31	0.31

The tract ID is CR19The Mark3 Index is 47: **Polymetallic replacement**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

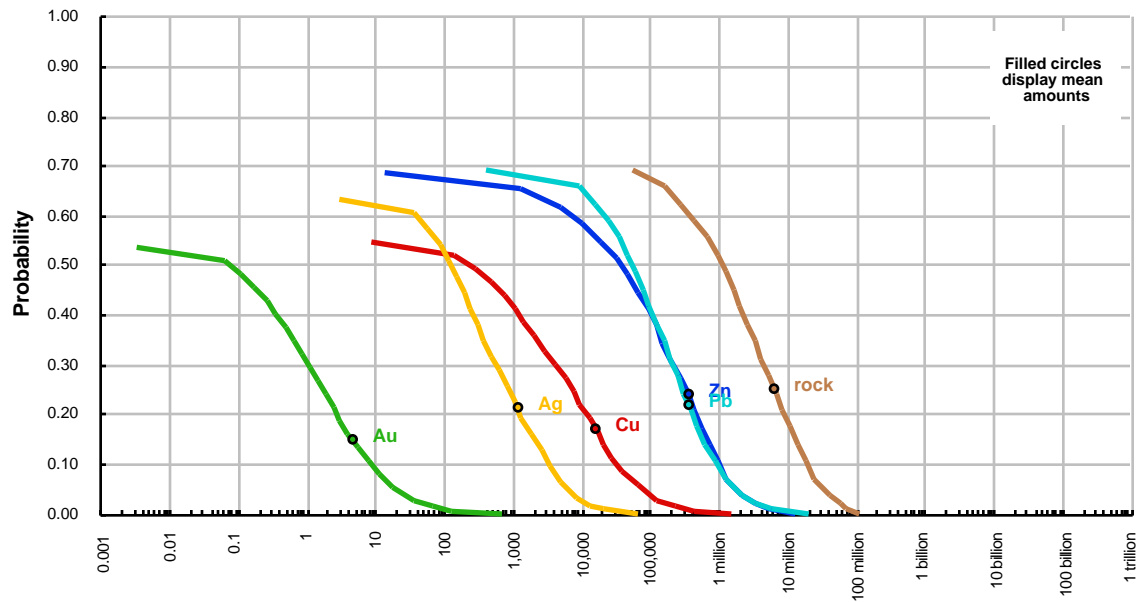
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

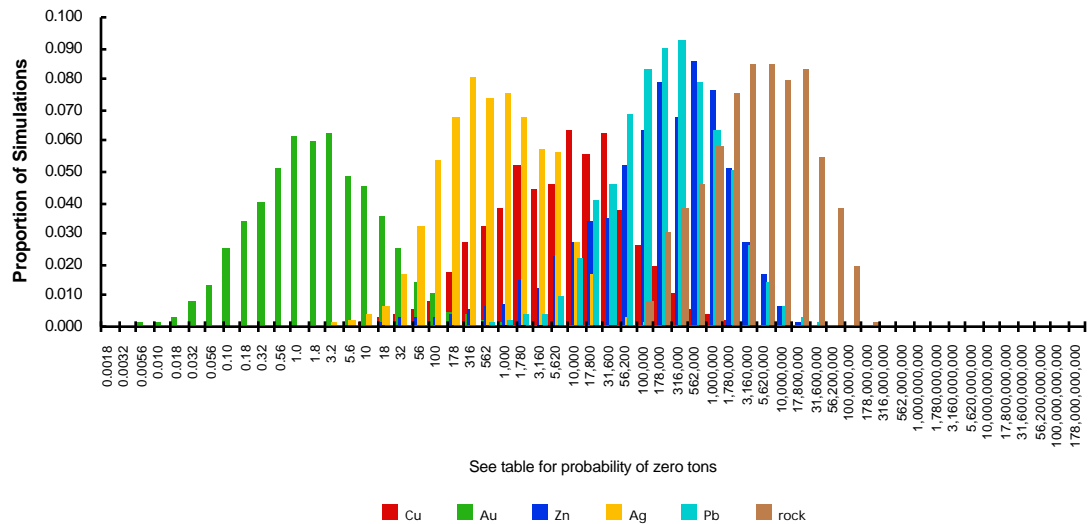
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	260	0	39,000	120	56,000	1,100,000
0.10	32,000	9	984,000	3,400	950,000	19,000,000
0.05	73,000	20	1,700,000	5,800	1,700,000	35,000,000
mean	17,000	5	360,000	1,200	370,000	6,500,000
Probability of mean	0.17	0.15	0.24	0.21	0.22	0.25
Probability of zero	0.45	0.47	0.32	0.37	0.31	0.31

The tract ID is CR19

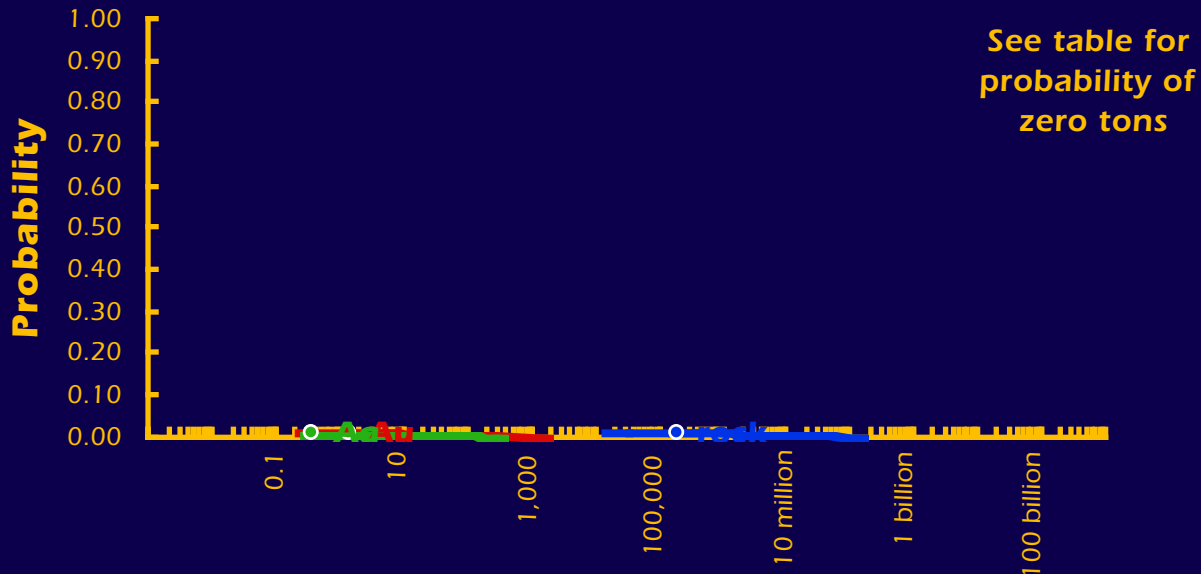
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

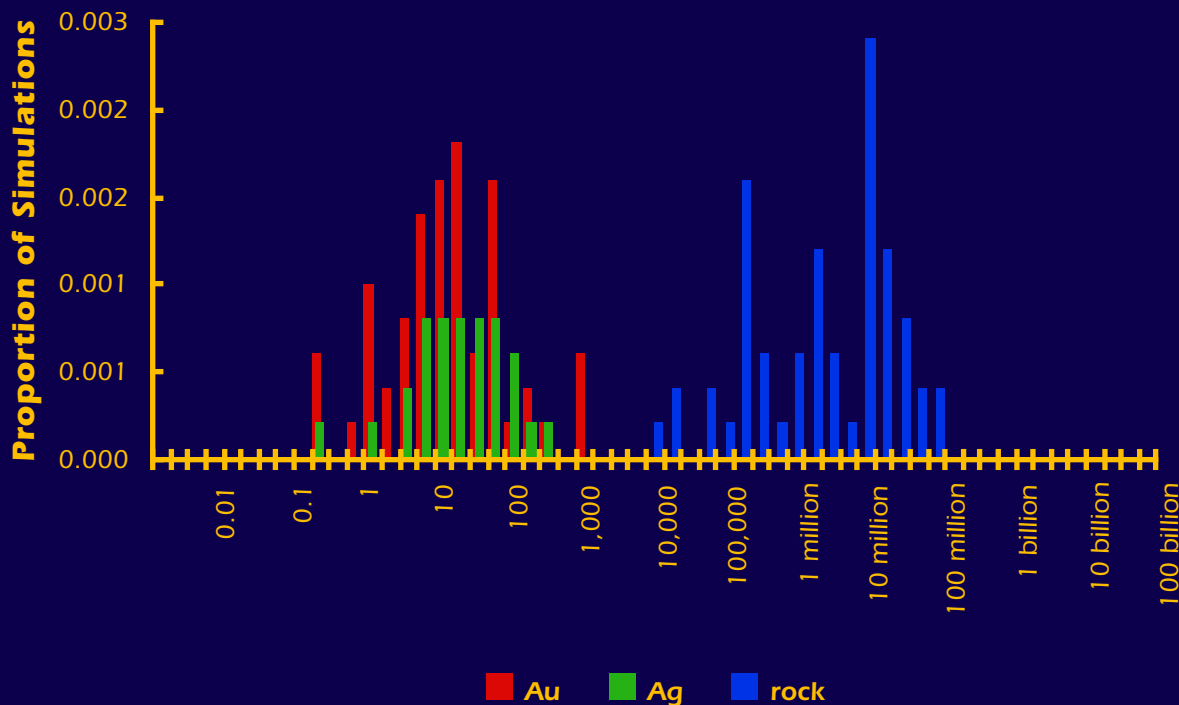


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR20

The Mark3 Index is 80:

Alkaline Au-Te

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	0	0
0.05	0	0	0
mean	1	0	180,000
Probability of mean	0.01	0.01	0.01
Probability of zero	0.99	0.99	0.99

The tract ID is CR20The Mark3 Index is 80: **Alkaline Au-Te**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

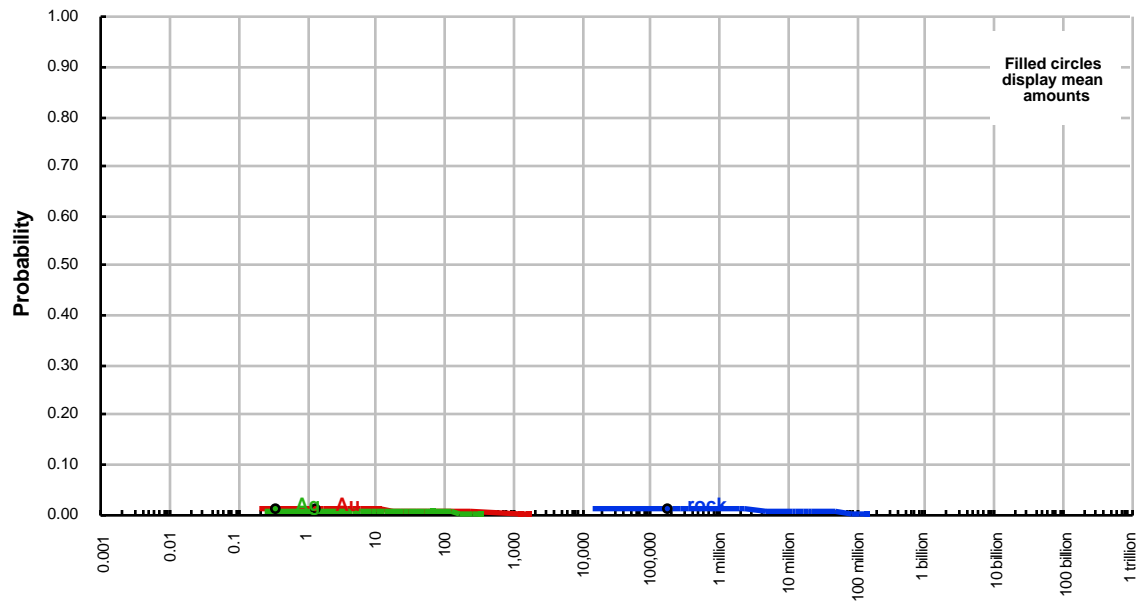
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

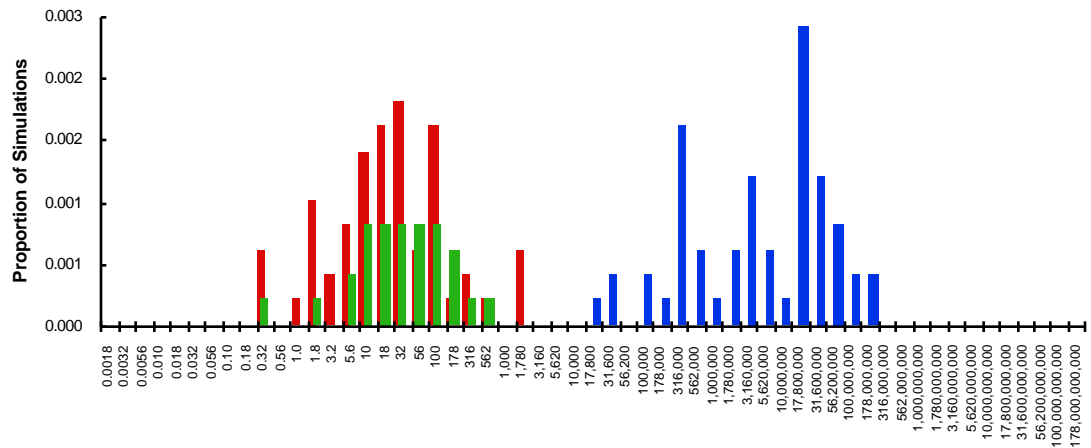
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	0	0
0.05	0	0	0
mean	1	0	180,000
Probability of mean	0.01	0.01	0.01
Probability of zero	0.99	0.99	0.99

The tract ID is CR20

Cumulative Distributions of Contained Metal and Mineralized Rock



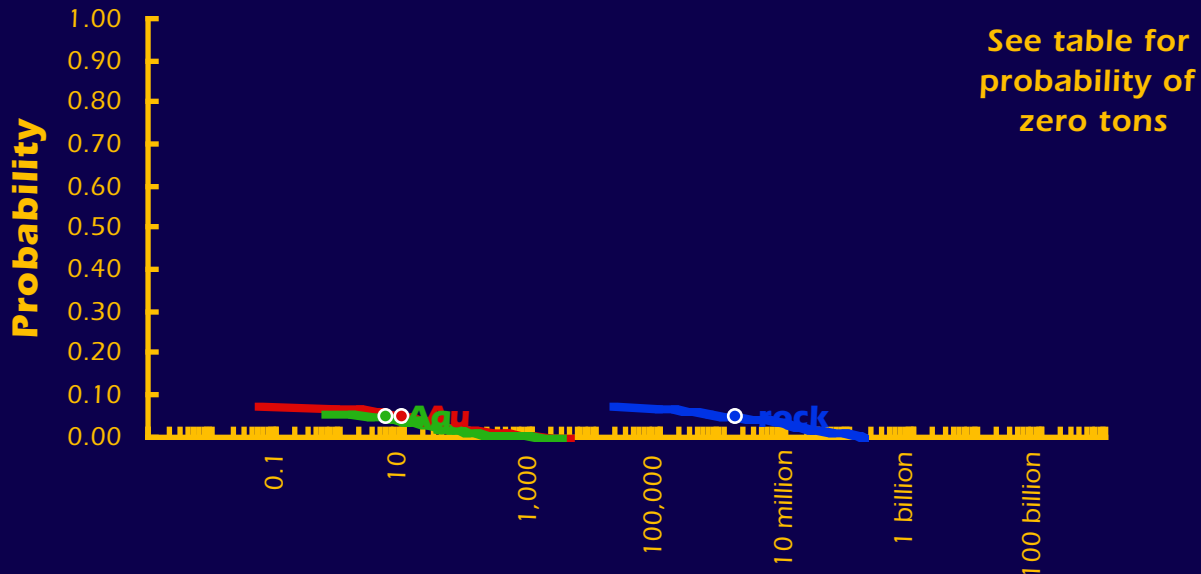
Histograms of Contained Metal and Mineralized Rock (metric tons)



See table for probability of zero tons

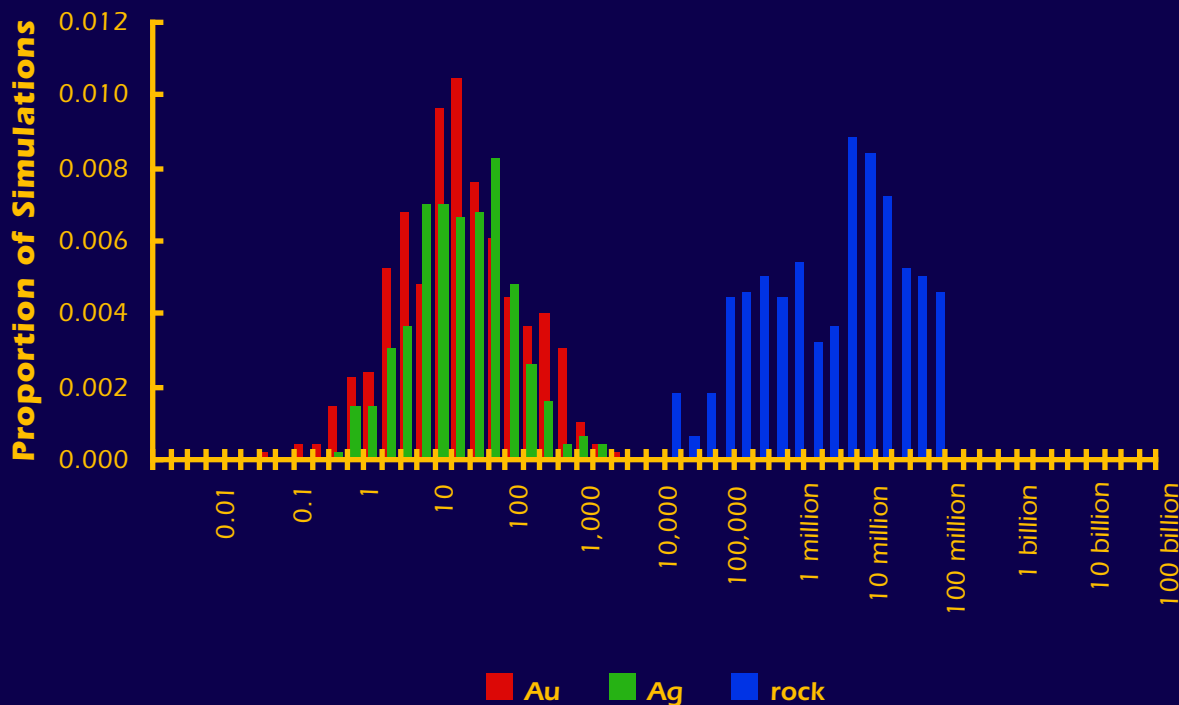
Au Ag rock

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR21

The Mark3 Index is 80:

Alkaline Au-Te

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	0	0
0.05	10	3	1,100,000
mean	9	5	1,600,000
Probability of mean	0.05	0.05	0.05
Probability of zero	0.93	0.94	0.93

The tract ID is CR21The Mark3 Index is 80: **Alkaline Au-Te**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

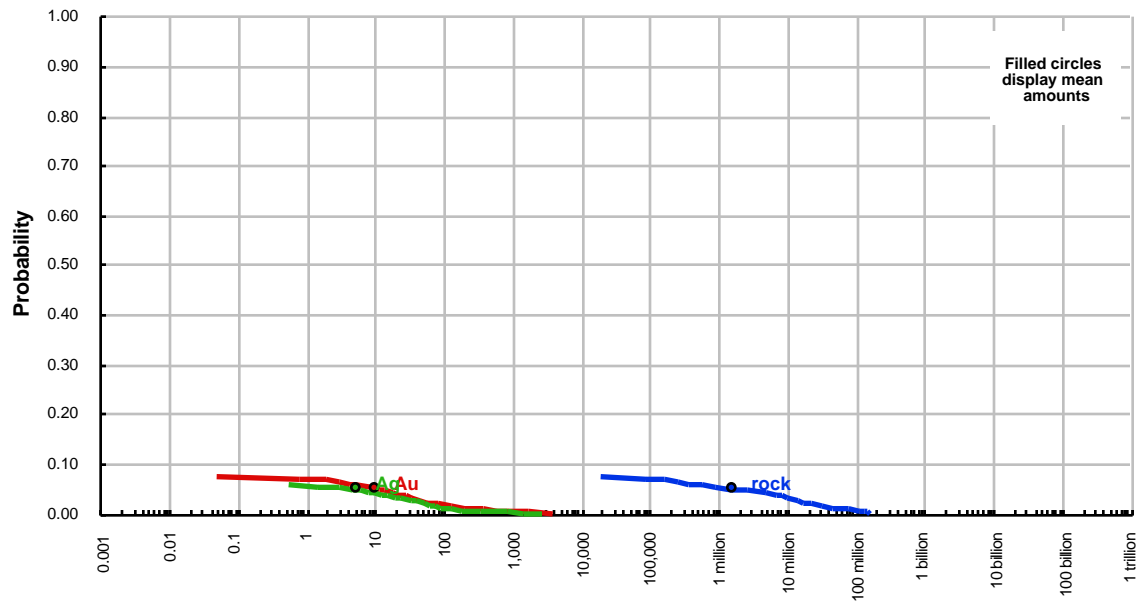
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

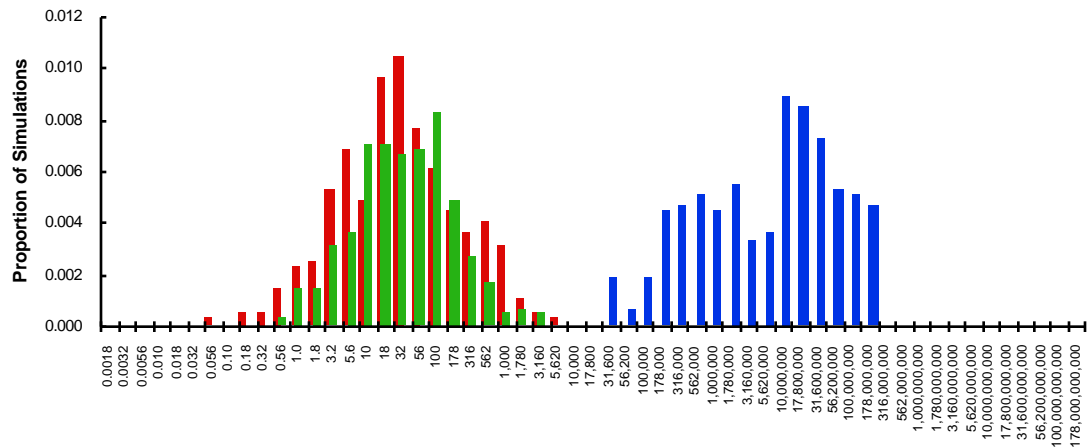
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	0	0
0.05	10	3	1,100,000
mean	9	5	1,600,000
Probability of mean	0.05	0.05	0.05
Probability of zero	0.93	0.94	0.93

The tract ID is CR21

Cumulative Distributions of Contained Metal and Mineralized Rock



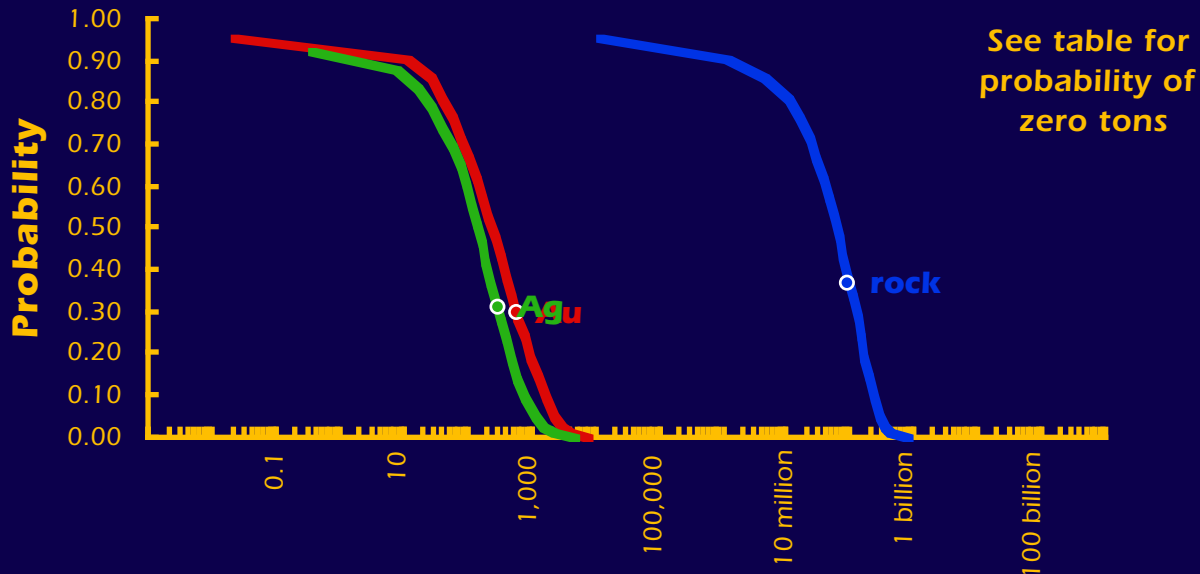
Histograms of Contained Metal and Mineralized Rock (metric tons)



See table for probability of zero tons

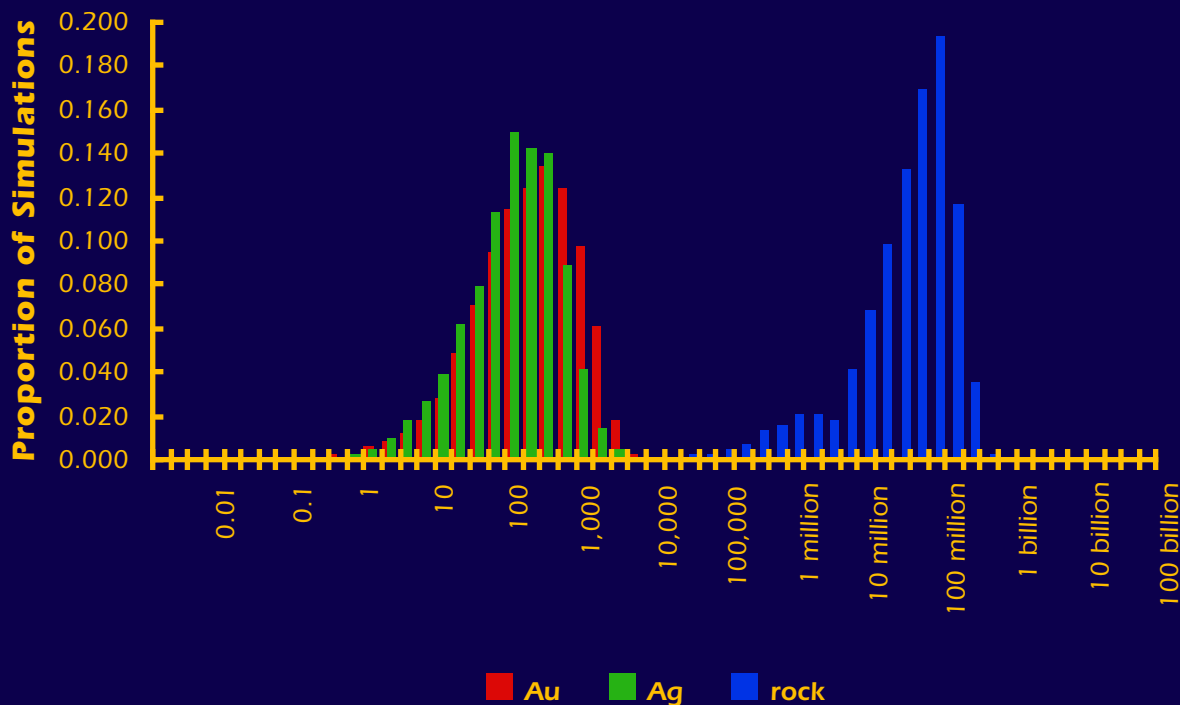
Au Ag rock

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR22

The Mark3 Index is 80:

Alkaline Au-Te

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 5 or more deposits.

There is a 10% or greater chance of 8 or more deposits.

There is a 5% or greater chance of 12 or more deposits.

There is a 1% or greater chance of 20 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	1	0	120,000
0.90	13	5	1,400,000
0.50	230	130	59,000,000
0.10	1,500	730	220,000,000
0.05	2,200	1,100	290,000,000
mean	550	290	90,000,000
Probability of mean	0.30	0.31	0.37
Probability of zero	0.04	0.07	0.04

The tract ID is CR22The Mark3 Index is 80: **Alkaline Au-Te**

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 5 or more deposits.

There is a 10% or greater chance of 8 or more deposits.

There is a 5% or greater chance of 12 or more deposits.

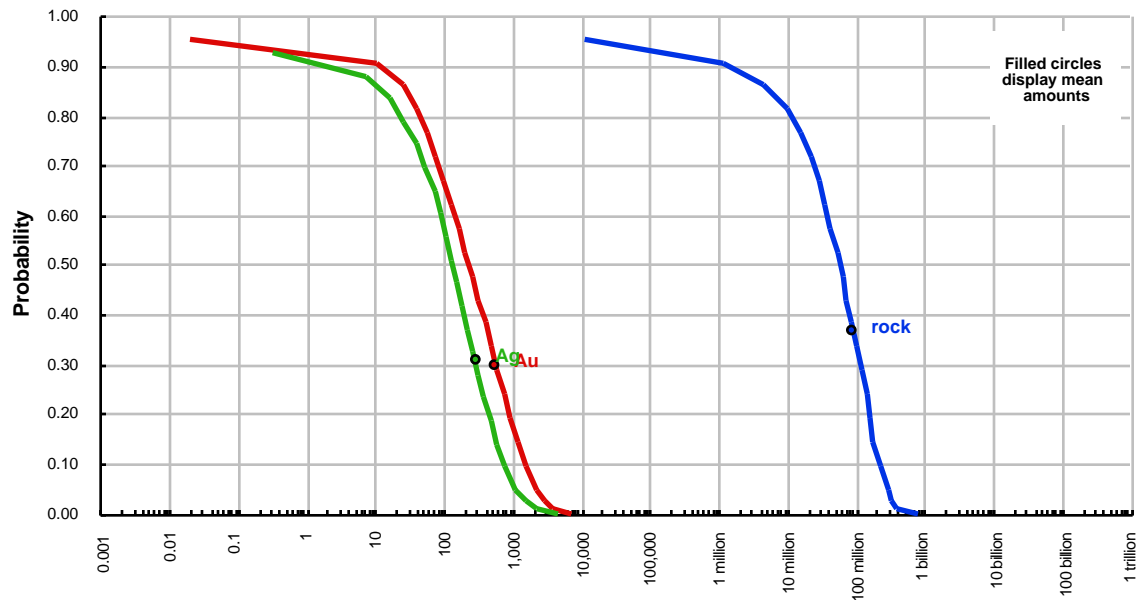
There is a 1% or greater chance of 20 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

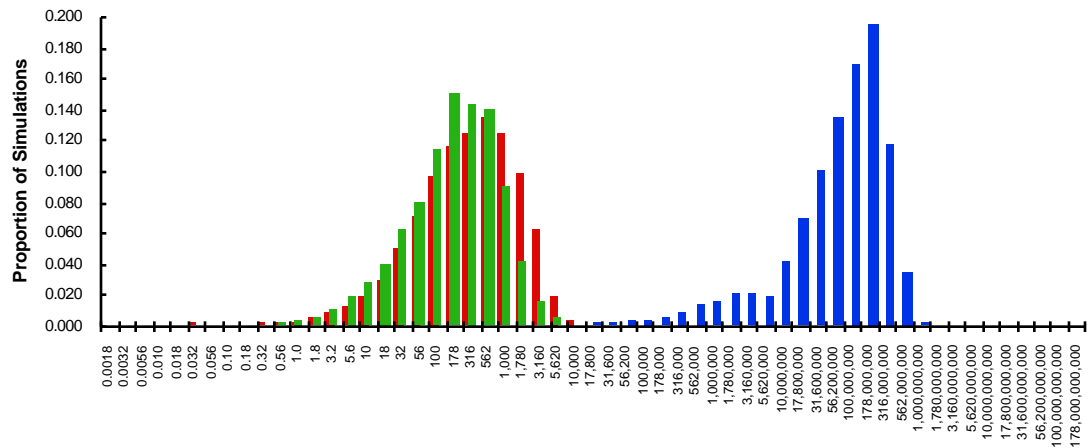
quantile	Au	Ag	rock
0.95	1	0	120,000
0.90	13	5	1,400,000
0.50	230	130	59,000,000
0.10	1,500	730	220,000,000
0.05	2,200	1,100	290,000,000
mean	550	290	90,000,000
Probability of mean	0.30	0.31	0.37
Probability of zero	0.04	0.07	0.04

The tract ID is CR22

Cumulative Distributions of Contained Metal and Mineralized Rock



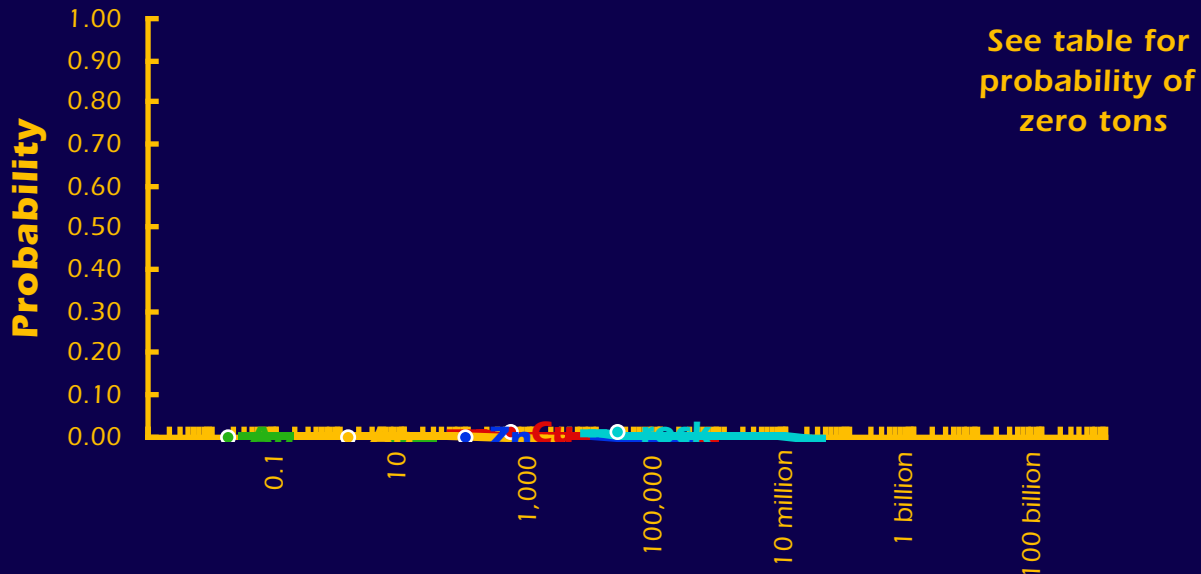
Histograms of Contained Metal and Mineralized Rock (metric tons)



See table for probability of zero tons

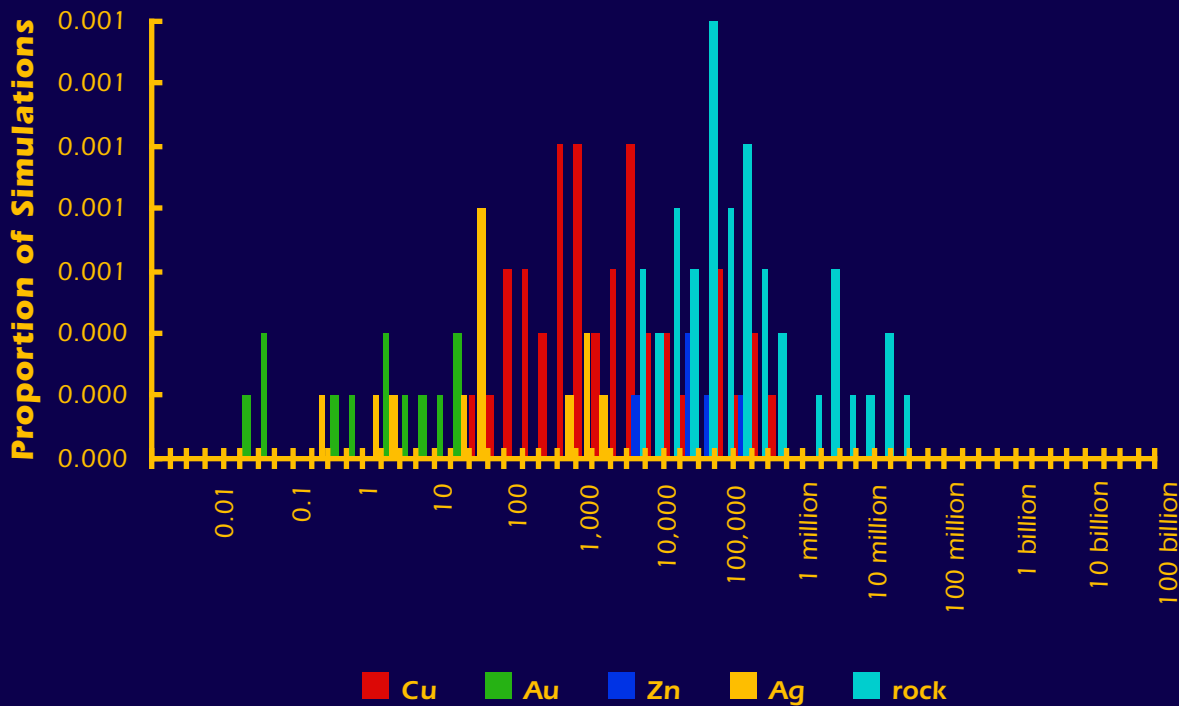
Au Ag rock

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR23

The Mark3 Index is 30:

Massive sulfide, Besshi

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	0	0	0	0	0
mean	450	0	96	1	23,000
Probability of mean	0.01	0.00	0.00	0.00	0.01
Probability of zero	0.99	1.00	1.00	1.00	0.99

The tract ID is CR23

The Mark3 Index is 30: **Massive sulfide, Besshi**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

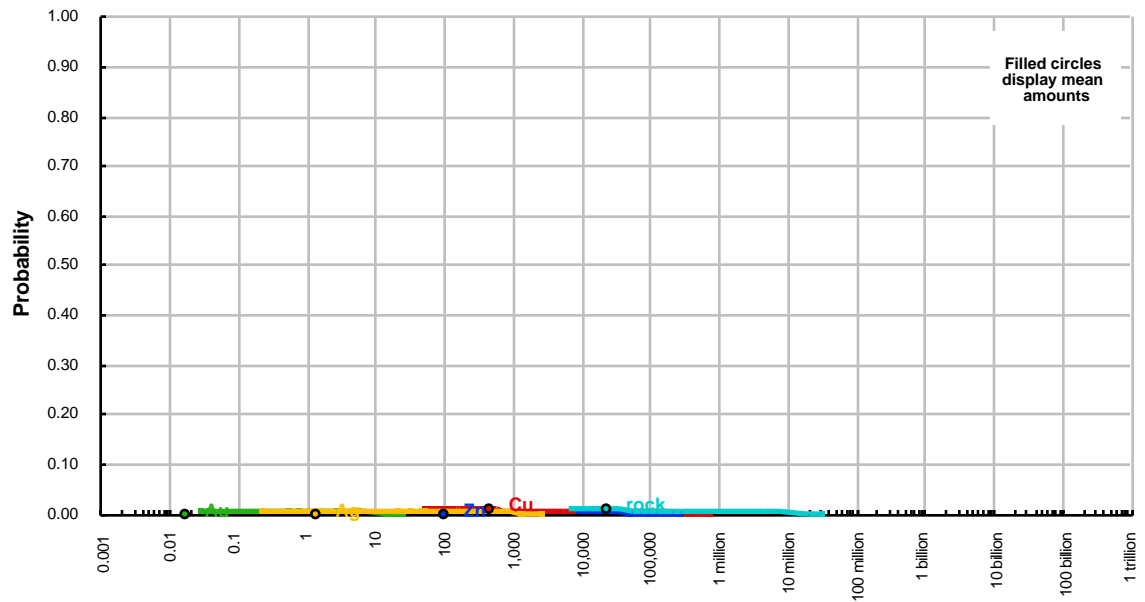
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

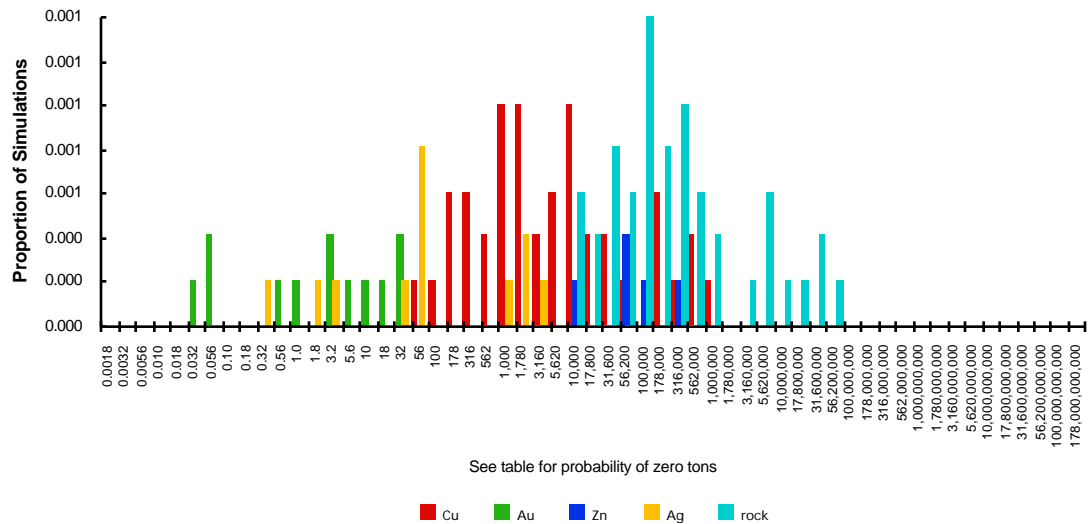
quantile	Cu	Au	Zn	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	0	0	0	0	0
mean	450	0	96	1	23,000
Probability of mean	0.01	0.00	0.00	0.00	0.01
Probability of zero	0.99	1.00	1.00	1.00	0.99

The tract ID is CR23

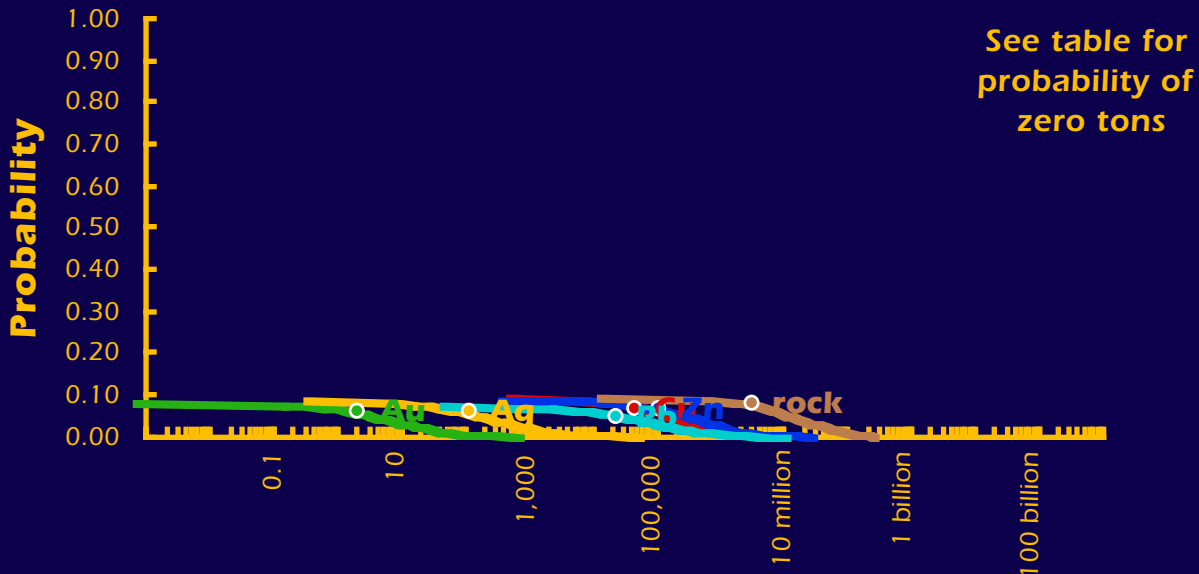
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

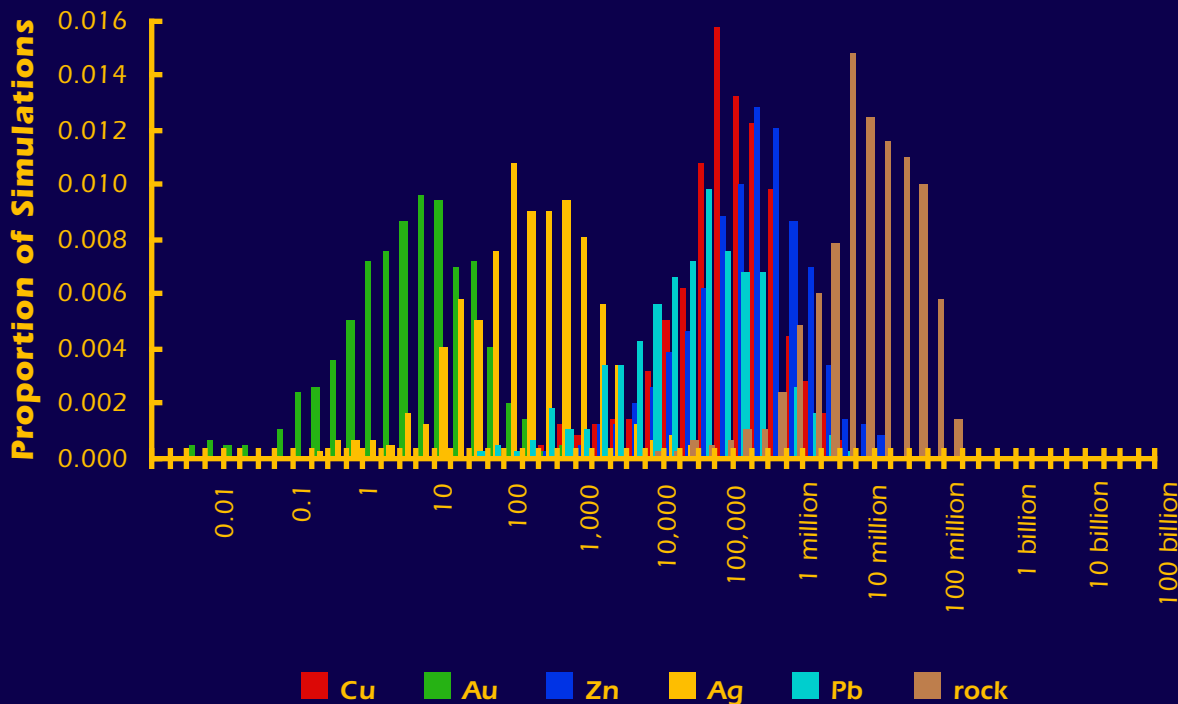


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR24

The Mark3 Index is 93:

Massive sulfide, kuroko

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	140,000	3	270,000	170	20,000	11,000,000
mean	42,000	2	110,000	110	23,000	2,900,000
Probability of mean	0.07	0.06	0.07	0.06	0.05	0.08
Probability of zero	0.91	0.92	0.91	0.91	0.93	0.91

The tract ID is CR24The Mark3 Index is 93: **Massive sulfide, kuroko**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

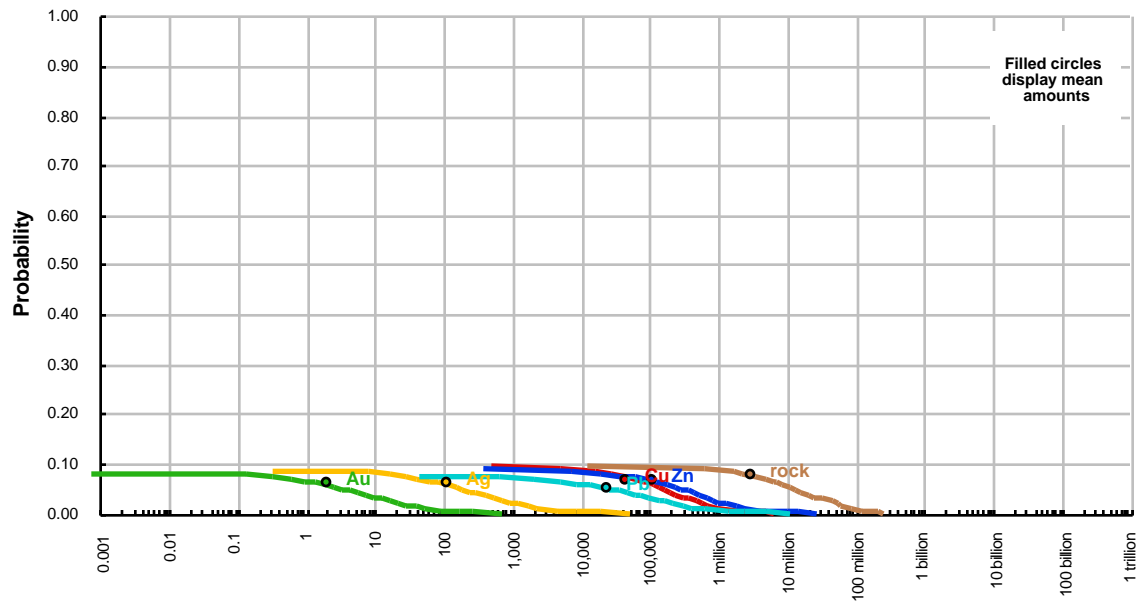
There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

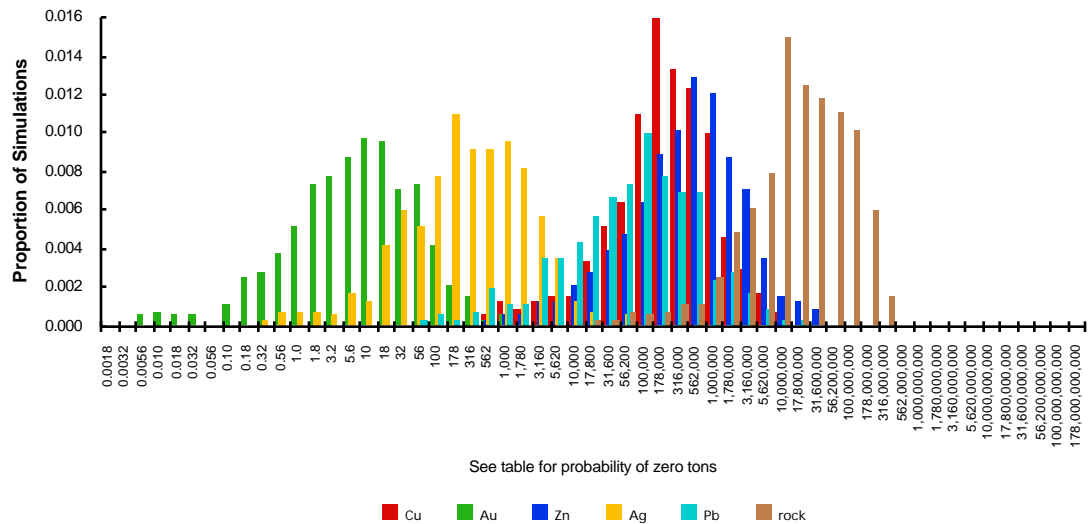
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	140,000	3	270,000	170	20,000	11,000,000
mean	42,000	2	110,000	110	23,000	2,900,000
Probability of mean	0.07	0.06	0.07	0.06	0.05	0.08
Probability of zero	0.91	0.92	0.91	0.91	0.93	0.91

The tract ID is CR24

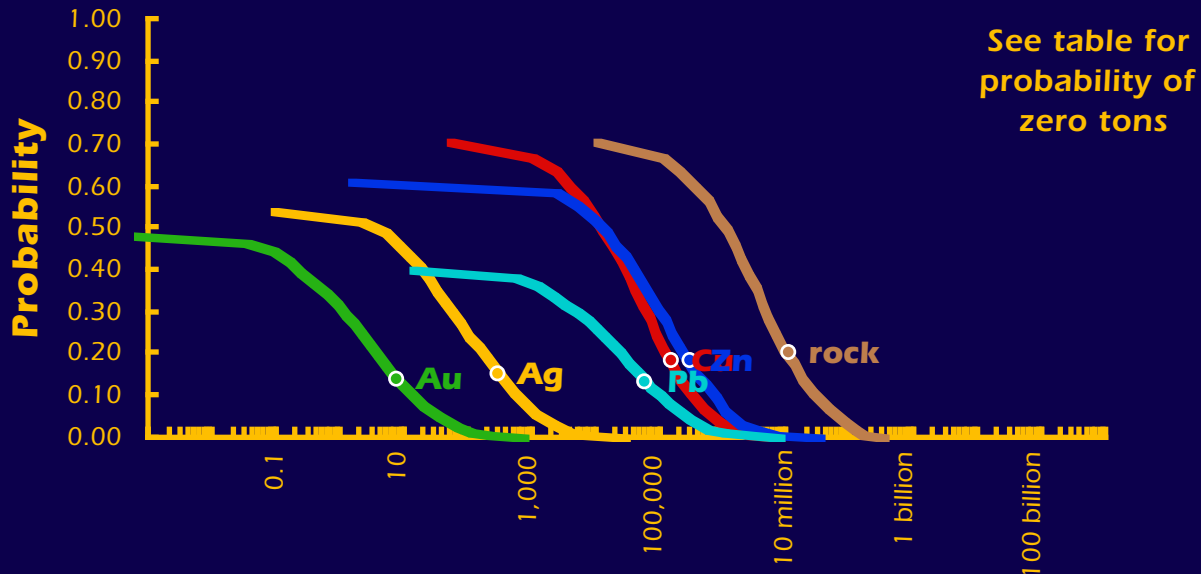
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

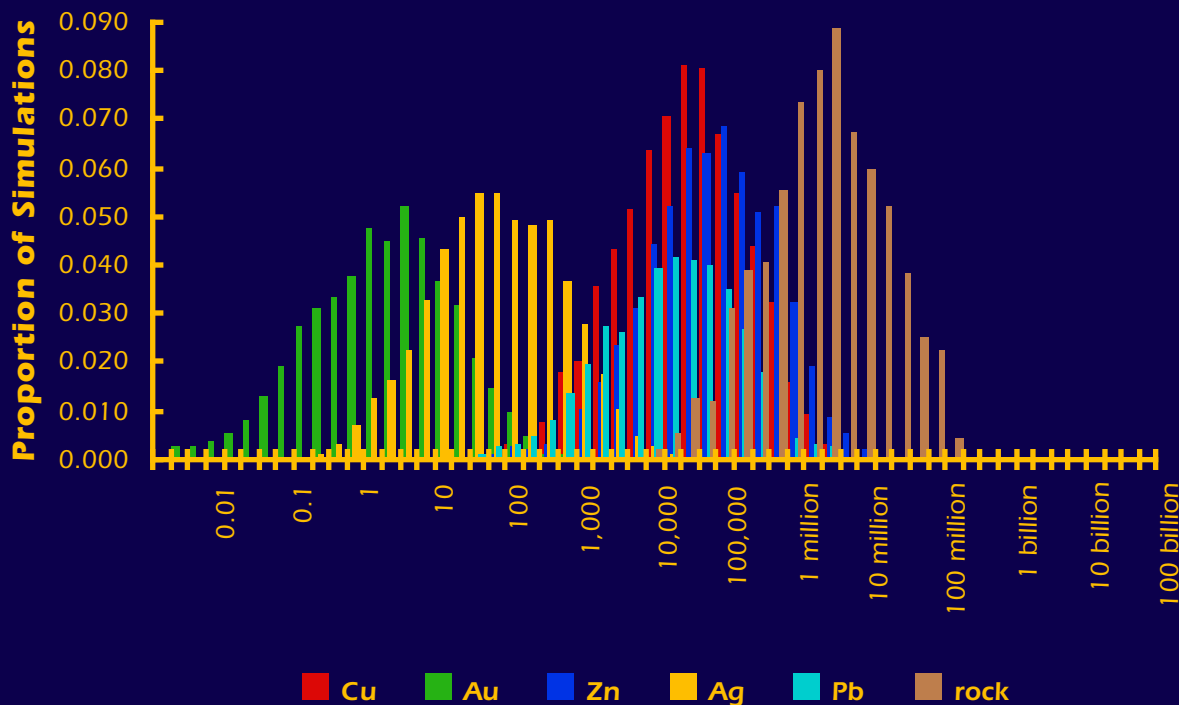


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR25

The Mark3 Index is 93:

Massive sulfide, kuroko

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

There is a 1% or greater chance of 6 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	12,000	0	13,000	3	0	1,100,000
0.10	340,000	13	675,000	560	100,000	29,000,000
0.05	690,000	33	1,300,000	1,300	250,000	57,000,000
mean	150,000	7	290,000	280	60,000	11,000,000
Probability of mean	0.18	0.14	0.18	0.15	0.13	0.20
Probability of zero	0.29	0.51	0.39	0.46	0.60	0.29

The tract ID is CR25

The Mark3 Index is 93: **Massive sulfide, kuroko**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

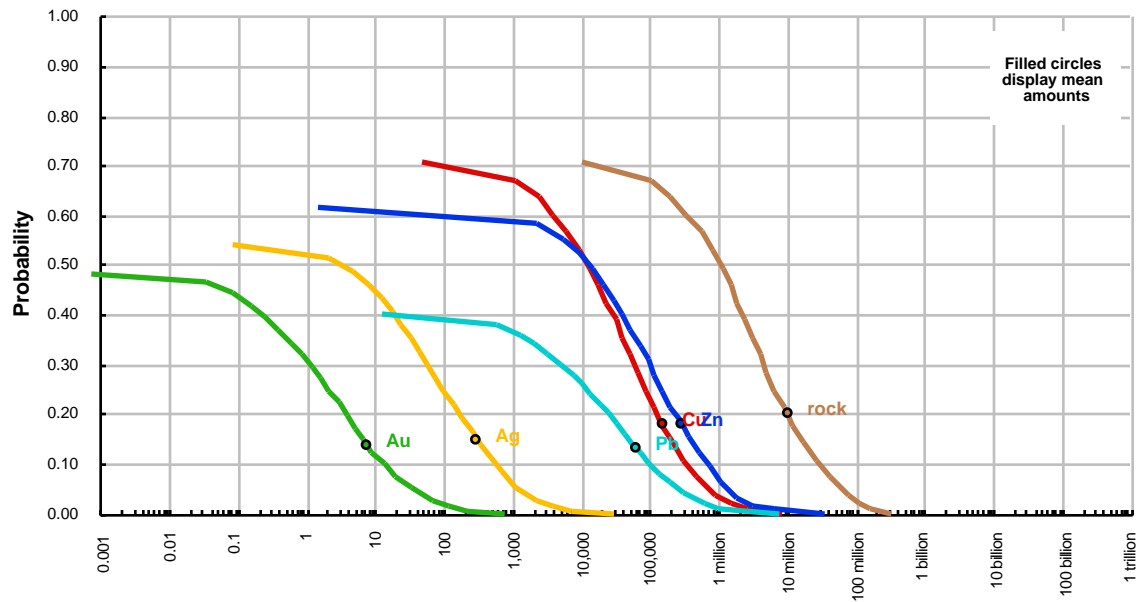
There is a 1% or greater chance of 6 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

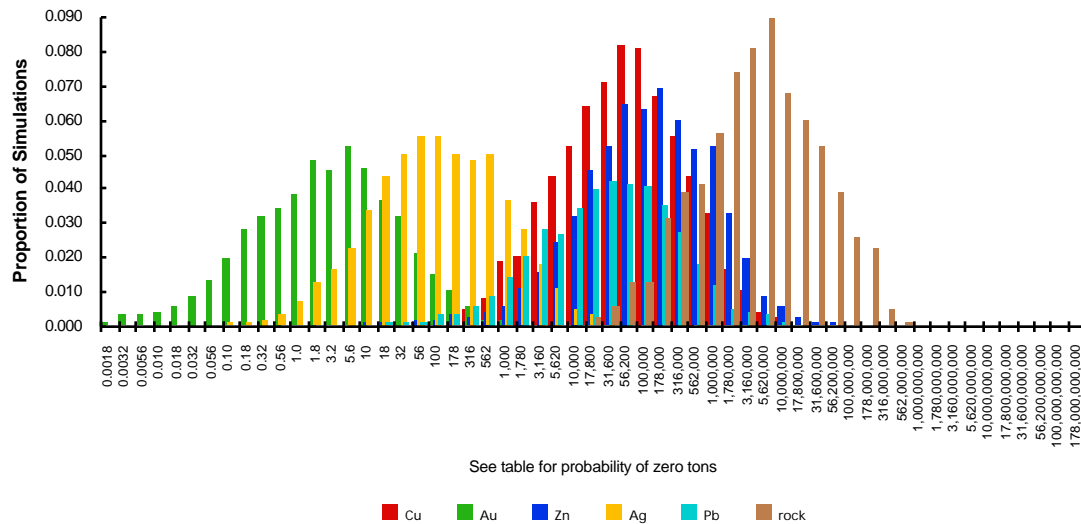
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	12,000	0	13,000	3	0	1,100,000
0.10	340,000	13	675,000	560	100,000	29,000,000
0.05	690,000	33	1,300,000	1,300	250,000	57,000,000
mean	150,000	7	290,000	280	60,000	11,000,000
Probability of mean	0.18	0.14	0.18	0.15	0.13	0.20
Probability of zero	0.29	0.51	0.39	0.46	0.60	0.29

The tract ID is CR25

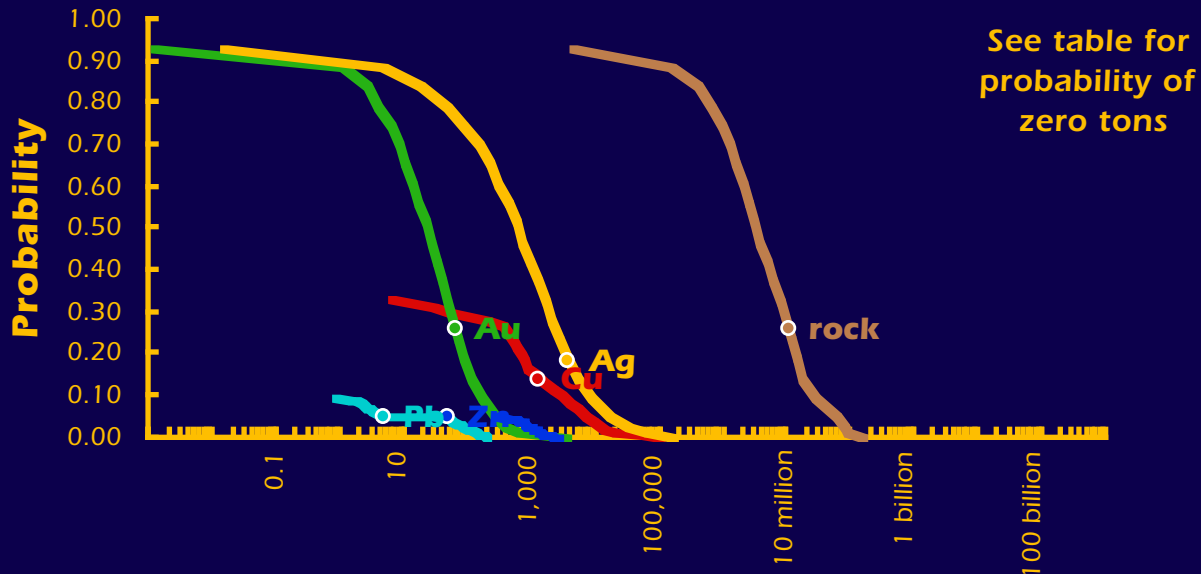
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

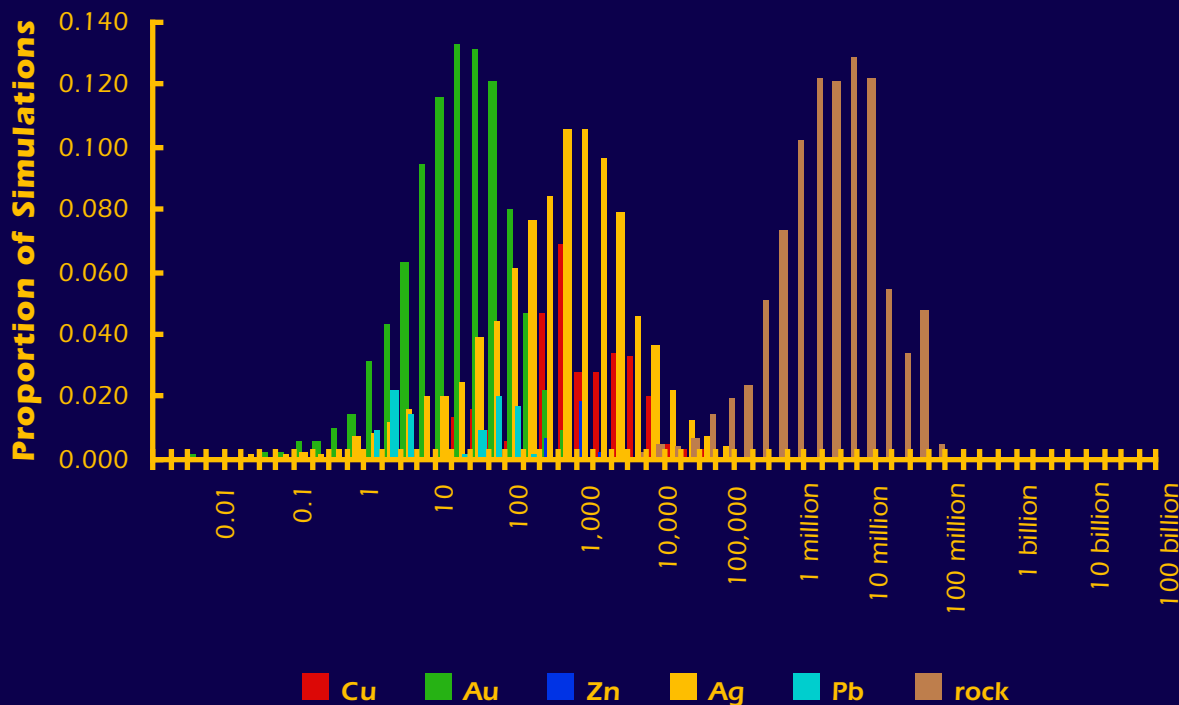


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR26

The Mark3 Index is 25:

Epithermal vein, quartz-adularia

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 7 or more deposits.

There is a 1% or greater chance of 10 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	1	0	3	0	110,000
0.50	0	22	0	610	0	3,300,000
0.10	3,000	150	0	7,800	0	26,000,000
0.05	7,000	250	0	17,000	5	58,000,000
mean	1,300	61	47	3,700	5	10,000,000
Probability of mean	0.14	0.26	0.05	0.18	0.05	0.26
Probability of zero	0.67	0.07	0.95	0.07	0.91	0.07

The tract ID is CR26The Mark3 Index is 25: **Epithermal vein, quartz-adularia**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 7 or more deposits.

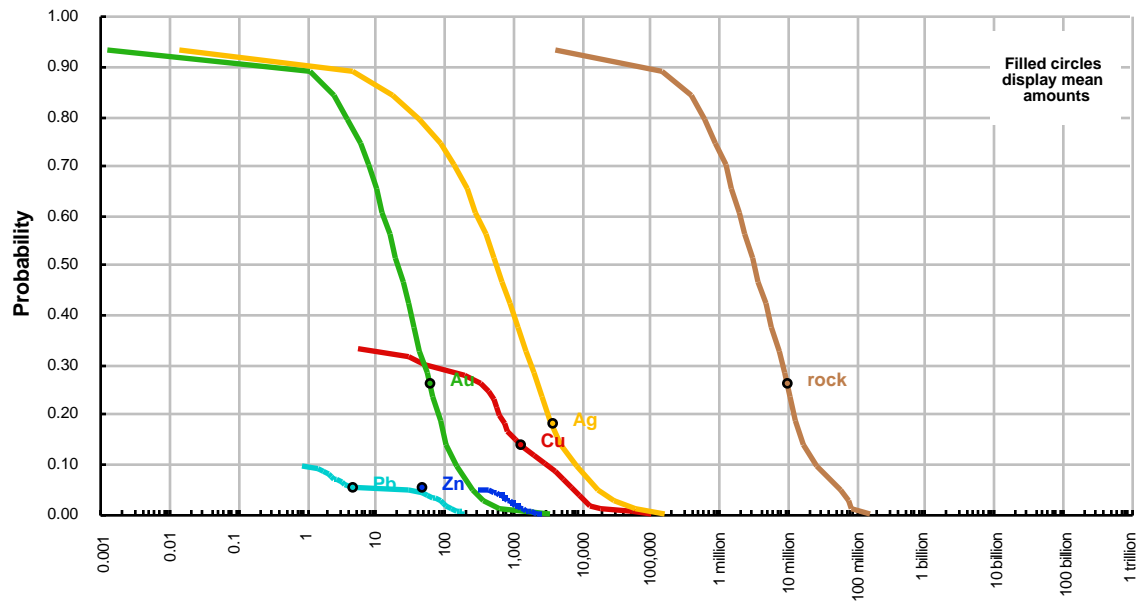
There is a 1% or greater chance of 10 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

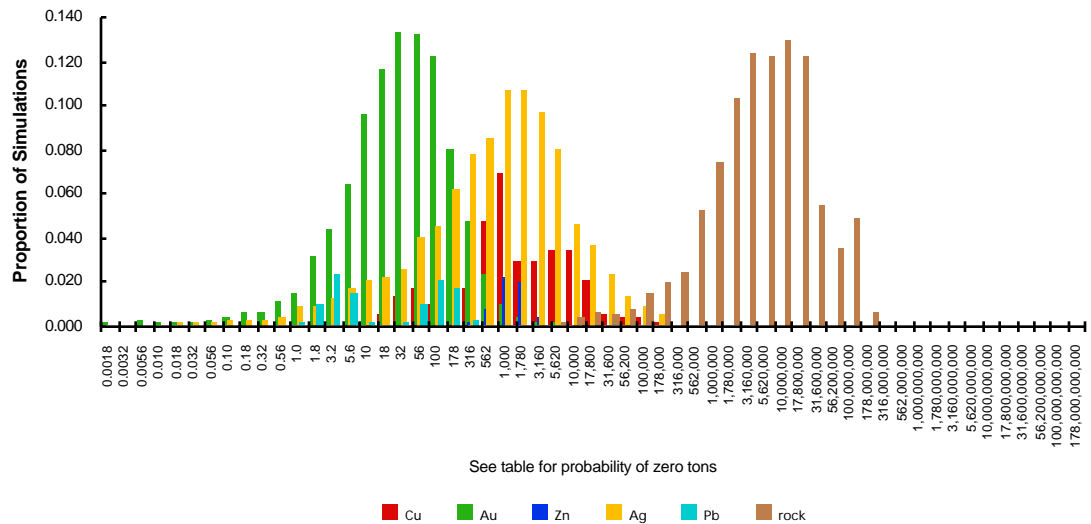
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	1	0	3	0	110,000
0.50	0	22	0	610	0	3,300,000
0.10	3,000	150	0	7,800	0	26,000,000
0.05	7,000	250	0	17,000	5	58,000,000
mean	1,300	61	47	3,700	5	10,000,000
Probability of mean	0.14	0.26	0.05	0.18	0.05	0.26
Probability of zero	0.67	0.07	0.95	0.07	0.91	0.07

The tract ID is CR26

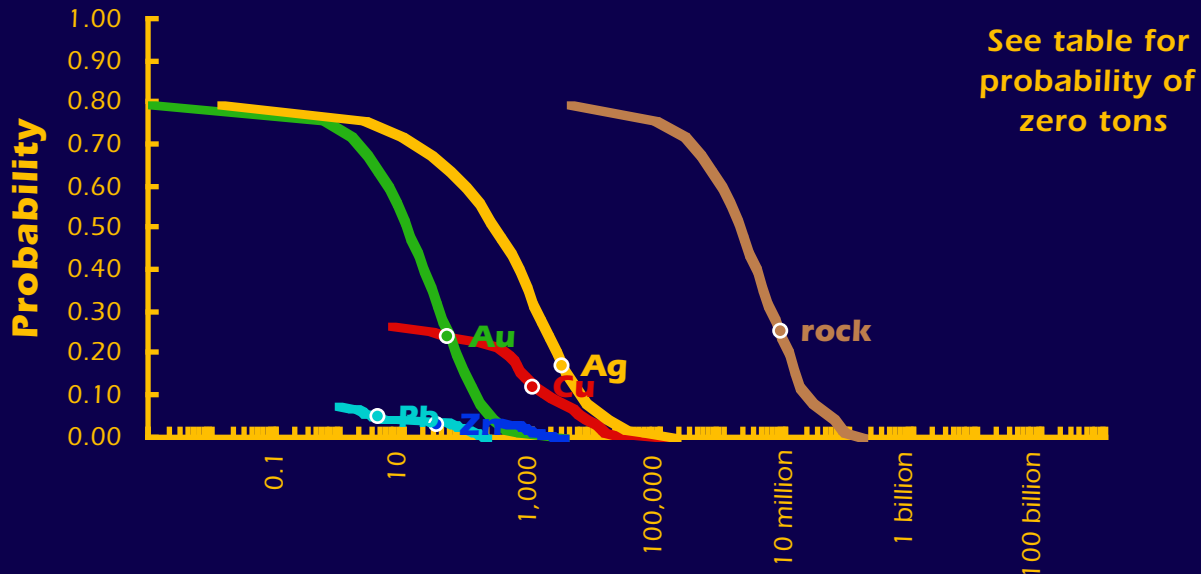
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

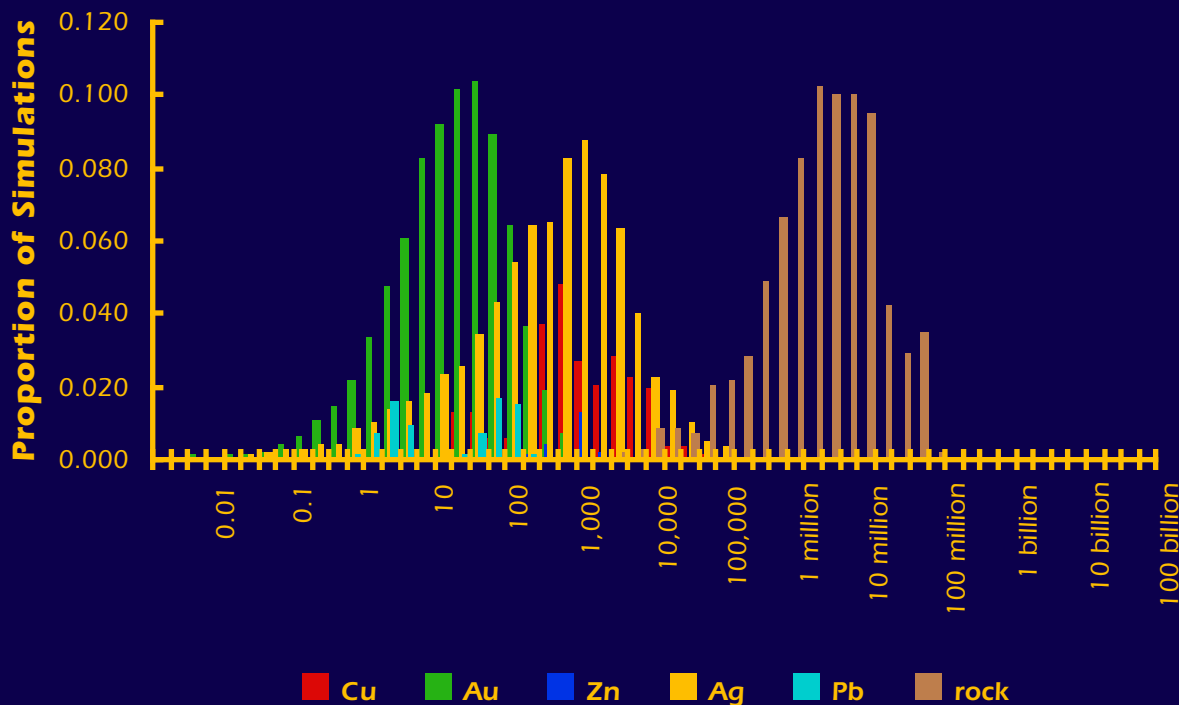


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR27

The Mark3 Index is 25:

Epithermal vein, quartz-adularia

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

There is a 1% or greater chance of 7 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	11	0	260	0	1,800,000
0.10	1,700	120	0	5,600	0	19,000,000
0.05	5,600	200	0	12,000	3	44,000,000
mean	1,000	48	33	2,900	4	7,800,000
Probability of mean	0.12	0.24	0.03	0.17	0.05	0.25
Probability of zero	0.74	0.20	0.97	0.20	0.93	0.20

The tract ID is CR27The Mark3 Index is 25: **Epithermal vein, quartz-adularia**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

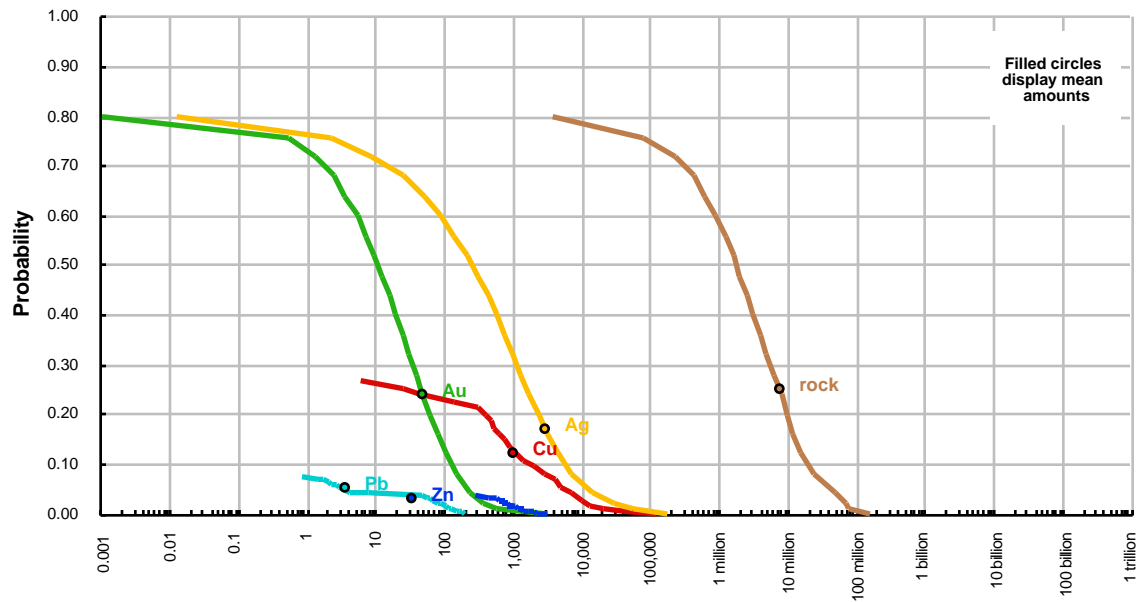
There is a 1% or greater chance of 7 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

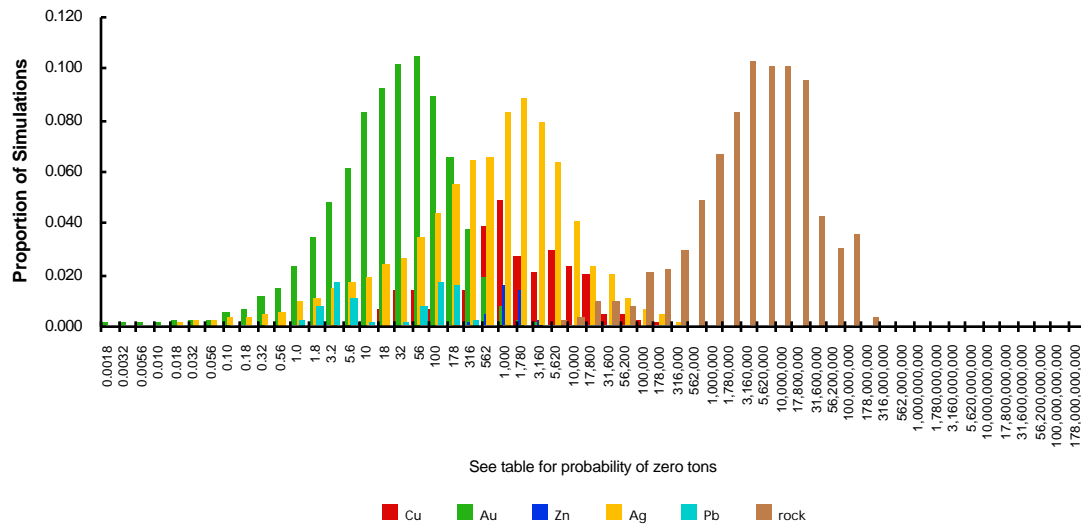
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	11	0	260	0	1,800,000
0.10	1,700	120	0	5,600	0	19,000,000
0.05	5,600	200	0	12,000	3	44,000,000
mean	1,000	48	33	2,900	4	7,800,000
Probability of mean	0.12	0.24	0.03	0.17	0.05	0.25
Probability of zero	0.74	0.20	0.97	0.20	0.93	0.20

The tract ID is CR27

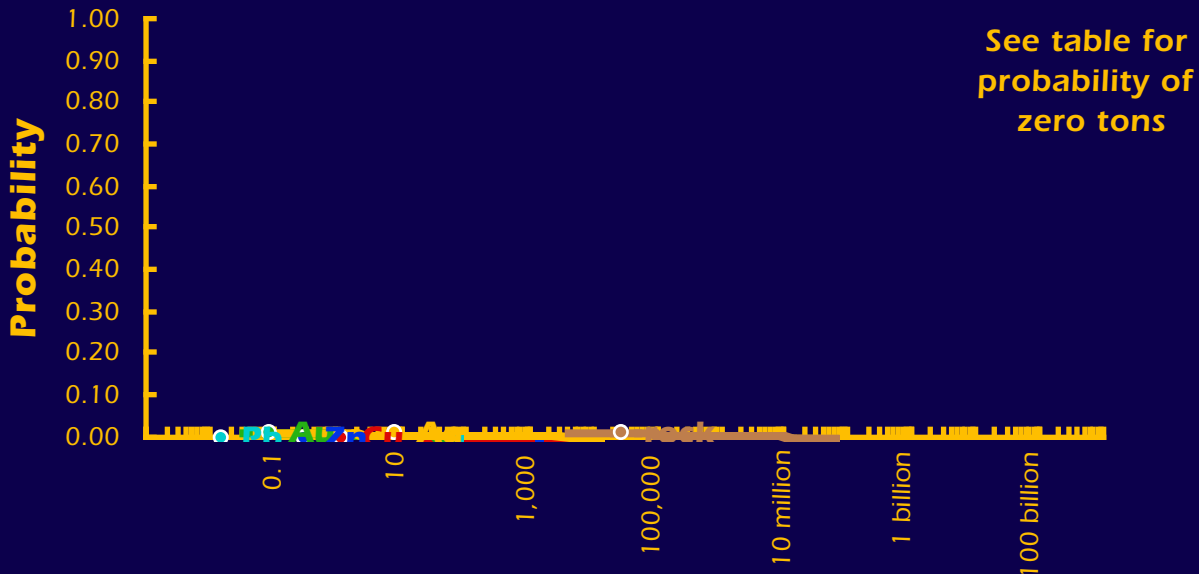
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

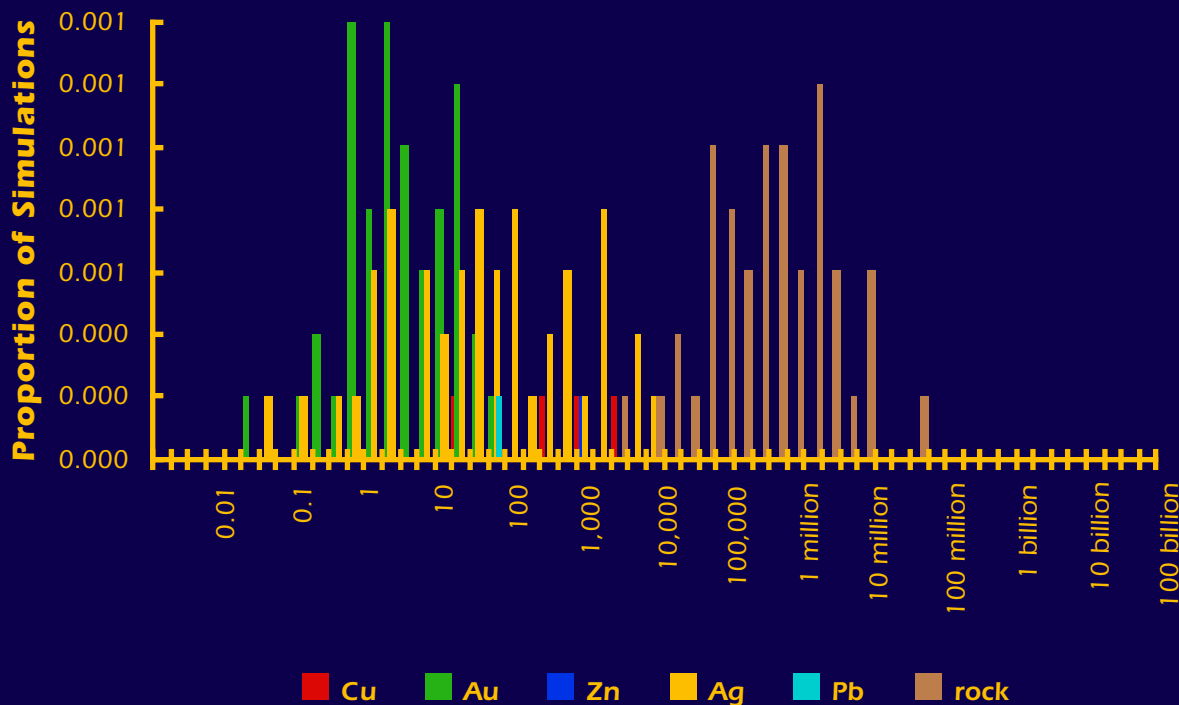


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR28

The Mark3 Index is 25:

Epithermal vein, quartz-adularia

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	1	0	0	8	0	28,000
Probability of mean	0.00	0.01	0.00	0.01	0.00	0.01
Probability of zero	1.00	0.99	1.00	0.99	1.00	0.99

The tract ID is CR28The Mark3 Index is 25: **Epithermal vein, quartz-adularia**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

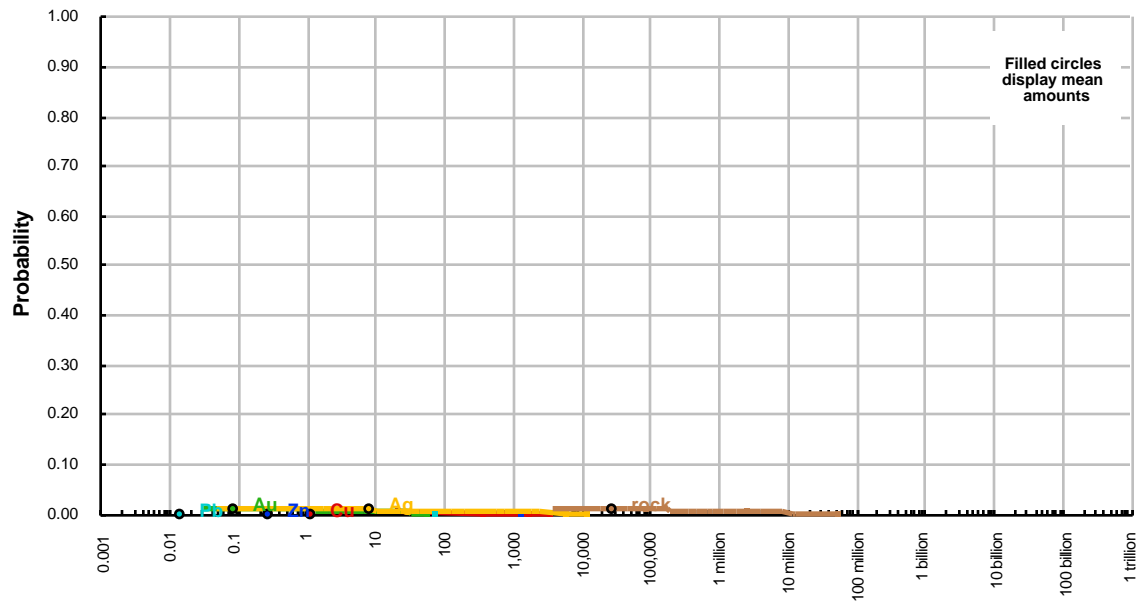
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

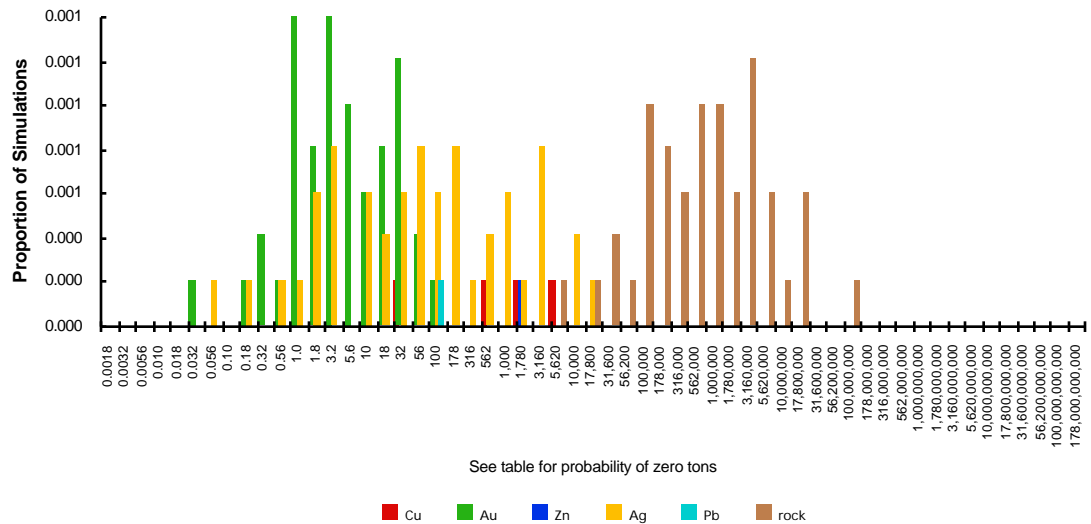
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	1	0	0	8	0	28,000
Probability of mean	0.00	0.01	0.00	0.01	0.00	0.01
Probability of zero	1.00	0.99	1.00	0.99	1.00	0.99

The tract ID is CR28

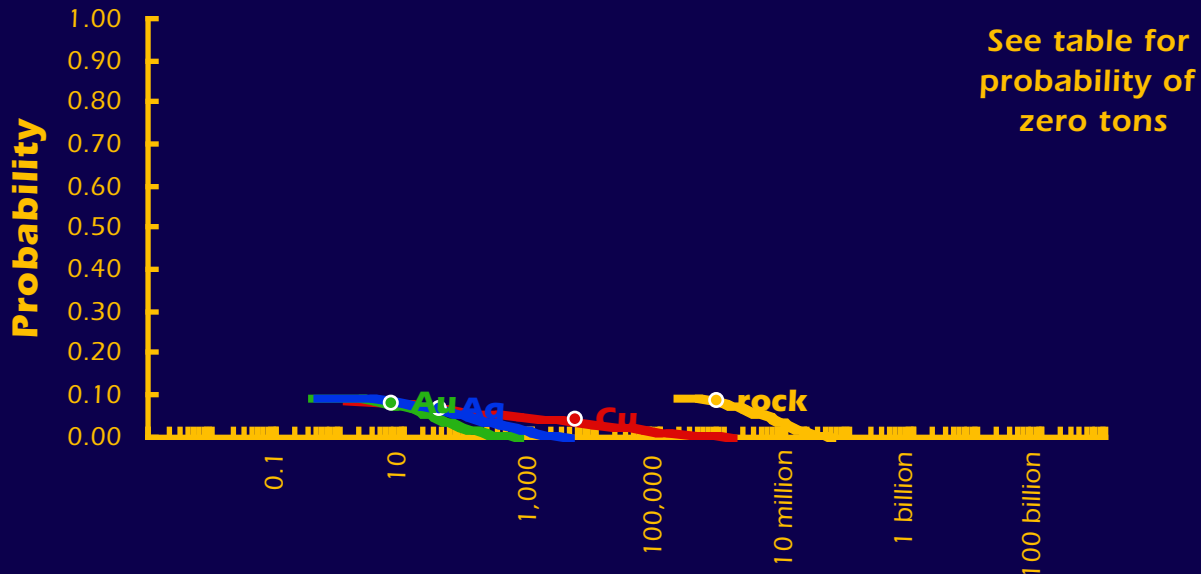
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

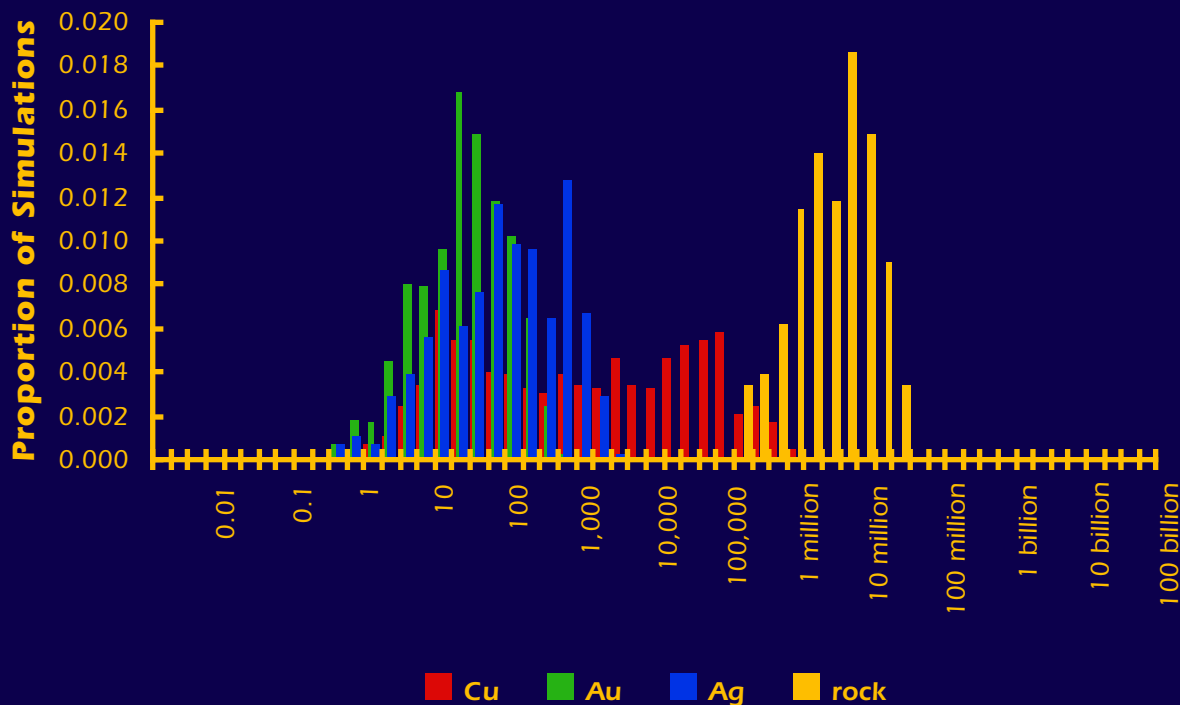


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR29

The Mark3 Index is 38:

Epithermal vein, quartz-alunite

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	530	29	93	4,700,000
mean	4,700	6	34	780,000
Probability of mean	0.04	0.08	0.07	0.09
Probability of zero	0.91	0.90	0.90	0.90

The tract ID is CR29The Mark3 Index is 38: **Epithermal vein, quartz-alunite**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

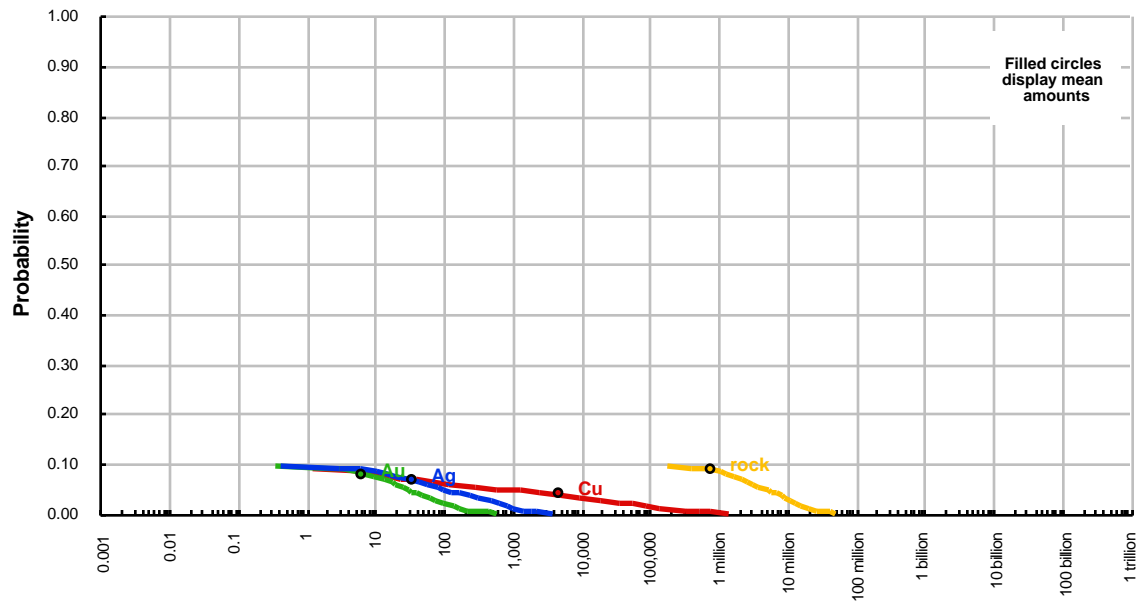
There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

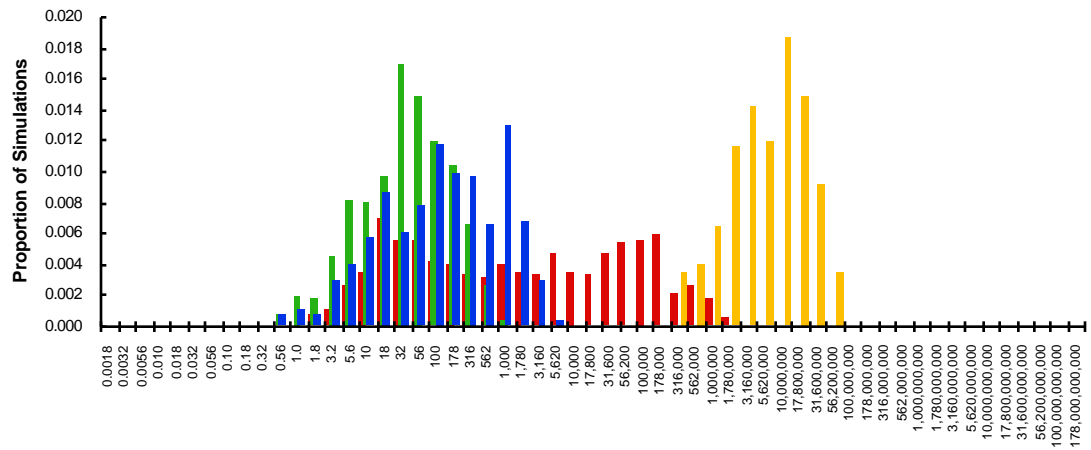
quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	530	29	93	4,700,000
mean	4,700	6	34	780,000
Probability of mean	0.04	0.08	0.07	0.09
Probability of zero	0.91	0.90	0.90	0.90

The tract ID is CR29

Cumulative Distributions of Contained Metal and Mineralized Rock



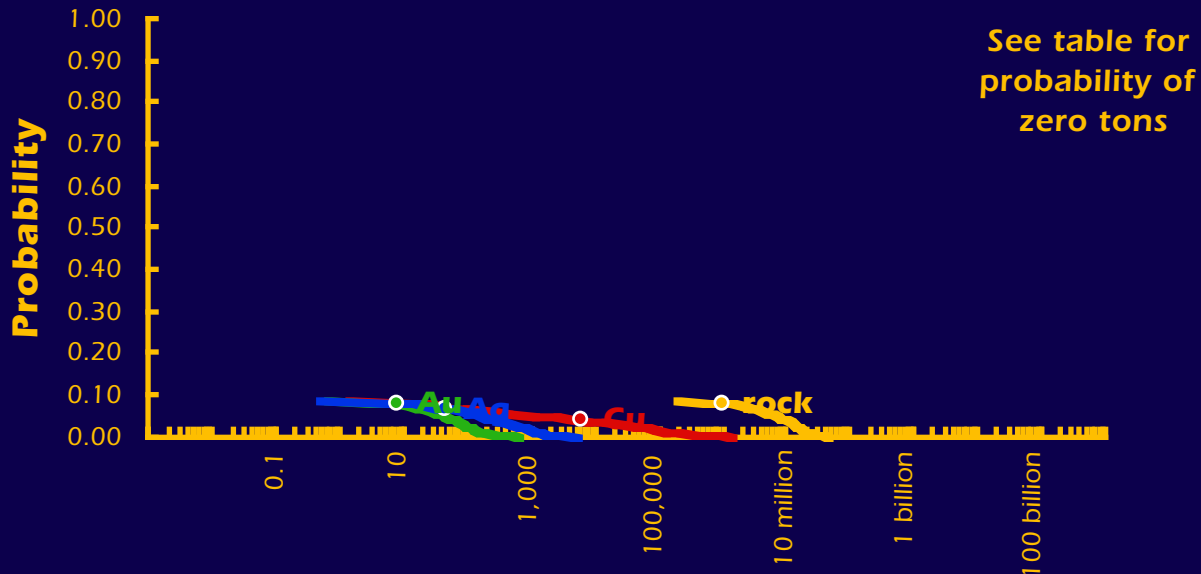
Histograms of Contained Metal and Mineralized Rock (metric tons)



See table for probability of zero tons

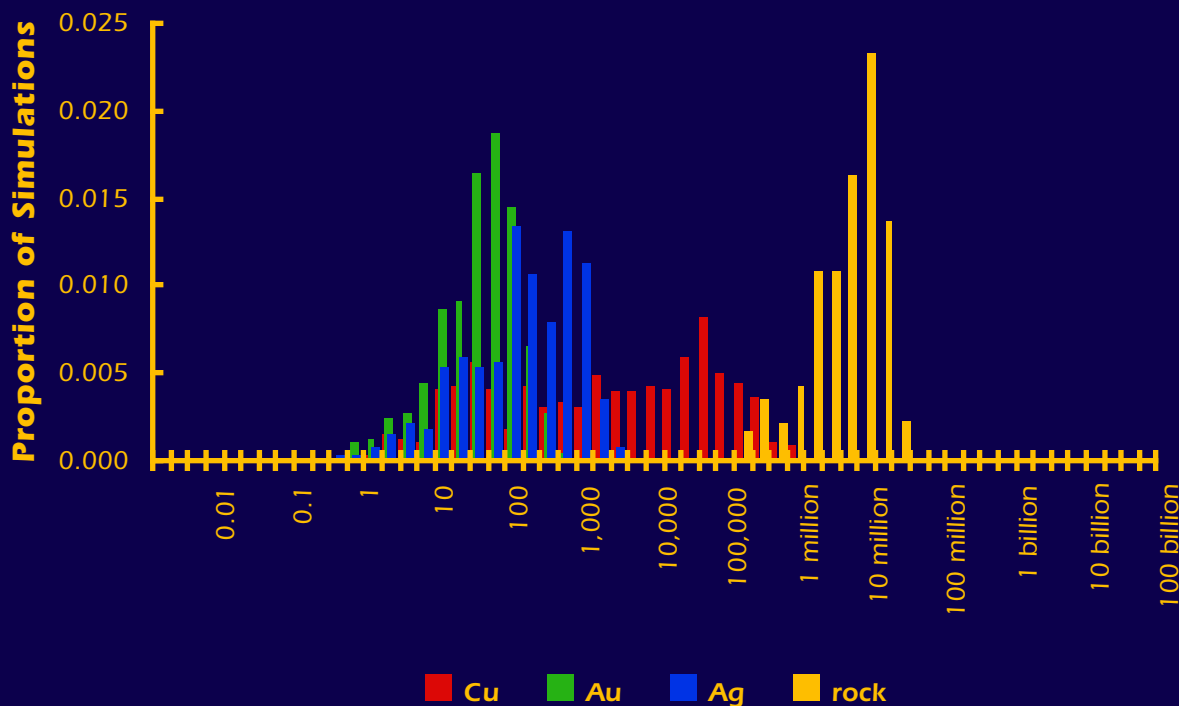
Cu Au Ag rock

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR30

The Mark3 Index is 38:

Epithermal vein, quartz-alunite

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	1,600	42	150	6,400,000
mean	6,000	7	43	910,000
Probability of mean	0.04	0.08	0.07	0.08
Probability of zero	0.91	0.91	0.91	0.91

The tract ID is CR30The Mark3 Index is 38: **Epithermal vein, quartz-alunite**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

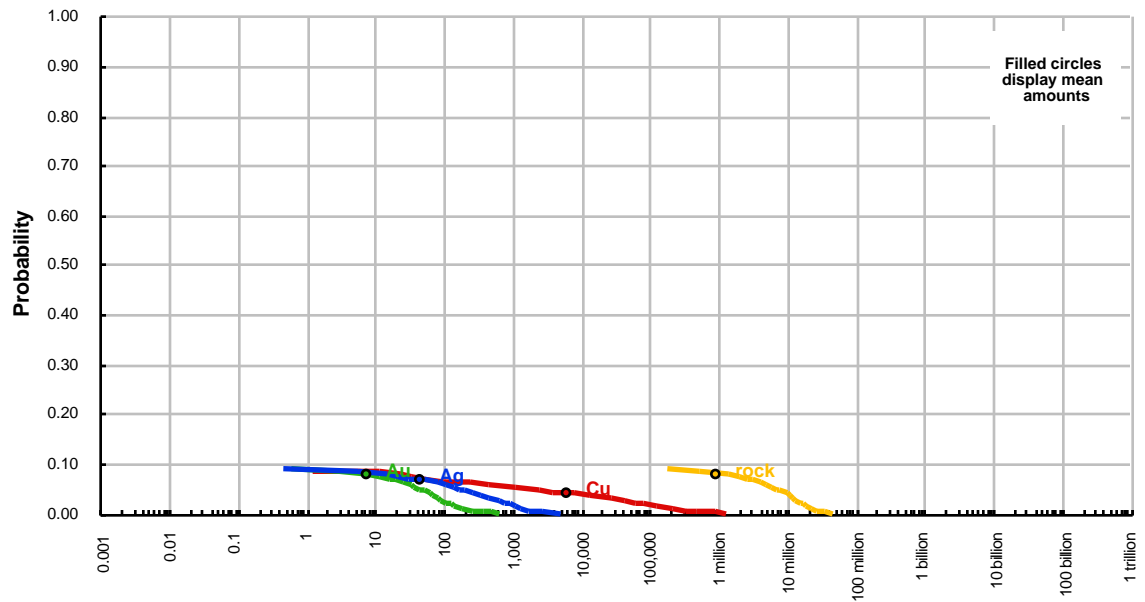
There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

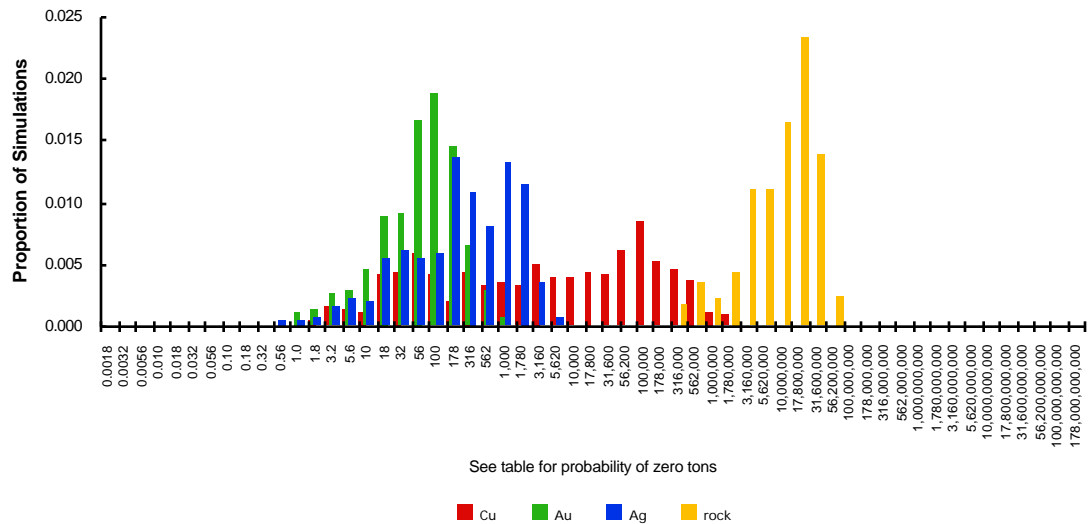
quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	1,600	42	150	6,400,000
mean	6,000	7	43	910,000
Probability of mean	0.04	0.08	0.07	0.08
Probability of zero	0.91	0.91	0.91	0.91

The tract ID is CR30

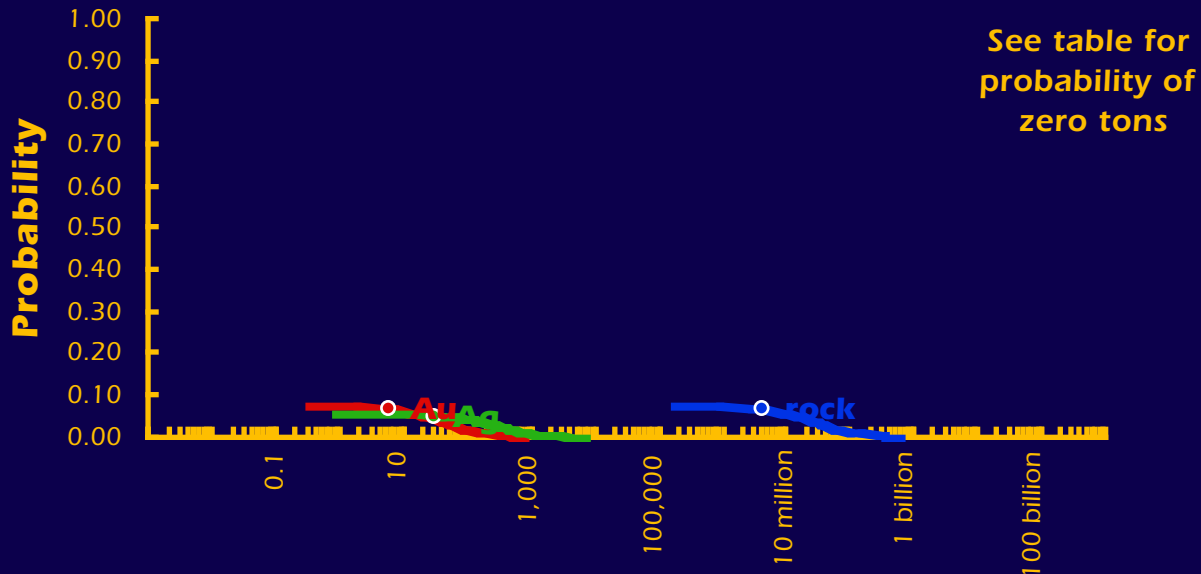
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

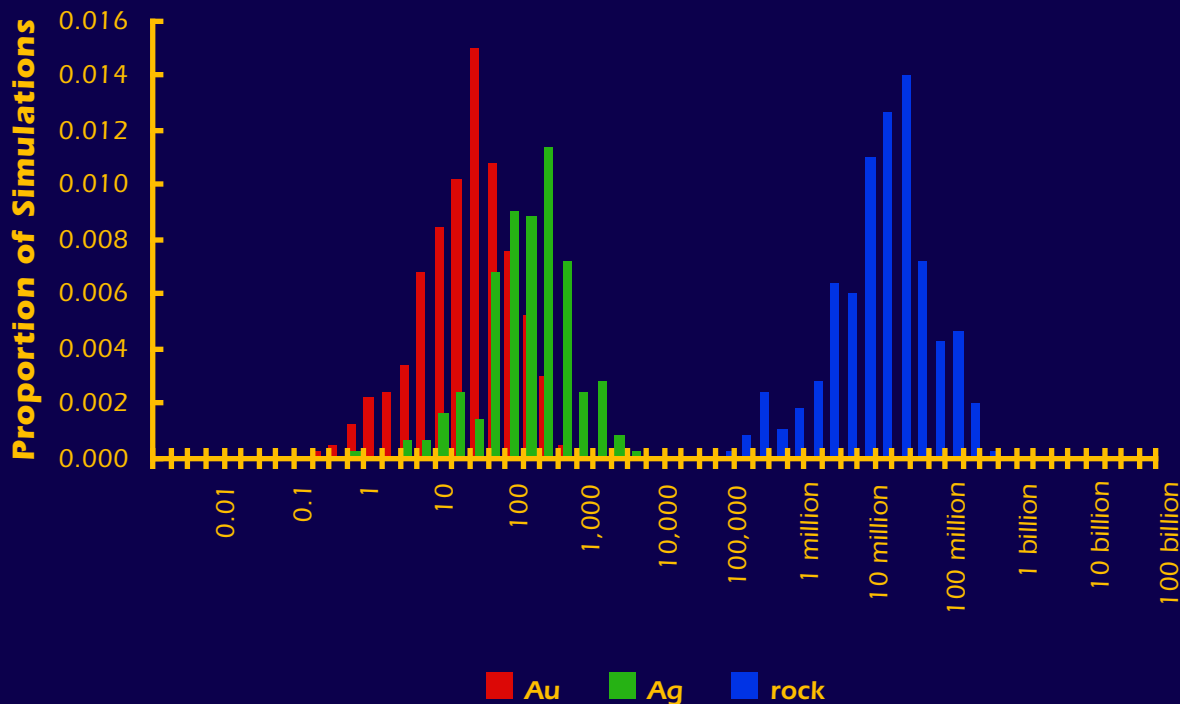


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR31

The Mark3 Index is 45:

Hot spring Au-Ag

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	0	0
0.05	20	53	14,000,000
mean	6	28	4,200,000
Probability of mean	0.07	0.05	0.07
Probability of zero	0.92	0.94	0.92

The tract ID is CR31The Mark3 Index is 45: **Hot spring Au-Ag**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

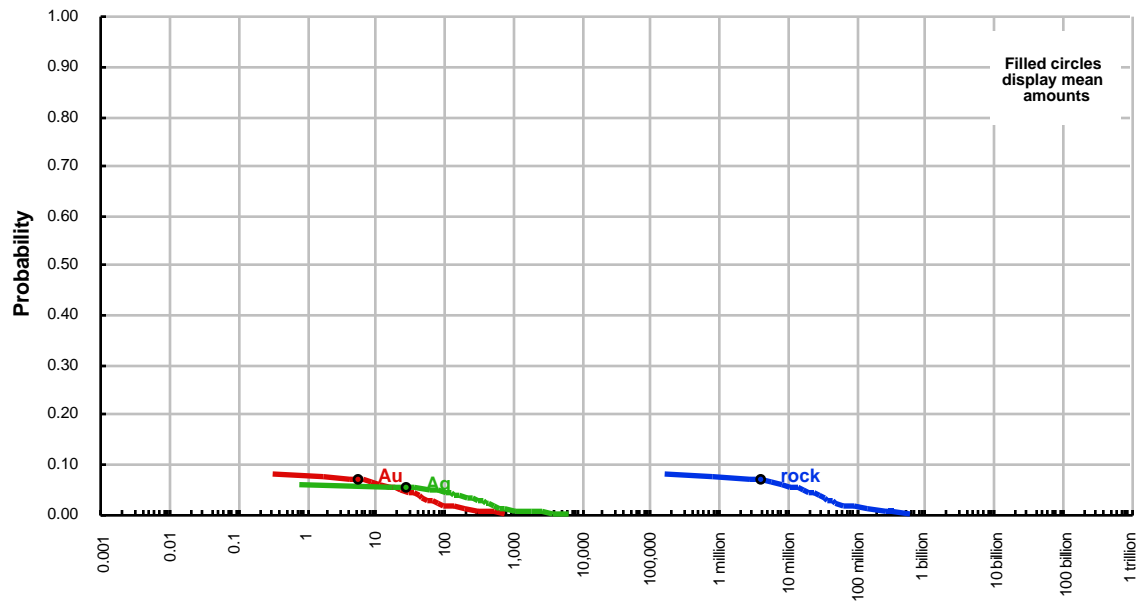
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

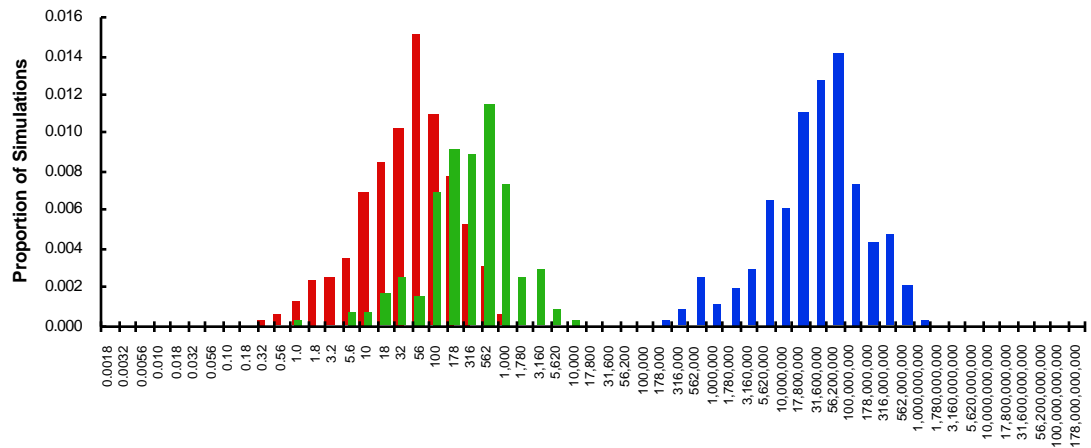
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	0	0
0.05	20	53	14,000,000
mean	6	28	4,200,000
Probability of mean	0.07	0.05	0.07
Probability of zero	0.92	0.94	0.92

The tract ID is CR31

Cumulative Distributions of Contained Metal and Mineralized Rock



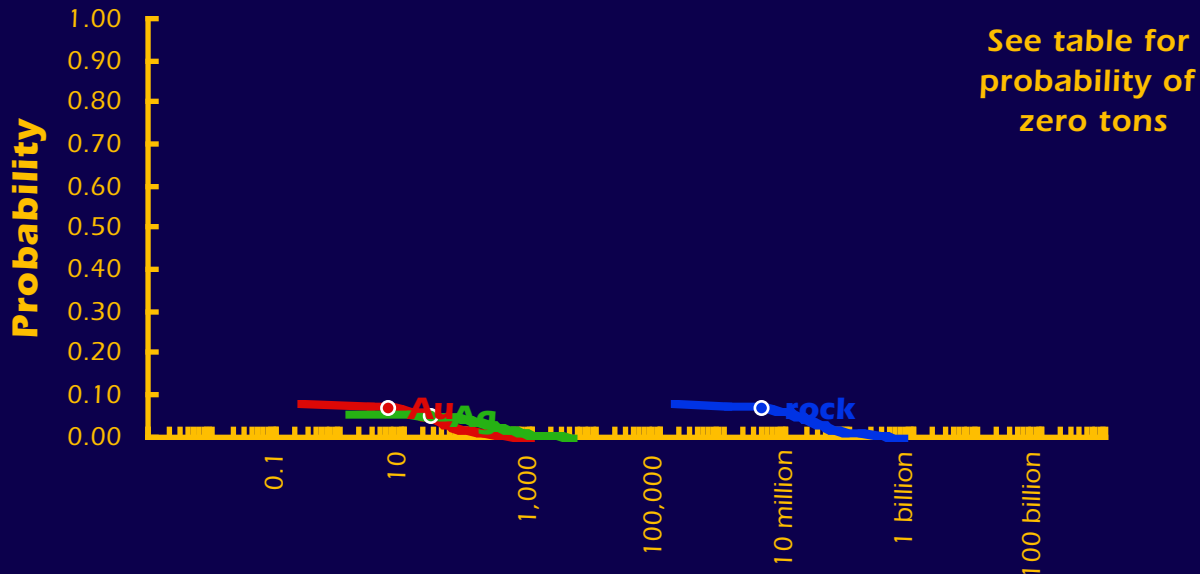
Histograms of Contained Metal and Mineralized Rock (metric tons)



See table for probability of zero tons

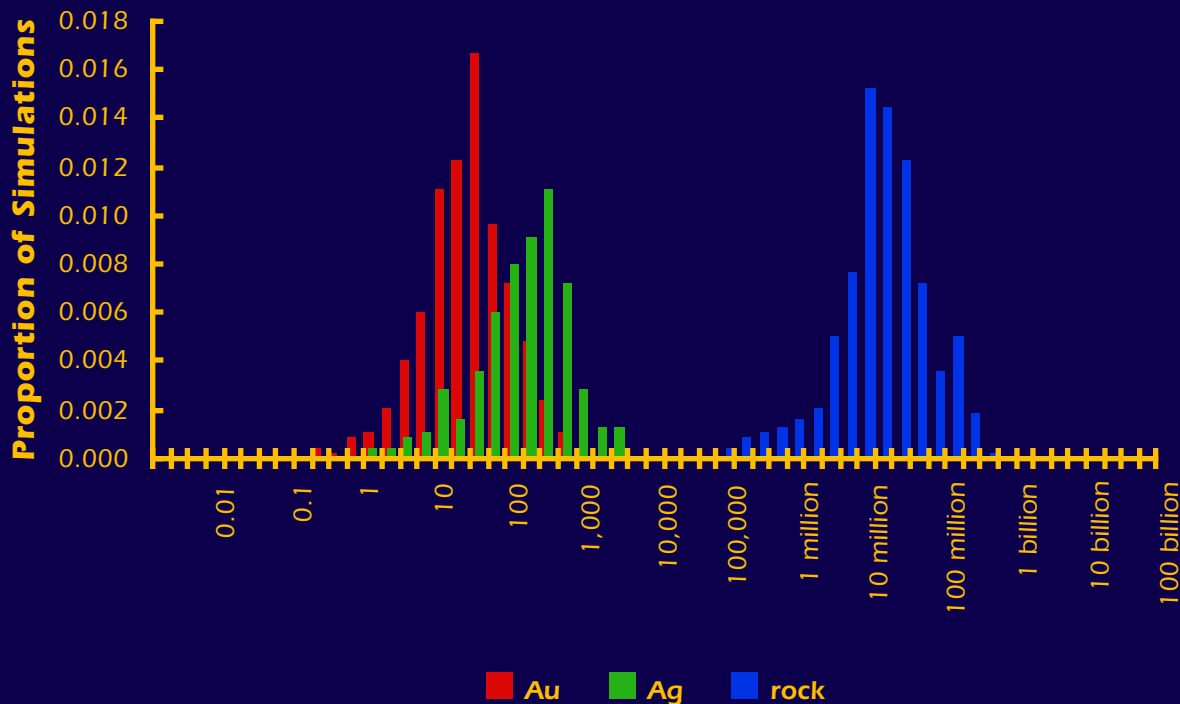
Au Ag rock

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR32

The Mark3 Index is 45:

Hot spring Au-Ag

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	0	0
0.05	22	32	15,000,000
mean	6	25	4,200,000
Probability of mean	0.07	0.05	0.07
Probability of zero	0.92	0.94	0.92

The tract ID is CR32The Mark3 Index is 45: **Hot spring Au-Ag**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

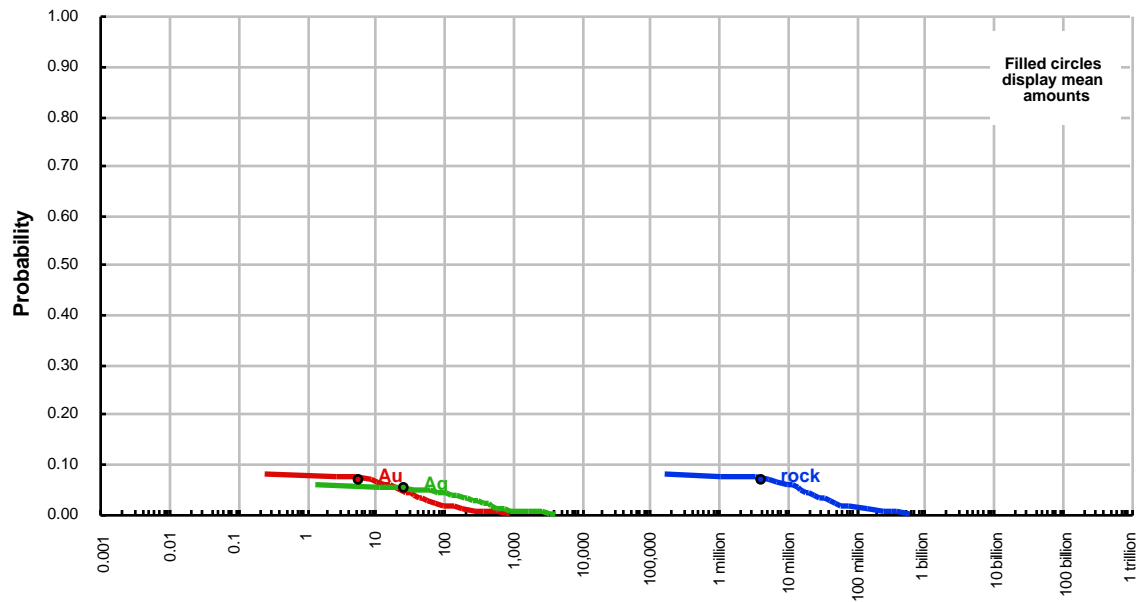
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

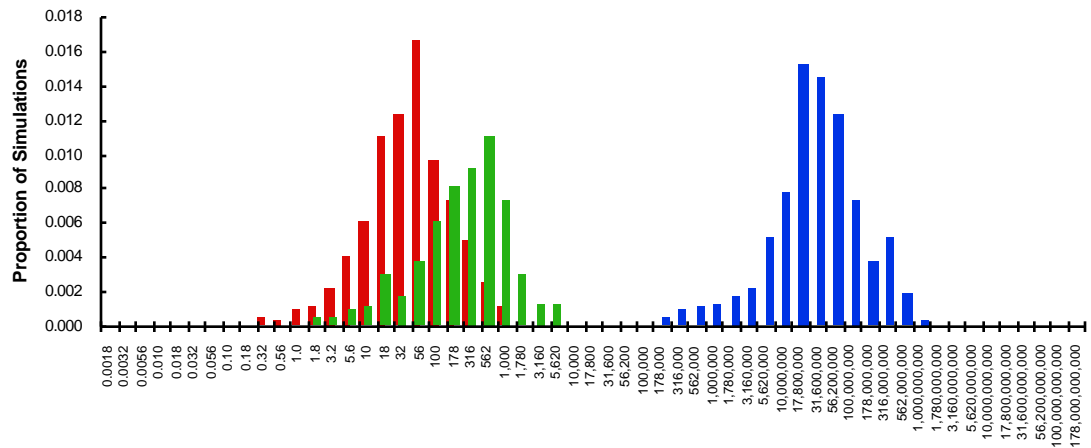
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	0	0
0.05	22	32	15,000,000
mean	6	25	4,200,000
Probability of mean	0.07	0.05	0.07
Probability of zero	0.92	0.94	0.92

The tract ID is CR32

Cumulative Distributions of Contained Metal and Mineralized Rock



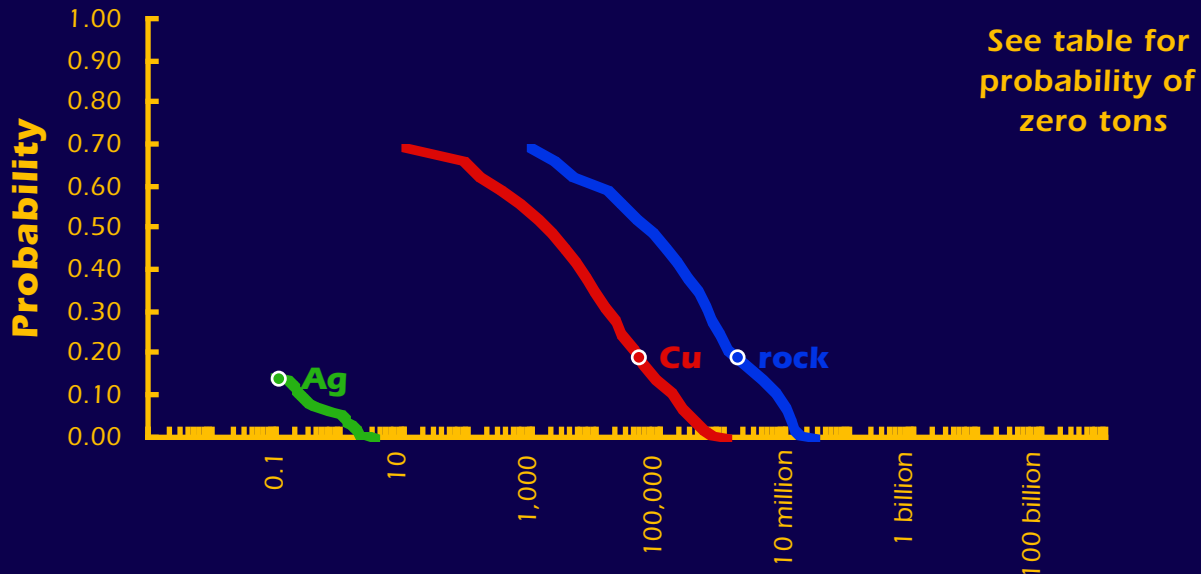
Histograms of Contained Metal and Mineralized Rock (metric tons)



See table for probability of zero tons

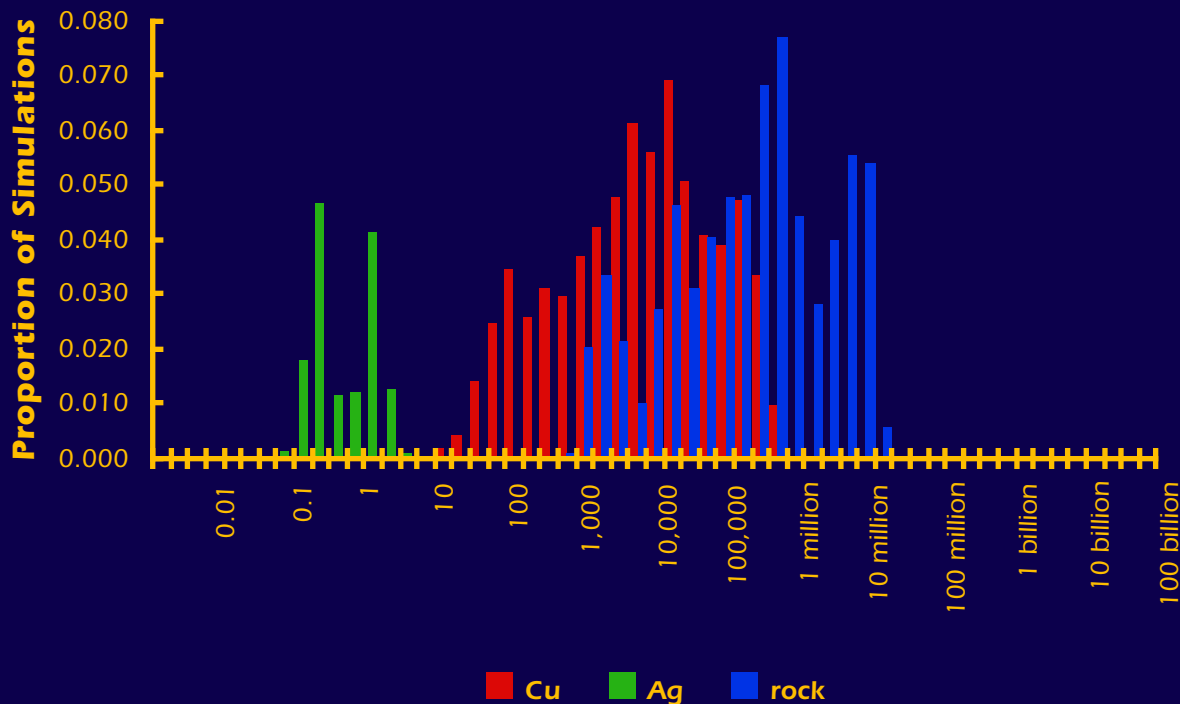
Au Ag rock

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR33

The Mark3 Index is 97:

Sediment-hosted Cu, red-bed

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	1,700	0	63,000
0.10	160,000	0	6,850,000
0.05	300,000	1	11,000,000
mean	46,000	0	1,600,000
Probability of mean	0.19	0.14	0.19
Probability of zero	0.30	0.86	0.30

The tract ID is CR33

The Mark3 Index is 97: **Sediment-hosted Cu, red-bed**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

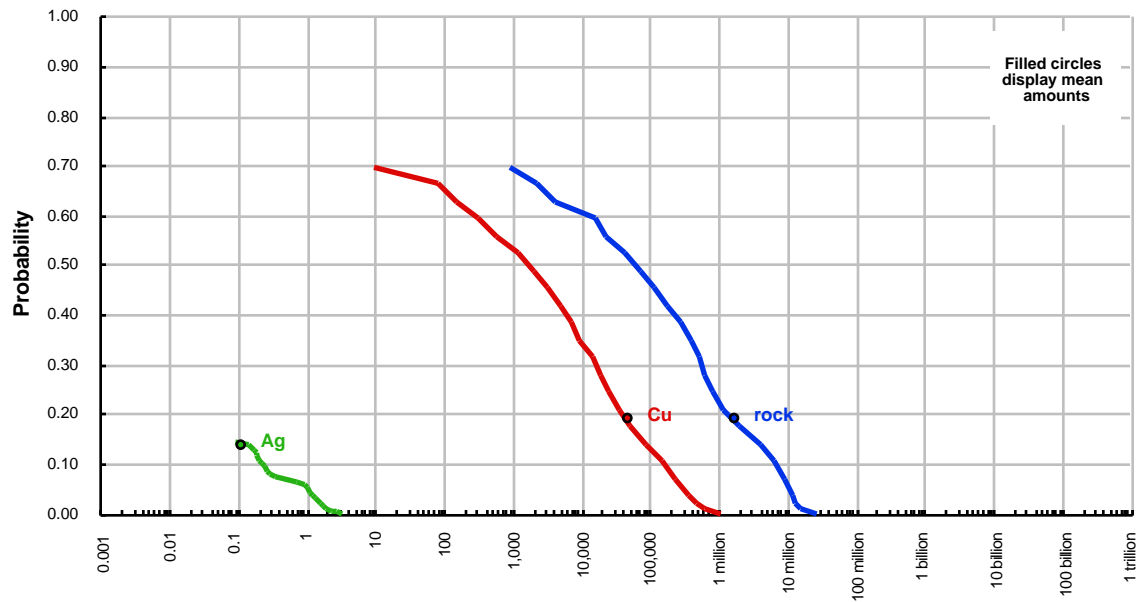
There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

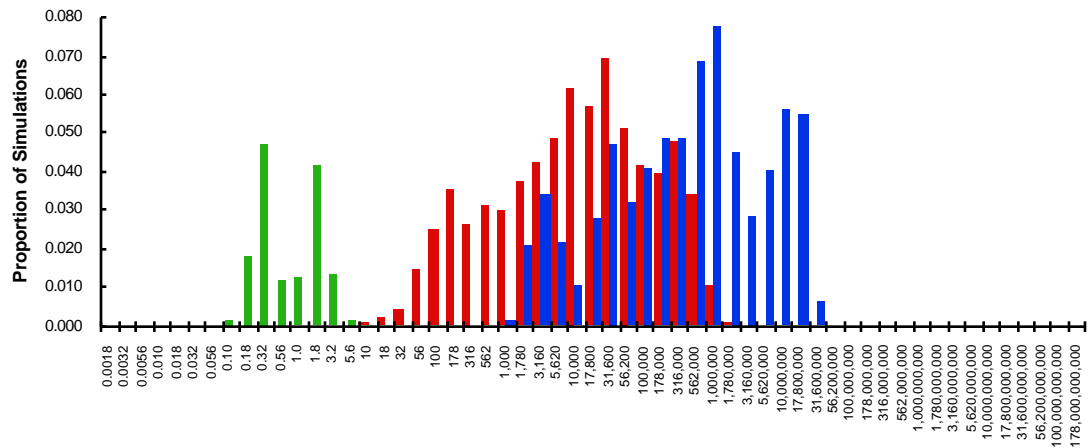
quantile	Cu	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	1,700	0	63,000
0.10	160,000	0	6,850,000
0.05	300,000	1	11,000,000
mean	46,000	0	1,600,000
Probability of mean	0.19	0.14	0.19
Probability of zero	0.30	0.86	0.30

The tract ID is CR33

Cumulative Distributions of Contained Metal and Mineralized Rock



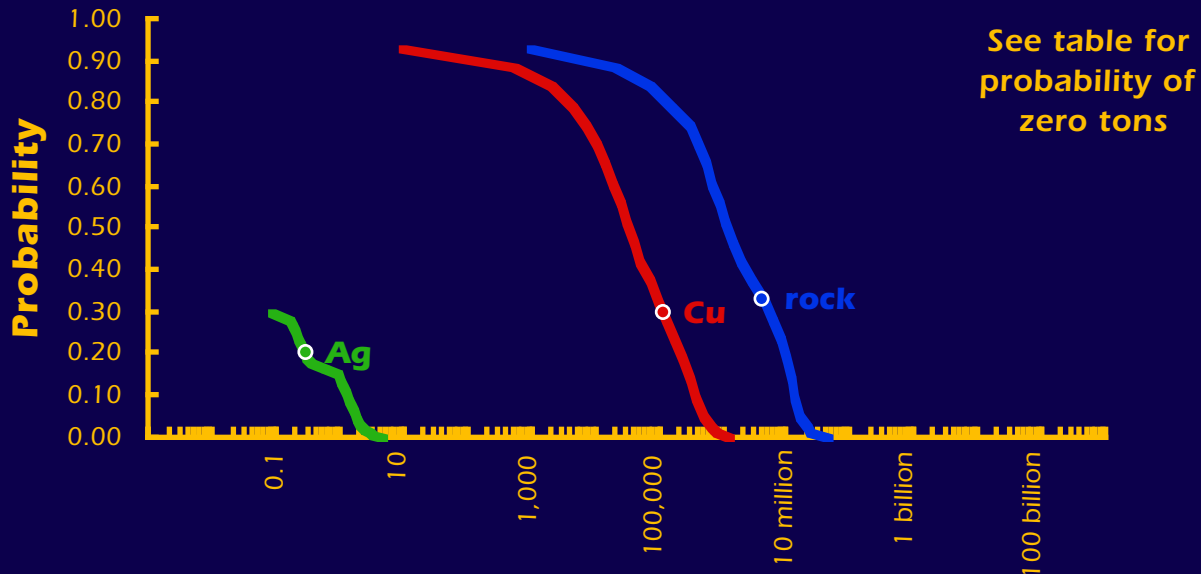
Histograms of Contained Metal and Mineralized Rock (metric tons)



See table for probability of zero tons

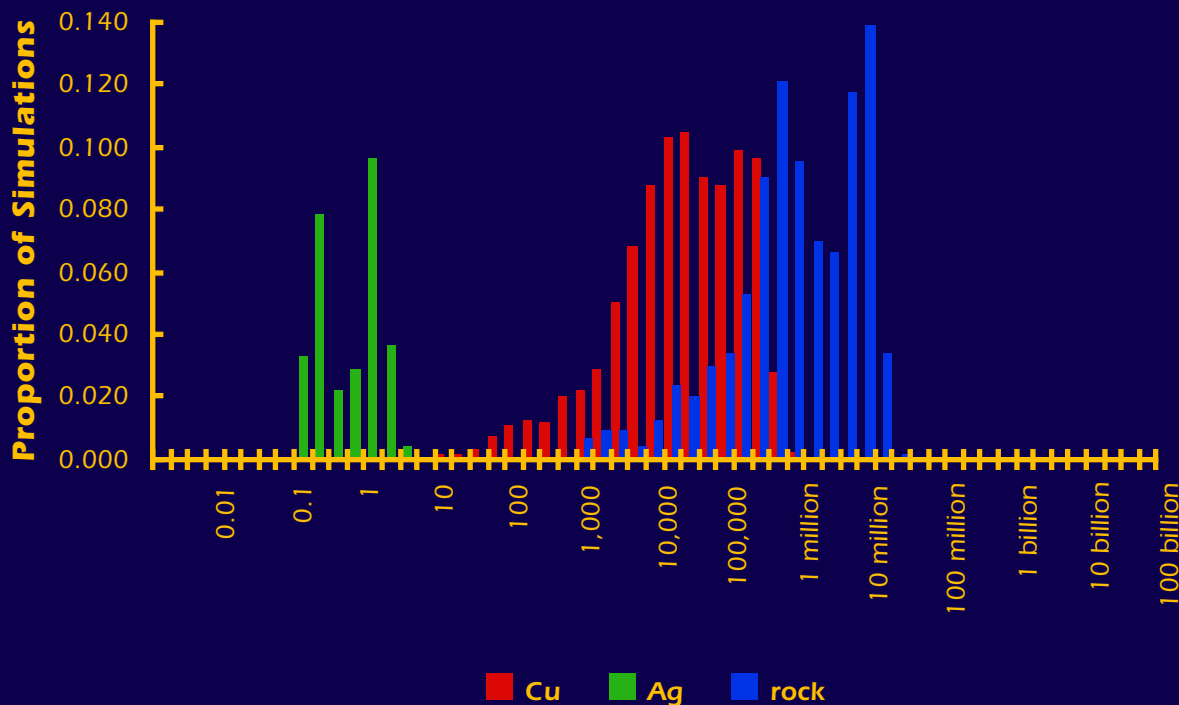
Cu Ag rock

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR34

The Mark3 Index is 97:

Sediment-hosted Cu, red-bed

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

There is a 1% or greater chance of 6 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Ag	rock
0.95	0	0	0
0.90	270	0	14,000
0.50	33,000	0	1,100,000
0.10	360,000	1	12,700,000
0.05	470,000	2	16,000,000
mean	110,000	0	4,200,000
Probability of mean	0.30	0.20	0.33
Probability of zero	0.07	0.70	0.07

The tract ID is CR34

The Mark3 Index is 97: **Sediment-hosted Cu, red-bed**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

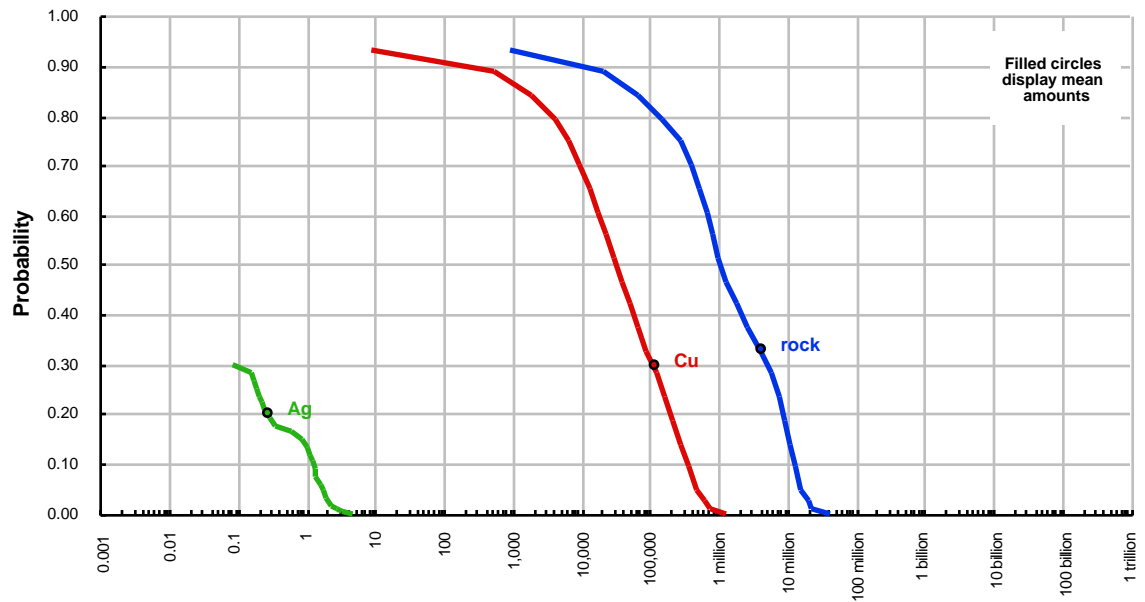
There is a 1% or greater chance of 6 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

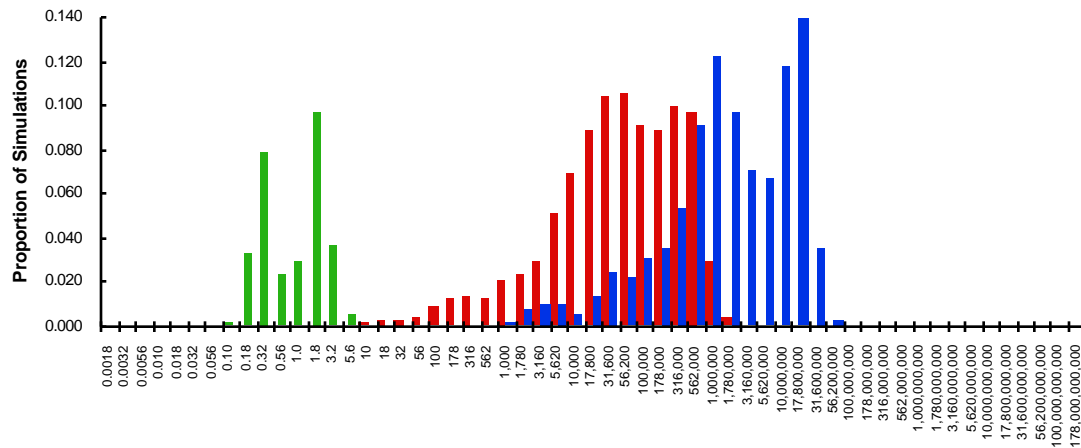
quantile	Cu	Ag	rock
0.95	0	0	0
0.90	270	0	14,000
0.50	33,000	0	1,100,000
0.10	360,000	1	12,700,000
0.05	470,000	2	16,000,000
mean	110,000	0	4,200,000
Probability of mean	0.30	0.20	0.33
Probability of zero	0.07	0.70	0.07

The tract ID is CR34

Cumulative Distributions of Contained Metal and Mineralized Rock



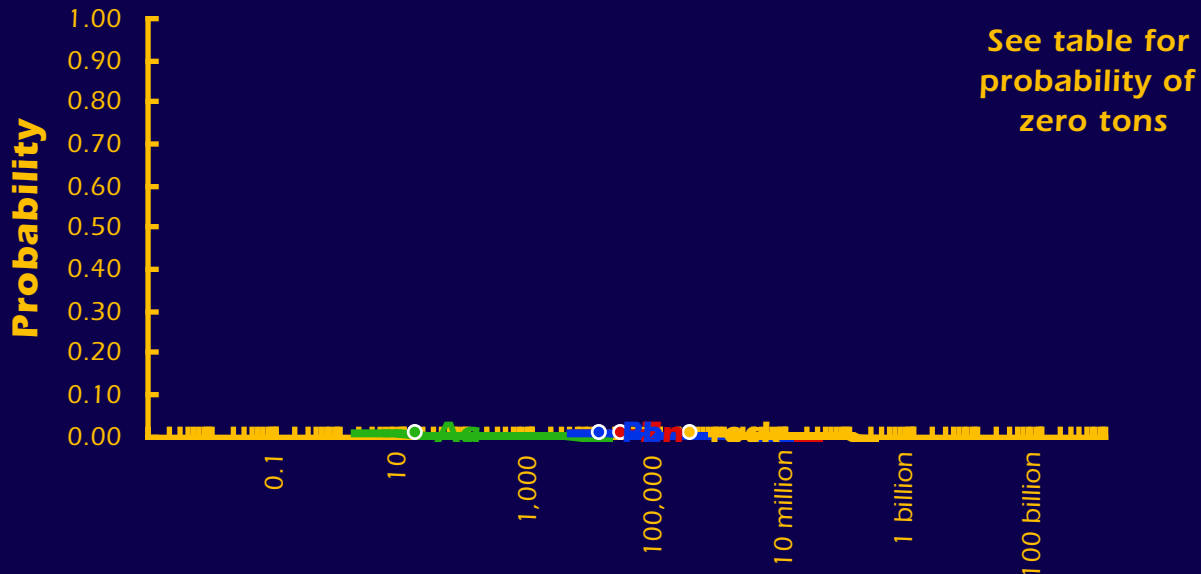
Histograms of Contained Metal and Mineralized Rock (metric tons)



See table for probability of zero tons

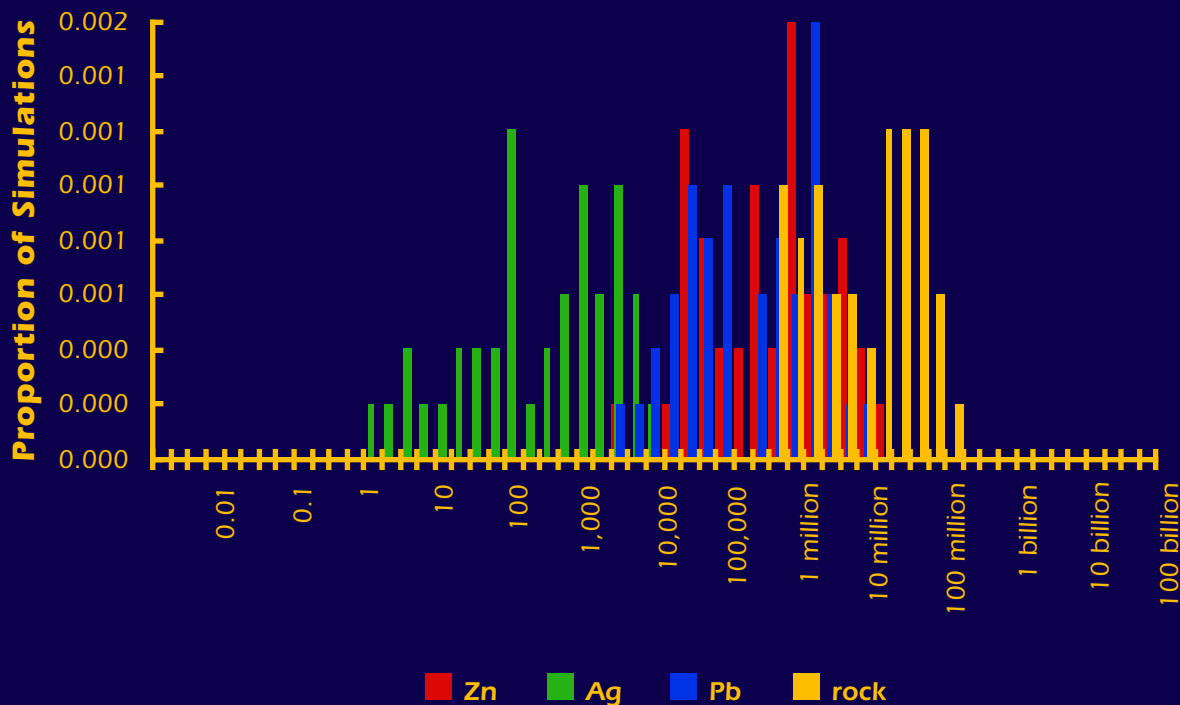
Cu Ag rock

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR35

The Mark3 Index is 13:

Sedimentary exhalative Zn-Pb

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Zn	Ag	Pb	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	0	0	0	0
mean	23,000	15	12,000	300,000
Probability of mean	0.01	0.01	0.01	0.01
Probability of zero	0.99	0.99	0.99	0.99

The tract ID is CR35

The Mark3 Index is 13: **Sedimentary exhalative Zn-Pb**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

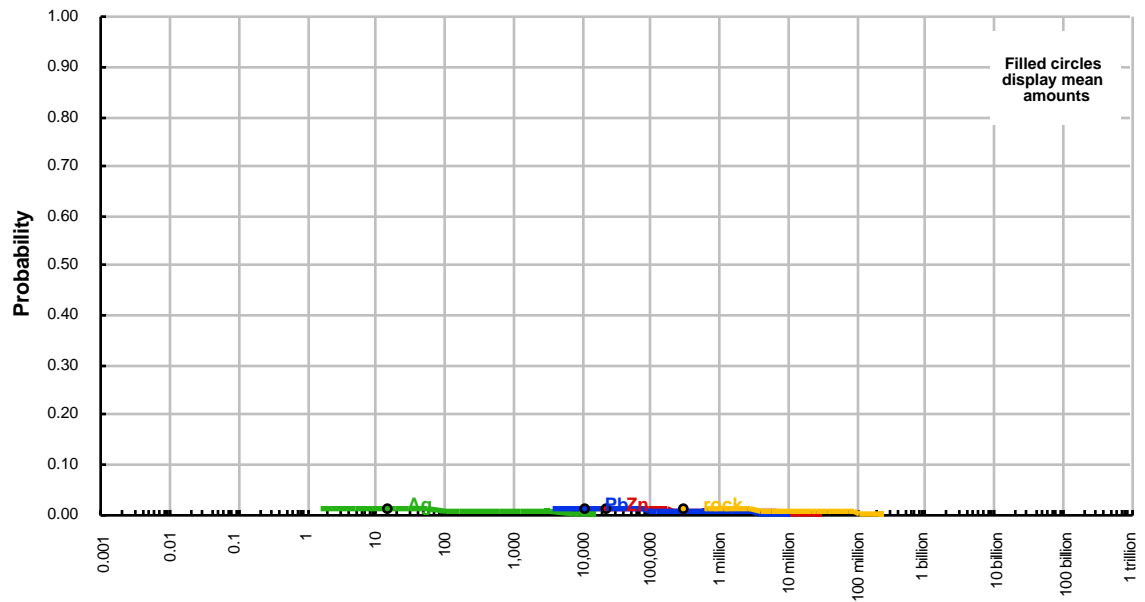
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

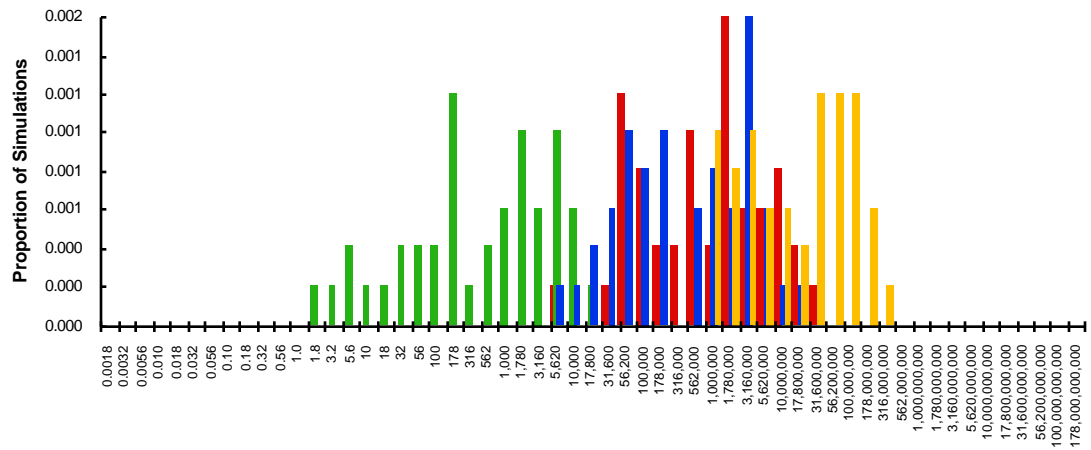
quantile	Zn	Ag	Pb	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	0	0	0	0
mean	23,000	15	12,000	300,000
Probability of mean	0.01	0.01	0.01	0.01
Probability of zero	0.99	0.99	0.99	0.99

The tract ID is CR35

Cumulative Distributions of Contained Metal and Mineralized Rock



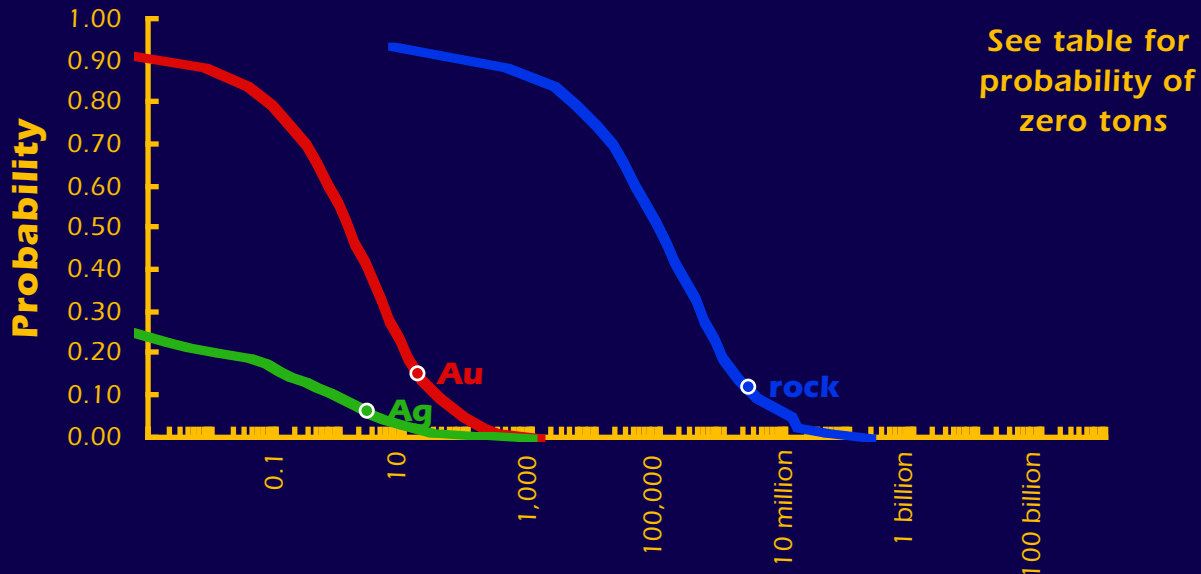
Histograms of Contained Metal and Mineralized Rock (metric tons)



See table for probability of zero tons

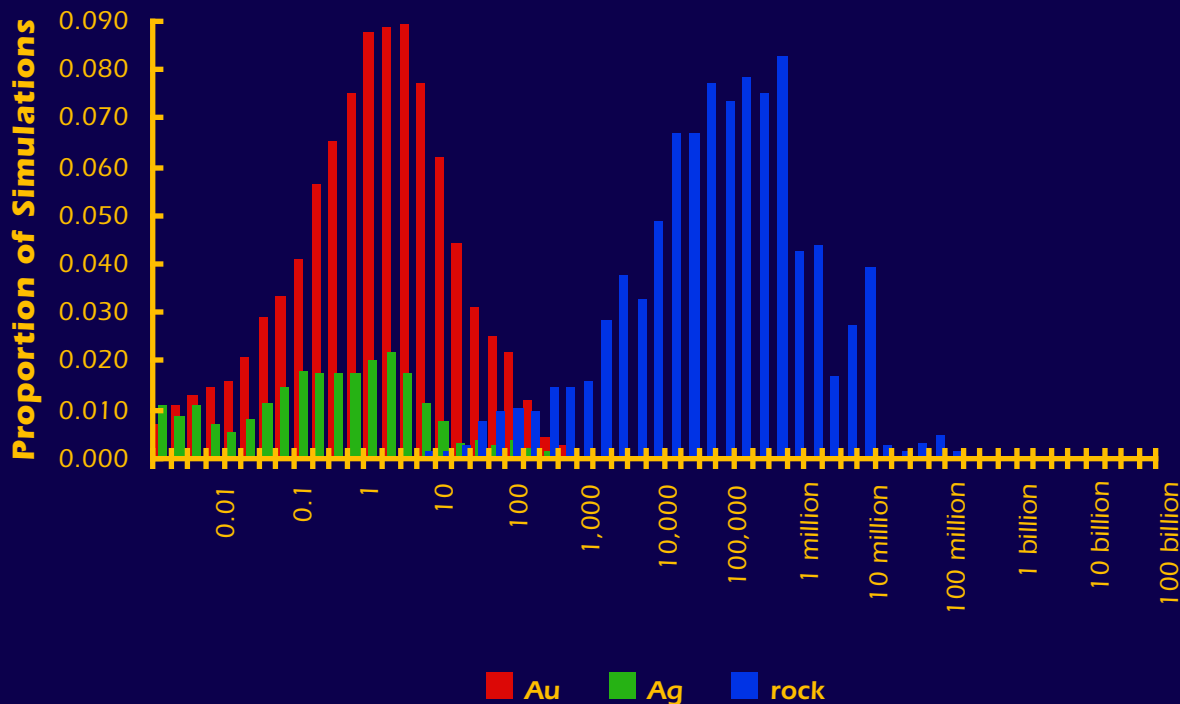
Zn Ag Pb rock

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is CR36

The Mark3 Index is 27:

Low sulfide Au-quartz vein

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	210
0.50	1	0	93,000
0.10	30	1	2,860,000
0.05	78	3	11,000,000
mean	16	3	2,400,000
Probability of mean	0.15	0.06	0.12
Probability of zero	0.07	0.73	0.07

The tract ID is CR36The Mark3 Index is 27: **Low sulfide Au-quartz vein**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

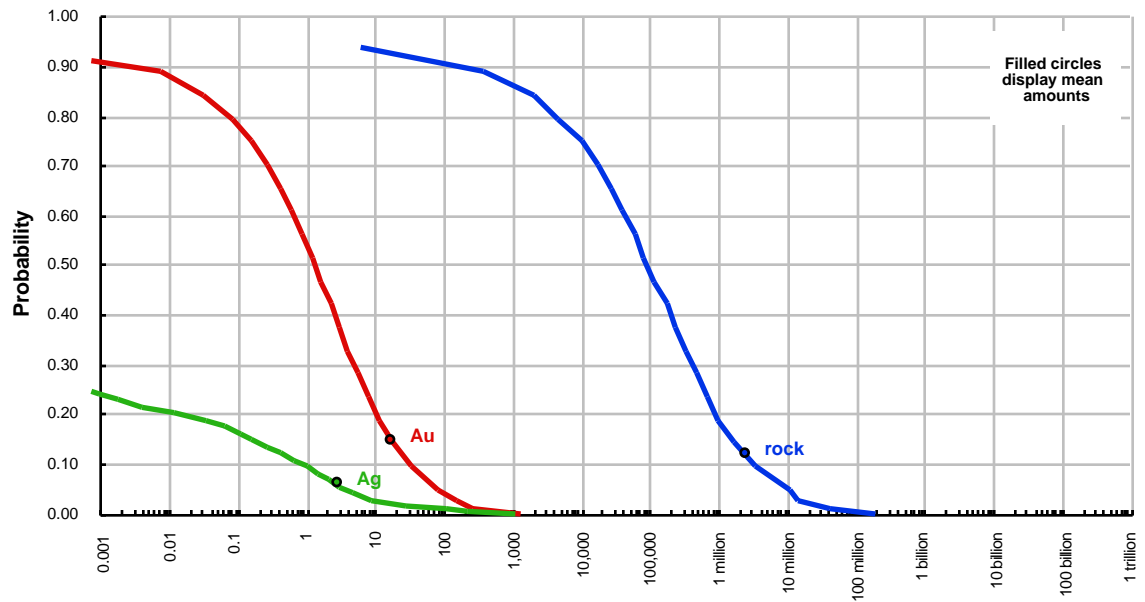
There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

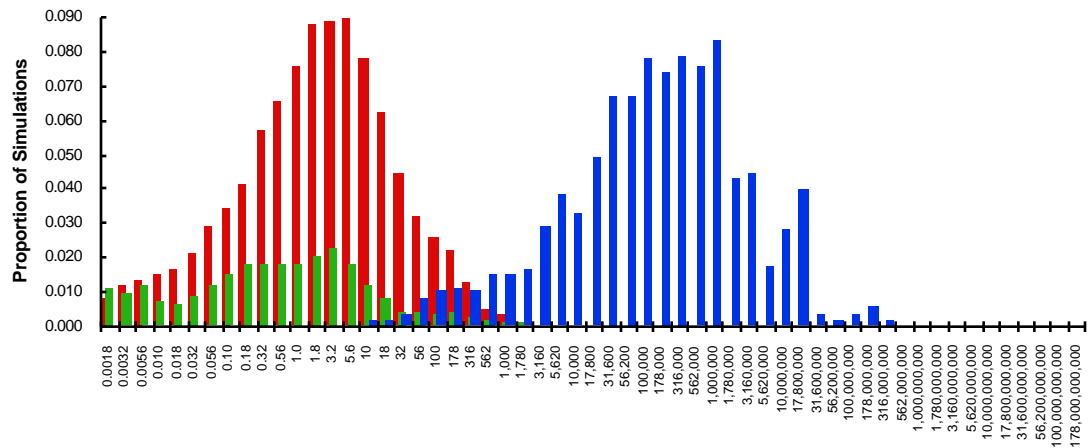
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	210
0.50	1	0	93,000
0.10	30	1	2,860,000
0.05	78	3	11,000,000
mean	16	3	2,400,000
Probability of mean	0.15	0.06	0.12
Probability of zero	0.07	0.73	0.07

The tract ID is CR36

Cumulative Distributions of Contained Metal and Mineralized Rock



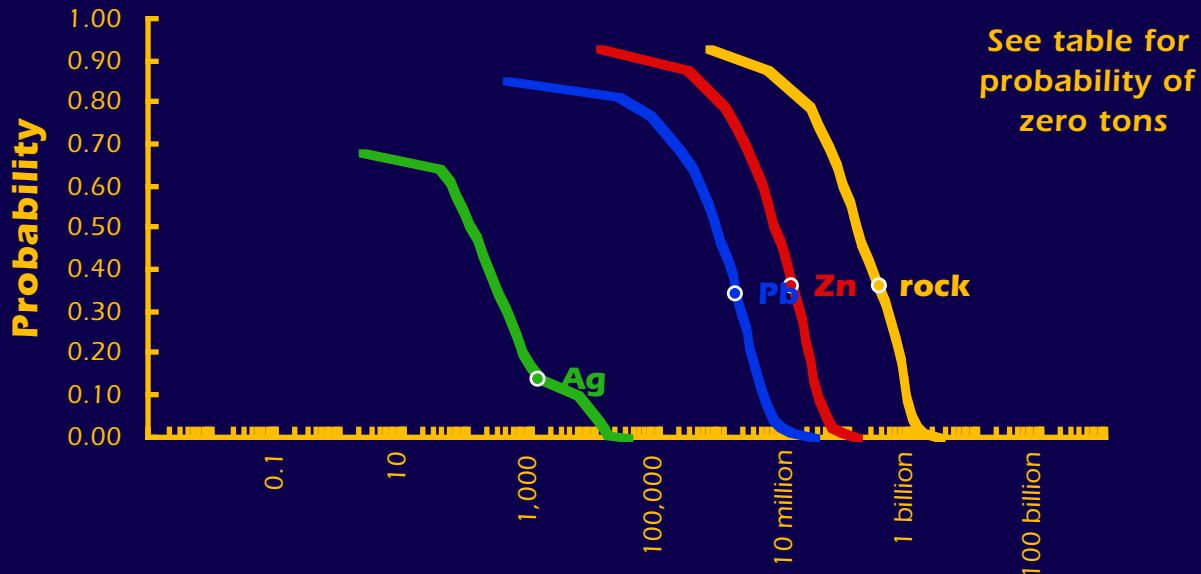
Histograms of Contained Metal and Mineralized Rock (metric tons)



See table for probability of zero tons

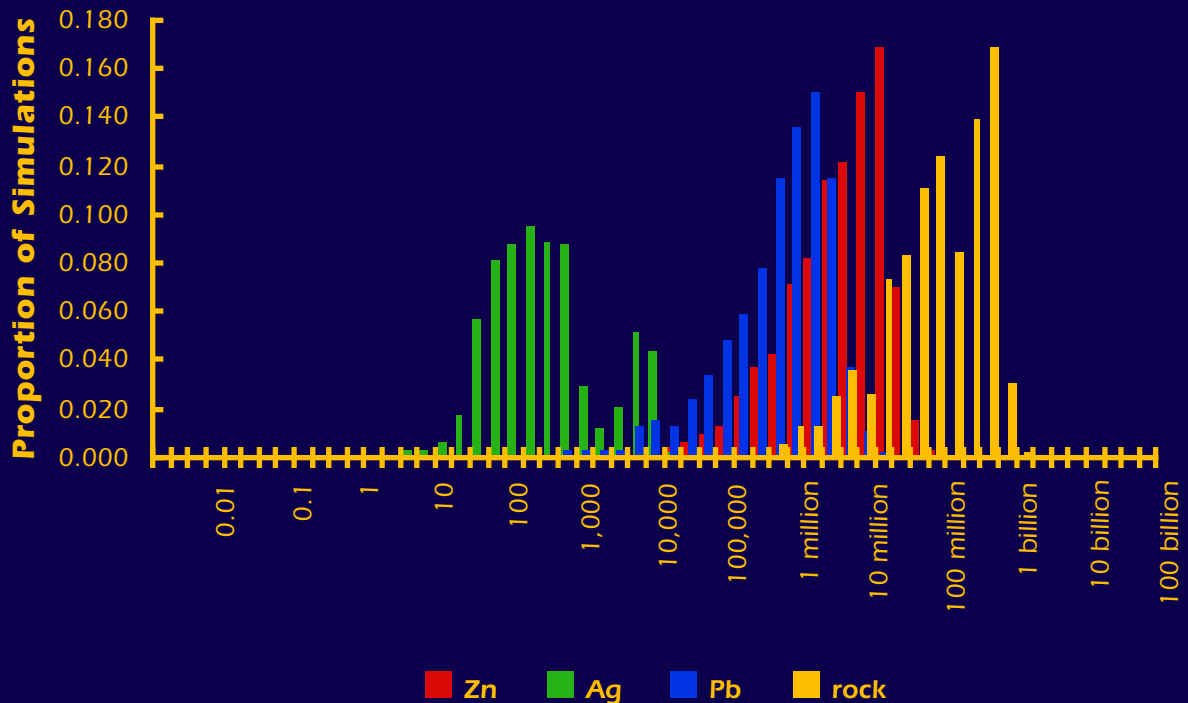
Au Ag rock

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is EC03

The Mark3 Index is 109:

Mississippi Valley (modified)

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Zn	Ag	Pb	rock
0.95	0	0	0	0
0.90	150,000	0	0	2,900,000
0.50	6,400,000	110	790,000	120,000,000
0.10	30,000,000	5,200	4,150,000	720,000,000
0.05	39,000,000	9,400	5,600,000	850,000,000
mean	12,000,000	1,300	1,600,000	270,000,000
Probability of mean	0.36	0.14	0.34	0.36
Probability of zero	0.07	0.32	0.14	0.07

The tract ID is EC03The Mark3 Index is 109: **Mississippi Valley (modified)**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

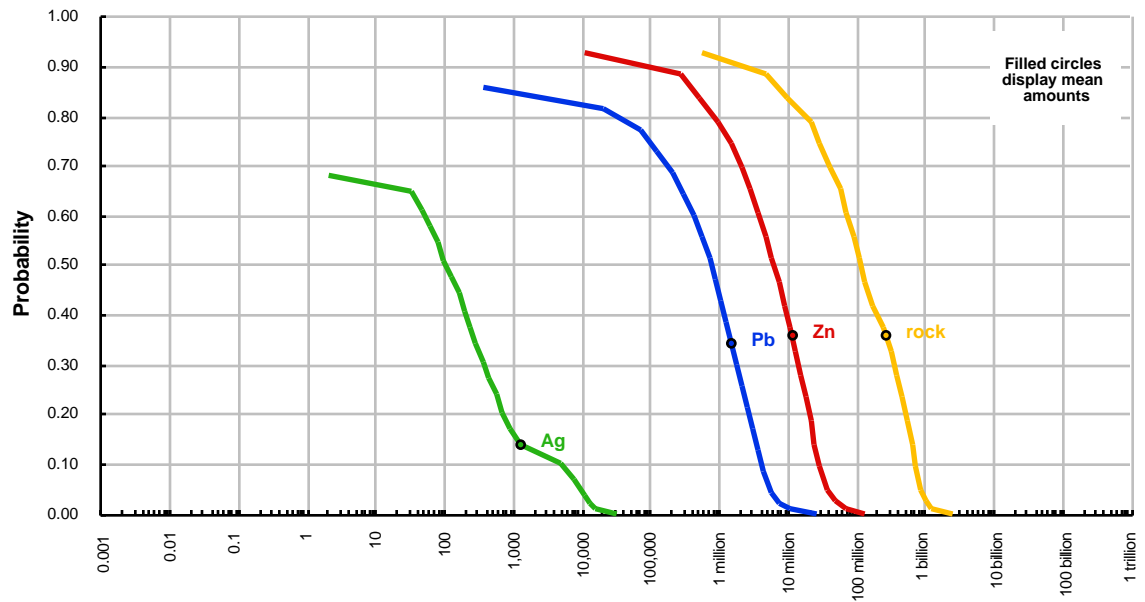
There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

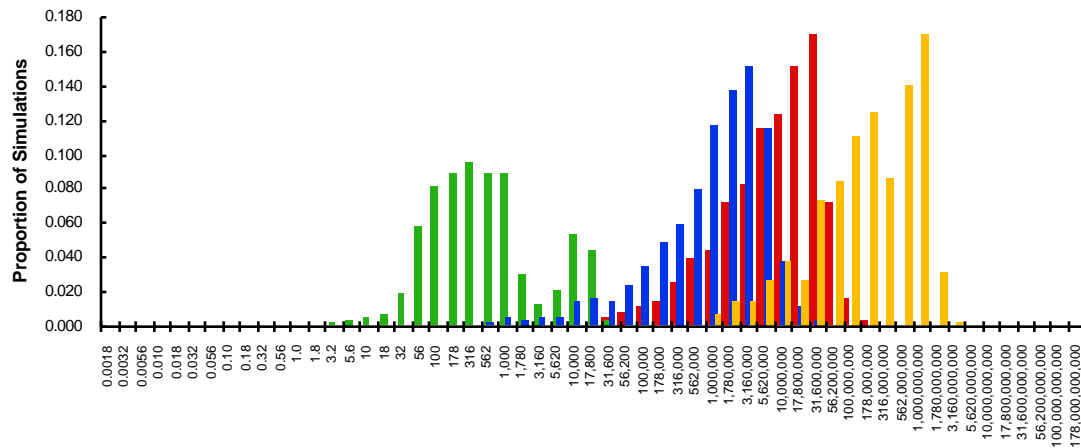
quantile	Zn	Ag	Pb	rock
0.95	0	0	0	0
0.90	150,000	0	0	2,900,000
0.50	6,400,000	110	790,000	120,000,000
0.10	30,000,000	5,200	4,150,000	720,000,000
0.05	39,000,000	9,400	5,600,000	850,000,000
mean	12,000,000	1,300	1,600,000	270,000,000
Probability of mean	0.36	0.14	0.34	0.36
Probability of zero	0.07	0.32	0.14	0.07

The tract ID is EC03

Cumulative Distributions of Contained Metal and Mineralized Rock



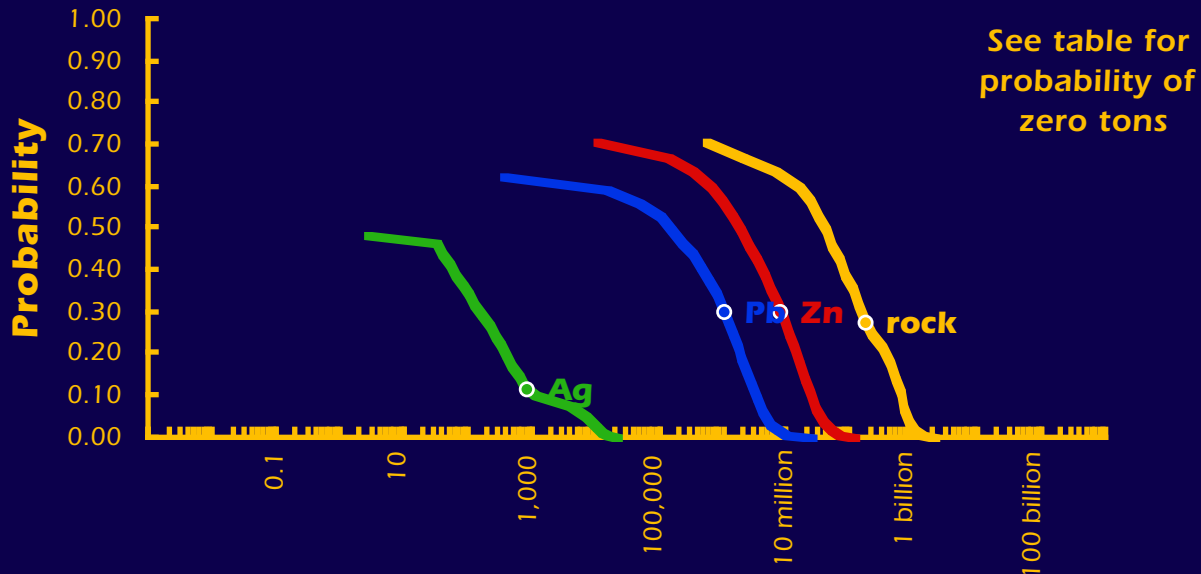
Histograms of Contained Metal and Mineralized Rock (metric tons)



See table for probability of zero tons

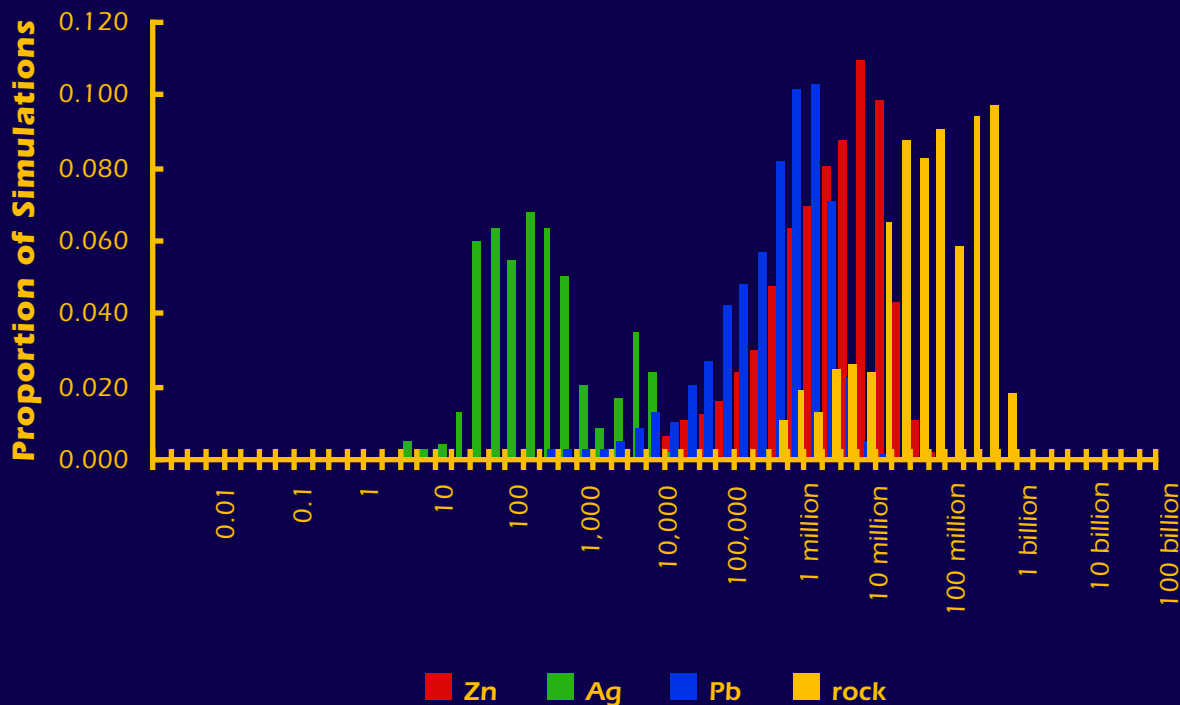
Zn Ag Pb rock

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is EC05

The Mark3 Index is 109:

Mississippi Valley (modified)

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Zn	Ag	Pb	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	1,800,000	0	160,000	39,000,000
0.10	24,000,000	1,100	3,140,000	610,000,000
0.05	33,000,000	6,900	4,400,000	750,000,000
mean	7,700,000	820	1,000,000	170,000,000
Probability of mean	0.30	0.11	0.30	0.27
Probability of zero	0.29	0.51	0.38	0.29

The tract ID is EC05The Mark3 Index is 109: **Mississippi Valley (modified)**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

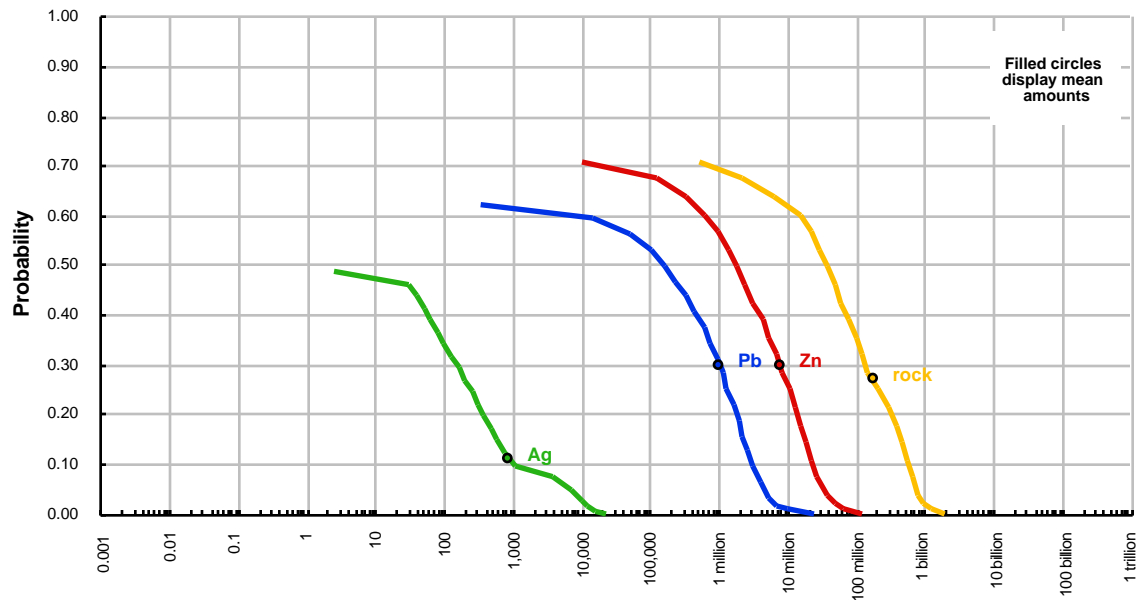
There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

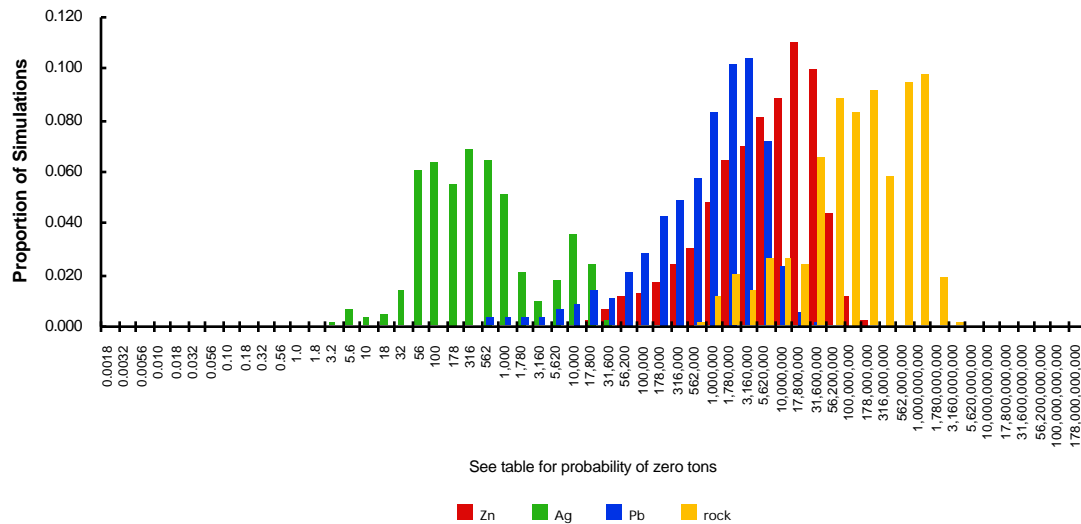
quantile	Zn	Ag	Pb	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	1,800,000	0	160,000	39,000,000
0.10	24,000,000	1,100	3,140,000	610,000,000
0.05	33,000,000	6,900	4,400,000	750,000,000
mean	7,700,000	820	1,000,000	170,000,000
Probability of mean	0.30	0.11	0.30	0.27
Probability of zero	0.29	0.51	0.38	0.29

The tract ID is EC05

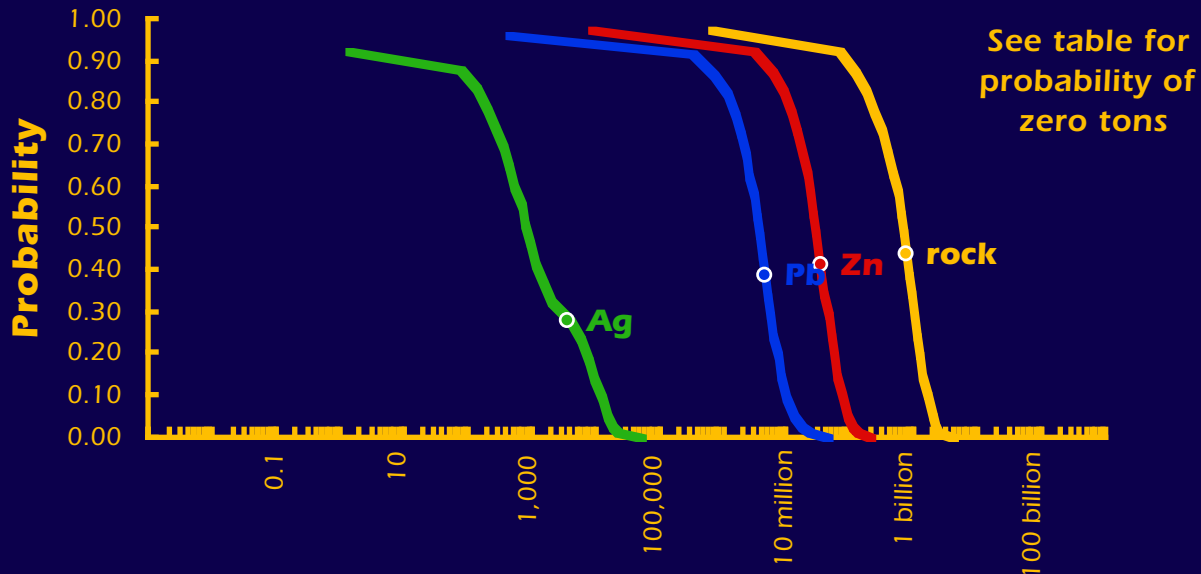
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

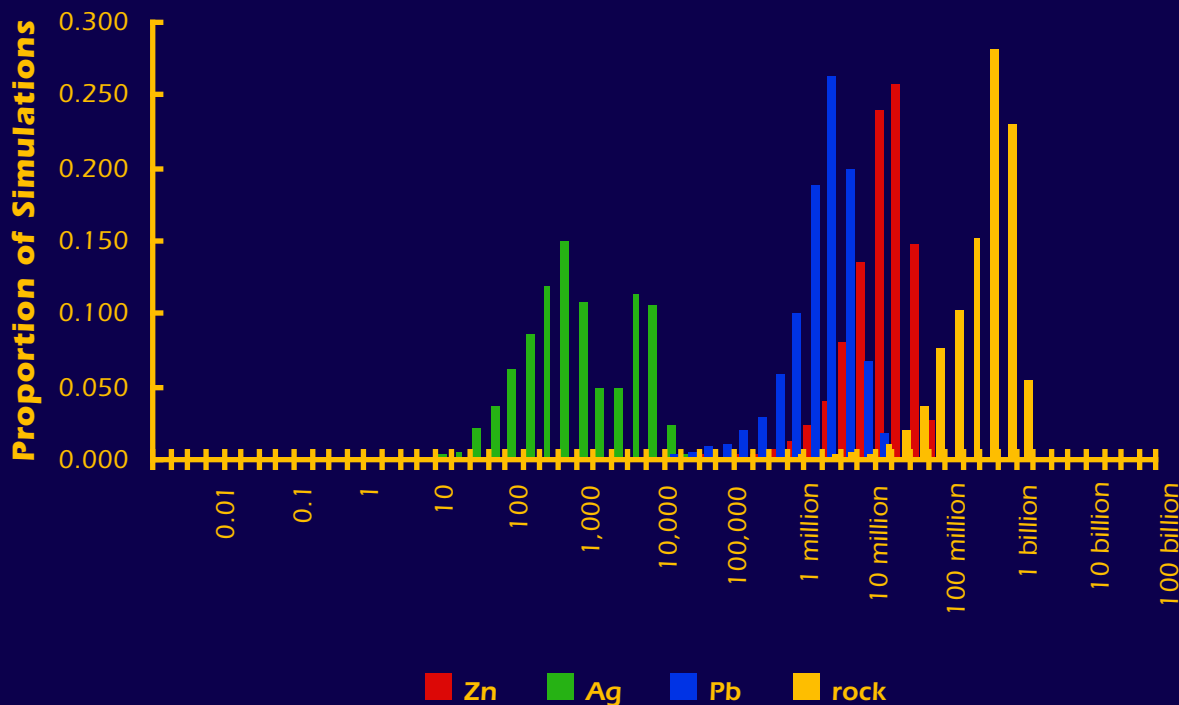


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is EC06

The Mark3 Index is 109:

Mississippi Valley (modified)

There is a 90% or greater chance of 3 or more deposits.

There is a 50% or greater chance of 6 or more deposits.

There is a 10% or greater chance of 8 or more deposits.

There is a 5% or greater chance of 11 or more deposits.

There is a 1% or greater chance of 14 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Zn	Ag	Pb	rock
0.95	1,500,000	0	73,000	32,000,000
0.90	4,500,000	45	470,000	93,000,000
0.50	28,000,000	800	3,500,000	670,000,000
0.10	70,000,000	12,000	9,400,000	1,500,000,000
0.05	84,000,000	15,000	12,000,000	1,800,000,000
mean	34,000,000	3,500	4,500,000	740,000,000
Probability of mean	0.41	0.28	0.39	0.44
Probability of zero	0.03	0.08	0.04	0.03

The tract ID is EC06The Mark3 Index is 109: **Mississippi Valley (modified)**

There is a 90% or greater chance of 3 or more deposits.

There is a 50% or greater chance of 6 or more deposits.

There is a 10% or greater chance of 8 or more deposits.

There is a 5% or greater chance of 11 or more deposits.

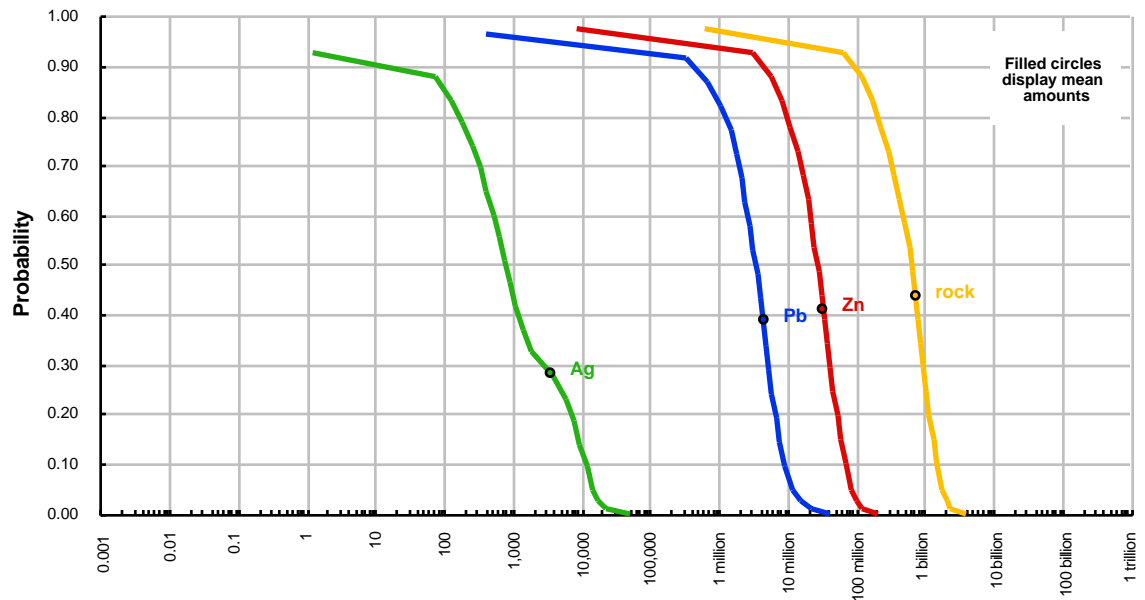
There is a 1% or greater chance of 14 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

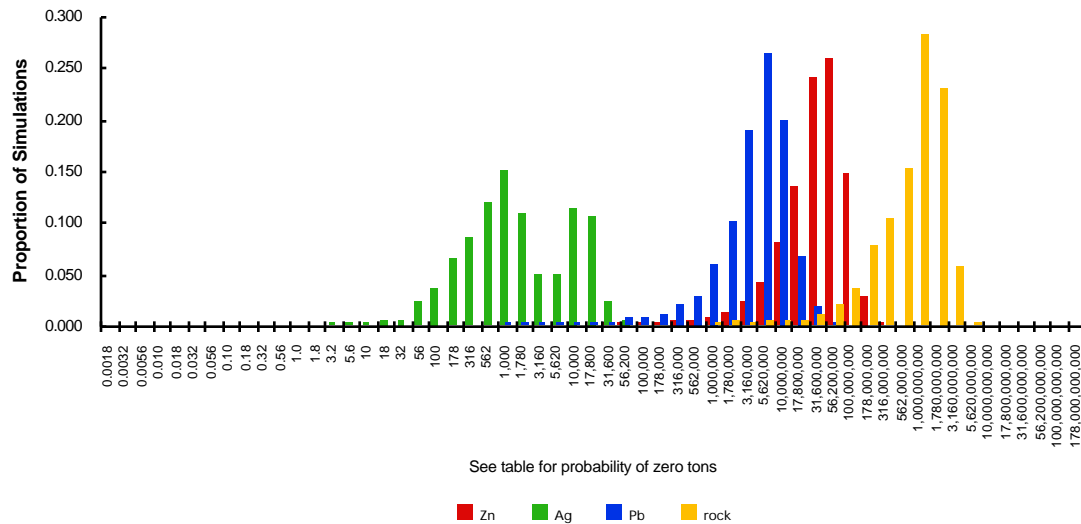
quantile	Zn	Ag	Pb	rock
0.95	1,500,000	0	73,000	32,000,000
0.90	4,500,000	45	470,000	93,000,000
0.50	28,000,000	800	3,500,000	670,000,000
0.10	70,000,000	12,000	9,400,000	1,500,000,000
0.05	84,000,000	15,000	12,000,000	1,800,000,000
mean	34,000,000	3,500	4,500,000	740,000,000
Probability of mean	0.41	0.28	0.39	0.44
Probability of zero	0.03	0.08	0.04	0.03

The tract ID is EC06

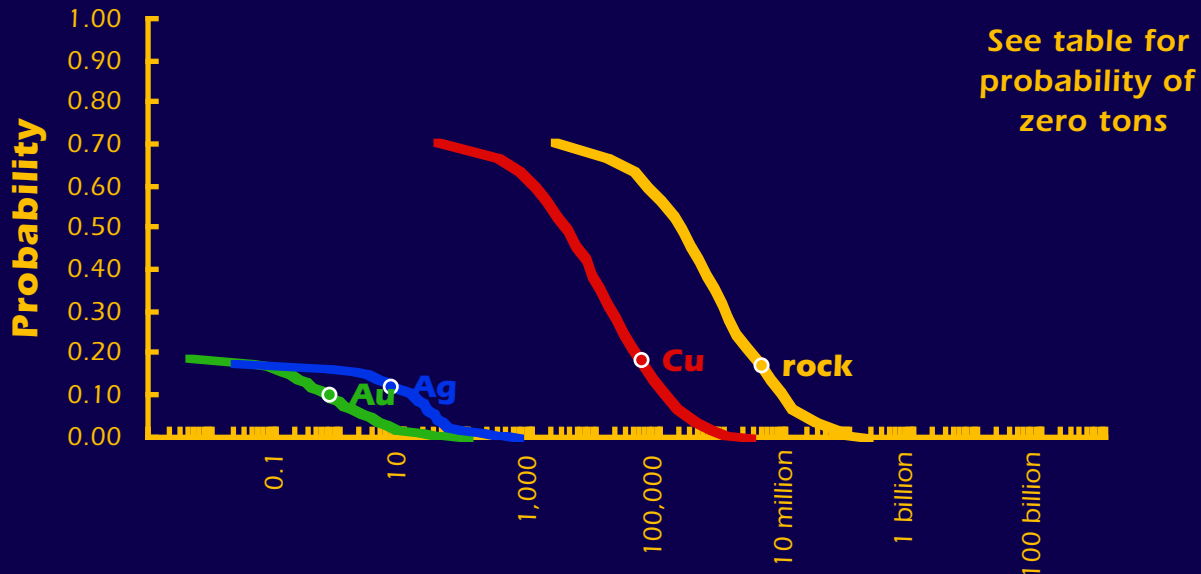
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

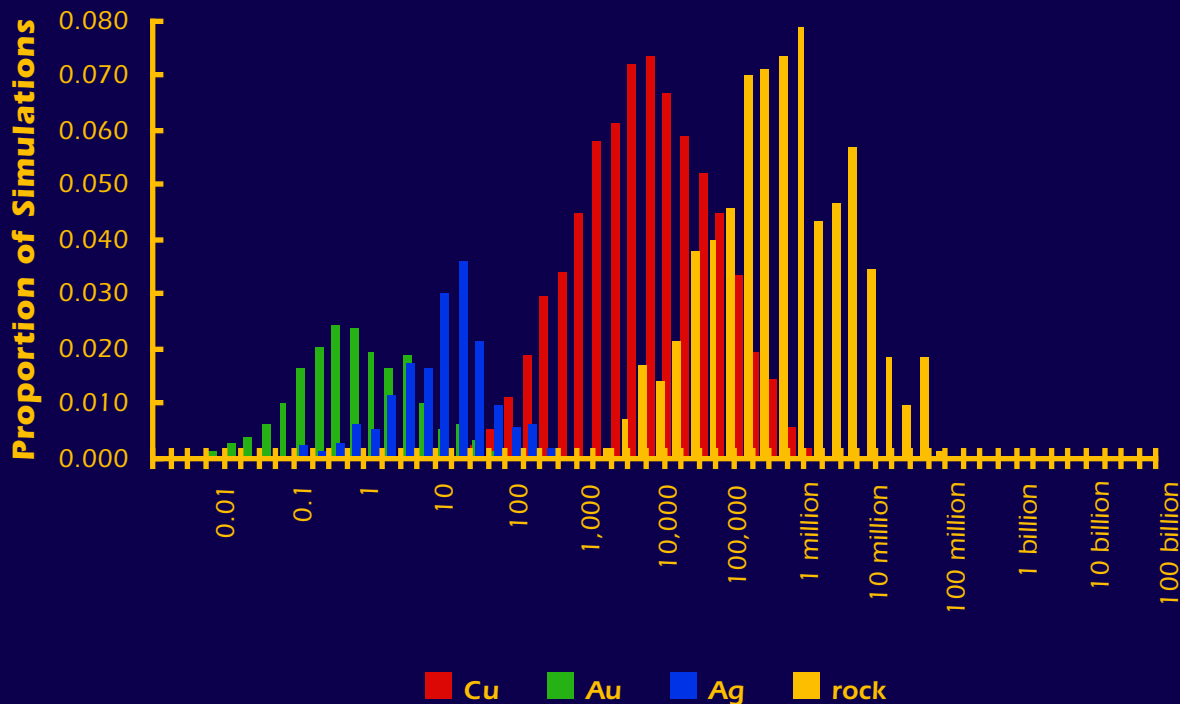


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GB01

The Mark3 Index is 8:

Skarn Cu

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	3,300	0	0	220,000
0.10	120,000	1	13	8,500,000
0.05	260,000	3	28	17,000,000
mean	53,000	1	6	3,900,000
Probability of mean	0.18	0.10	0.12	0.17
Probability of zero	0.29	0.81	0.83	0.29

The tract ID is GB01The Mark3 Index is 8: **Skarn Cu**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

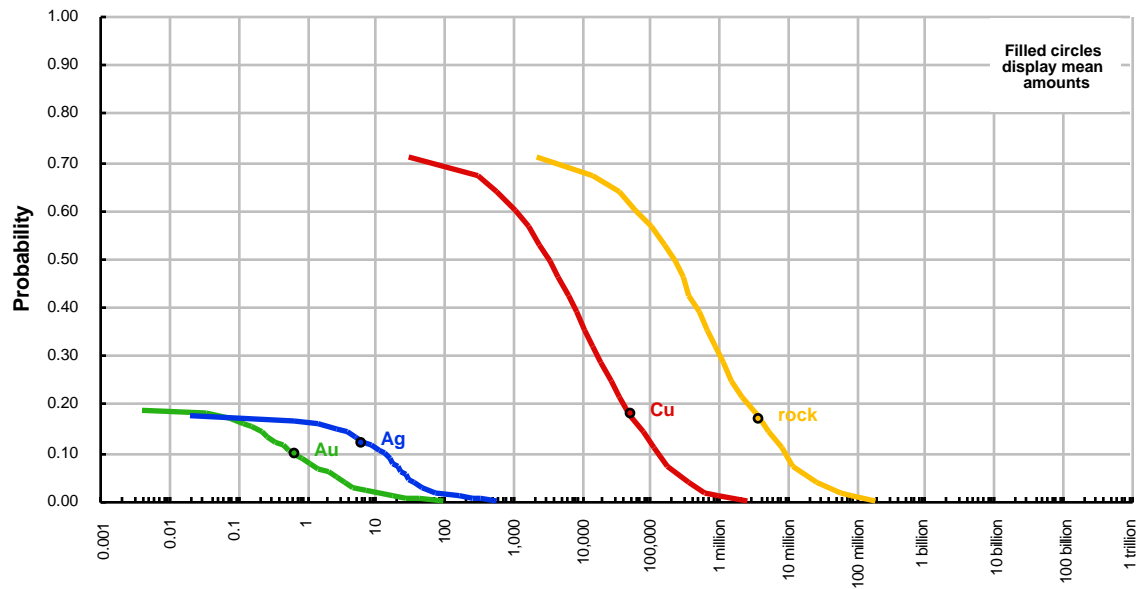
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

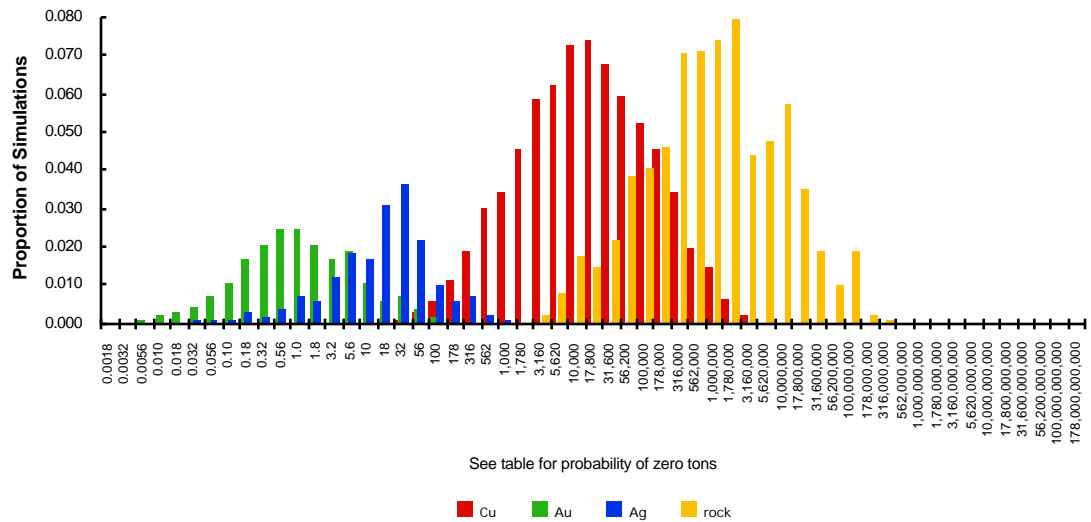
quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	3,300	0	0	220,000
0.10	120,000	1	13	8,500,000
0.05	260,000	3	28	17,000,000
mean	53,000	1	6	3,900,000
Probability of mean	0.18	0.10	0.12	0.17
Probability of zero	0.29	0.81	0.83	0.29

The tract ID is GB01

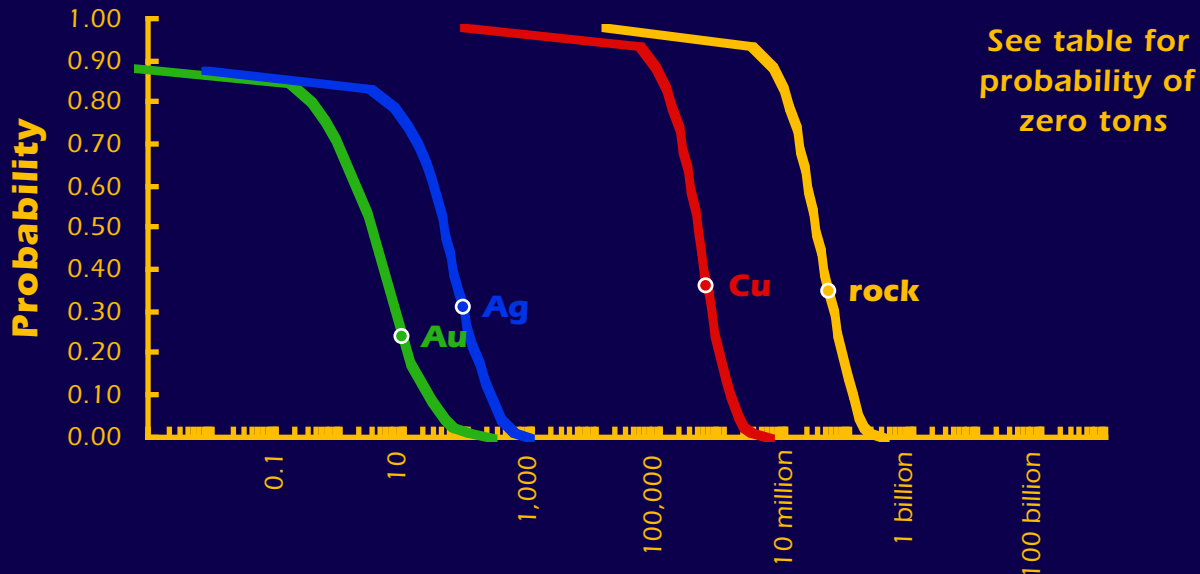
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

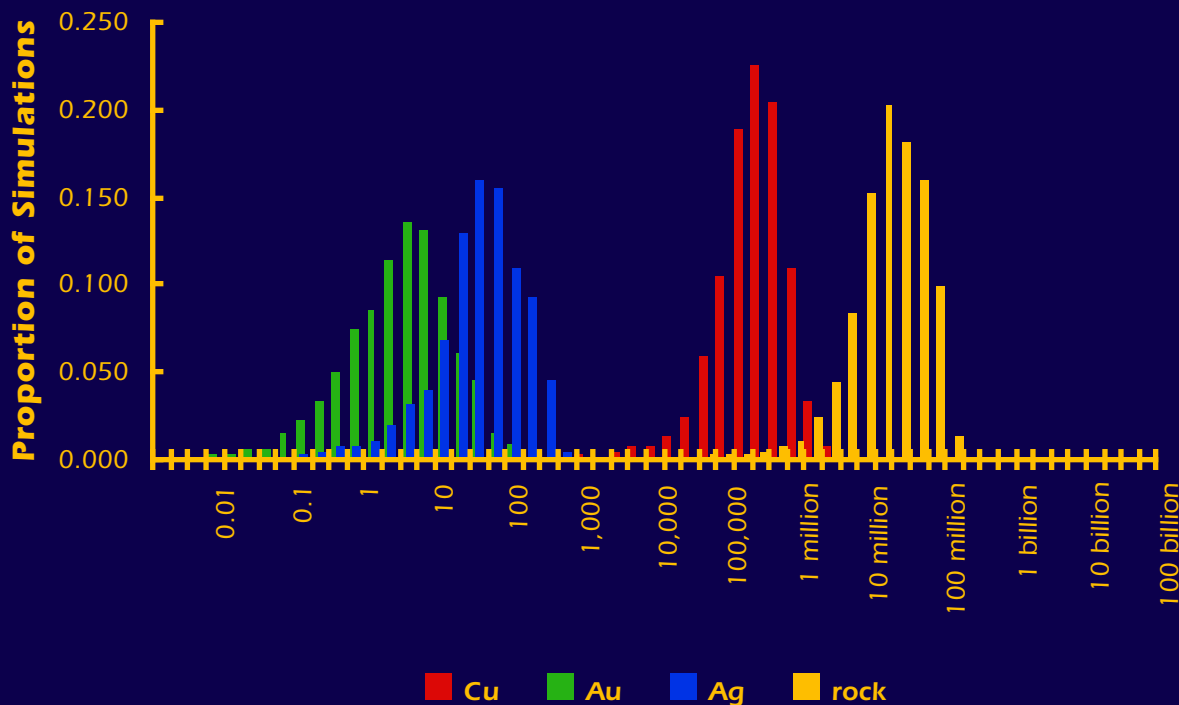


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GB02

The Mark3 Index is 8:

Skarn Cu

There is a 90% or greater chance of 6 or more deposits.
There is a 50% or greater chance of 10 or more deposits.
There is a 10% or greater chance of 14 or more deposits.
There is a 5% or greater chance of 16 or more deposits.
There is a 1% or greater chance of 18 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Ag	rock
0.95	33,000	0	0	1,900,000
0.90	77,000	0	0	4,900,000
0.50	390,000	3	41	28,000,000
0.10	1,200,000	23	223	100,000,000
0.05	1,600,000	38	310	130,000,000
mean	550,000	9	81	43,000,000
Probability of mean	0.36	0.24	0.31	0.35
Probability of zero	0.02	0.11	0.12	0.02

The tract ID is GB02The Mark3 Index is 8: **Skarn Cu**

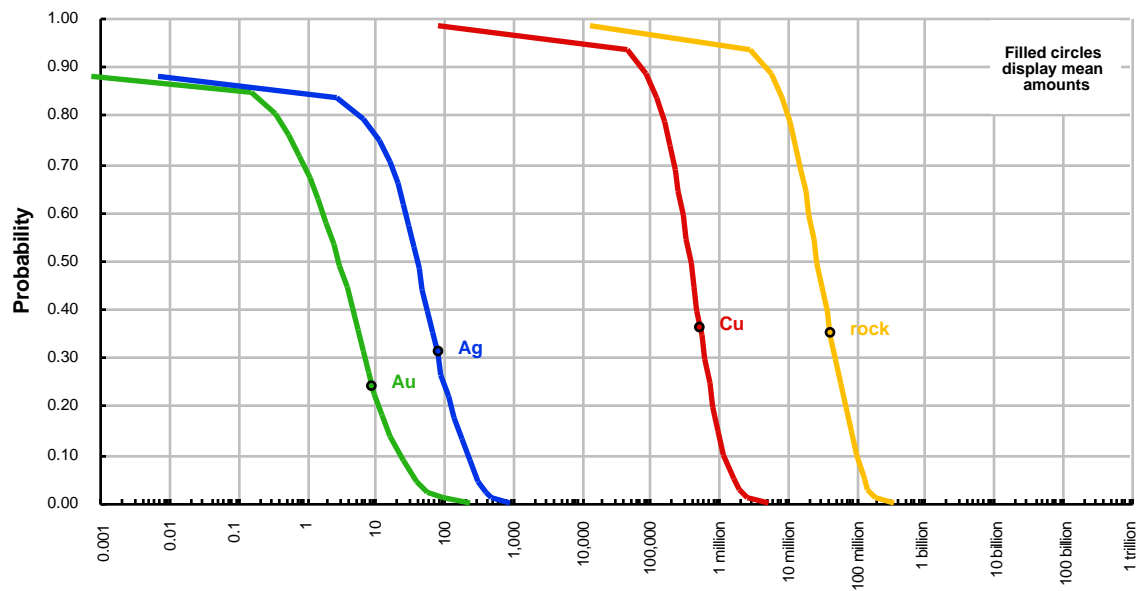
There is a 90% or greater chance of 6 or more deposits.
 There is a 50% or greater chance of 10 or more deposits.
 There is a 10% or greater chance of 14 or more deposits.
 There is a 5% or greater chance of 16 or more deposits.
 There is a 1% or greater chance of 18 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

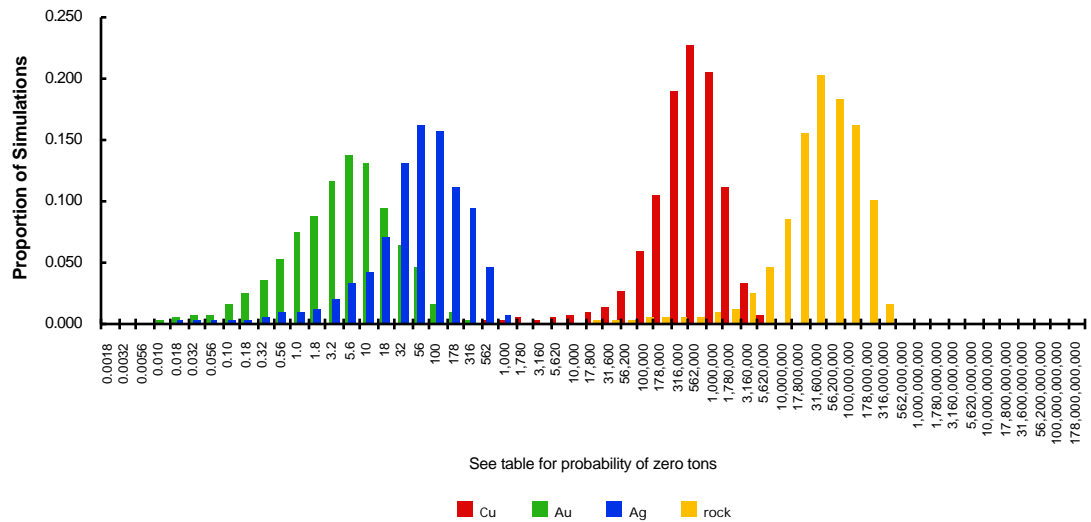
quantile	Cu	Au	Ag	rock
0.95	33,000	0	0	1,900,000
0.90	77,000	0	0	4,900,000
0.50	390,000	3	41	28,000,000
0.10	1,200,000	23	223	100,000,000
0.05	1,600,000	38	310	130,000,000
mean	550,000	9	81	43,000,000
Probability of mean	0.36	0.24	0.31	0.35
Probability of zero	0.02	0.11	0.12	0.02

The tract ID is GB02

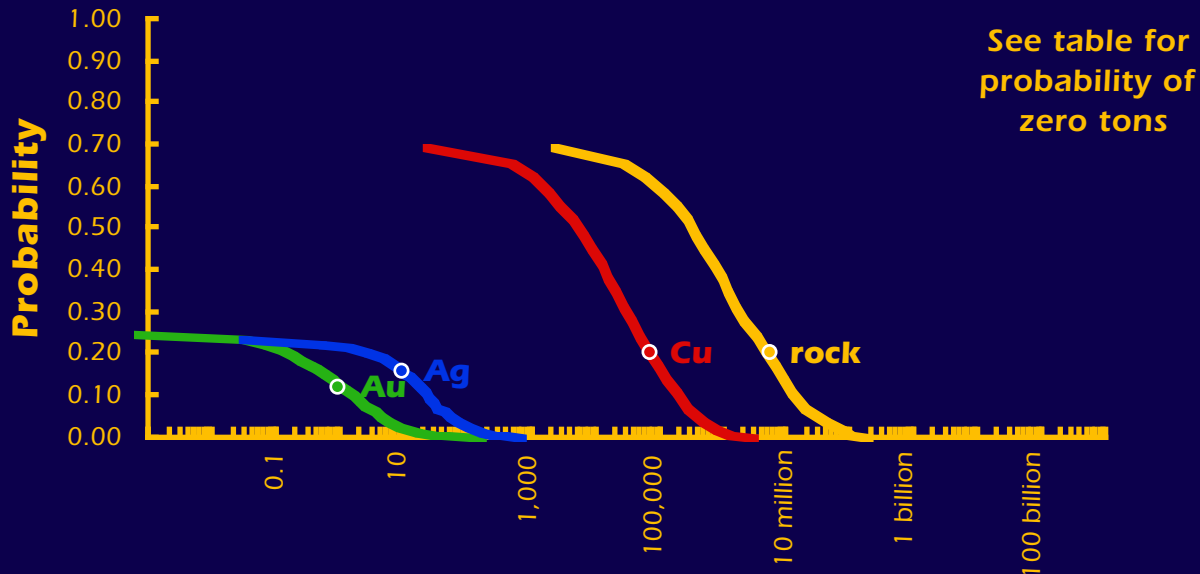
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

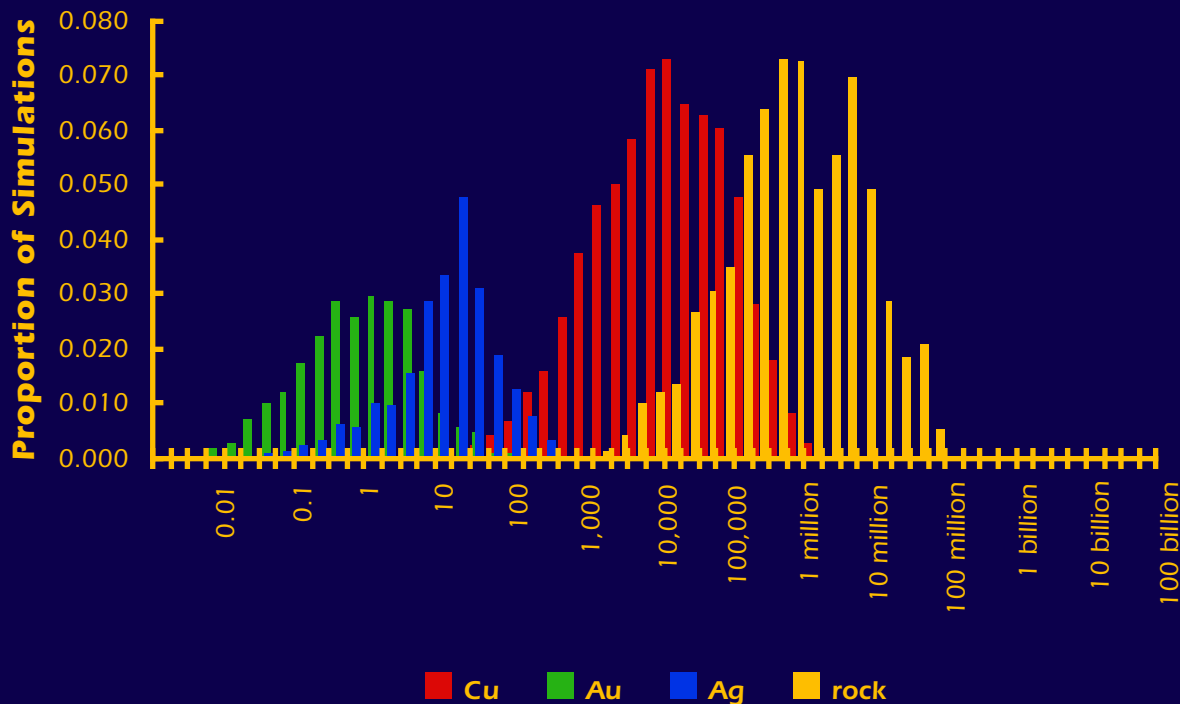


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GB03

The Mark3 Index is 8:

Skarn Cu

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

There is a 1% or greater chance of 6 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	5,300	0	0	330,000
0.10	190,000	2	23	13,000,000
0.05	360,000	4	47	28,000,000
mean	71,000	1	9	5,400,000
Probability of mean	0.20	0.12	0.16	0.20
Probability of zero	0.31	0.75	0.76	0.31

The tract ID is GB03The Mark3 Index is 8: **Skarn Cu**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

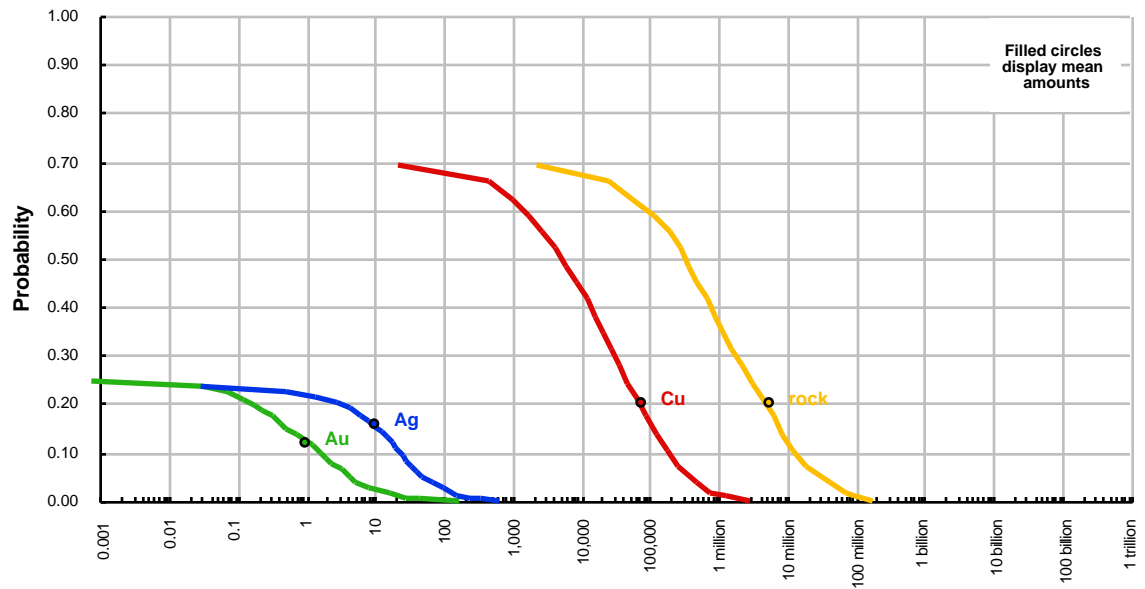
There is a 1% or greater chance of 6 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

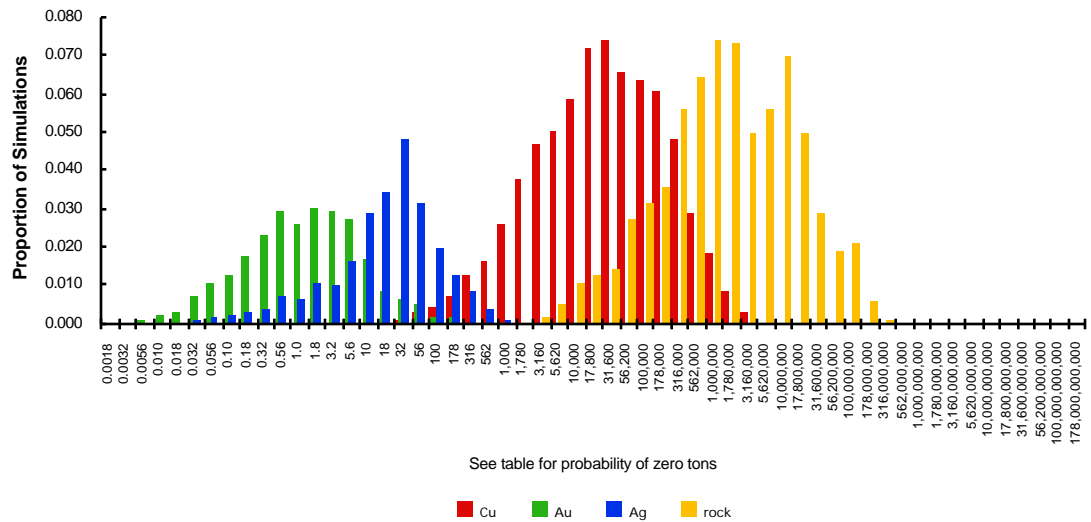
quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	5,300	0	0	330,000
0.10	190,000	2	23	13,000,000
0.05	360,000	4	47	28,000,000
mean	71,000	1	9	5,400,000
Probability of mean	0.20	0.12	0.16	0.20
Probability of zero	0.31	0.75	0.76	0.31

The tract ID is GB03

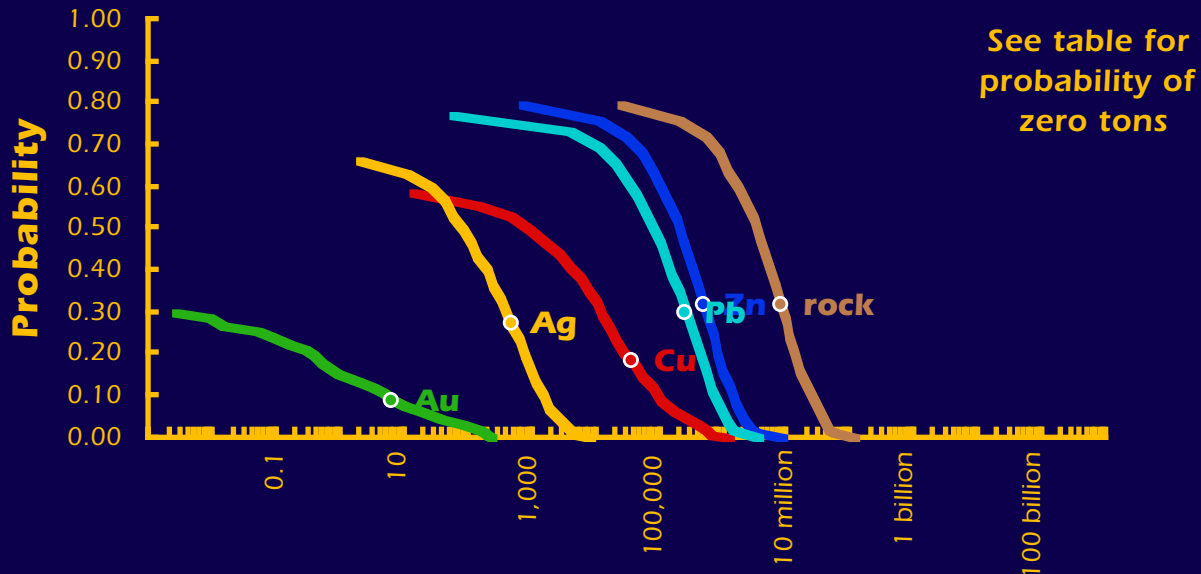
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

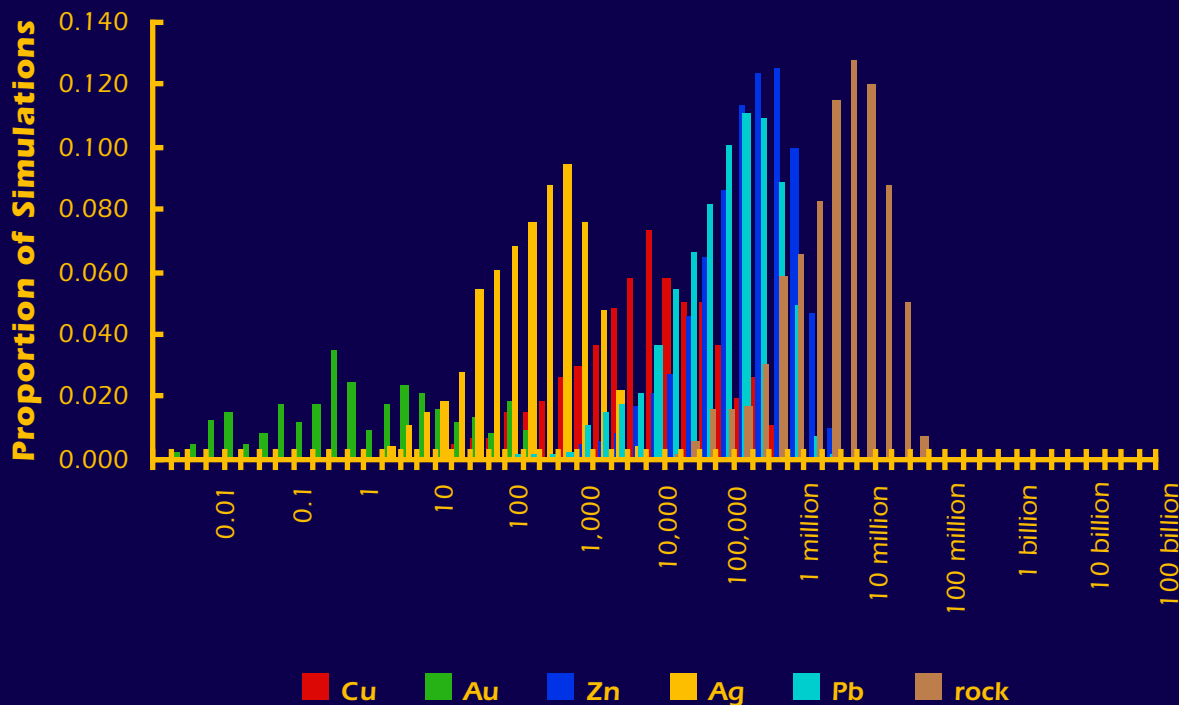


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GB04

The Mark3 Index is 22:

Skarn Zn-Pb

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

There is a 1% or greater chance of 7 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	880	0	200,000	81	78,000	3,300,000
0.10	93,000	5	1,340,000	1,500	730,000	24,000,000
0.05	210,000	29	1,900,000	2,300	1,100,000	34,000,000
mean	37,000	6	470,000	470	250,000	8,100,000
Probability of mean	0.18	0.09	0.32	0.27	0.30	0.32
Probability of zero	0.42	0.70	0.20	0.34	0.23	0.20

The tract ID is GB04The Mark3 Index is 22: **Skarn Zn-Pb**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

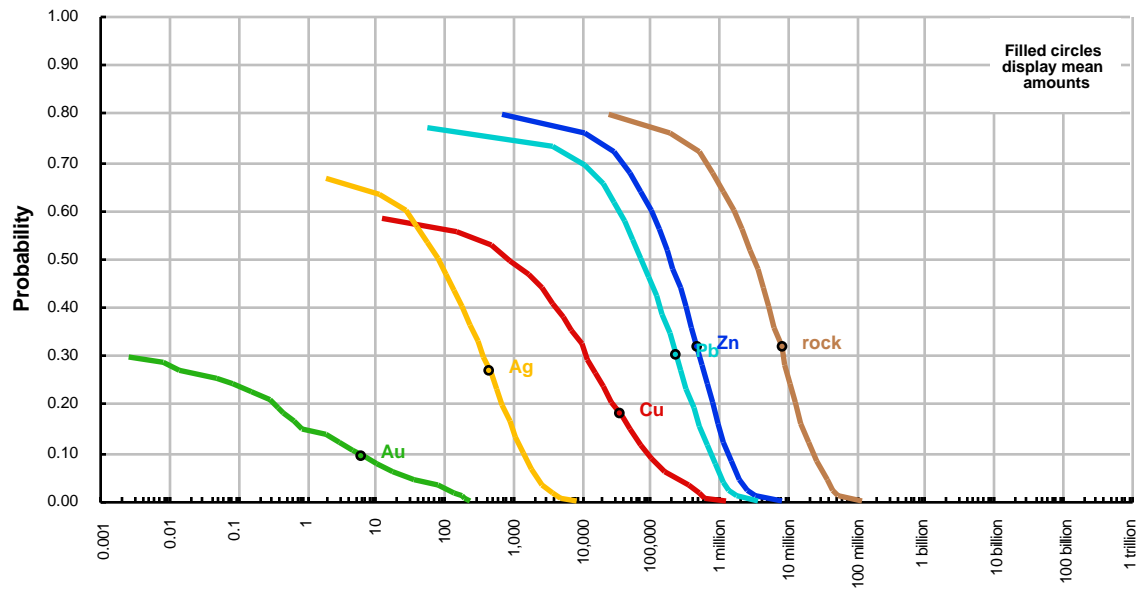
There is a 1% or greater chance of 7 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

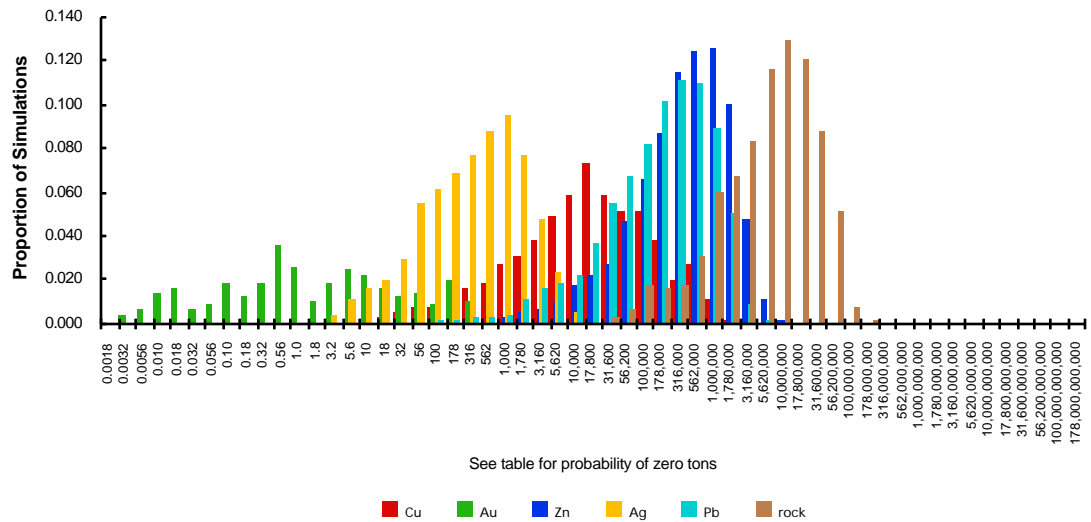
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	880	0	200,000	81	78,000	3,300,000
0.10	93,000	5	1,340,000	1,500	730,000	24,000,000
0.05	210,000	29	1,900,000	2,300	1,100,000	34,000,000
mean	37,000	6	470,000	470	250,000	8,100,000
Probability of mean	0.18	0.09	0.32	0.27	0.30	0.32
Probability of zero	0.42	0.70	0.20	0.34	0.23	0.20

The tract ID is GB04

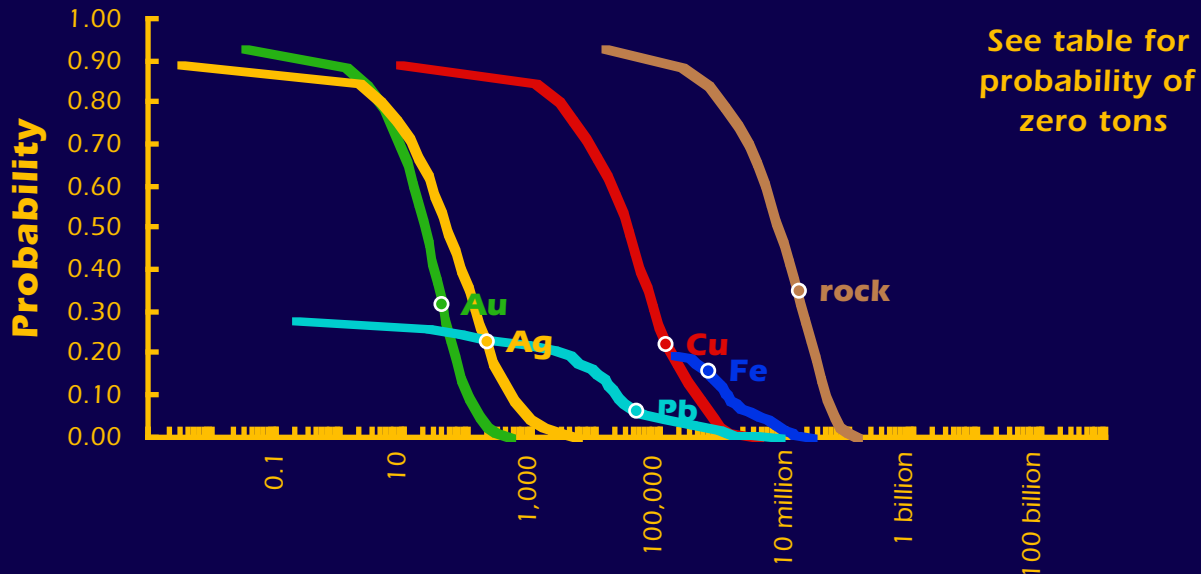
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

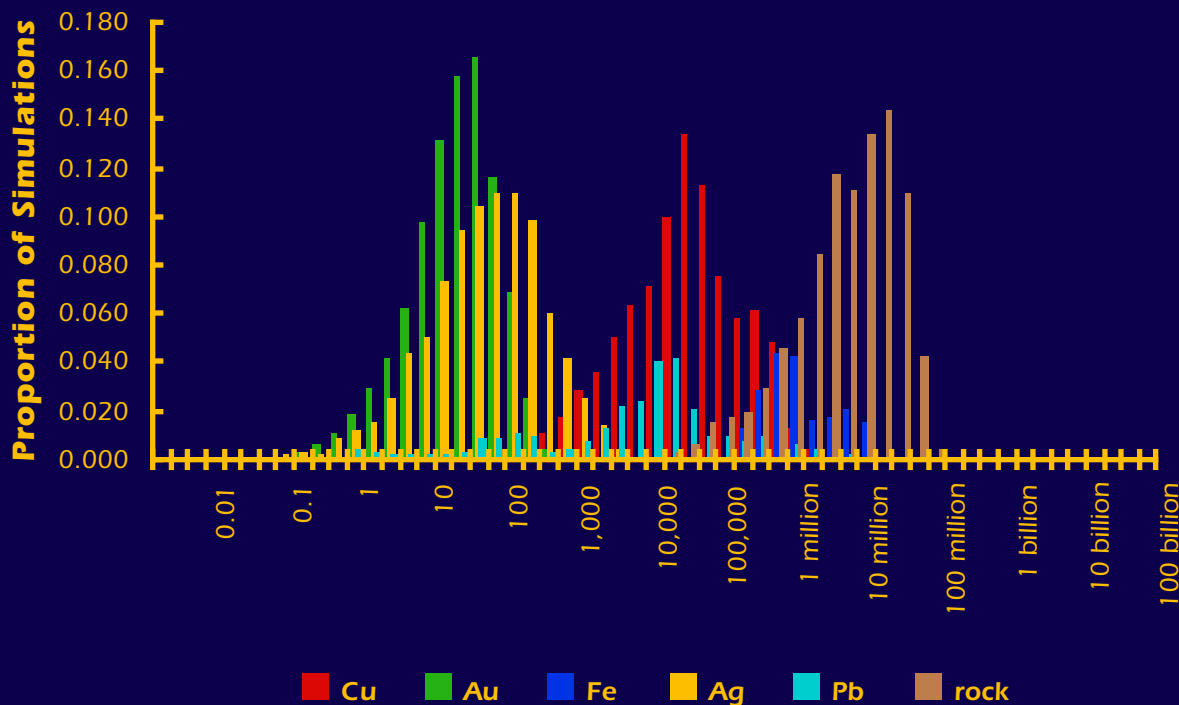


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GB05

The Mark3 Index is 105:

Skarn Au, truncated

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 8 or more deposits.

There is a 1% or greater chance of 12 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Fe	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	1	0	0	0	140,000
0.50	32,000	21	0	46	0	7,100,000
0.10	400,000	100	1,150,000	480	21,000	41,000,000
0.05	650,000	140	3,600,000	880	66,000	54,000,000
mean	130,000	39	570,000	190	43,000	15,000,000
Probability of mean	0.22	0.32	0.16	0.23	0.06	0.35
Probability of zero	0.11	0.07	0.80	0.11	0.72	0.07

The tract ID is GB05The Mark3 Index is 105: **Skarn Au, truncated**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 8 or more deposits.

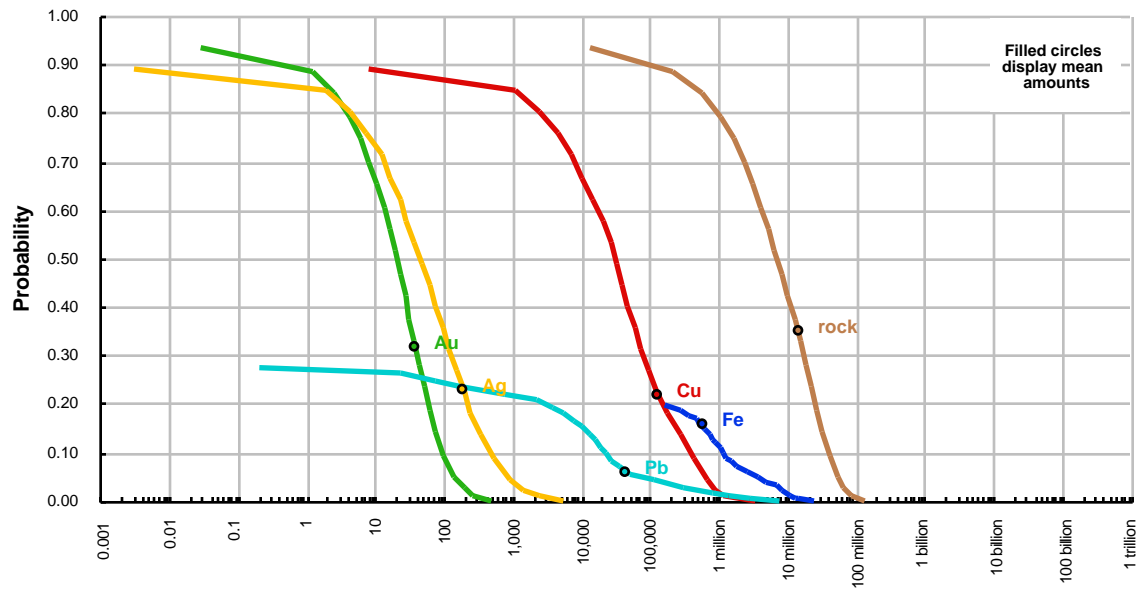
There is a 1% or greater chance of 12 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

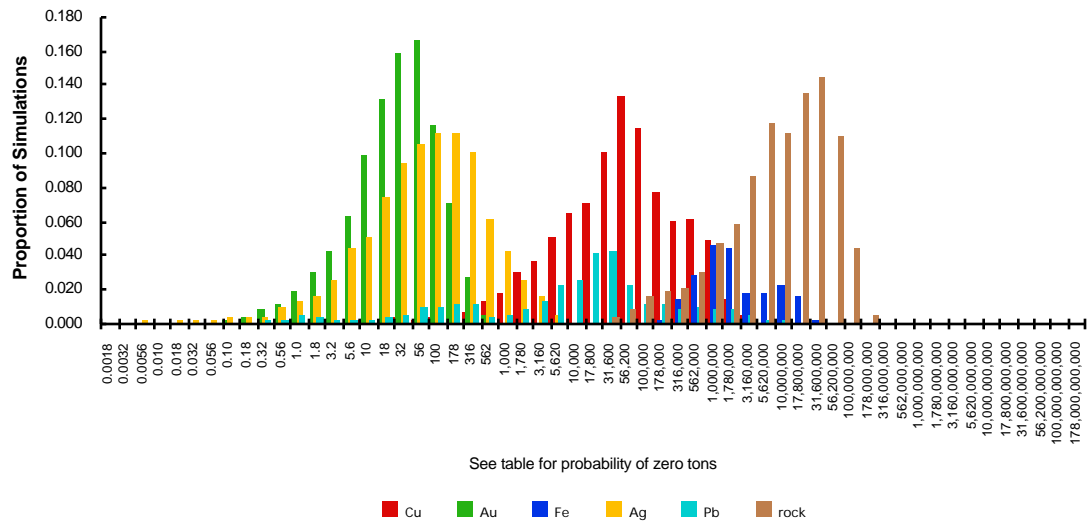
quantile	Cu	Au	Fe	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	1	0	0	0	140,000
0.50	32,000	21	0	46	0	7,100,000
0.10	400,000	100	1,150,000	480	21,000	41,000,000
0.05	650,000	140	3,600,000	880	66,000	54,000,000
mean	130,000	39	570,000	190	43,000	15,000,000
Probability of mean	0.22	0.32	0.16	0.23	0.06	0.35
Probability of zero	0.11	0.07	0.80	0.11	0.72	0.07

The tract ID is GB05

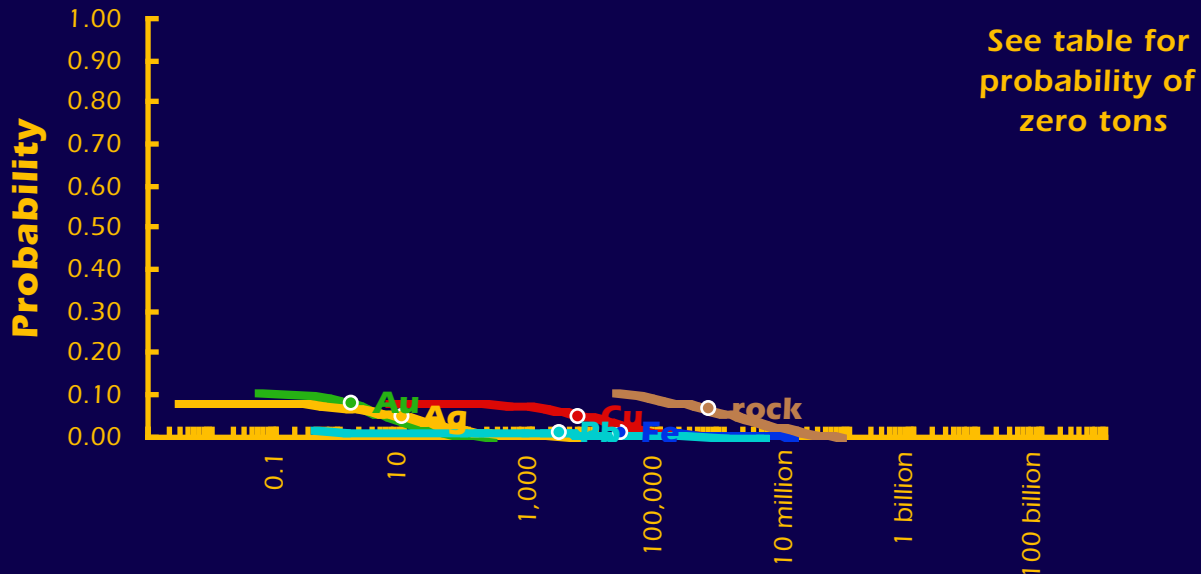
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

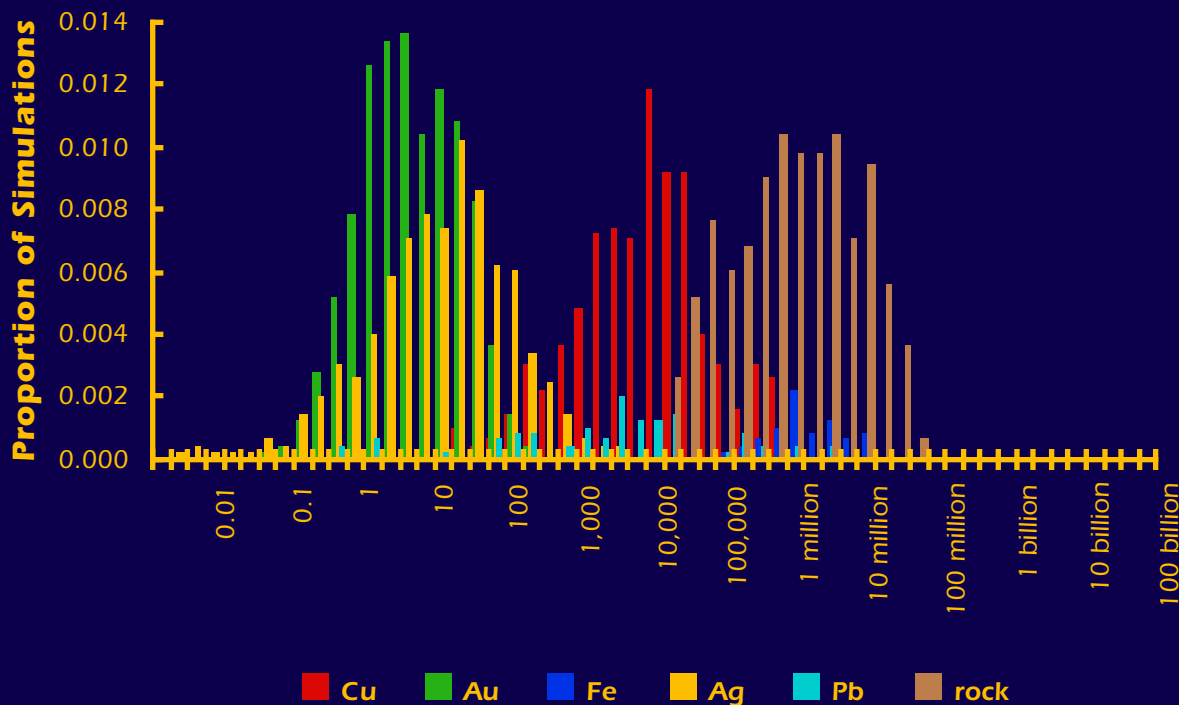


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GB06

The Mark3 Index is 105:

Skarn Au, truncated

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Fe	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	38,000
0.05	6,700	5	0	8	0	1,600,000
mean	5,400	2	25,000	9	2,700	600,000
Probability of mean	0.05	0.08	0.01	0.05	0.01	0.07
Probability of zero	0.92	0.90	0.99	0.92	0.99	0.90

The tract ID is GB06The Mark3 Index is 105: **Skarn Au, truncated**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

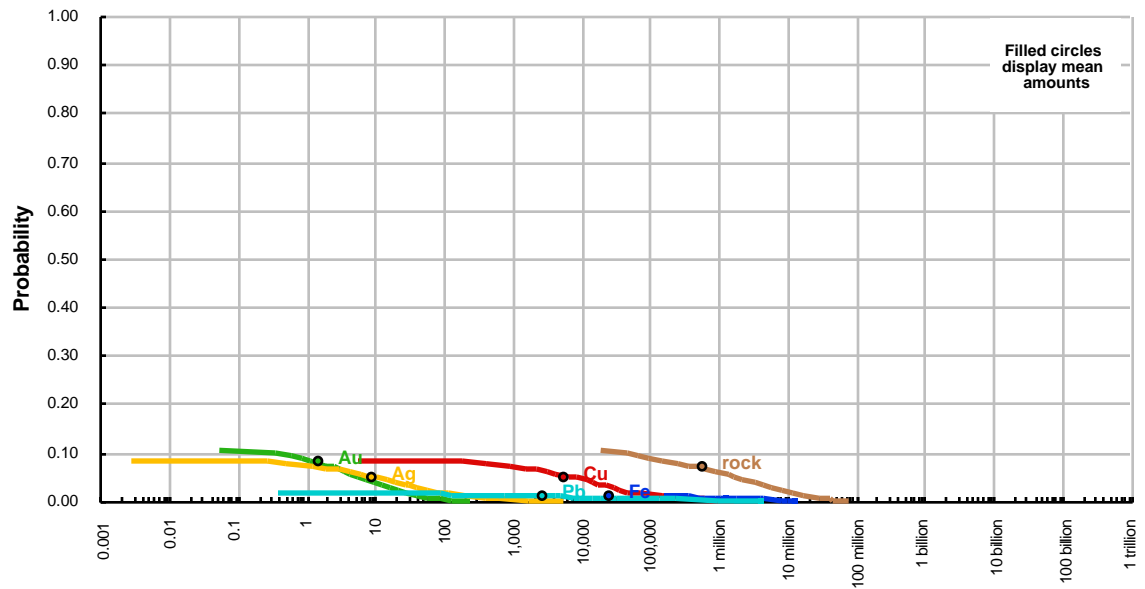
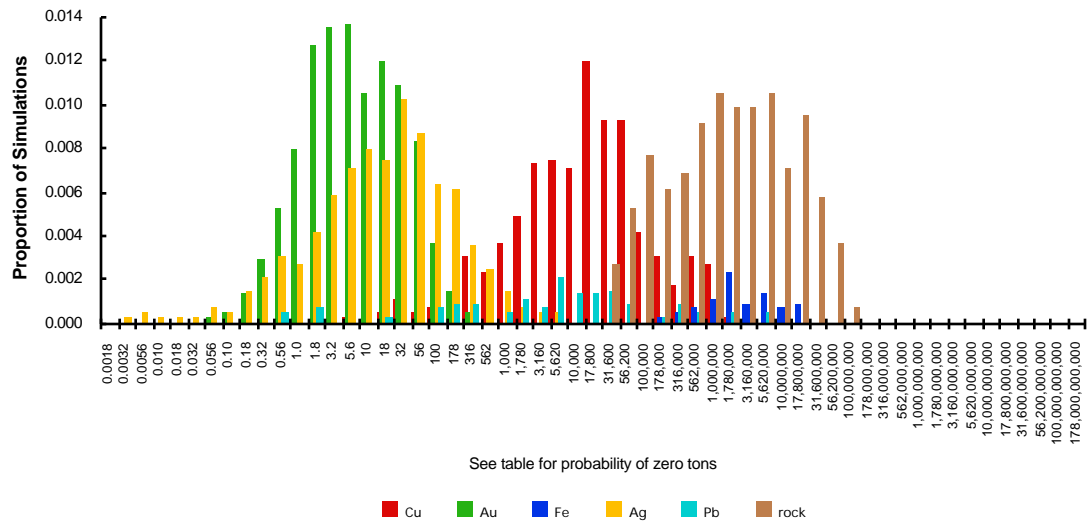
There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

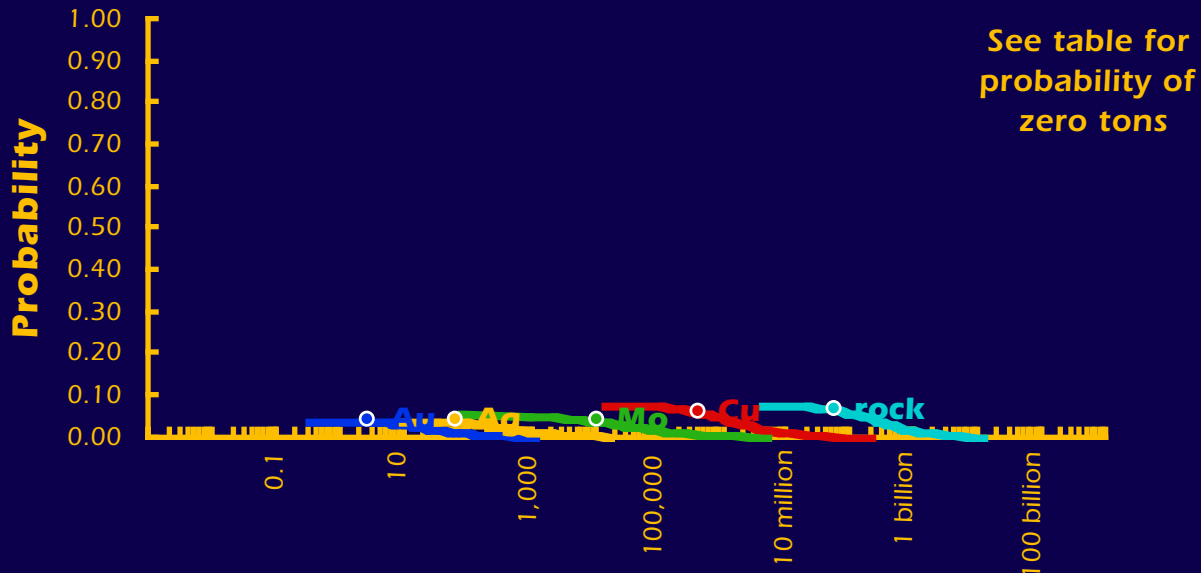
quantile	Cu	Au	Fe	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	38,000
0.05	6,700	5	0	8	0	1,600,000
mean	5,400	2	25,000	9	2,700	600,000
Probability of mean	0.05	0.08	0.01	0.05	0.01	0.07
Probability of zero	0.92	0.90	0.99	0.92	0.99	0.90

The tract ID is GB06

Cumulative Distributions of Contained Metal and Mineralized Rock

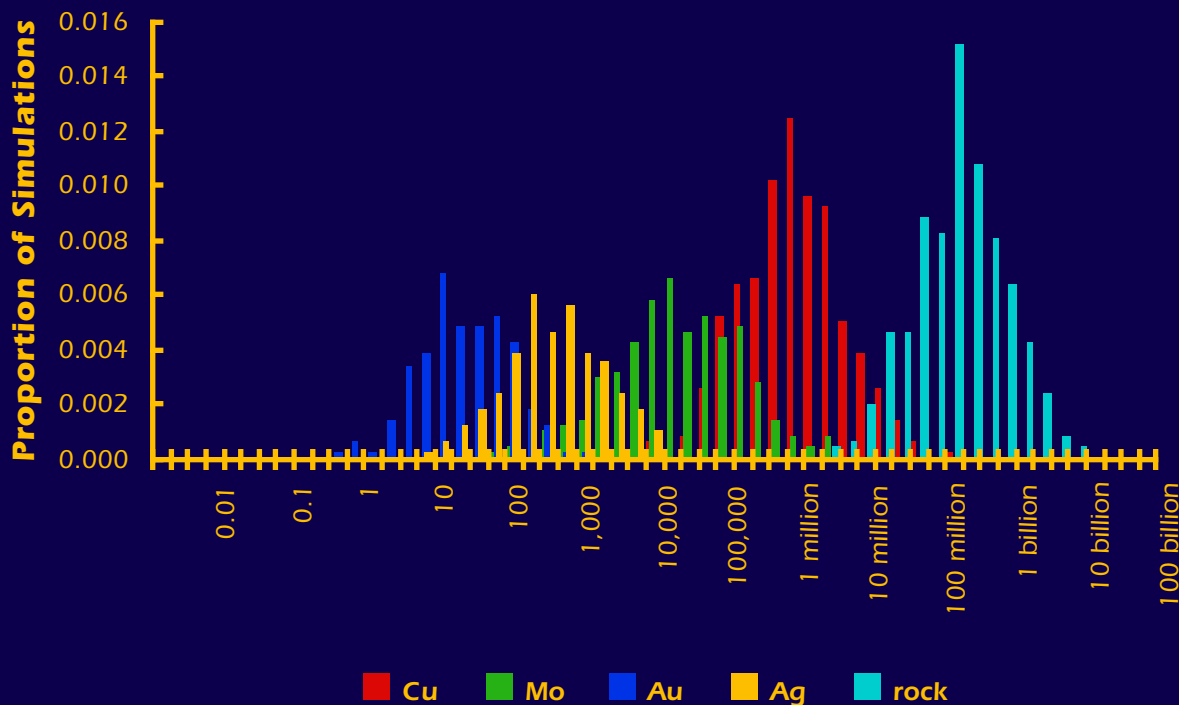
Histograms of Contained Metal and Mineralized Rock
(metric tons)

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GB07

The Mark3 Index is 4:

Porphry Cu

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	760,000	770	0	0	160,000,000
mean	380,000	9,900	3	59	55,000,000
Probability of mean	0.06	0.04	0.04	0.04	0.07
Probability of zero	0.92	0.95	0.96	0.96	0.92

The tract ID is GB07The Mark3 Index is 4: **Porphyry Cu**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

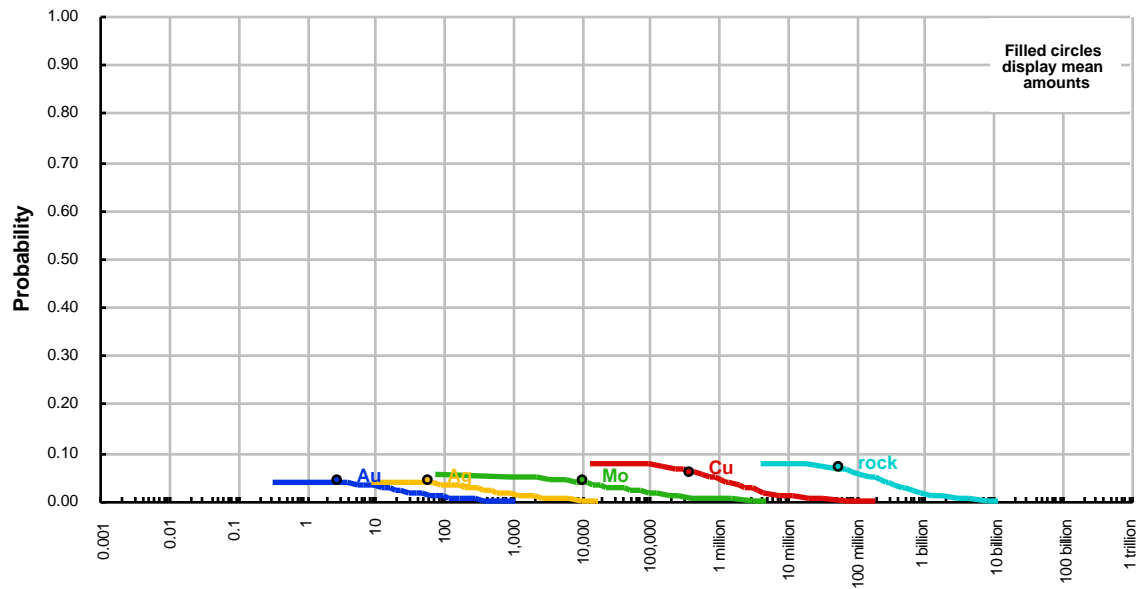
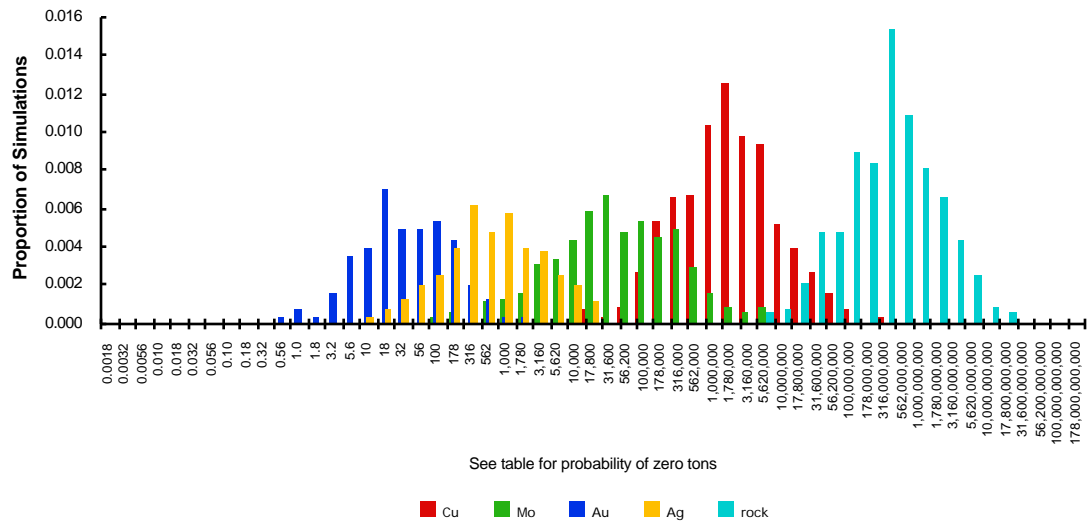
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

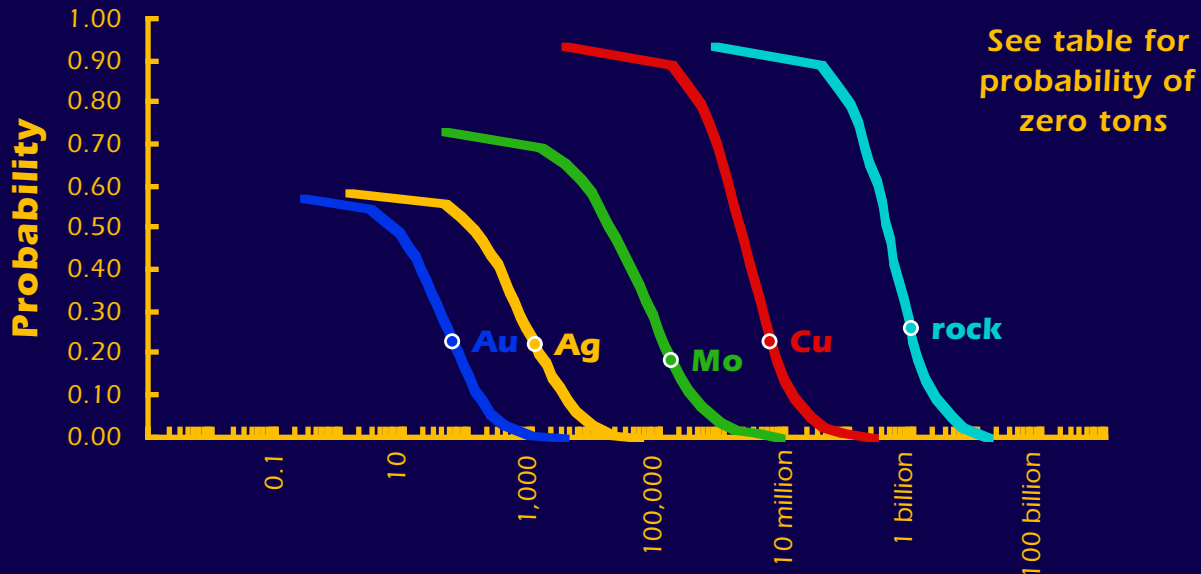
quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	760,000	770	0	0	160,000,000
mean	380,000	9,900	3	59	55,000,000
Probability of mean	0.06	0.04	0.04	0.04	0.07
Probability of zero	0.92	0.95	0.96	0.96	0.92

The tract ID is GB07

Cumulative Distributions of Contained Metal and Mineralized Rock

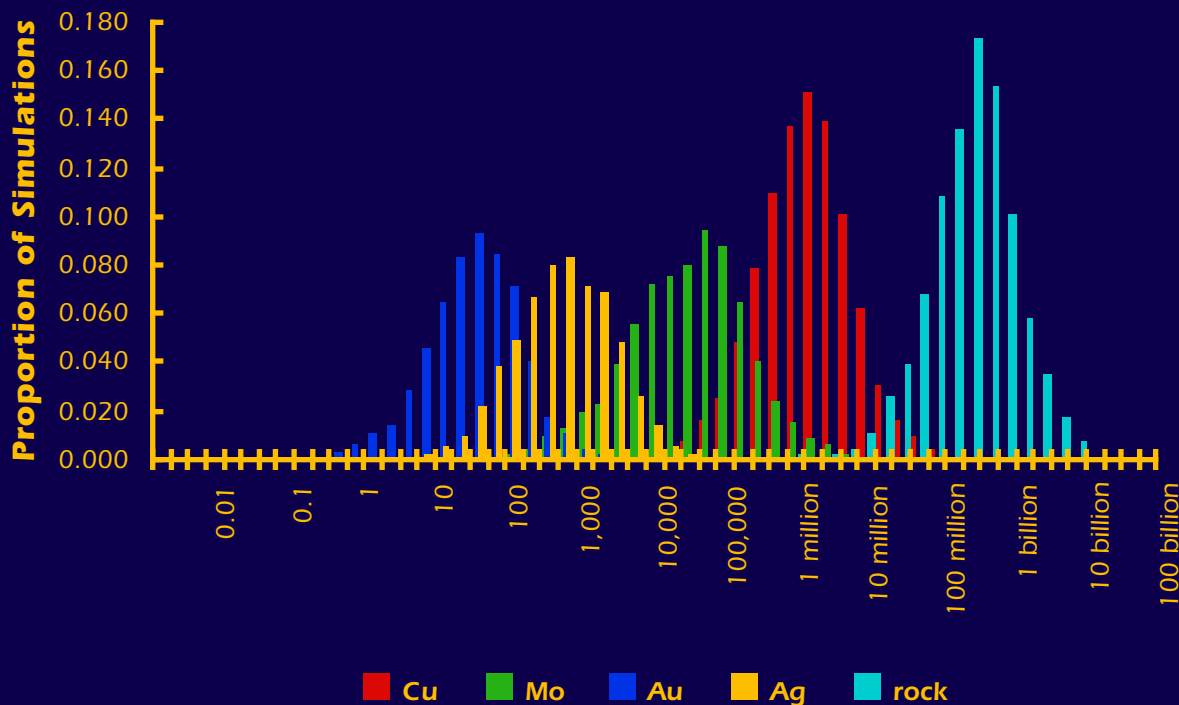
Histograms of Contained Metal and Mineralized Rock
(metric tons)

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GB08

The Mark3 Index is 4:

Porphyry Cu

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	120,000	0	0	0	27,000,000
0.50	1,900,000	17,000	7	120	360,000,000
0.10	12,000,000	300,000	139	3,000	2,000,000,000
0.05	22,000,000	640,000	230	5,300	3,500,000,000
mean	5,500,000	150,000	55	1,100	850,000,000
Probability of mean	0.23	0.18	0.23	0.22	0.26
Probability of zero	0.06	0.27	0.43	0.41	0.06

The tract ID is GB08The Mark3 Index is 4: **Porphyry Cu**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

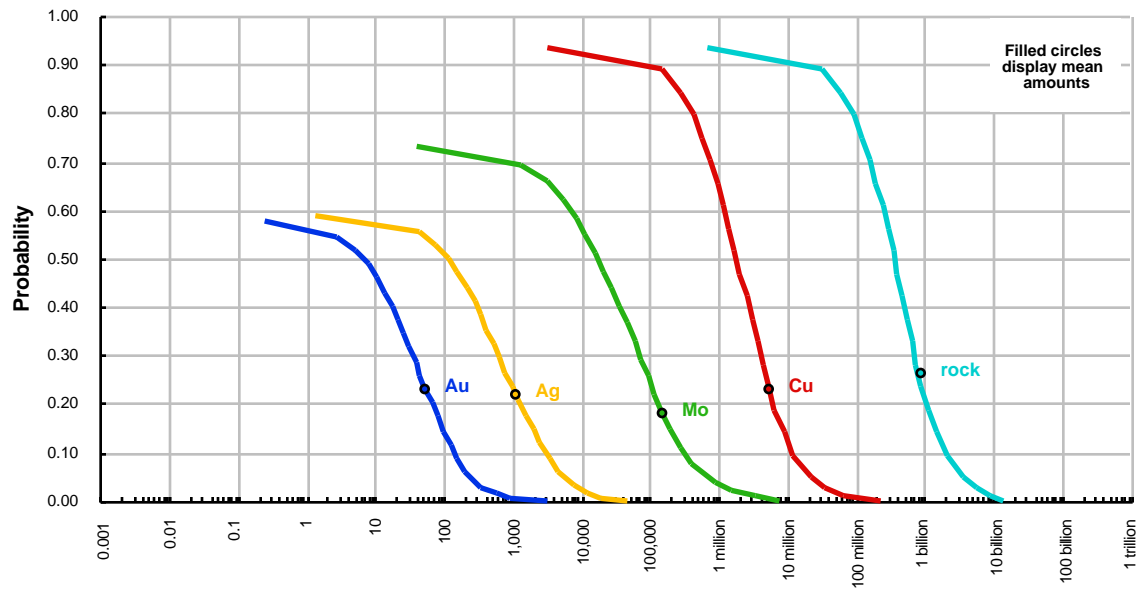
There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

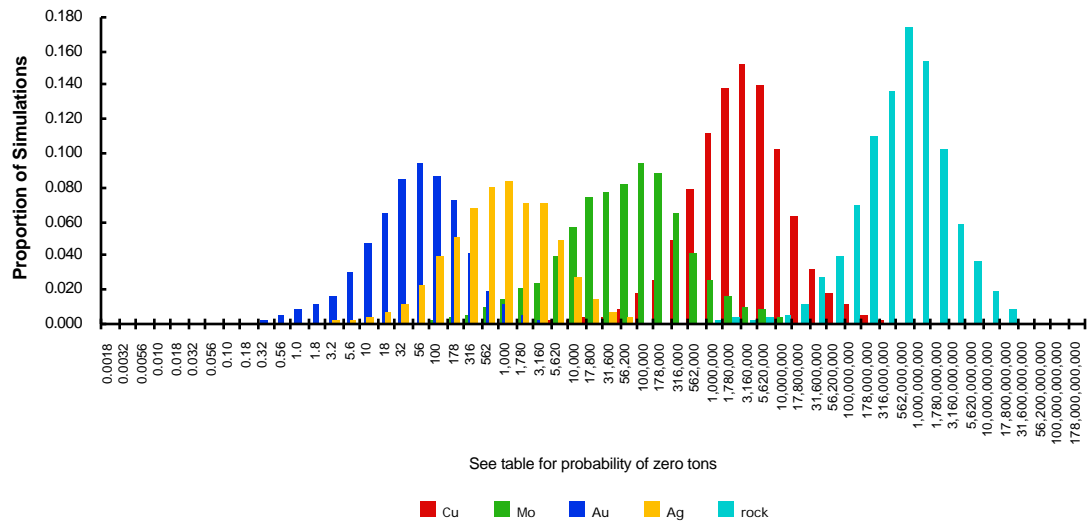
quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	120,000	0	0	0	27,000,000
0.50	1,900,000	17,000	7	120	360,000,000
0.10	12,000,000	300,000	139	3,000	2,000,000,000
0.05	22,000,000	640,000	230	5,300	3,500,000,000
mean	5,500,000	150,000	55	1,100	850,000,000
Probability of mean	0.23	0.18	0.23	0.22	0.26
Probability of zero	0.06	0.27	0.43	0.41	0.06

The tract ID is GB08

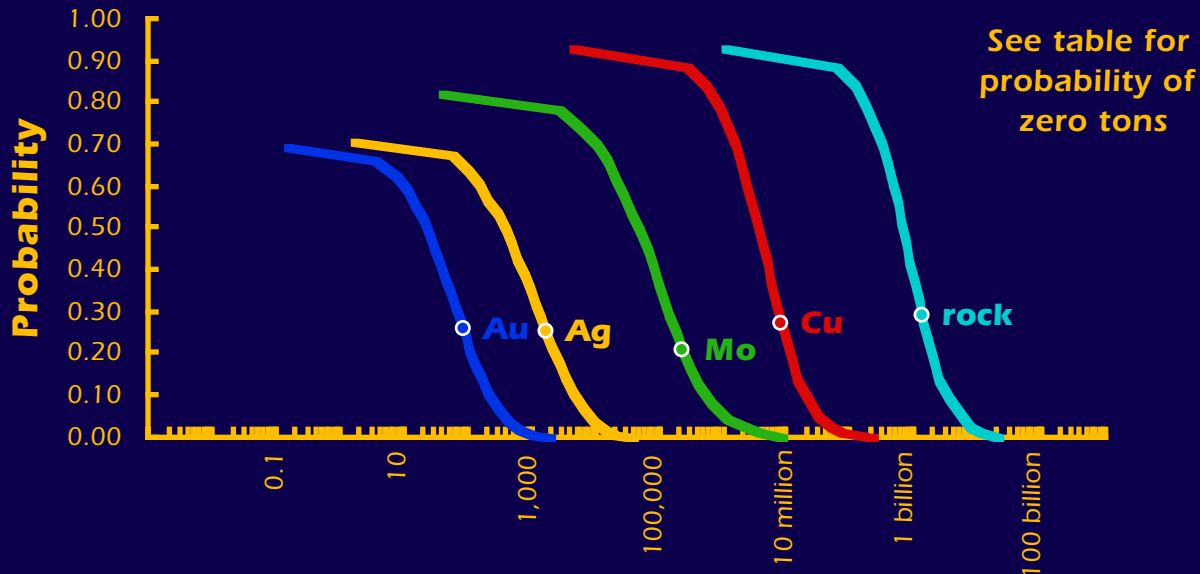
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

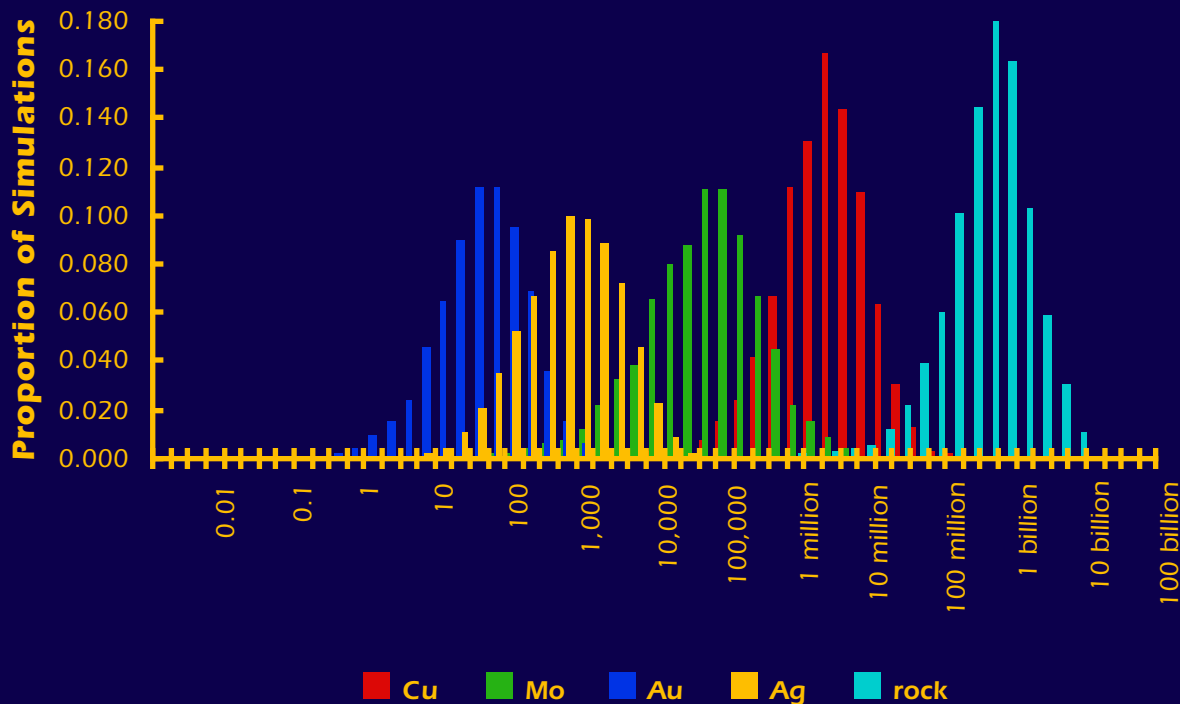


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GB09

The Mark3 Index is 4:

Porphyry Cu

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	180,000	0	0	0	43,000,000
0.50	3,500,000	47,000	23	370	640,000,000
0.10	19,000,000	510,000	212	4,700	3,200,000,000
0.05	30,000,000	980,000	340	7,800	5,100,000,000
mean	8,000,000	230,000	79	1,700	1,300,000,000
Probability of mean	0.27	0.21	0.26	0.25	0.29
Probability of zero	0.07	0.18	0.30	0.29	0.07

The tract ID is GB09The Mark3 Index is 4: **Porphyry Cu**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

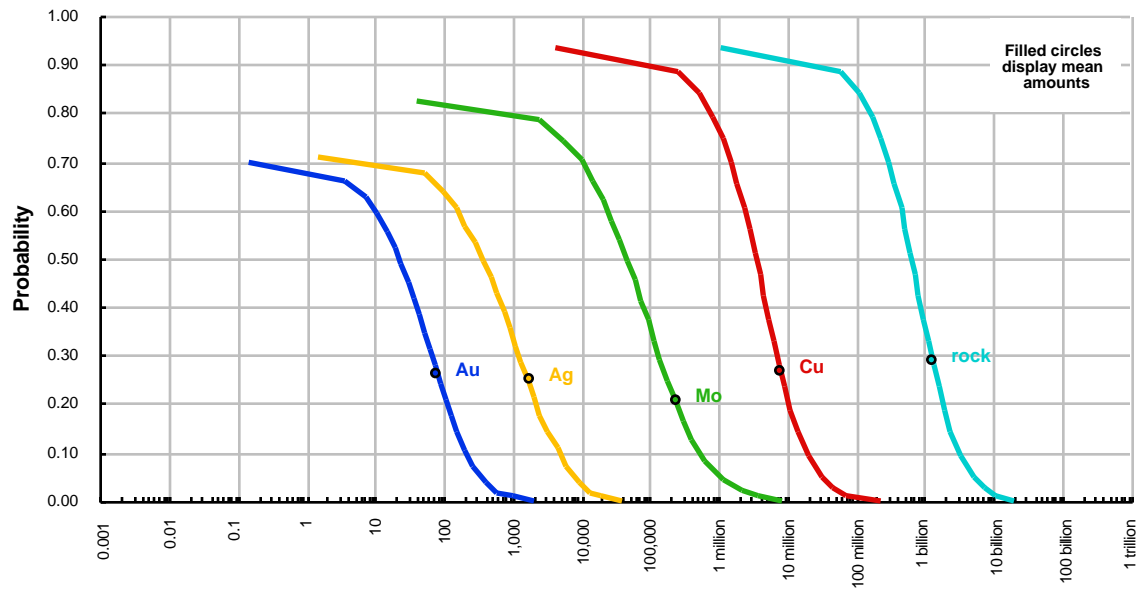
There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

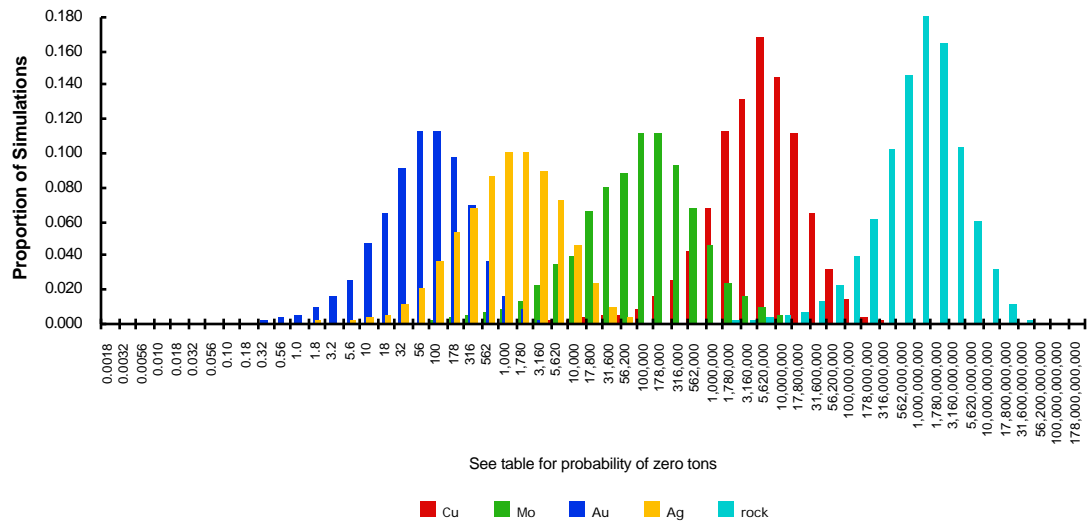
quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	180,000	0	0	0	43,000,000
0.50	3,500,000	47,000	23	370	640,000,000
0.10	19,000,000	510,000	212	4,700	3,200,000,000
0.05	30,000,000	980,000	340	7,800	5,100,000,000
mean	8,000,000	230,000	79	1,700	1,300,000,000
Probability of mean	0.27	0.21	0.26	0.25	0.29
Probability of zero	0.07	0.18	0.30	0.29	0.07

The tract ID is GB09

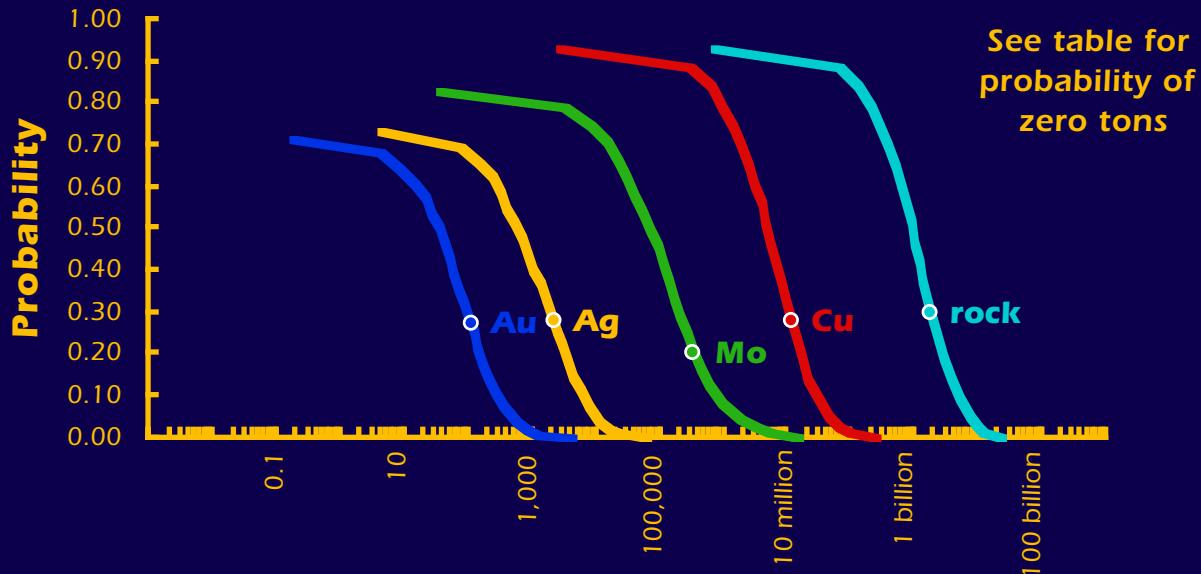
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

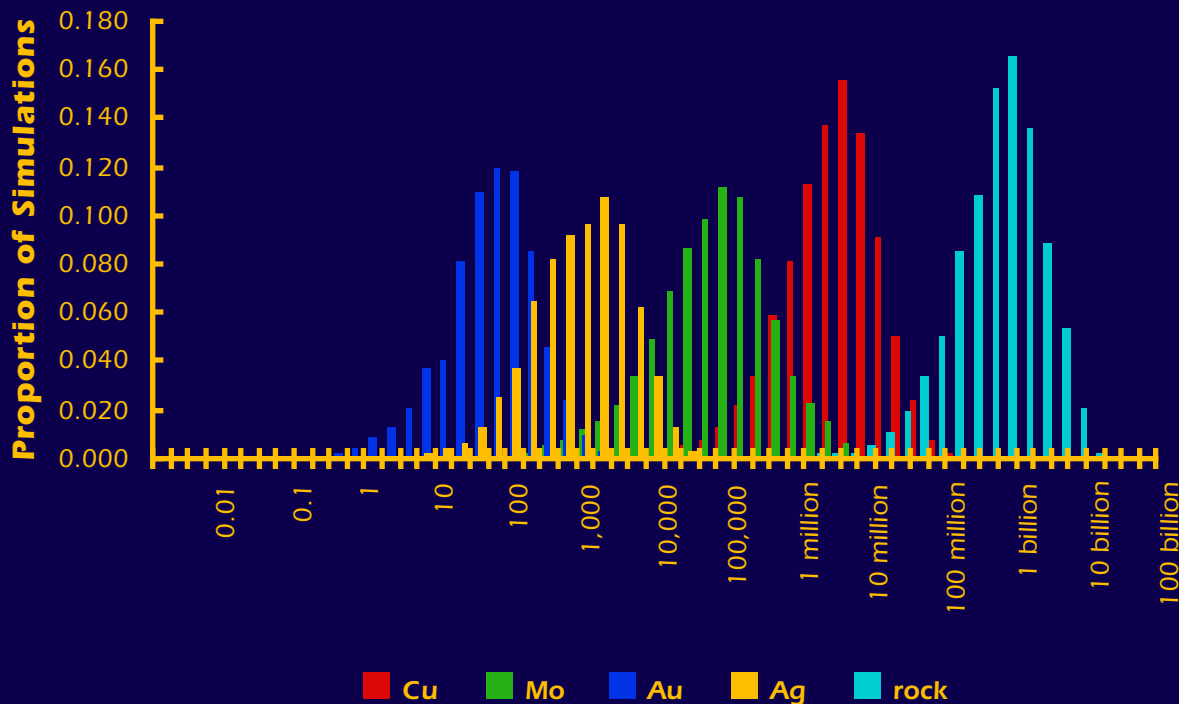


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GB10

The Mark3 Index is 4:

Porphyry Cu

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 9 or more deposits.

There is a 1% or greater chance of 12 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	210,000	0	0	0	49,000,000
0.50	4,900,000	69,000	34	570	890,000,000
0.10	28,000,000	760,000	273	6,200	4,600,000,000
0.05	43,000,000	1,600,000	460	9,800	6,900,000,000
mean	11,000,000	340,000	110	2,200	1,800,000,000
Probability of mean	0.28	0.20	0.27	0.28	0.30
Probability of zero	0.07	0.17	0.29	0.27	0.07

The tract ID is GB10The Mark3 Index is 4: **Porphyry Cu**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 9 or more deposits.

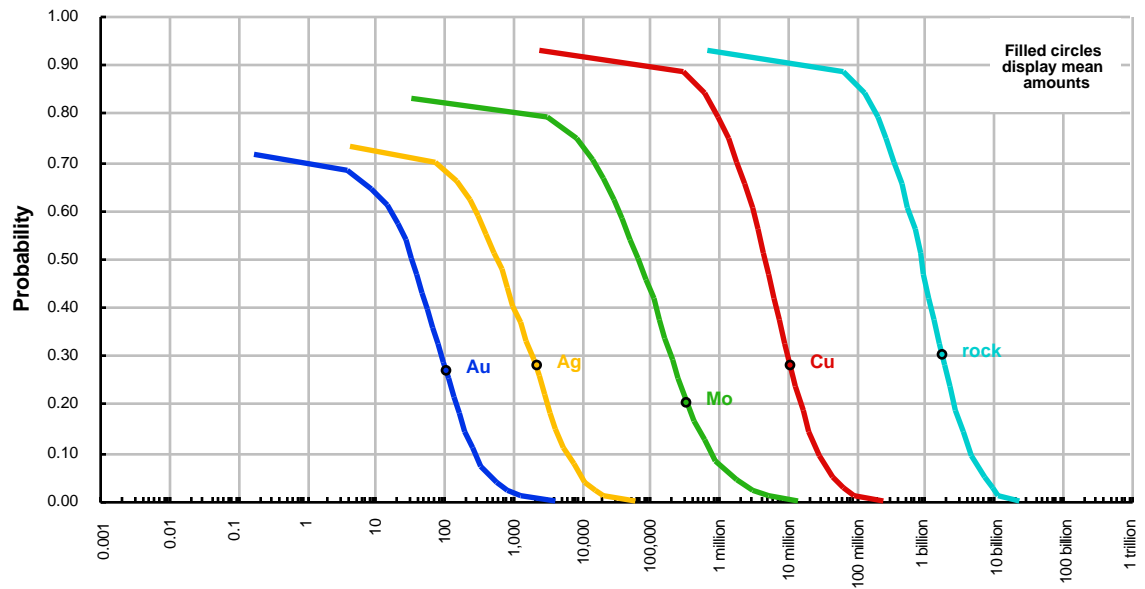
There is a 1% or greater chance of 12 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

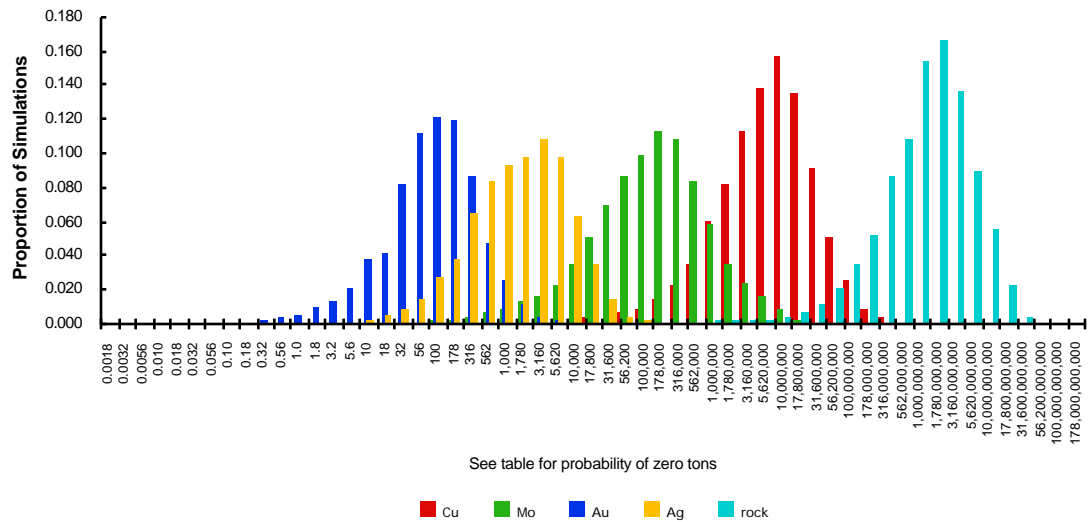
quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	210,000	0	0	0	49,000,000
0.50	4,900,000	69,000	34	570	890,000,000
0.10	28,000,000	760,000	273	6,200	4,600,000,000
0.05	43,000,000	1,600,000	460	9,800	6,900,000,000
mean	11,000,000	340,000	110	2,200	1,800,000,000
Probability of mean	0.28	0.20	0.27	0.28	0.30
Probability of zero	0.07	0.17	0.29	0.27	0.07

The tract ID is GB10

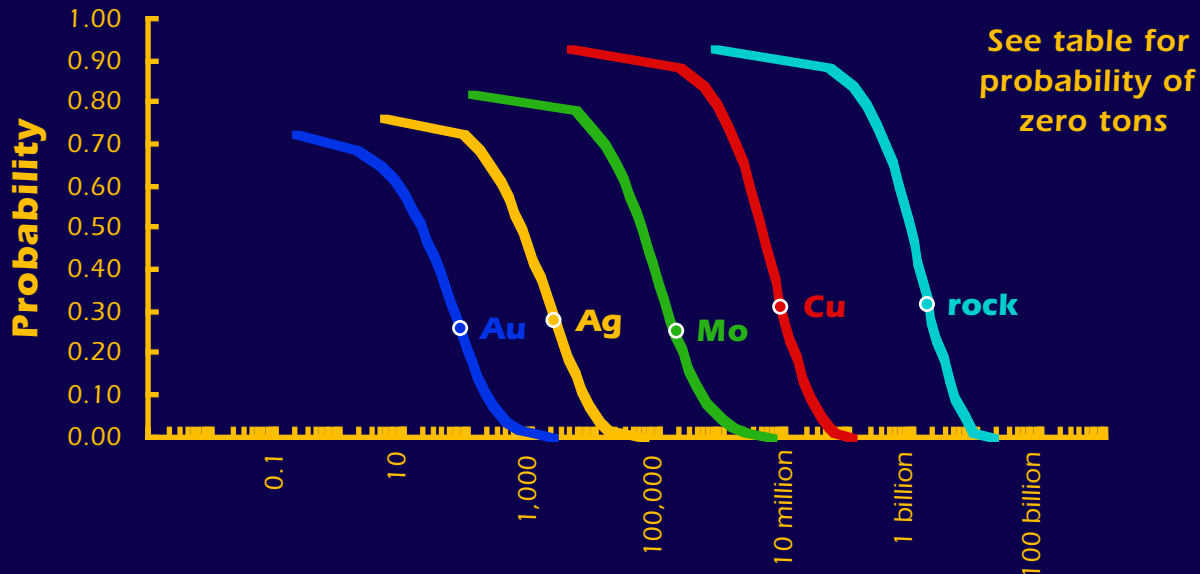
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

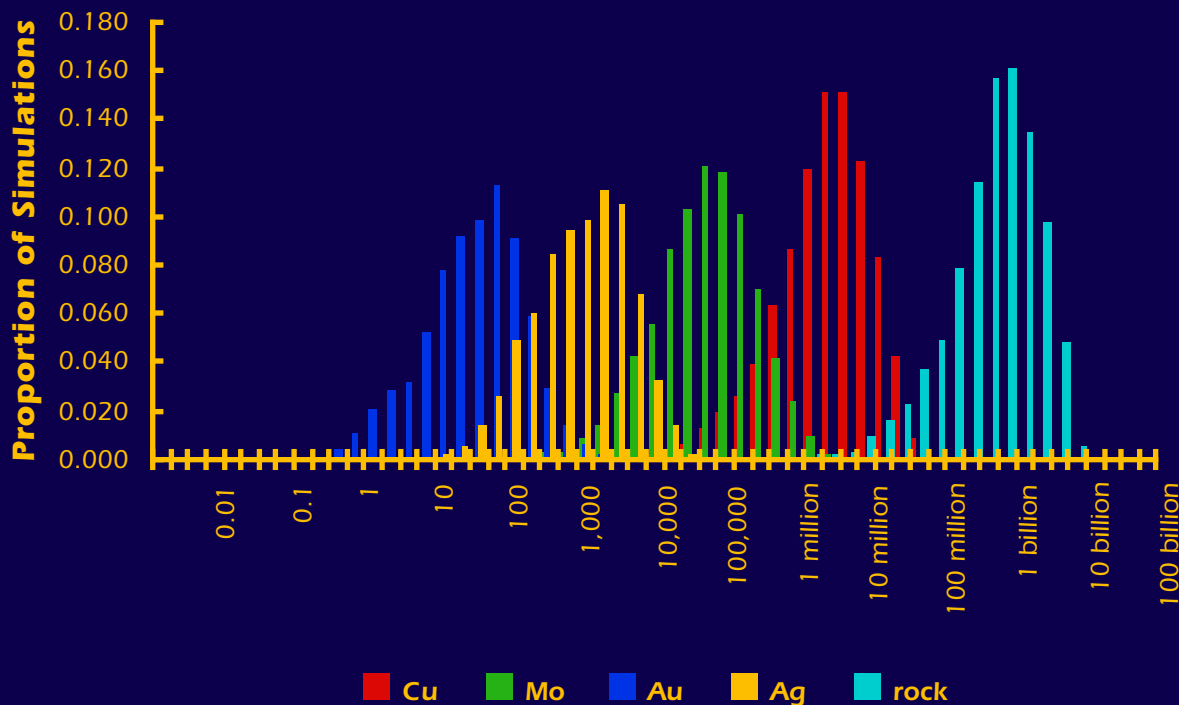


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GB11

The Mark3 Index is 81:

Porphyry Cu (North America)

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 8 or more deposits.

There is a 1% or greater chance of 11 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	130,000	0	0	0	33,000,000
0.50	3,900,000	52,000	18	660	830,000,000
0.10	23,000,000	440,000	196	6,300	4,200,000,000
0.05	32,000,000	790,000	320	9,800	5,700,000,000
mean	8,200,000	180,000	74	2,300	1,500,000,000
Probability of mean	0.31	0.25	0.26	0.28	0.32
Probability of zero	0.07	0.18	0.27	0.24	0.07

The tract ID is GB11The Mark3 Index is 81: **Porphyry Cu (North America)**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 8 or more deposits.

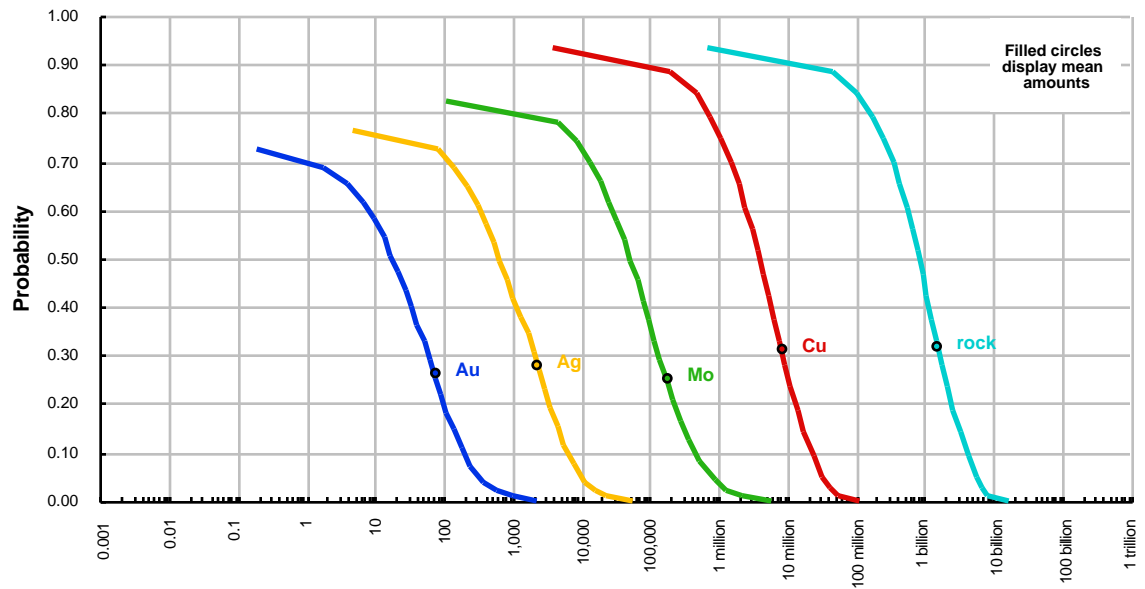
There is a 1% or greater chance of 11 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

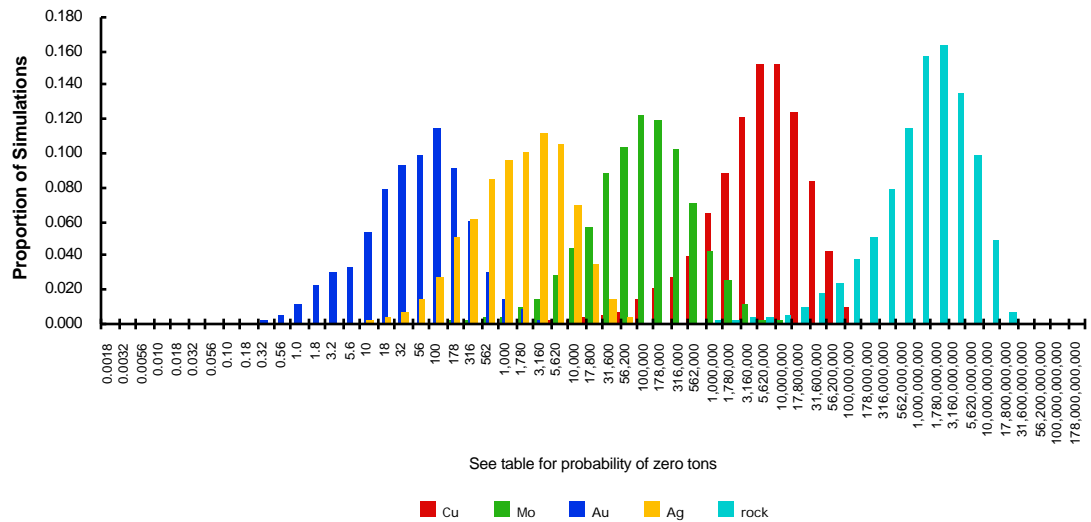
quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	130,000	0	0	0	33,000,000
0.50	3,900,000	52,000	18	660	830,000,000
0.10	23,000,000	440,000	196	6,300	4,200,000,000
0.05	32,000,000	790,000	320	9,800	5,700,000,000
mean	8,200,000	180,000	74	2,300	1,500,000,000
Probability of mean	0.31	0.25	0.26	0.28	0.32
Probability of zero	0.07	0.18	0.27	0.24	0.07

The tract ID is GB11

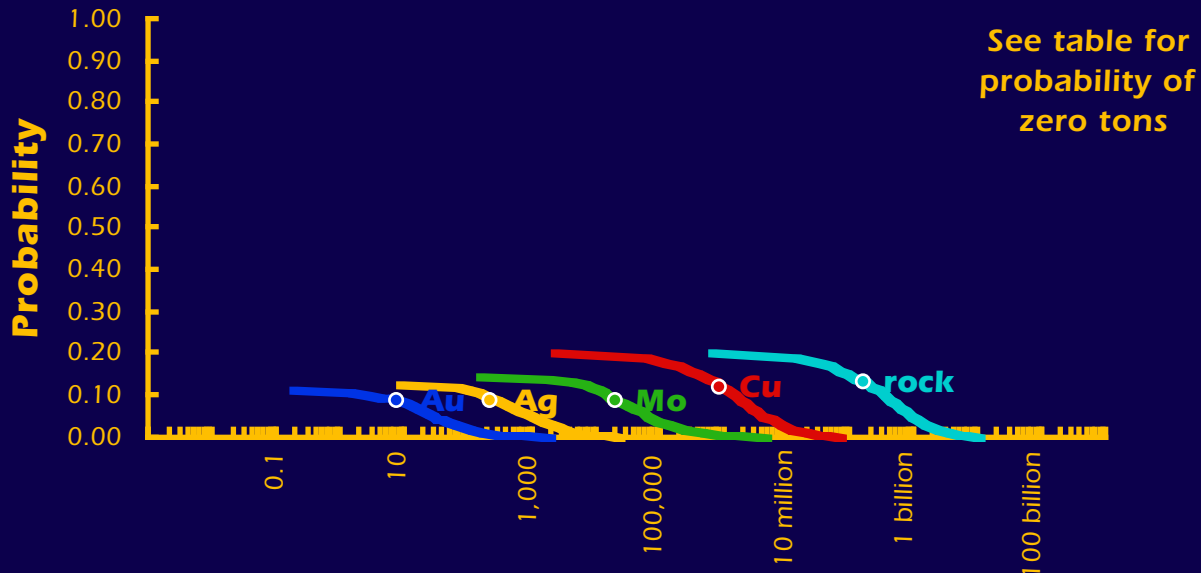
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

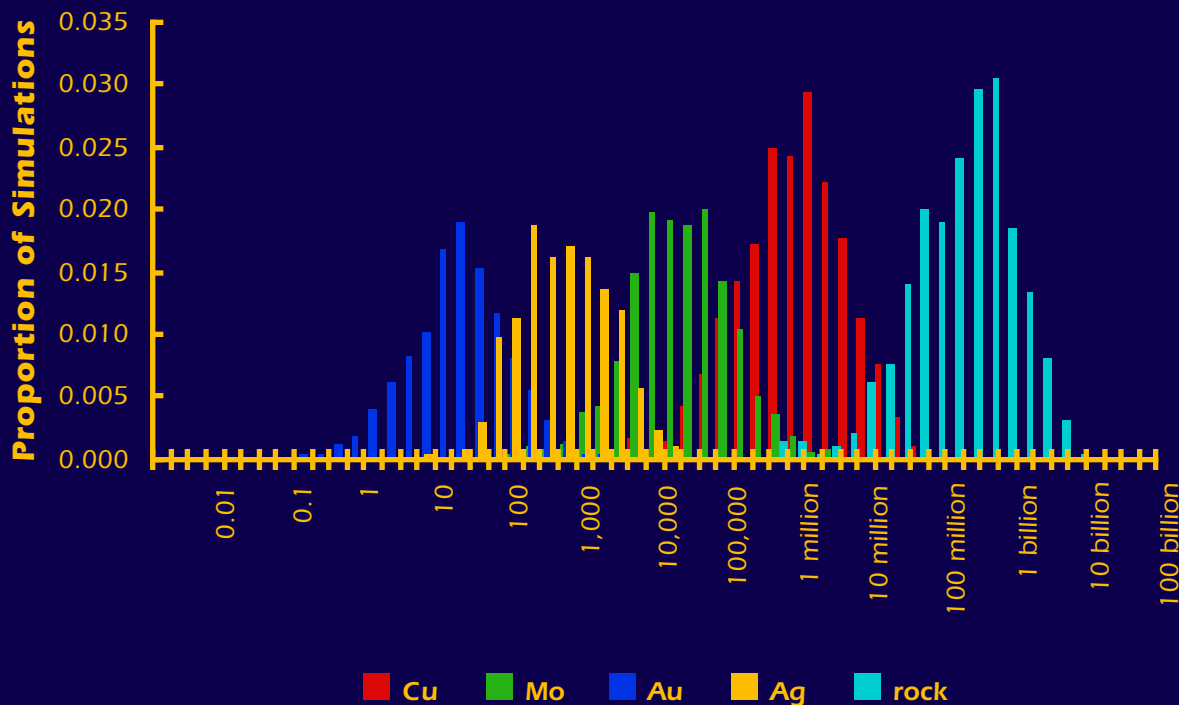


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GB12

The Mark3 Index is 81:

Porphyry Cu (North America)

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	1,500,000	16,000	3	190	330,000,000
0.05	4,200,000	67,000	28	1,000	880,000,000
mean	880,000	20,000	8	220	160,000,000
Probability of mean	0.12	0.09	0.09	0.09	0.13
Probability of zero	0.80	0.85	0.89	0.87	0.80

The tract ID is GB12The Mark3 Index is 81: **Porphyry Cu (North America)**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

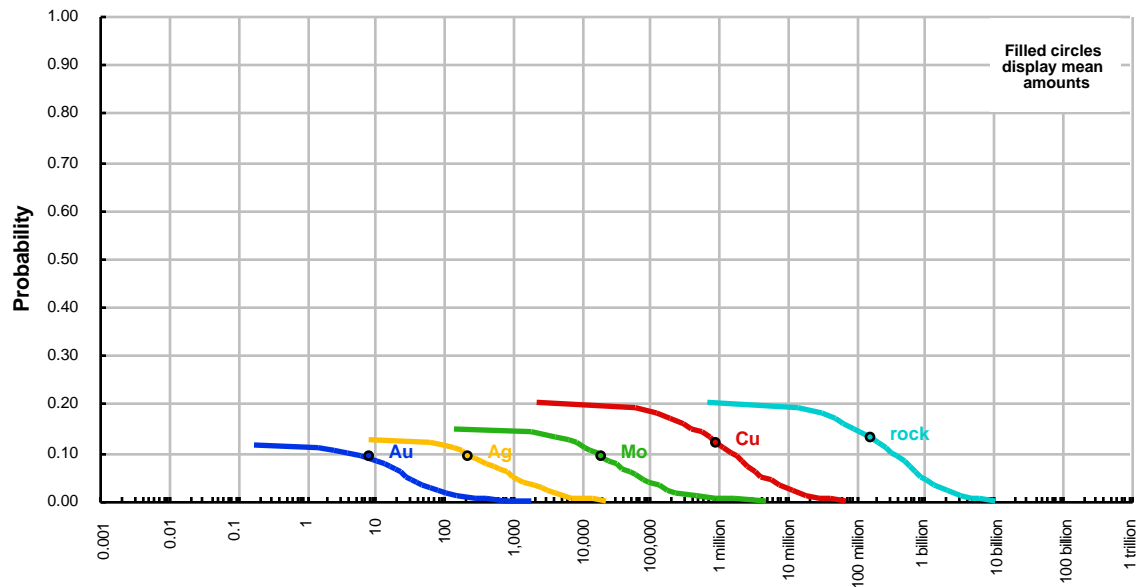
There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

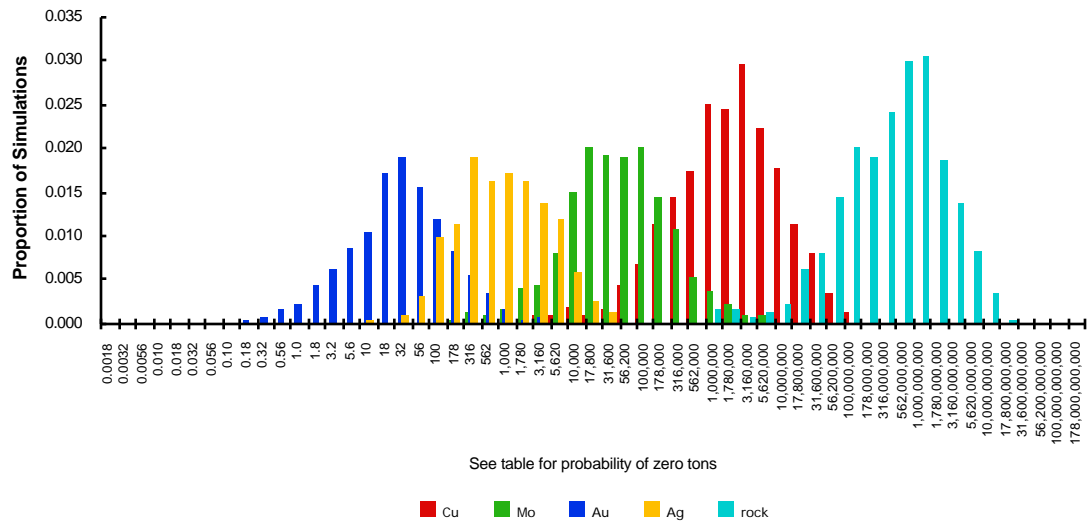
quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	1,500,000	16,000	3	190	330,000,000
0.05	4,200,000	67,000	28	1,000	880,000,000
mean	880,000	20,000	8	220	160,000,000
Probability of mean	0.12	0.09	0.09	0.09	0.13
Probability of zero	0.80	0.85	0.89	0.87	0.80

The tract ID is GB12

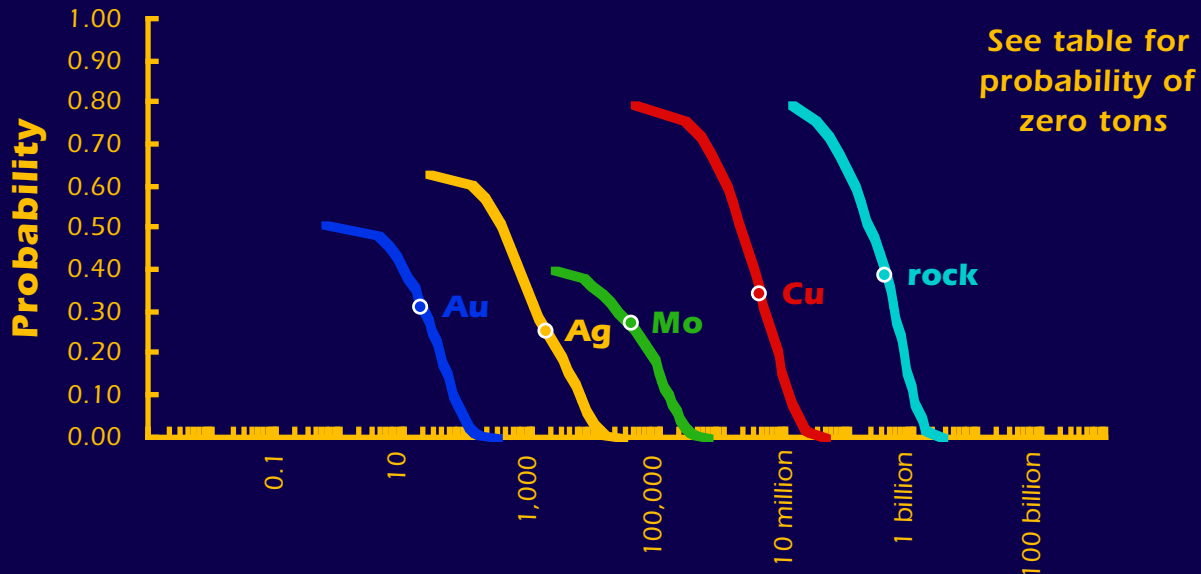
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

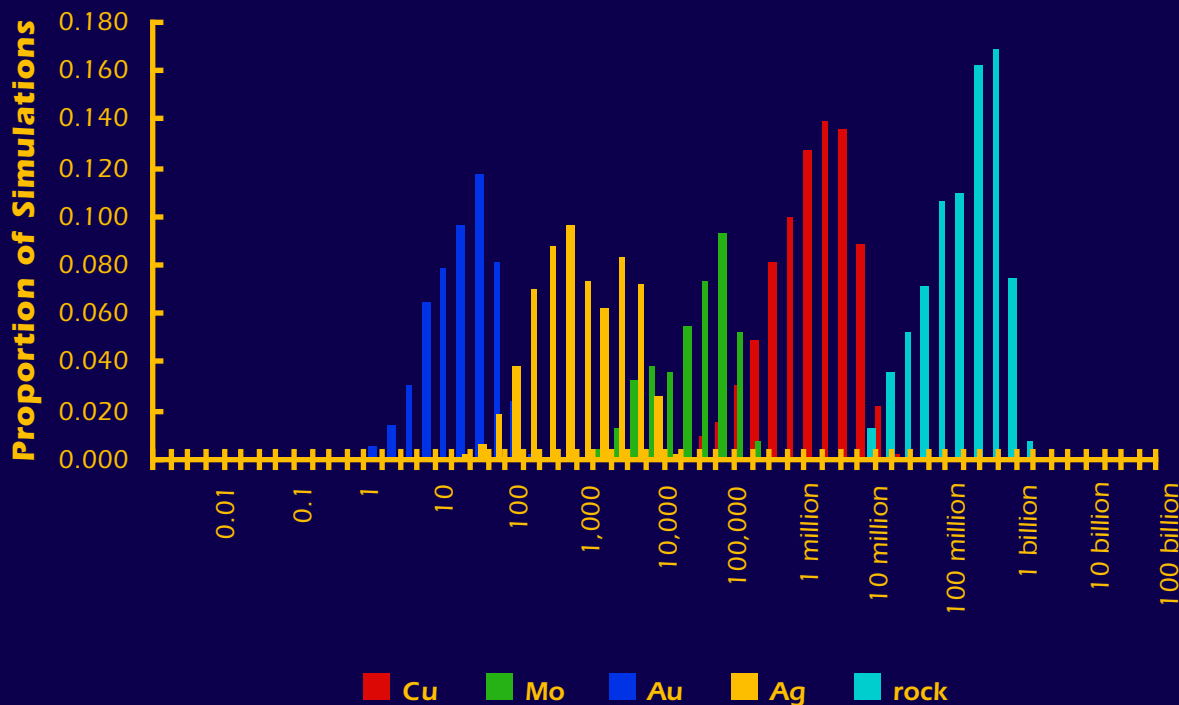


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GB13

The Mark3 Index is 9:

Porphyry Cu, skarn related

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	1,900,000	0	2	320	200,000,000
0.10	11,000,000	130,000	58	5,600	920,000,000
0.05	14,000,000	190,000	80	7,900	1,200,000,000
mean	3,800,000	37,000	18	1,600	350,000,000
Probability of mean	0.34	0.27	0.31	0.25	0.39
Probability of zero	0.20	0.60	0.49	0.37	0.20

The tract ID is GB13The Mark3 Index is 9: **Porphyry Cu, skarn related**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

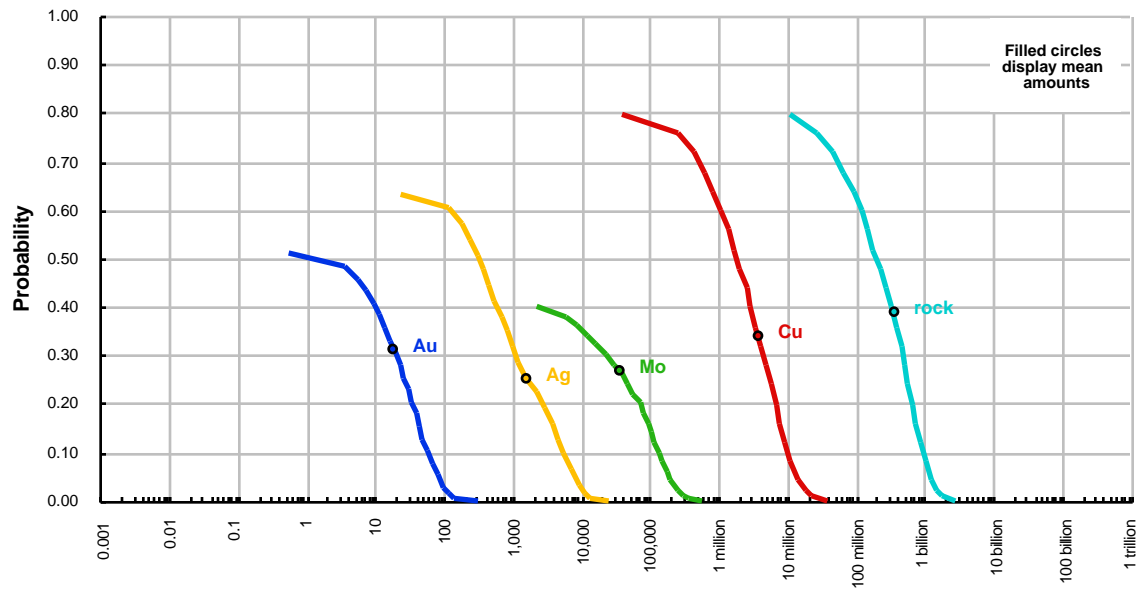
There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

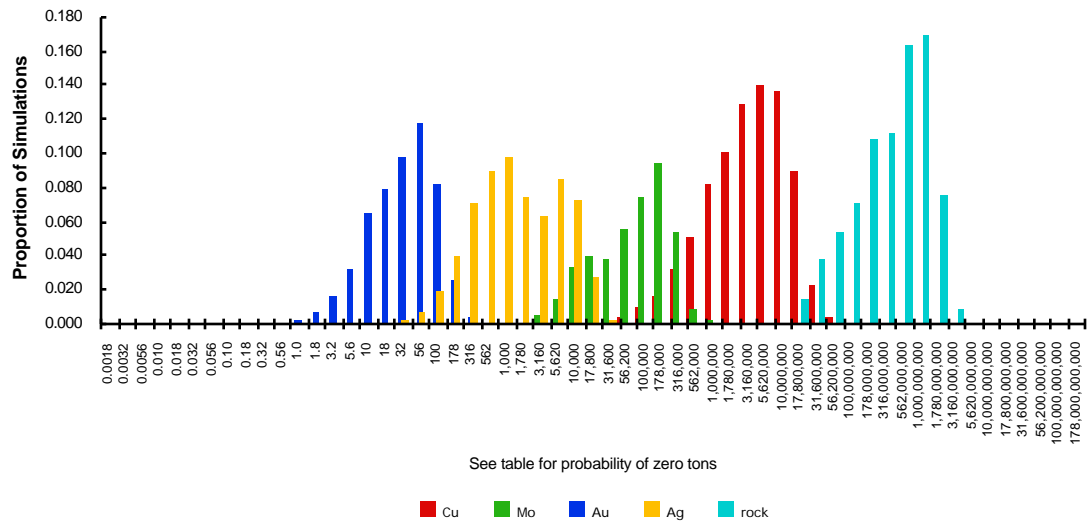
quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	1,900,000	0	2	320	200,000,000
0.10	11,000,000	130,000	58	5,600	920,000,000
0.05	14,000,000	190,000	80	7,900	1,200,000,000
mean	3,800,000	37,000	18	1,600	350,000,000
Probability of mean	0.34	0.27	0.31	0.25	0.39
Probability of zero	0.20	0.60	0.49	0.37	0.20

The tract ID is GB13

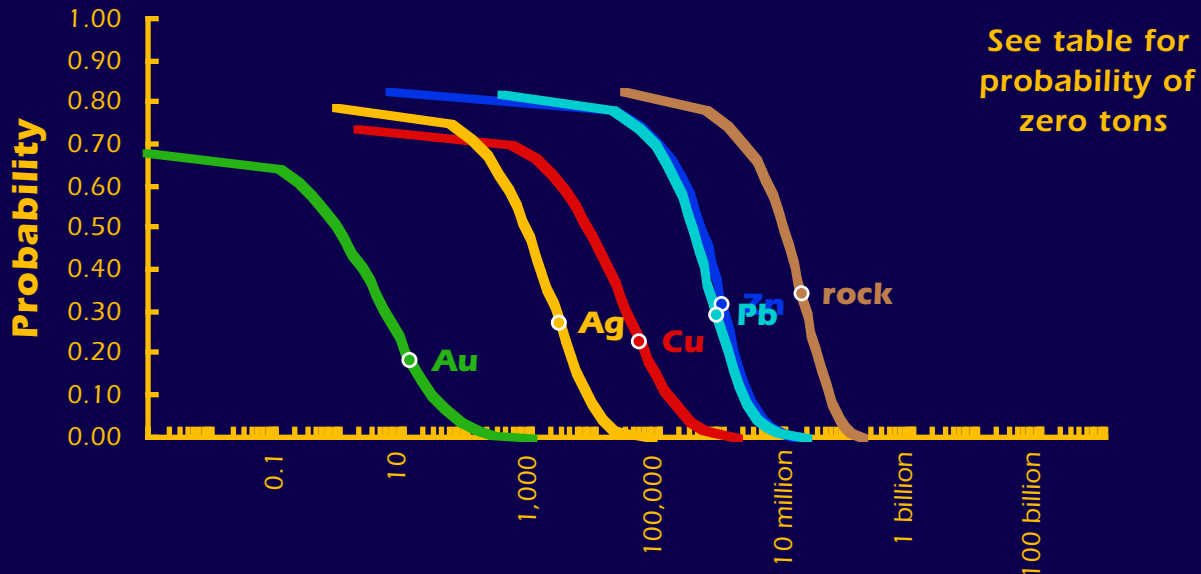
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

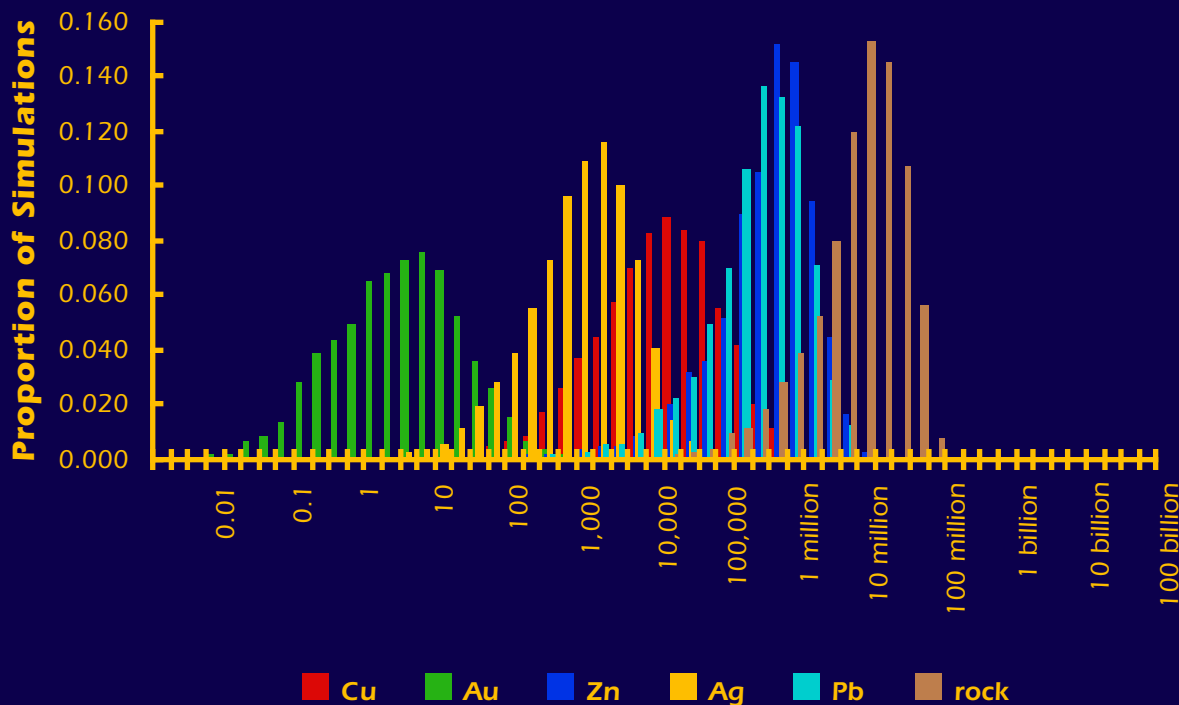


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GB14

The Mark3 Index is 92:

Polymetallic Replacement + skarn Zn-Pb

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 8 or more deposits.

There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	7,500	1	440,000	790	320,000	8,600,000
0.10	130,000	27	2,410,000	7,100	2,000,000	44,000,000
0.05	240,000	58	3,600,000	12,000	3,000,000	62,000,000
mean	50,000	13	940,000	2,600	770,000	16,000,000
Probability of mean	0.23	0.18	0.32	0.27	0.29	0.34
Probability of zero	0.26	0.32	0.17	0.21	0.18	0.17

The tract ID is GB14The Mark3 Index is 92: **Polymetallic Replacement + skarn Zn-Pb**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 8 or more deposits.

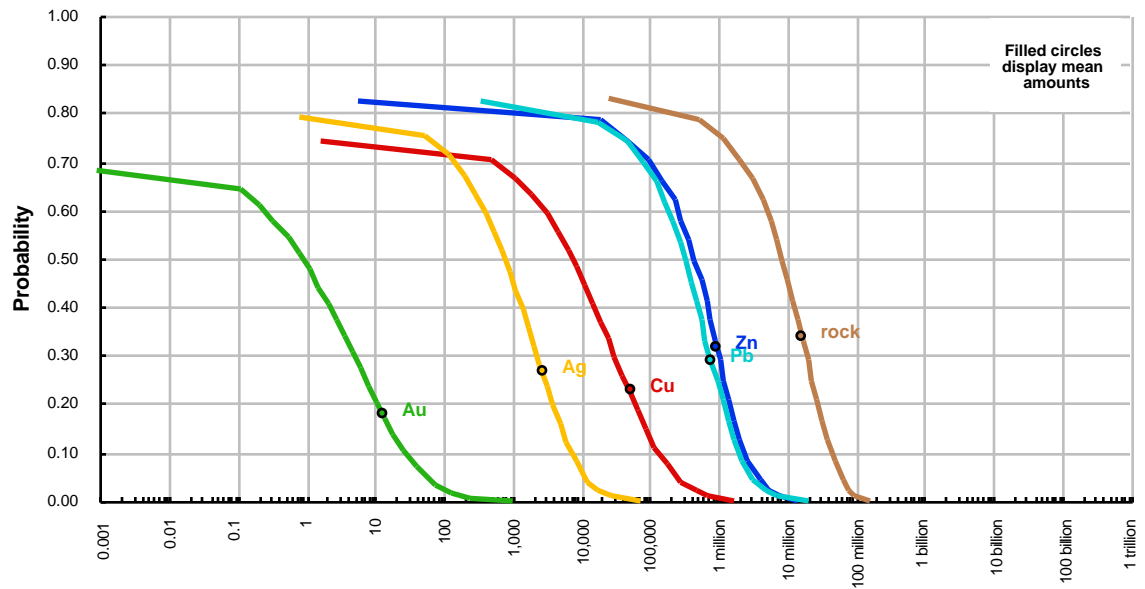
There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

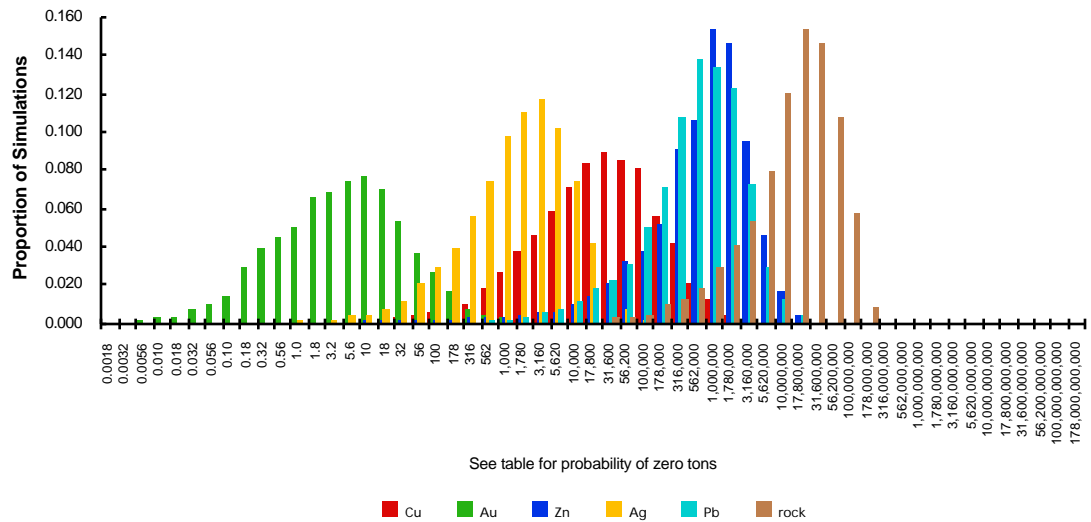
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	7,500	1	440,000	790	320,000	8,600,000
0.10	130,000	27	2,410,000	7,100	2,000,000	44,000,000
0.05	240,000	58	3,600,000	12,000	3,000,000	62,000,000
mean	50,000	13	940,000	2,600	770,000	16,000,000
Probability of mean	0.23	0.18	0.32	0.27	0.29	0.34
Probability of zero	0.26	0.32	0.17	0.21	0.18	0.17

The tract ID is GB14

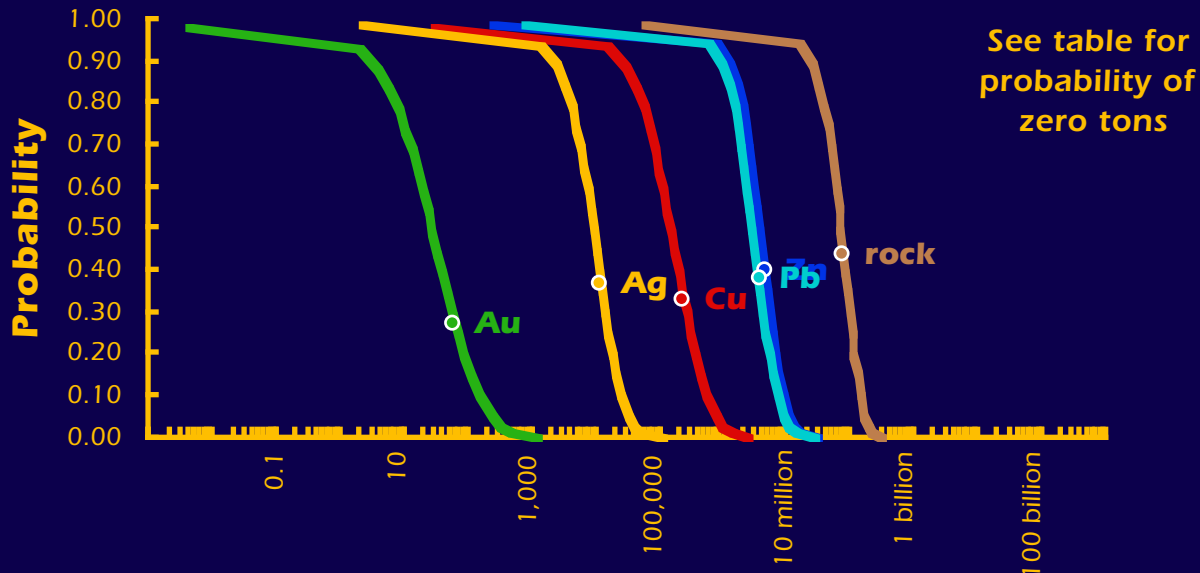
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

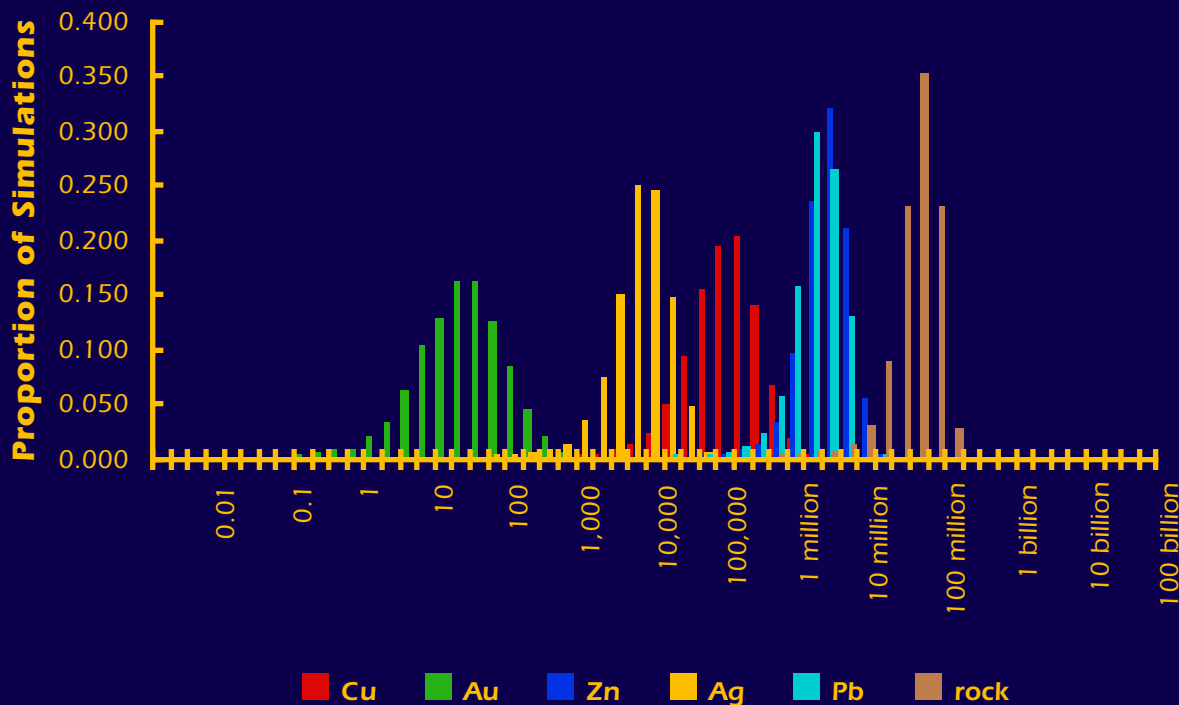


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GB15

The Mark3 Index is 92:

Polymetallic Replacement + skarn Zn-Pb

There is a 90% or greater chance of 9 or more deposits.

There is a 50% or greater chance of 14 or more deposits.

There is a 10% or greater chance of 18 or more deposits.

There is a 5% or greater chance of 20 or more deposits.

There is a 1% or greater chance of 22 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	11,000	1	670,000	1,100	480,000	13,000,000
0.90	26,000	3	1,200,000	2,200	900,000	24,000,000
0.50	150,000	26	3,700,000	9,000	2,800,000	68,000,000
0.10	530,000	150	8,400,000	25,000	6,900,000	140,000,000
0.05	760,000	230	11,000,000	32,000	8,700,000	160,000,000
mean	230,000	59	4,400,000	12,000	3,500,000	75,000,000
Probability of mean	0.33	0.27	0.40	0.37	0.38	0.44
Probability of zero	0.02	0.02	0.01	0.01	0.01	0.01

The tract ID is GB15The Mark3 Index is 92: **Polymetallic Replacement + skarn Zn-Pb**

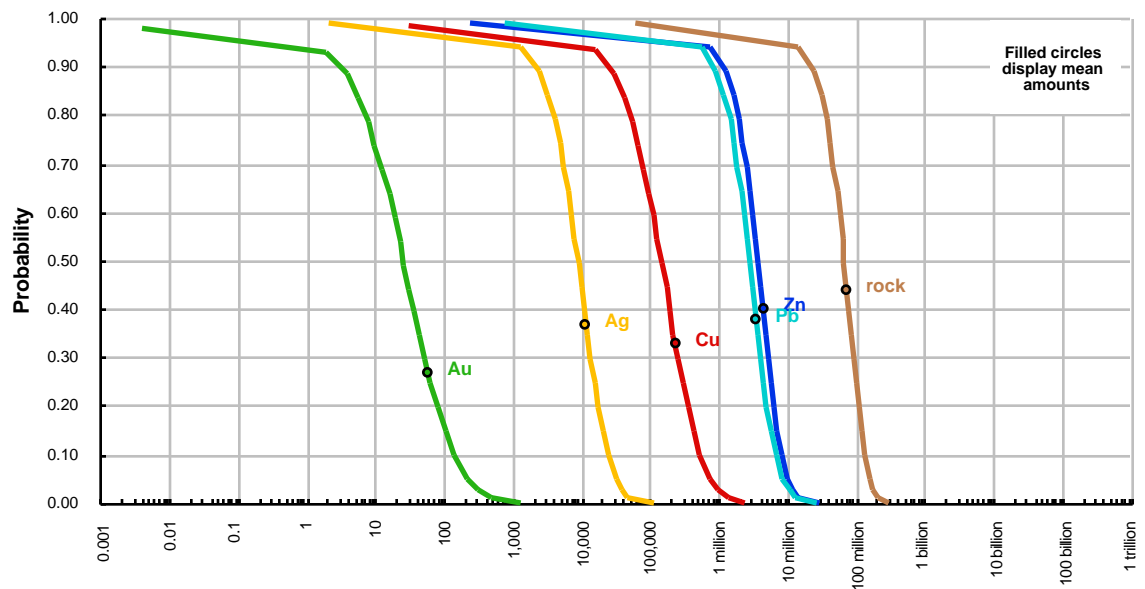
There is a 90% or greater chance of 9 or more deposits.
 There is a 50% or greater chance of 14 or more deposits.
 There is a 10% or greater chance of 18 or more deposits.
 There is a 5% or greater chance of 20 or more deposits.
 There is a 1% or greater chance of 22 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

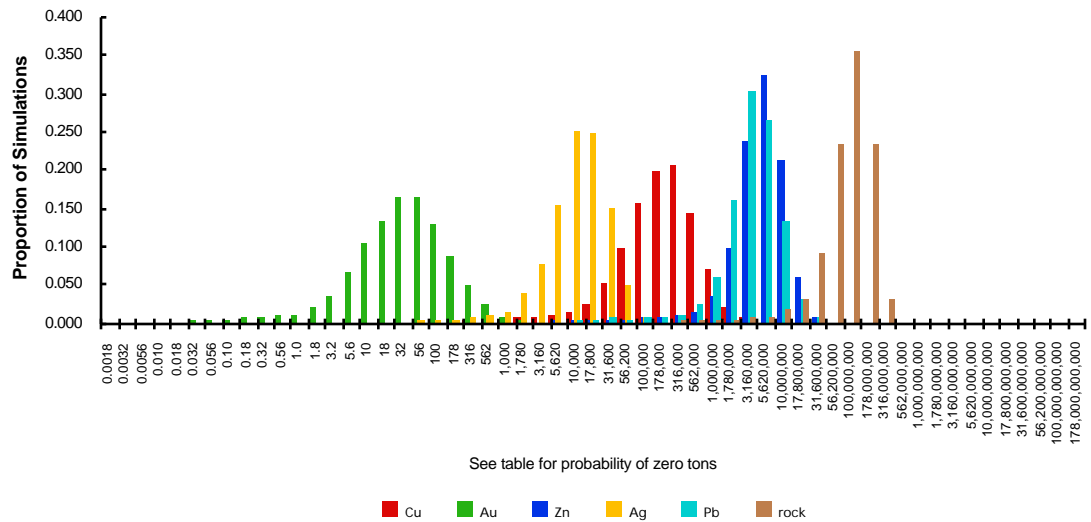
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	11,000	1	670,000	1,100	480,000	13,000,000
0.90	26,000	3	1,200,000	2,200	900,000	24,000,000
0.50	150,000	26	3,700,000	9,000	2,800,000	68,000,000
0.10	530,000	150	8,400,000	25,000	6,900,000	140,000,000
0.05	760,000	230	11,000,000	32,000	8,700,000	160,000,000
mean	230,000	59	4,400,000	12,000	3,500,000	75,000,000
Probability of mean	0.33	0.27	0.40	0.37	0.38	0.44
Probability of zero	0.02	0.02	0.01	0.01	0.01	0.01

The tract ID is GB15

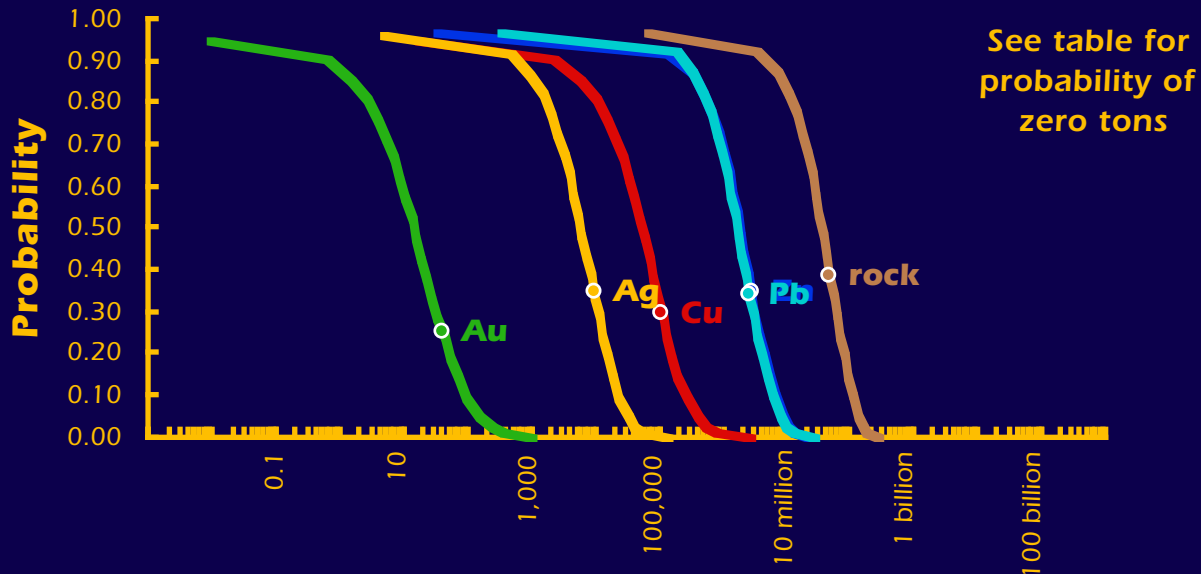
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

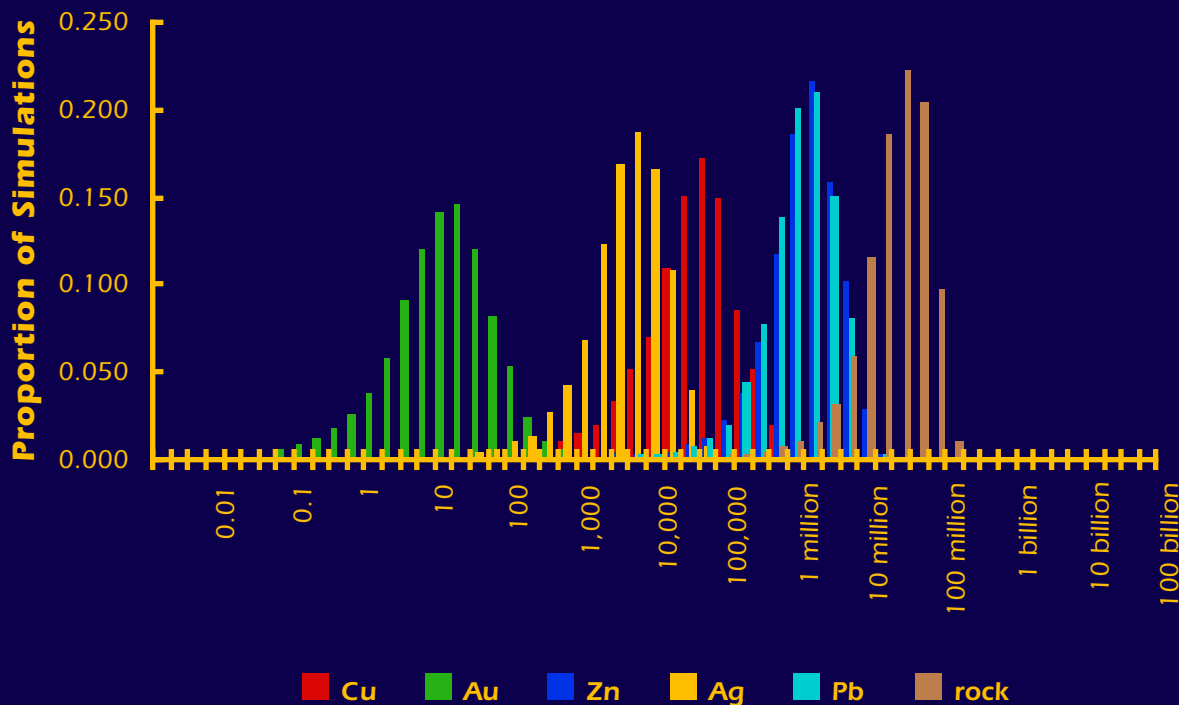


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GB16

The Mark3 Index is 47:

Polymetallic replacement

There is a 90% or greater chance of 3 or more deposits.

There is a 50% or greater chance of 7 or more deposits.

There is a 10% or greater chance of 11 or more deposits.

There is a 5% or greater chance of 13 or more deposits.

There is a 1% or greater chance of 20 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	73	0	34,000	140	67,000	1,400,000
0.90	2,700	1	220,000	620	250,000	5,100,000
0.50	52,000	14	1,800,000	5,700	1,600,000	35,000,000
0.10	250,000	90	6,410,000	22,000	5,800,000	100,000,000
0.05	390,000	150	8,500,000	30,000	8,100,000	130,000,000
mean	100,000	37	2,700,000	9,300	2,500,000	46,000,000
Probability of mean	0.30	0.25	0.35	0.35	0.34	0.39
Probability of zero	0.05	0.05	0.03	0.03	0.03	0.03

The tract ID is GB16The Mark3 Index is 47: **Polymetallic replacement**

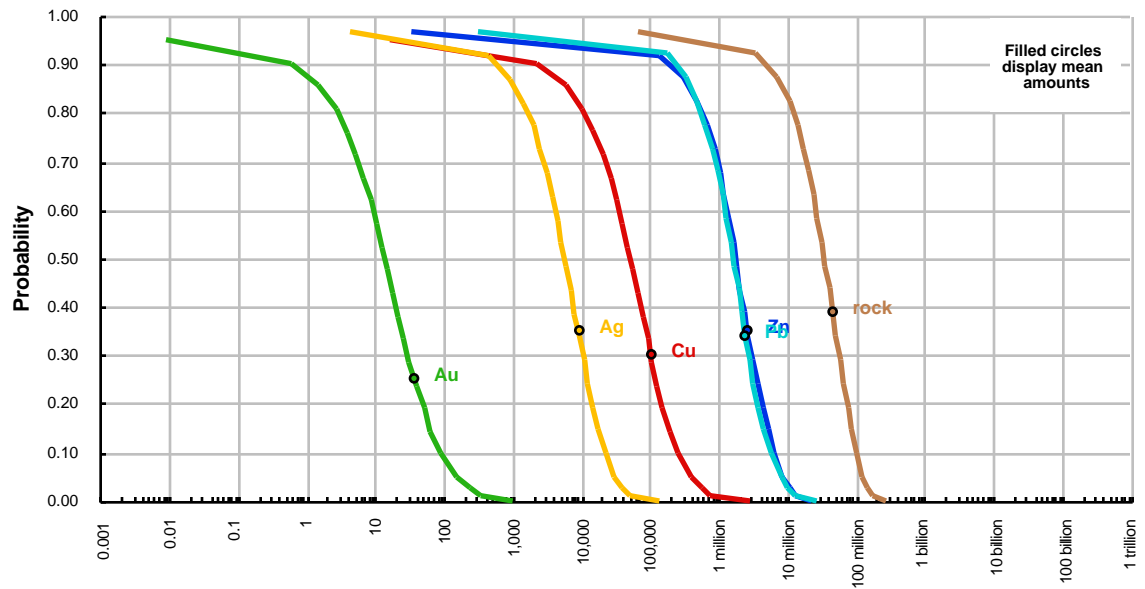
There is a 90% or greater chance of 3 or more deposits.
 There is a 50% or greater chance of 7 or more deposits.
 There is a 10% or greater chance of 11 or more deposits.
 There is a 5% or greater chance of 13 or more deposits.
 There is a 1% or greater chance of 20 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

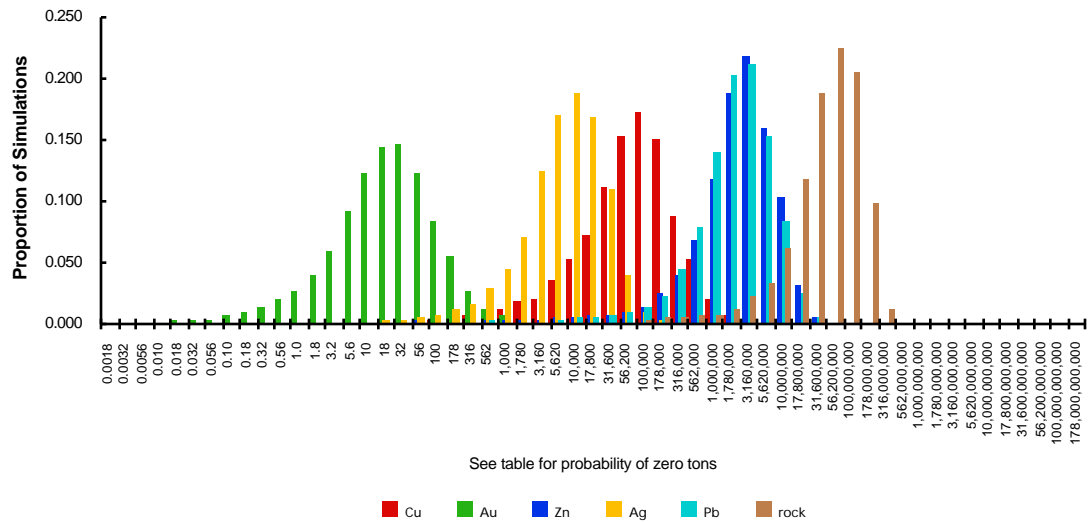
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	73	0	34,000	140	67,000	1,400,000
0.90	2,700	1	220,000	620	250,000	5,100,000
0.50	52,000	14	1,800,000	5,700	1,600,000	35,000,000
0.10	250,000	90	6,410,000	22,000	5,800,000	100,000,000
0.05	390,000	150	8,500,000	30,000	8,100,000	130,000,000
mean	100,000	37	2,700,000	9,300	2,500,000	46,000,000
Probability of mean	0.30	0.25	0.35	0.35	0.34	0.39
Probability of zero	0.05	0.05	0.03	0.03	0.03	0.03

The tract ID is GB16

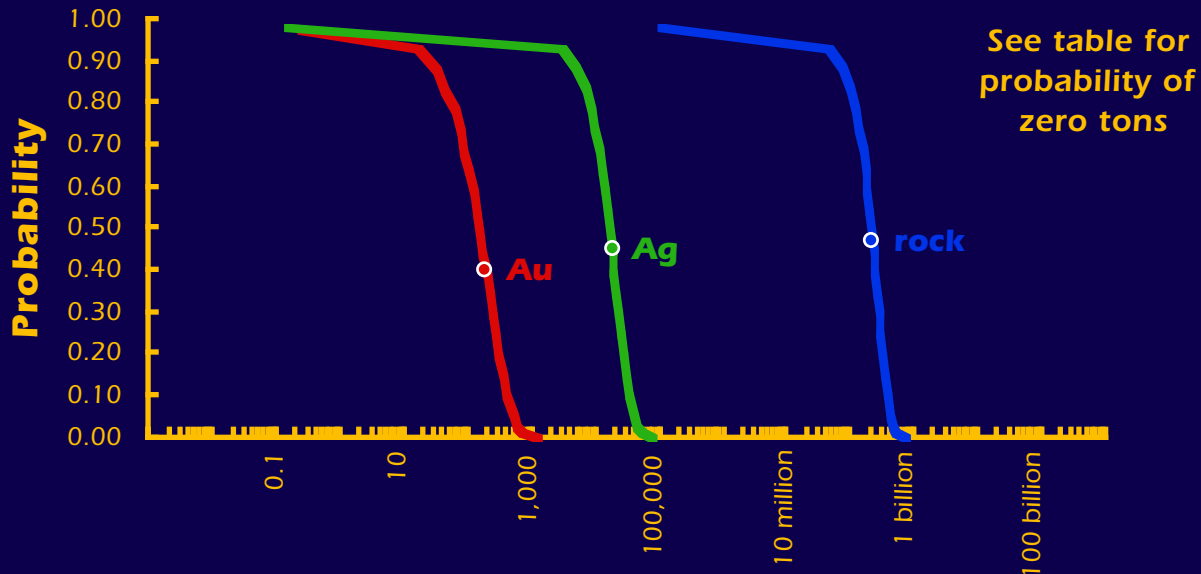
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

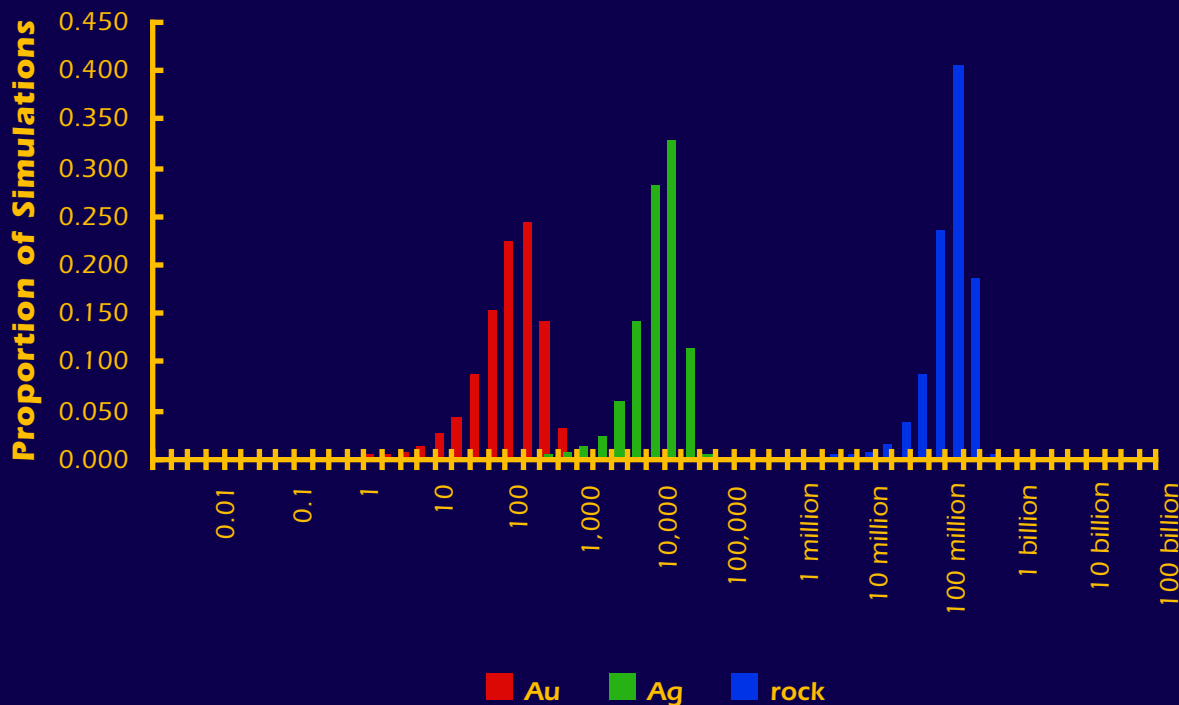


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GB18

The Mark3 Index is 18:

Distal disseminated Ag-Au

There is a 90% or greater chance of 6 or more deposits.
There is a 50% or greater chance of 10 or more deposits.
There is a 10% or greater chance of 14 or more deposits.
There is a 5% or greater chance of 15 or more deposits.
There is a 1% or greater chance of 17 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	9	1,800	29,000,000
0.90	25	4,300	63,000,000
0.50	150	16,000	200,000,000
0.10	400	33,000	373,000,000
0.05	500	39,000	420,000,000
mean	190	18,000	210,000,000
Probability of mean	0.40	0.45	0.47
Probability of zero	0.02	0.02	0.02

The tract ID is GB18The Mark3 Index is 18: **Distal disseminated Ag-Au**

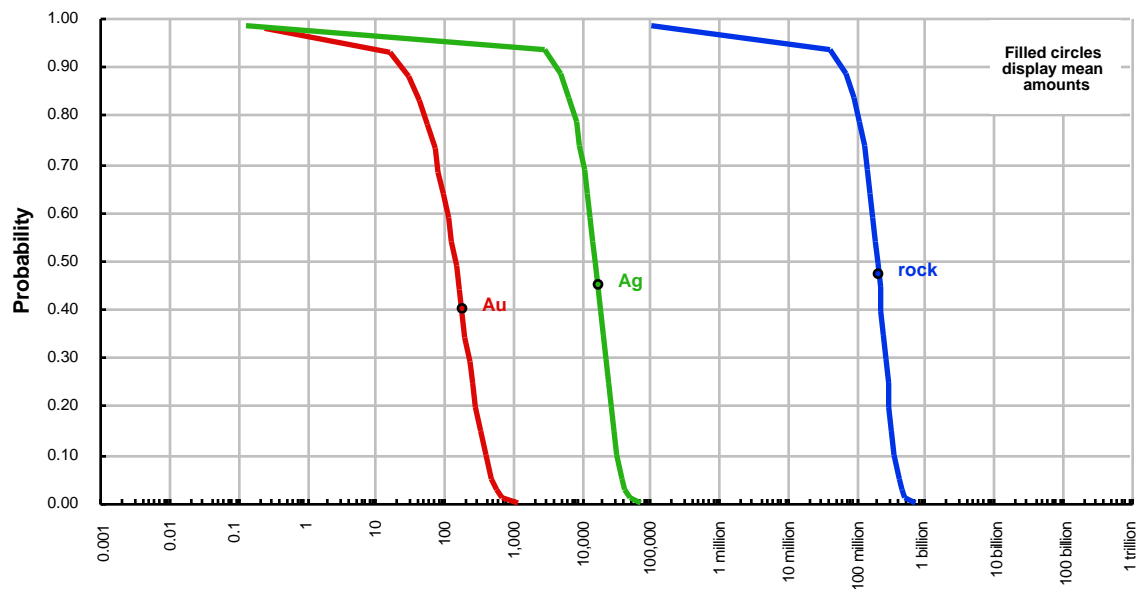
There is a 90% or greater chance of 6 or more deposits.
 There is a 50% or greater chance of 10 or more deposits.
 There is a 10% or greater chance of 14 or more deposits.
 There is a 5% or greater chance of 15 or more deposits.
 There is a 1% or greater chance of 17 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

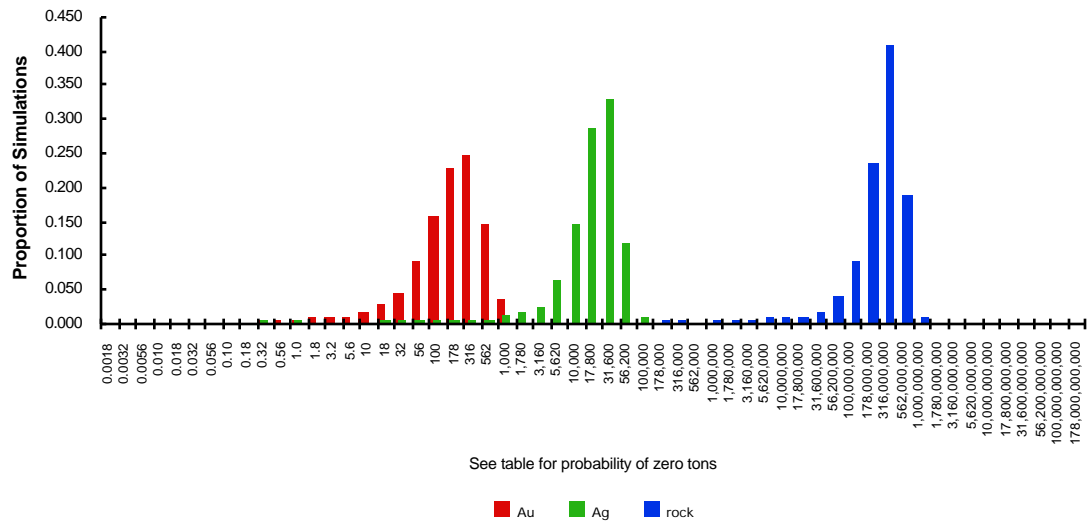
quantile	Au	Ag	rock
0.95	9	1,800	29,000,000
0.90	25	4,300	63,000,000
0.50	150	16,000	200,000,000
0.10	400	33,000	373,000,000
0.05	500	39,000	420,000,000
mean	190	18,000	210,000,000
Probability of mean	0.40	0.45	0.47
Probability of zero	0.02	0.02	0.02

The tract ID is GB18

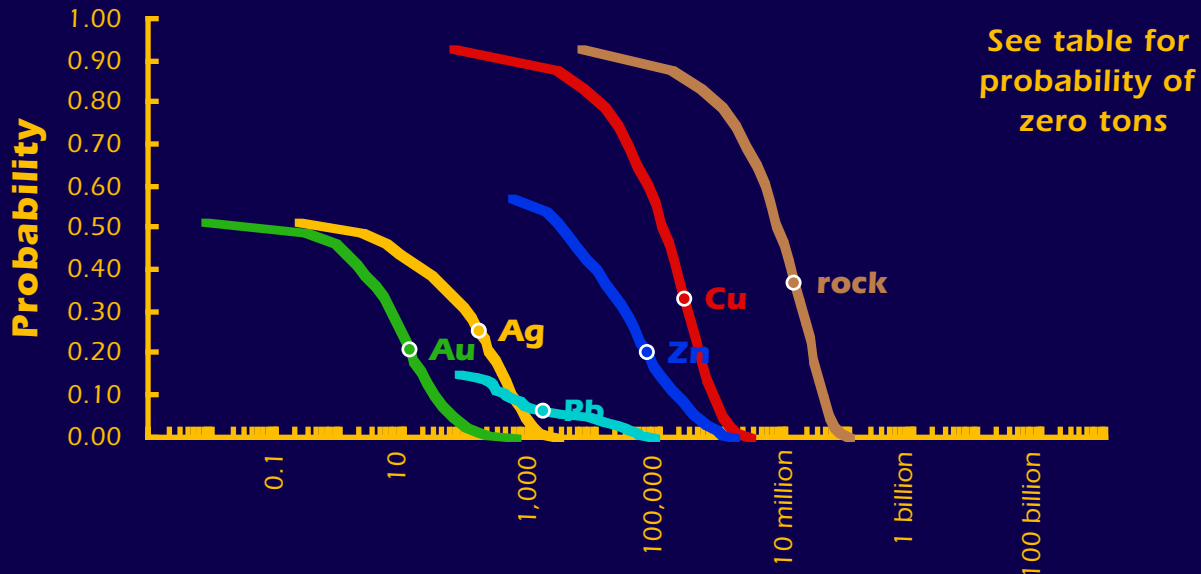
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

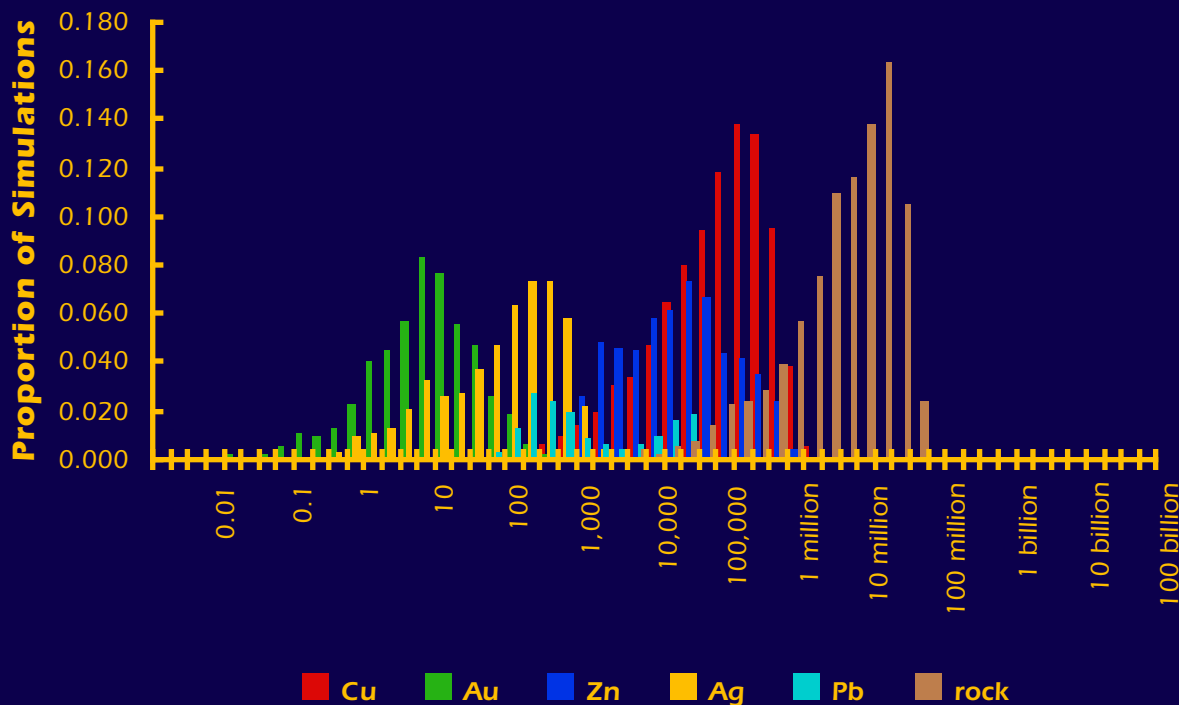


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GB19

The Mark3 Index is 11:

Massive sulfide, Cyprus

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 7 or more deposits.

There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	1,300	0	0	0	0	93,000
0.50	110,000	0	2,900	1	0	7,100,000
0.10	680,000	31	186,000	490	400	35,000,000
0.05	940,000	57	380,000	770	5,300	45,000,000
mean	250,000	12	63,000	140	1,400	13,000,000
Probability of mean	0.33	0.21	0.20	0.25	0.06	0.37
Probability of zero	0.07	0.49	0.43	0.49	0.85	0.07

The tract ID is GB19The Mark3 Index is 11: **Massive sulfide, Cyprus**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 7 or more deposits.

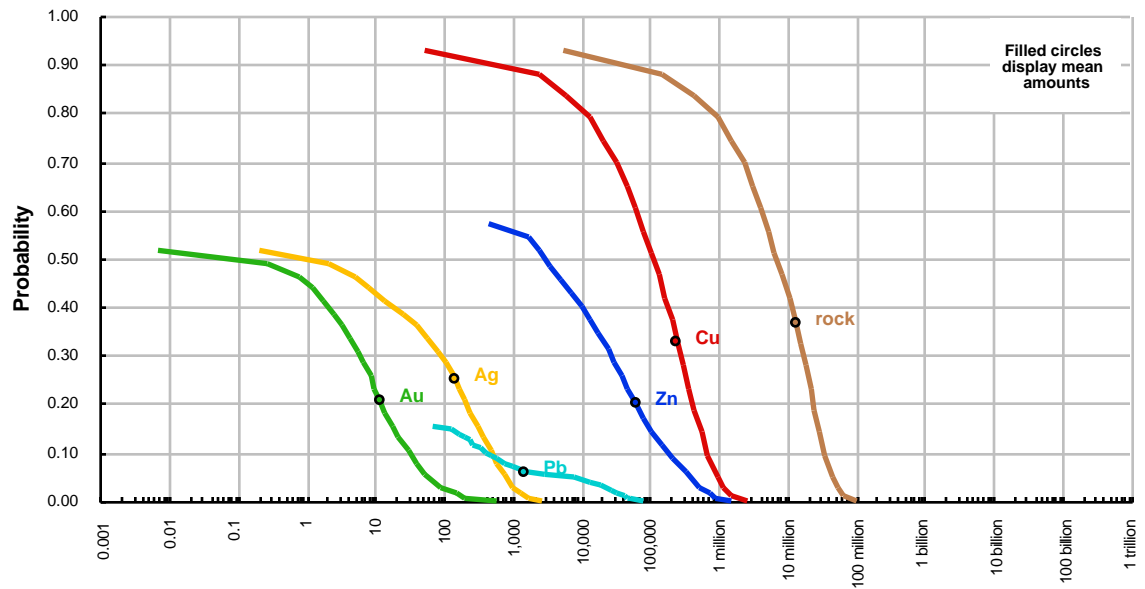
There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

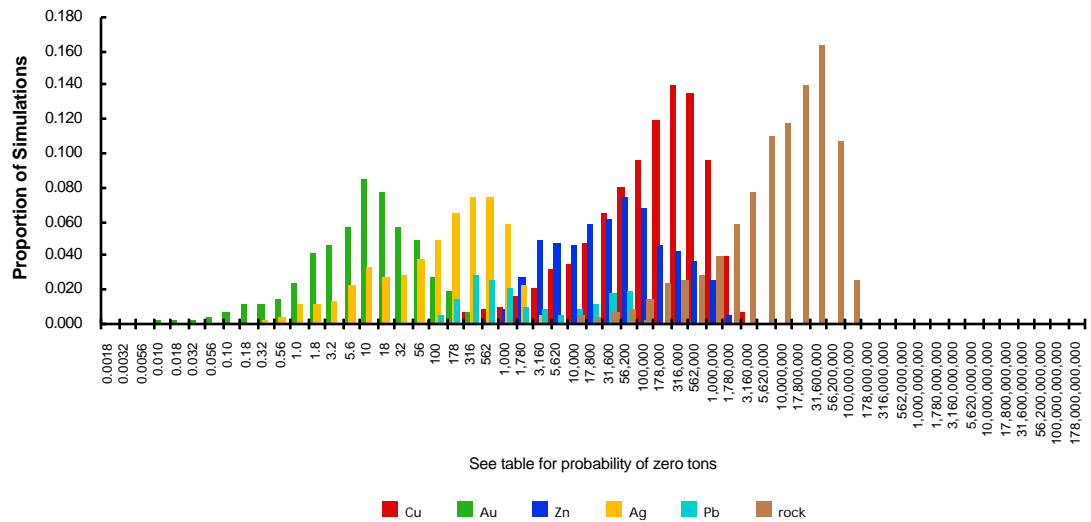
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	1,300	0	0	0	0	93,000
0.50	110,000	0	2,900	1	0	7,100,000
0.10	680,000	31	186,000	490	400	35,000,000
0.05	940,000	57	380,000	770	5,300	45,000,000
mean	250,000	12	63,000	140	1,400	13,000,000
Probability of mean	0.33	0.21	0.20	0.25	0.06	0.37
Probability of zero	0.07	0.49	0.43	0.49	0.85	0.07

The tract ID is GB19

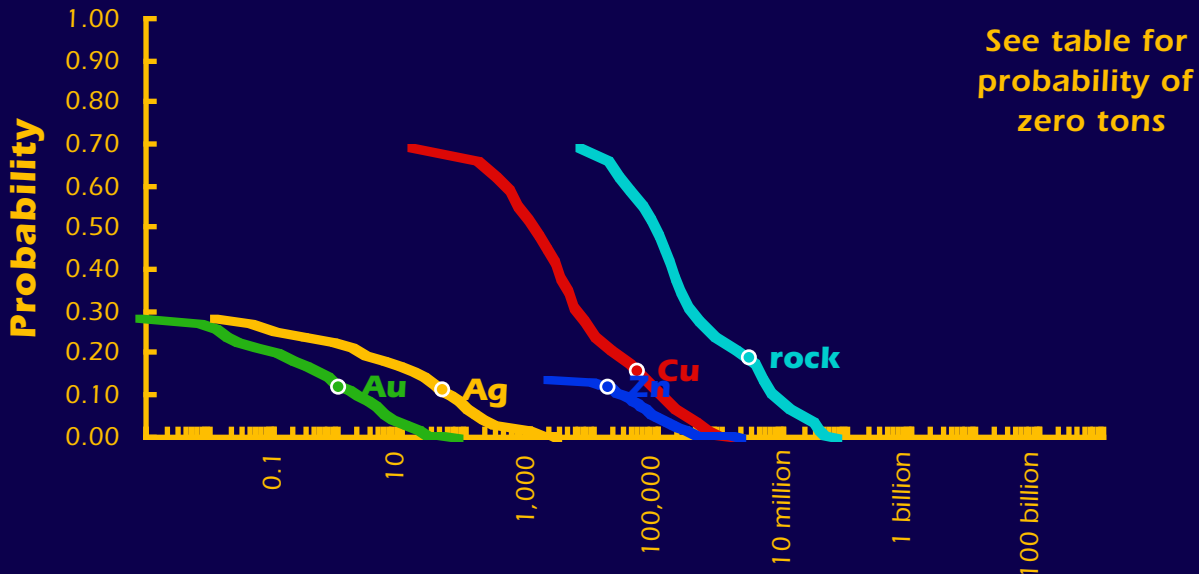
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

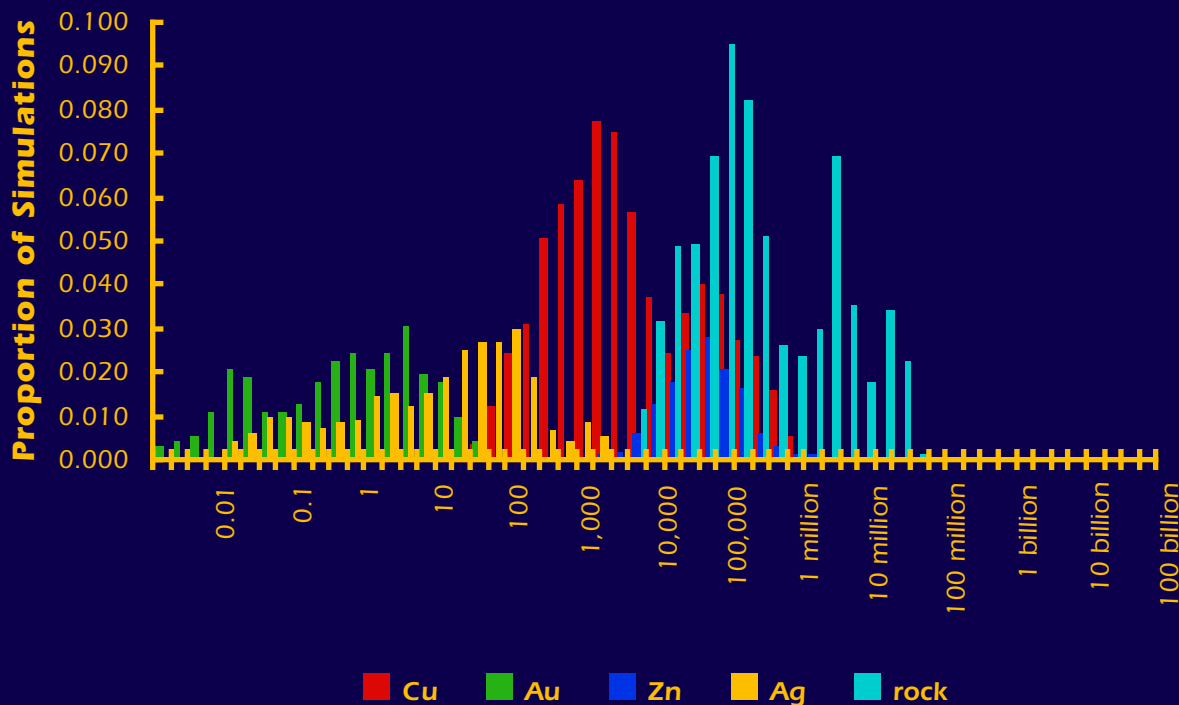


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GB20

The Mark3 Index is 30:

Massive sulfide, Besshi

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	1,200	0	0	0	92,000
0.10	110,000	2	30,800	56	6,000,000
0.05	280,000	6	87,000	160	21,000,000
mean	46,000	1	17,000	42	2,700,000
Probability of mean	0.16	0.12	0.12	0.11	0.19
Probability of zero	0.31	0.72	0.86	0.72	0.31

The tract ID is GB20The Mark3 Index is 30: **Massive sulfide, Besshi**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

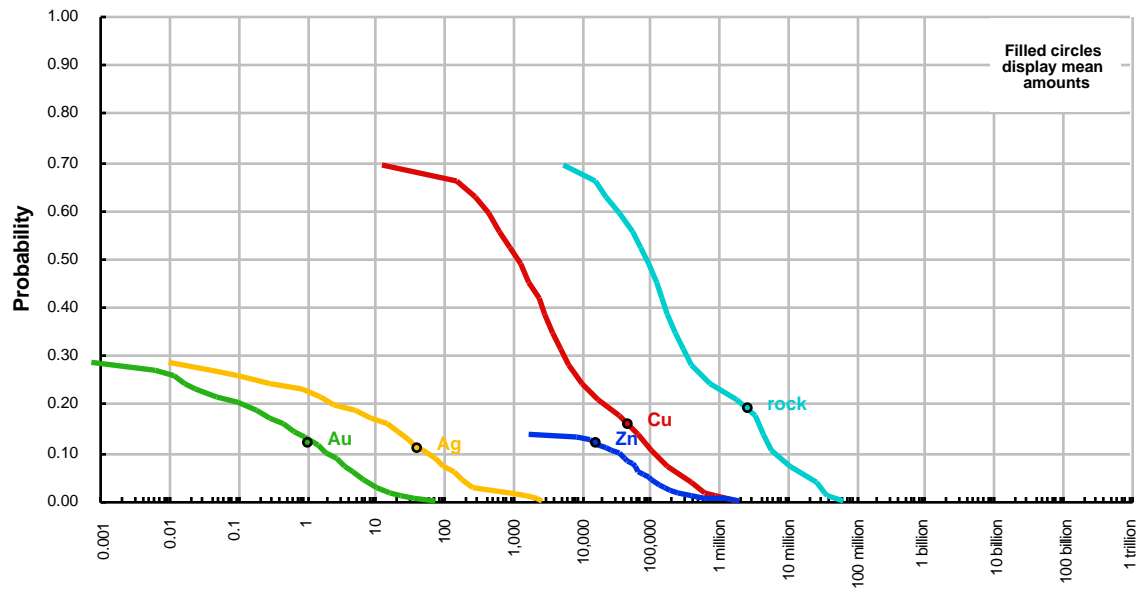
There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

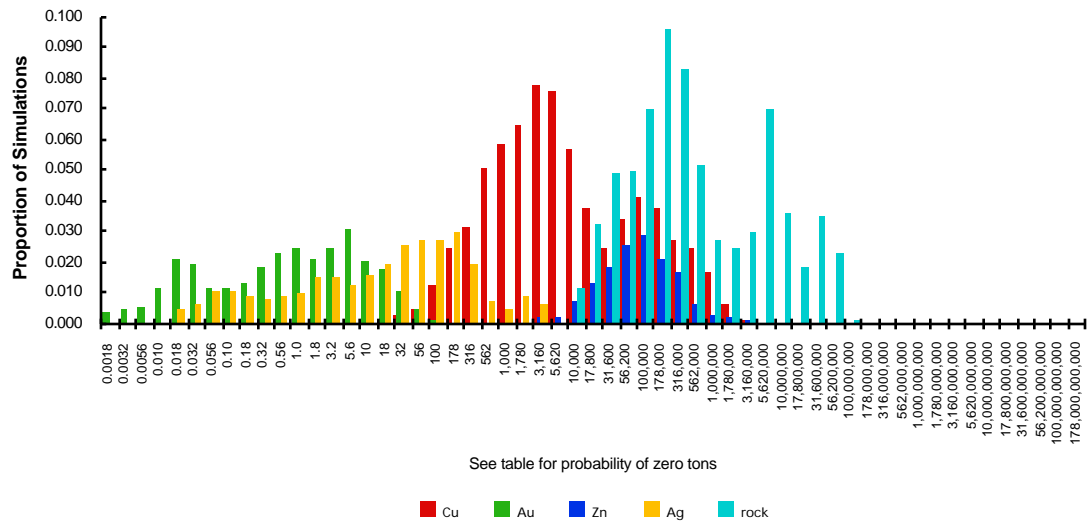
quantile	Cu	Au	Zn	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	1,200	0	0	0	92,000
0.10	110,000	2	30,800	56	6,000,000
0.05	280,000	6	87,000	160	21,000,000
mean	46,000	1	17,000	42	2,700,000
Probability of mean	0.16	0.12	0.12	0.11	0.19
Probability of zero	0.31	0.72	0.86	0.72	0.31

The tract ID is GB20

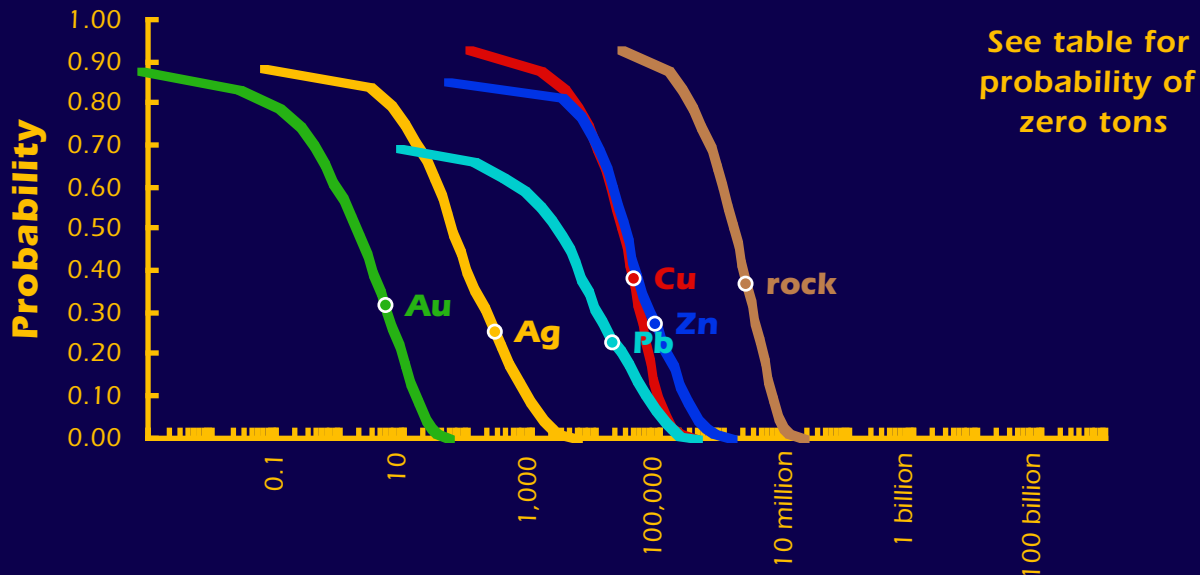
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

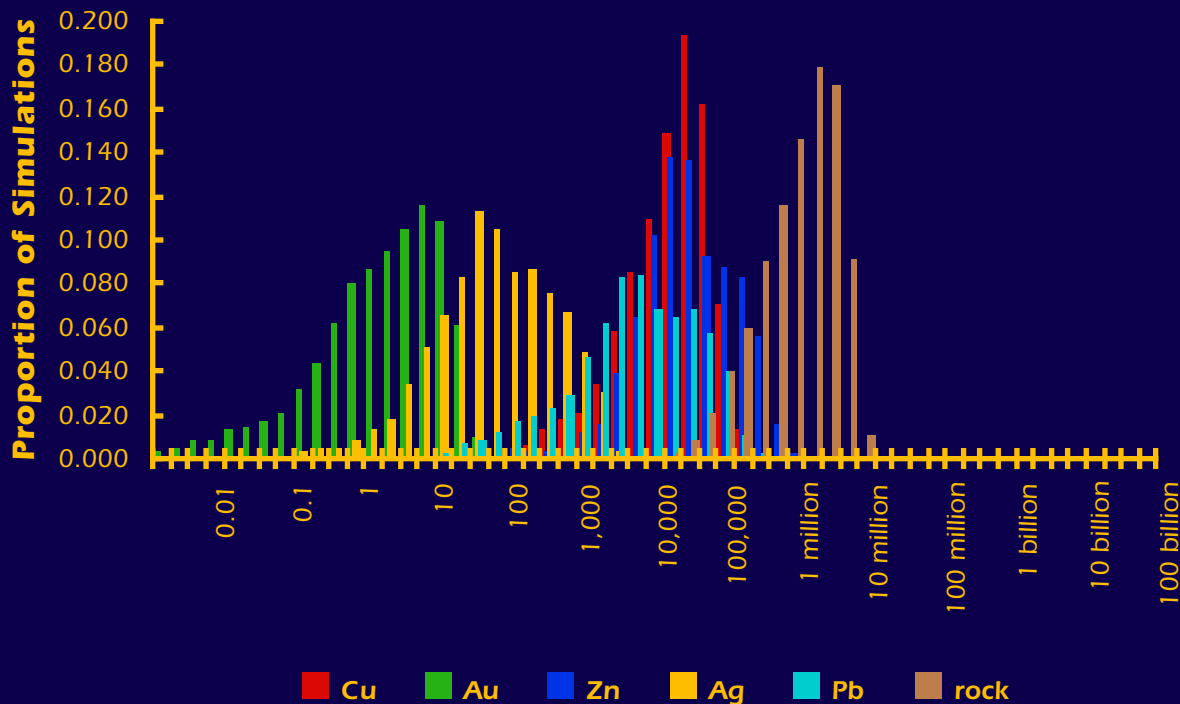


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GB21

The Mark3 Index is 44:

Massive sulfide, Sierran kuroko

There is a 90% or greater chance of 1 or more deposits.
There is a 50% or greater chance of 3 or more deposits.
There is a 10% or greater chance of 6 or more deposits.
There is a 5% or greater chance of 7 or more deposits.
There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	770	0	0	0	0	95,000
0.50	25,000	2	28,000	55	2,500	1,500,000
0.10	92,000	15	255,000	820	60,000	5,600,000
0.05	120,000	20	380,000	1,400	100,000	6,900,000
mean	38,000	5	85,000	270	19,000	2,300,000
Probability of mean	0.38	0.32	0.27	0.25	0.23	0.37
Probability of zero	0.07	0.12	0.14	0.11	0.31	0.07

The tract ID is GB21

The Mark3 Index is 44: **Massive sulfide, Sierran kuroko**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 7 or more deposits.

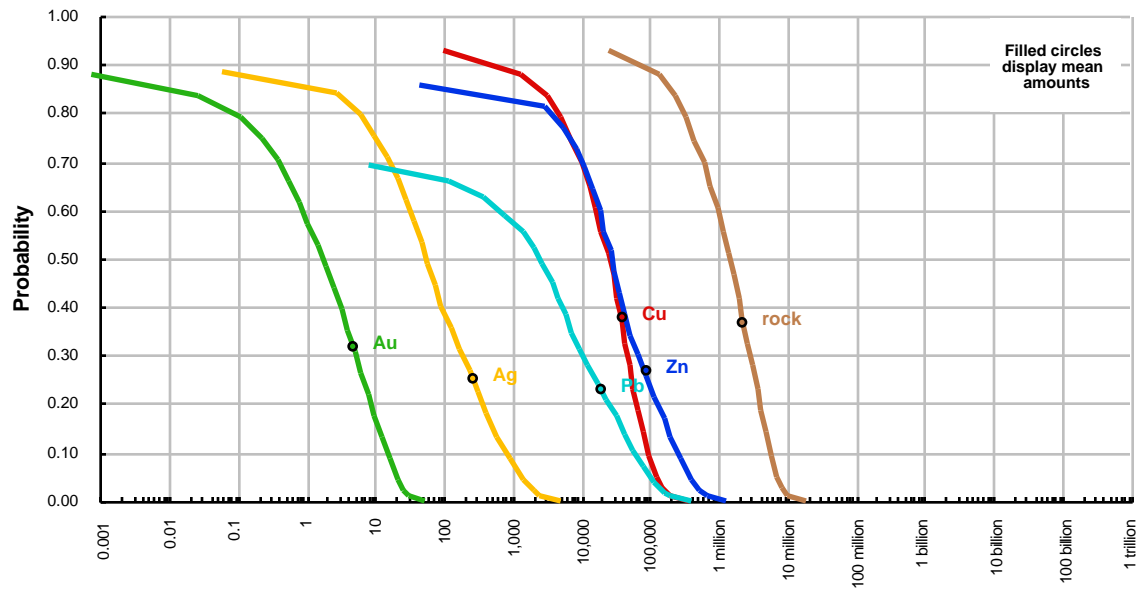
There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

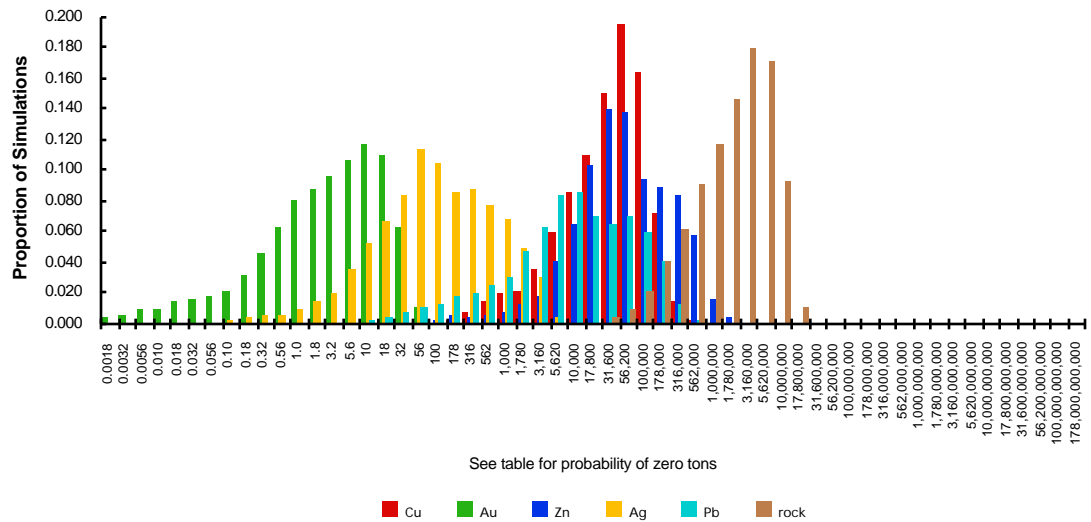
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	770	0	0	0	0	95,000
0.50	25,000	2	28,000	55	2,500	1,500,000
0.10	92,000	15	255,000	820	60,000	5,600,000
0.05	120,000	20	380,000	1,400	100,000	6,900,000
mean	38,000	5	85,000	270	19,000	2,300,000
Probability of mean	0.38	0.32	0.27	0.25	0.23	0.37
Probability of zero	0.07	0.12	0.14	0.11	0.31	0.07

The tract ID is GB21

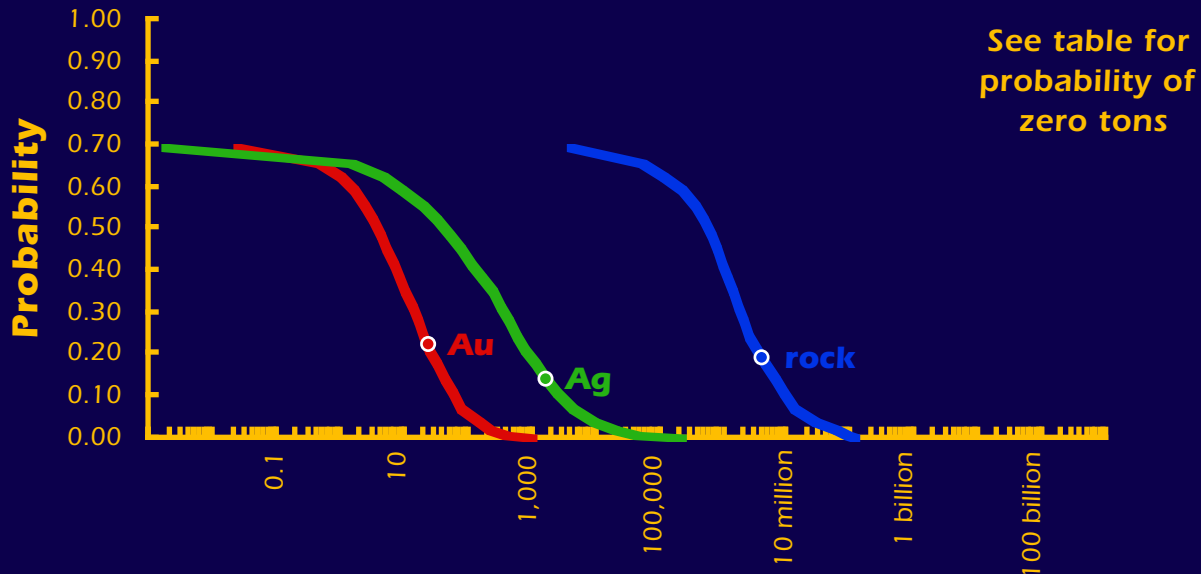
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

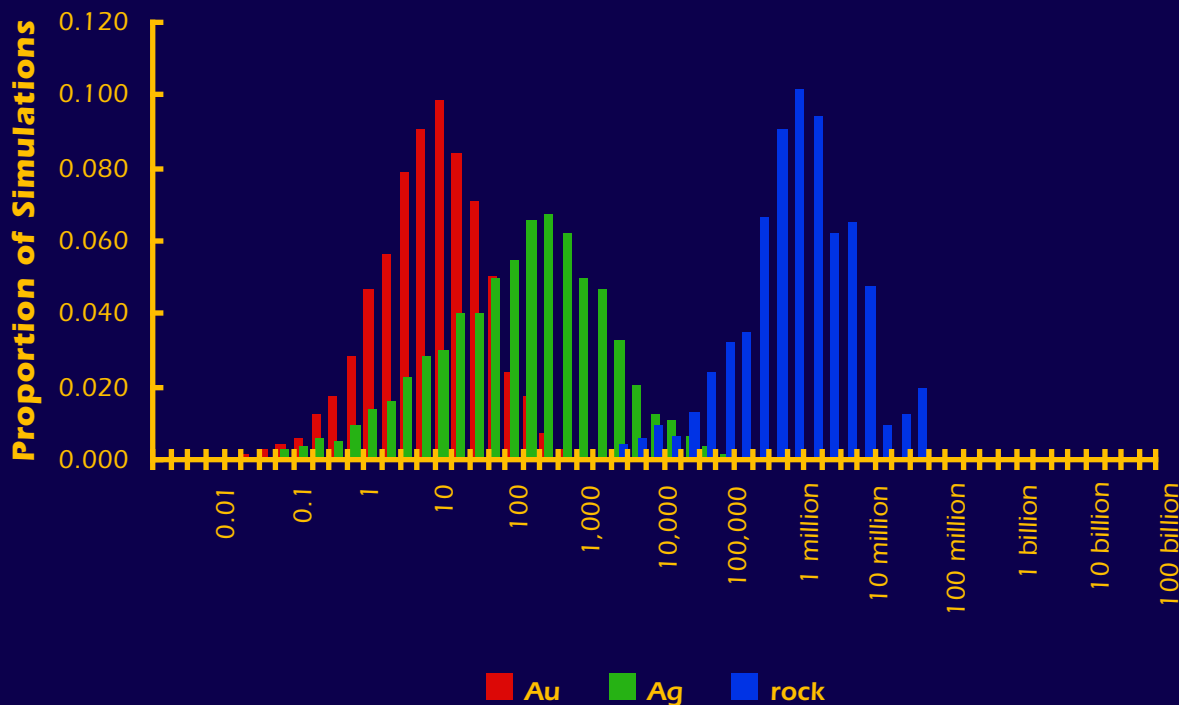


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GB22

The Mark3 Index is 16:

Epithermal vein, Comstock

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	4	41	560,000
0.10	57	2,600	9,330,000
0.05	100	6,100	15,000,000
mean	23	1,700	4,100,000
Probability of mean	0.22	0.14	0.19
Probability of zero	0.31	0.31	0.31

The tract ID is GB22

The Mark3 Index is 16: **Epithermal vein, Comstock**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

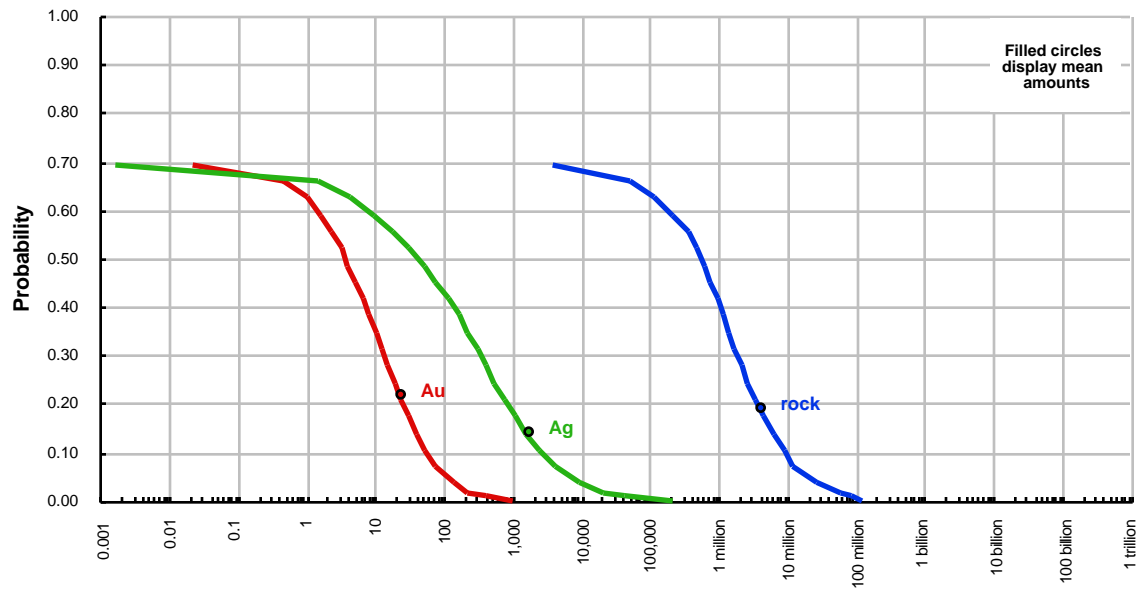
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

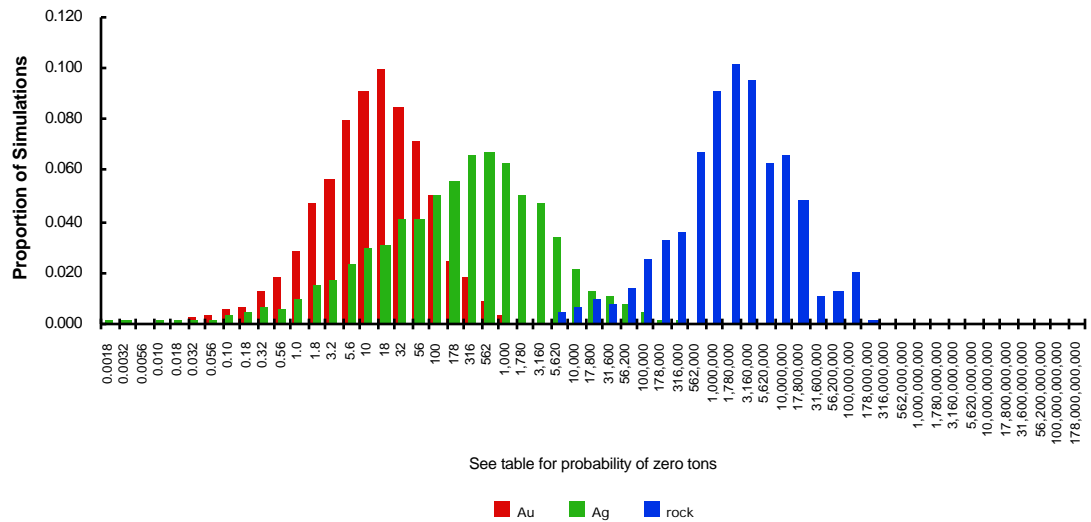
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	4	41	560,000
0.10	57	2,600	9,330,000
0.05	100	6,100	15,000,000
mean	23	1,700	4,100,000
Probability of mean	0.22	0.14	0.19
Probability of zero	0.31	0.31	0.31

The tract ID is GB22

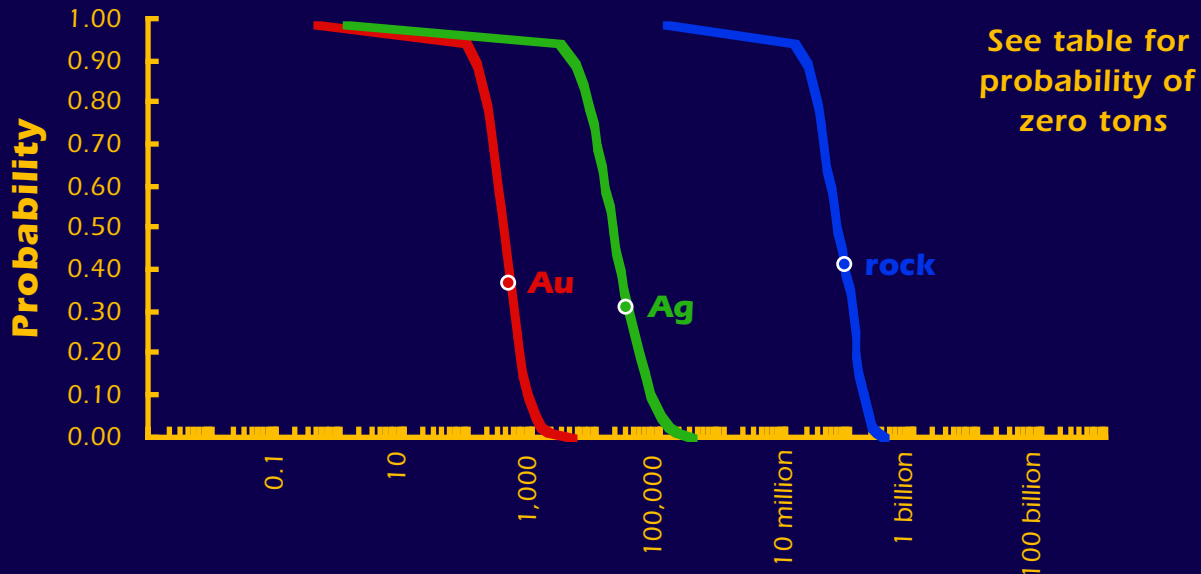
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

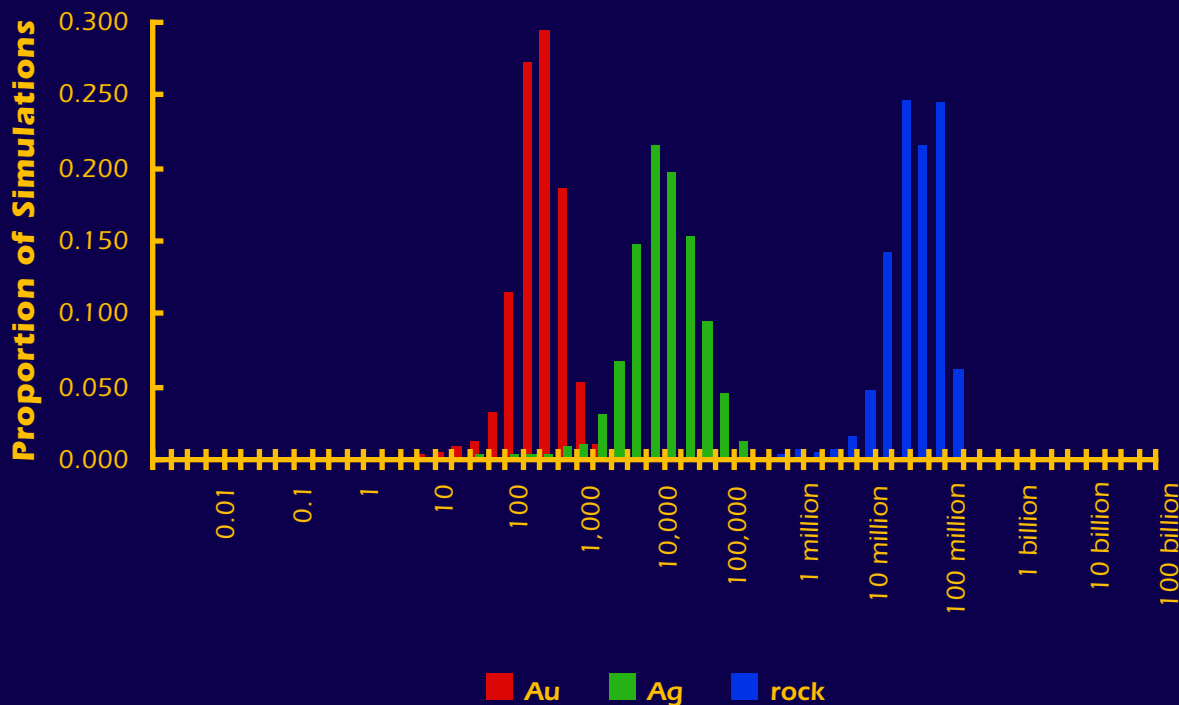


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GB23

The Mark3 Index is 16:

Epithermal vein, Comstock

There is a 90% or greater chance of 14 or more deposits.

There is a 50% or greater chance of 18 or more deposits.

There is a 10% or greater chance of 24 or more deposits.

There is a 5% or greater chance of 26 or more deposits.

There is a 1% or greater chance of 29 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	77	2,300	11,000,000
0.90	130	4,400	19,000,000
0.50	340	18,000	60,000,000
0.10	840	73,000	152,000,000
0.05	1,100	110,000	190,000,000
mean	440	31,000	76,000,000
Probability of mean	0.37	0.31	0.41
Probability of zero	0.01	0.01	0.01

The tract ID is GB23The Mark3 Index is 16: **Epithermal vein, Comstock**

There is a 90% or greater chance of 14 or more deposits.

There is a 50% or greater chance of 18 or more deposits.

There is a 10% or greater chance of 24 or more deposits.

There is a 5% or greater chance of 26 or more deposits.

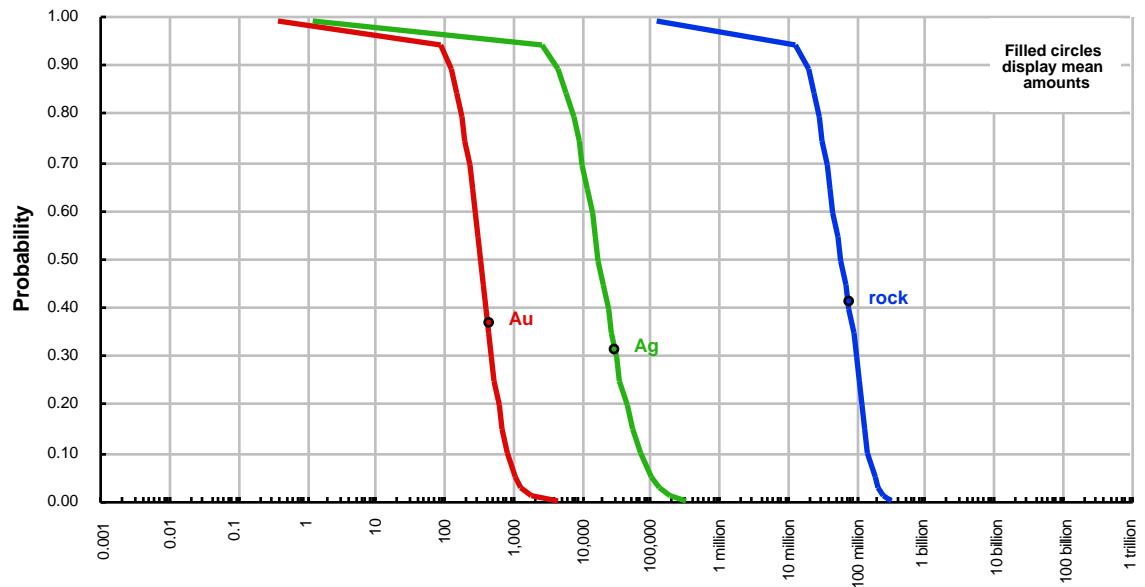
There is a 1% or greater chance of 29 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

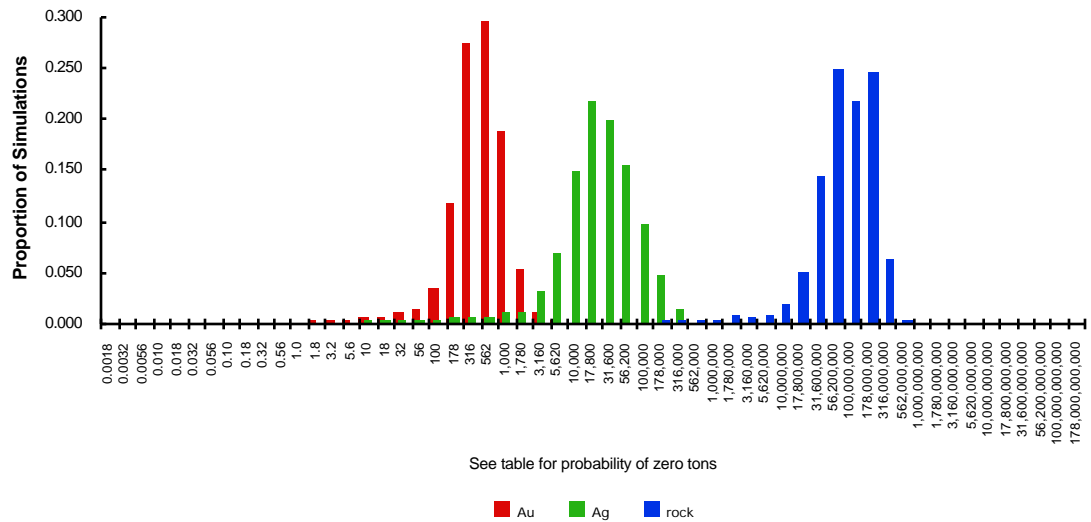
quantile	Au	Ag	rock
0.95	77	2,300	11,000,000
0.90	130	4,400	19,000,000
0.50	340	18,000	60,000,000
0.10	840	73,000	152,000,000
0.05	1,100	110,000	190,000,000
mean	440	31,000	76,000,000
Probability of mean	0.37	0.31	0.41
Probability of zero	0.01	0.01	0.01

The tract ID is GB23

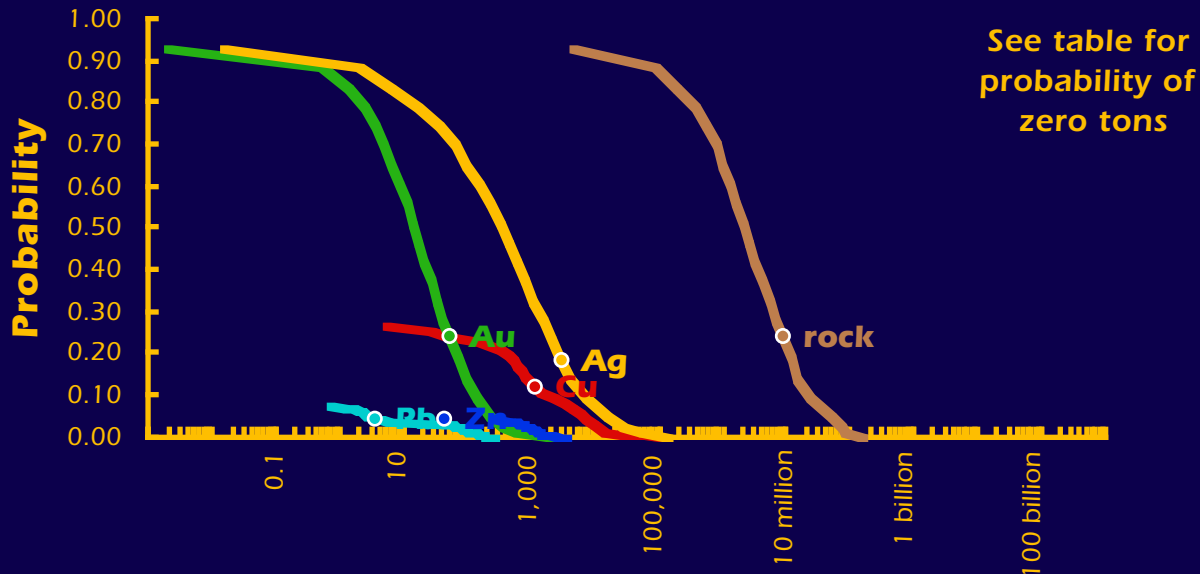
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

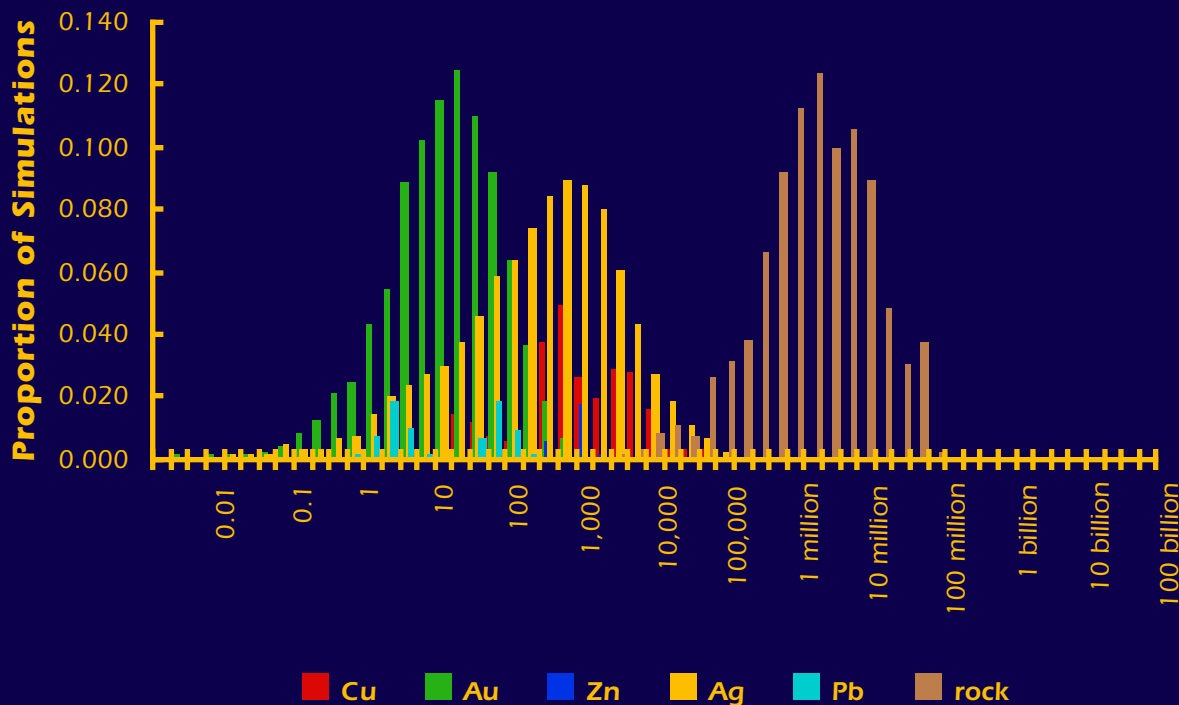


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GB24

The Mark3 Index is 25:

Epithermal vein, quartz-adularia

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

There is a 1% or greater chance of 9 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	1	0	61,000
0.50	0	14	0	340	0	2,100,000
0.10	1,800	120	0	6,200	0	21,000,000
0.05	5,900	210	0	14,000	3	46,000,000
mean	1,100	50	41	3,000	3	8,300,000
Probability of mean	0.12	0.24	0.04	0.18	0.04	0.24
Probability of zero	0.74	0.07	0.96	0.07	0.93	0.07

The tract ID is GB24The Mark3 Index is 25: **Epithermal vein, quartz-adularia**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

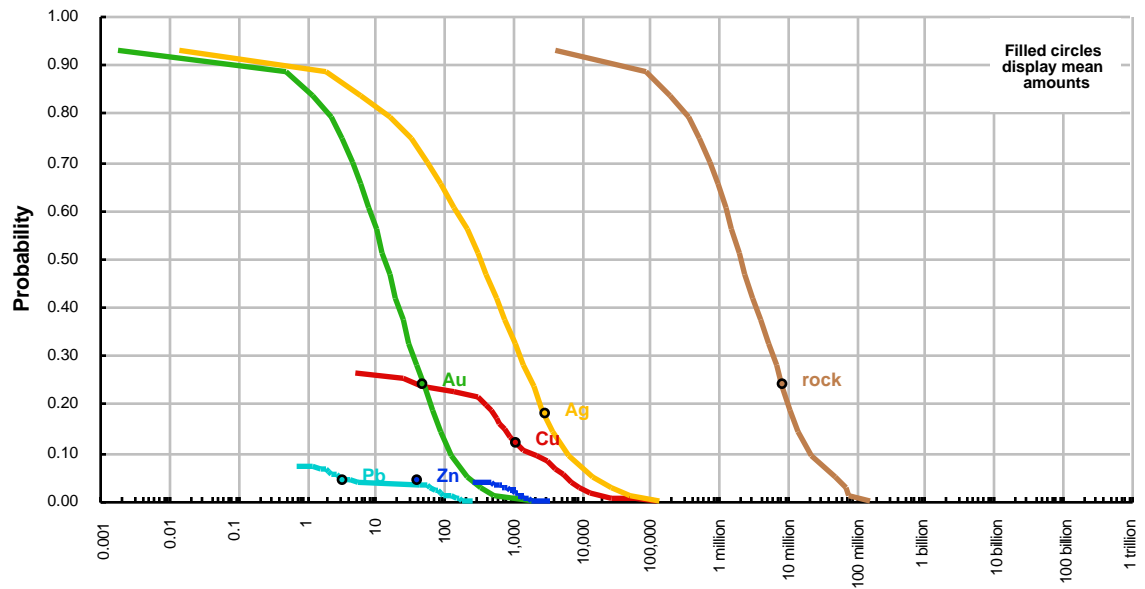
There is a 1% or greater chance of 9 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

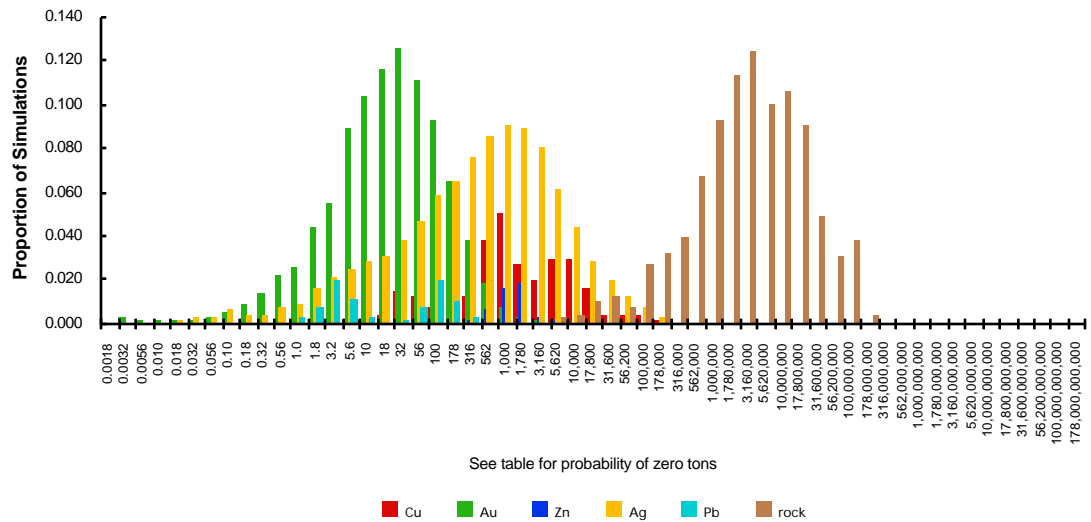
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	1	0	61,000
0.50	0	14	0	340	0	2,100,000
0.10	1,800	120	0	6,200	0	21,000,000
0.05	5,900	210	0	14,000	3	46,000,000
mean	1,100	50	41	3,000	3	8,300,000
Probability of mean	0.12	0.24	0.04	0.18	0.04	0.24
Probability of zero	0.74	0.07	0.96	0.07	0.93	0.07

The tract ID is GB24

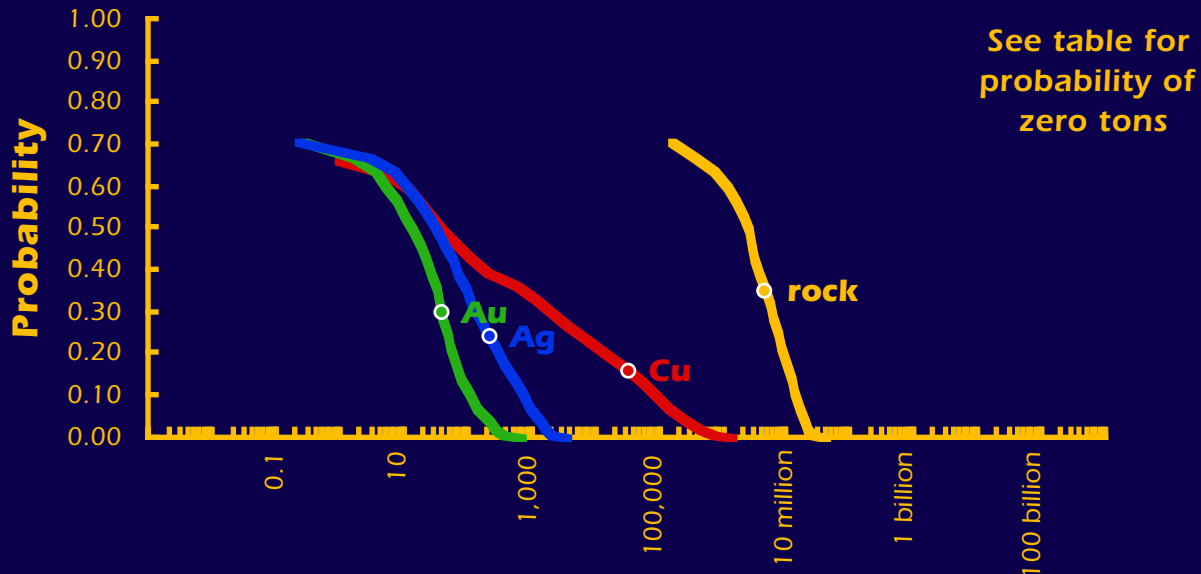
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

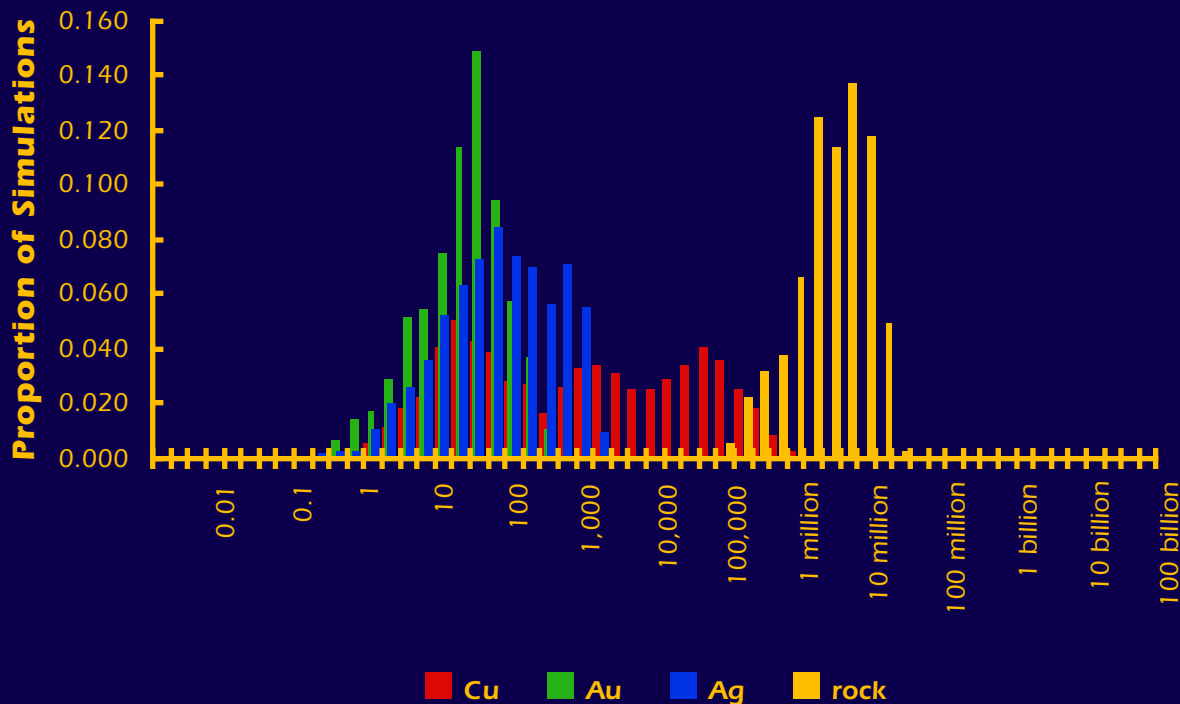


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GB25

The Mark3 Index is 38:

Epithermal vein, quartz-alunite

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	37	13	29	2,300,000
0.10	85,000	100	749	14,000,000
0.05	190,000	170	1,200	18,000,000
mean	33,000	38	210	4,600,000
Probability of mean	0.16	0.30	0.24	0.35
Probability of zero	0.34	0.29	0.29	0.29

The tract ID is GB25The Mark3 Index is 38: **Epithermal vein, quartz-alunite**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

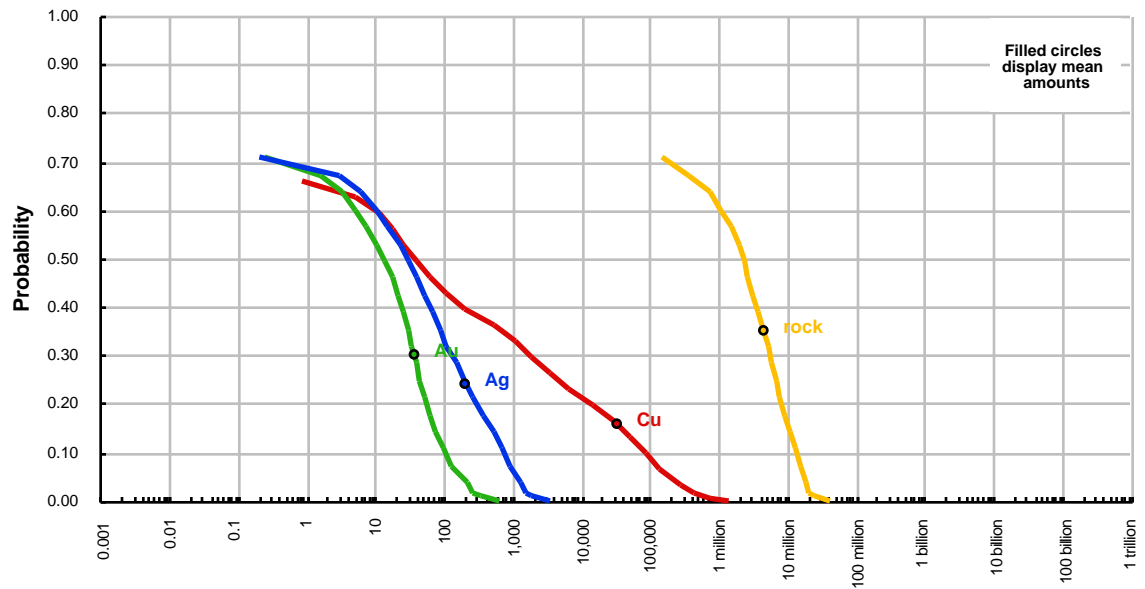
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

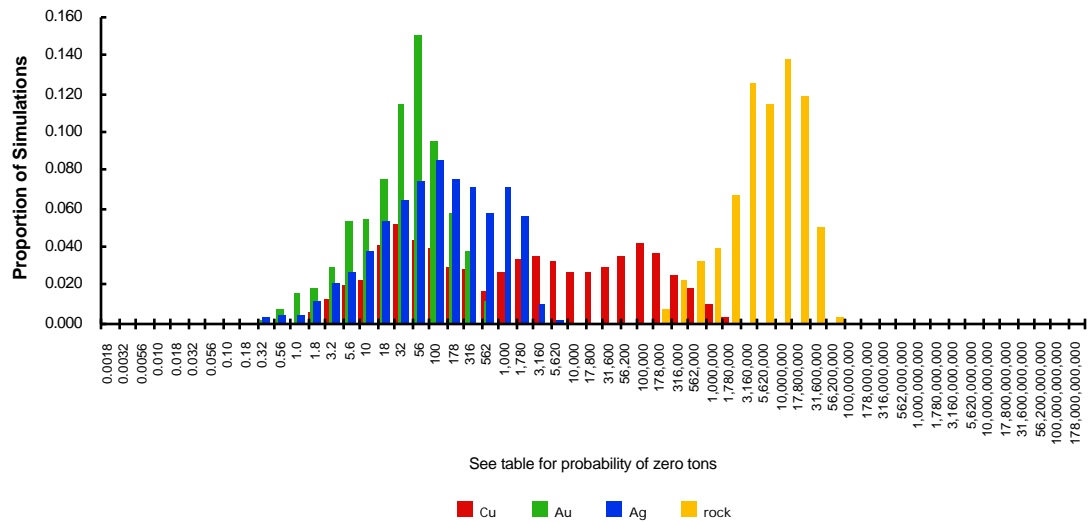
quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	37	13	29	2,300,000
0.10	85,000	100	749	14,000,000
0.05	190,000	170	1,200	18,000,000
mean	33,000	38	210	4,600,000
Probability of mean	0.16	0.30	0.24	0.35
Probability of zero	0.34	0.29	0.29	0.29

The tract ID is GB25

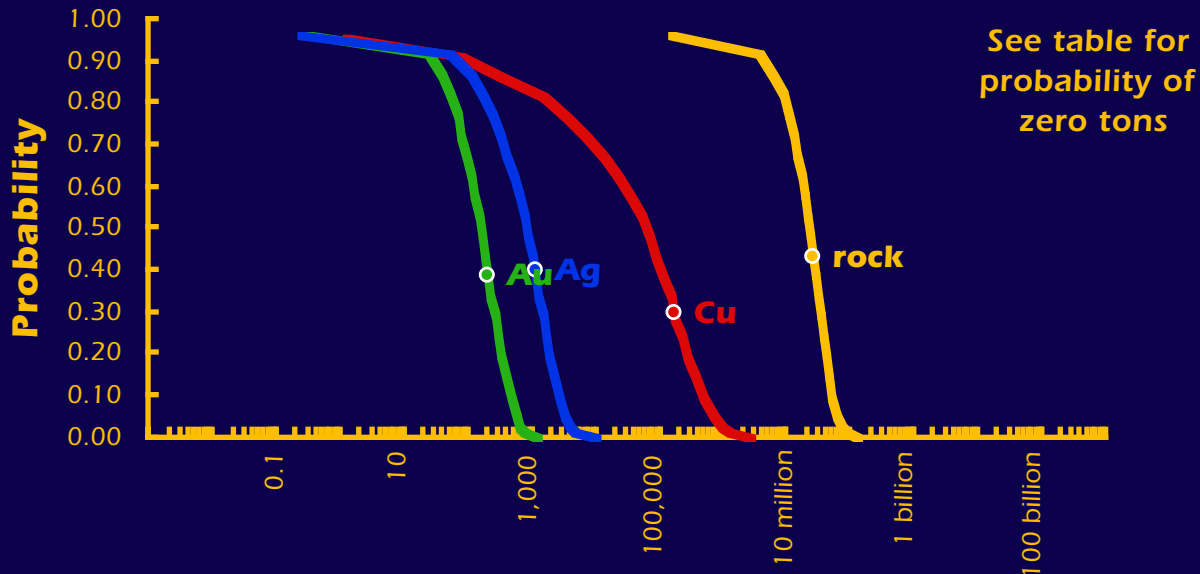
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

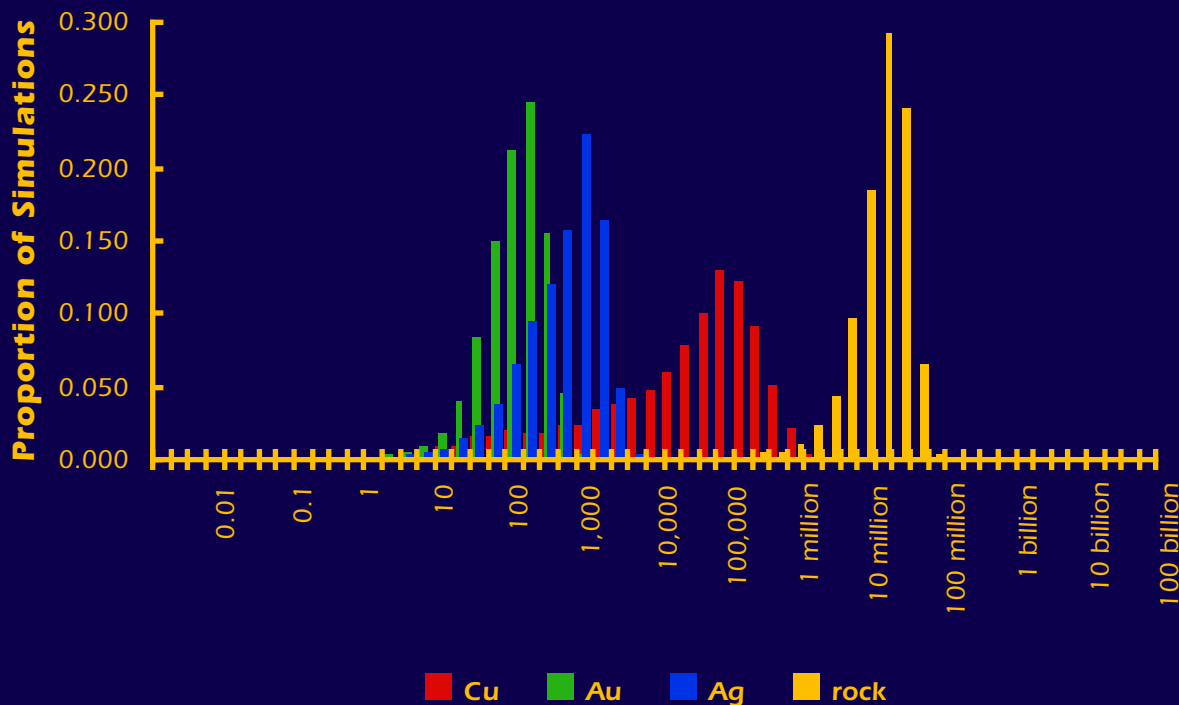


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GB26

The Mark3 Index is 38:

Epithermal vein, quartz-alunite

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 5 or more deposits.

There is a 10% or greater chance of 9 or more deposits.

There is a 5% or greater chance of 12 or more deposits.

There is a 1% or greater chance of 15 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Ag	rock
0.95	10	7	14	1,400,000
0.90	110	28	69	4,400,000
0.50	60,000	160	820	22,000,000
0.10	460,000	440	2,520	50,000,000
0.05	690,000	550	3,200	60,000,000
mean	160,000	200	1,100	25,000,000
Probability of mean	0.30	0.39	0.40	0.43
Probability of zero	0.04	0.04	0.04	0.04

The tract ID is GB26The Mark3 Index is 38: **Epithermal vein, quartz-alunite**

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 5 or more deposits.

There is a 10% or greater chance of 9 or more deposits.

There is a 5% or greater chance of 12 or more deposits.

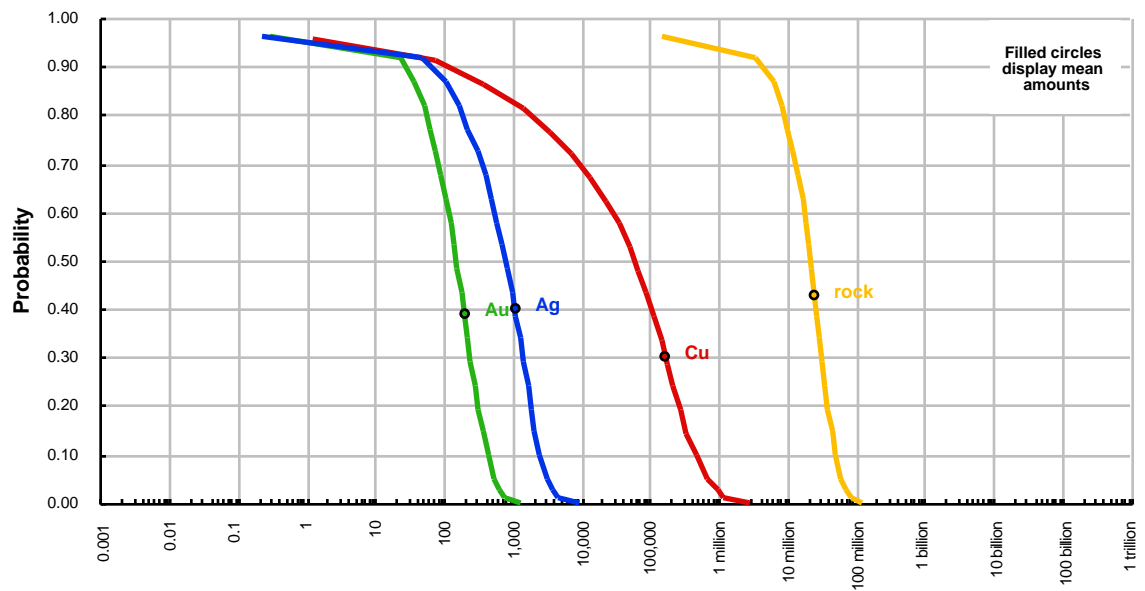
There is a 1% or greater chance of 15 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

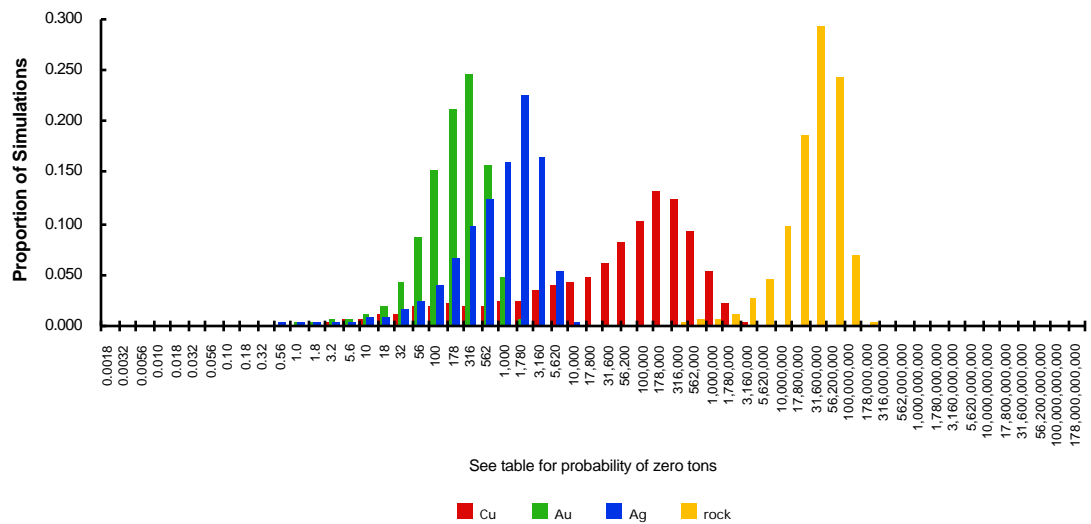
quantile	Cu	Au	Ag	rock
0.95	10	7	14	1,400,000
0.90	110	28	69	4,400,000
0.50	60,000	160	820	22,000,000
0.10	460,000	440	2,520	50,000,000
0.05	690,000	550	3,200	60,000,000
mean	160,000	200	1,100	25,000,000
Probability of mean	0.30	0.39	0.40	0.43
Probability of zero	0.04	0.04	0.04	0.04

The tract ID is GB26

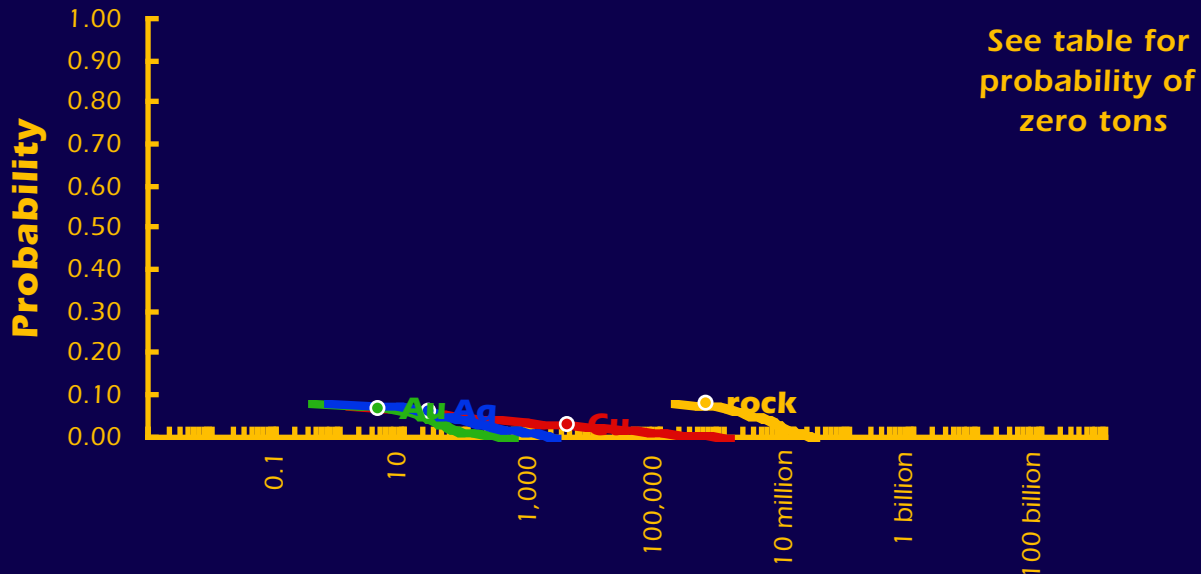
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

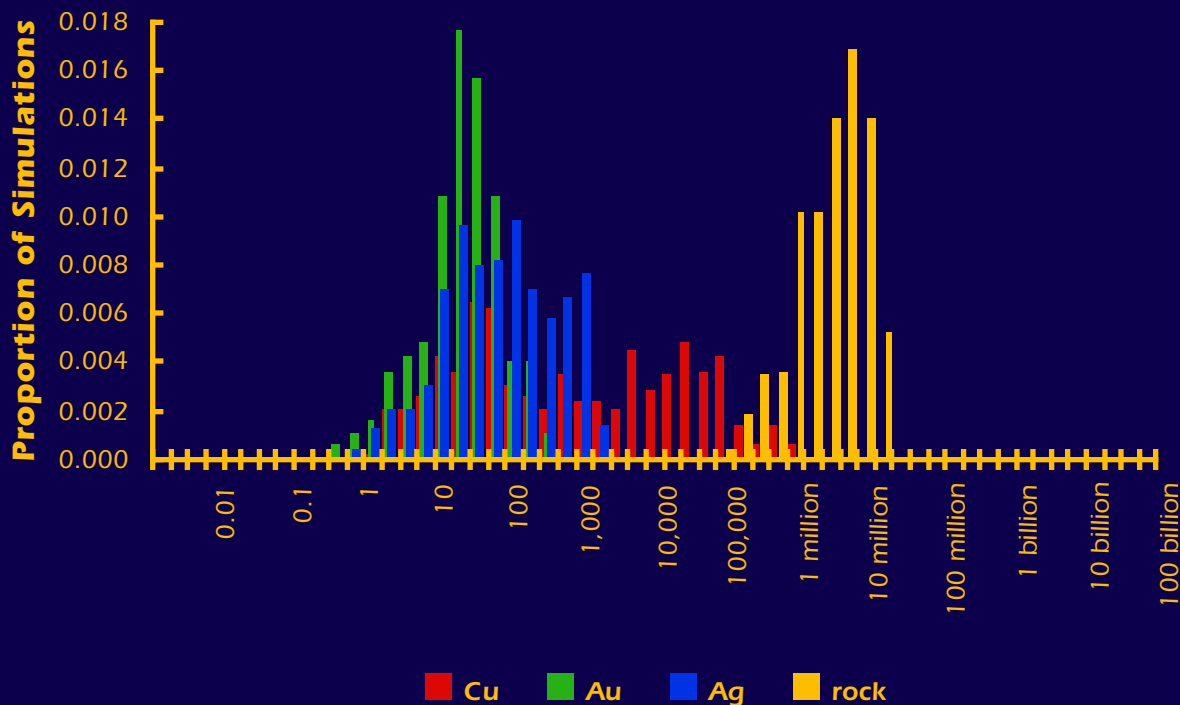


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GB27

The Mark3 Index is 38:

Epithermal vein, quartz-alunite

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	63	20	45	3,200,000
mean	3,500	4	24	530,000
Probability of mean	0.03	0.07	0.06	0.08
Probability of zero	0.93	0.92	0.92	0.92

The tract ID is GB27The Mark3 Index is 38: **Epithermal vein, quartz-alunite**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

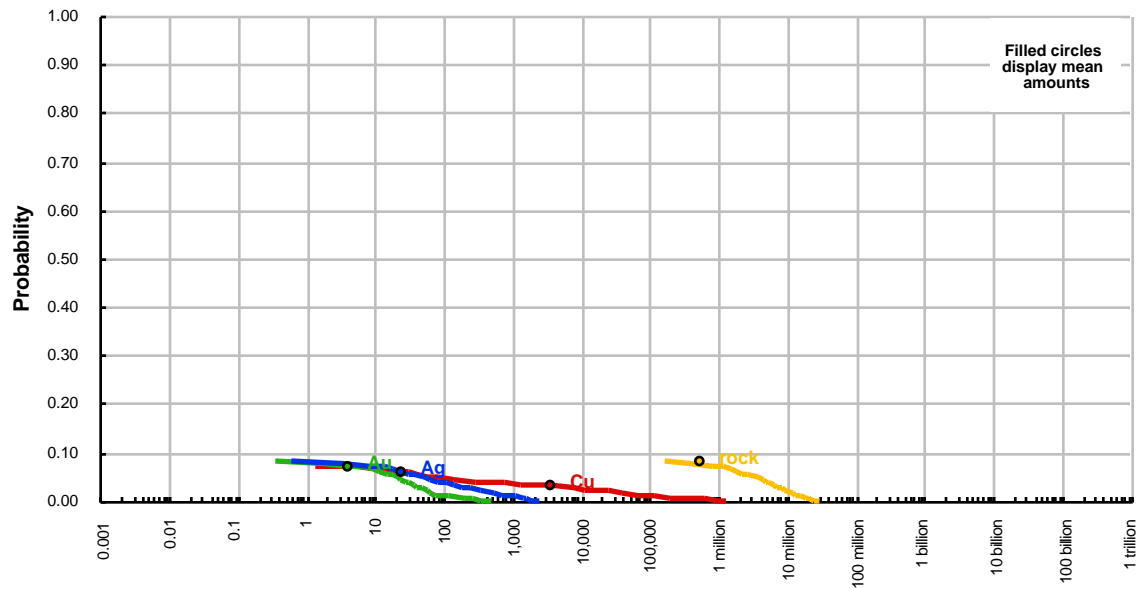
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

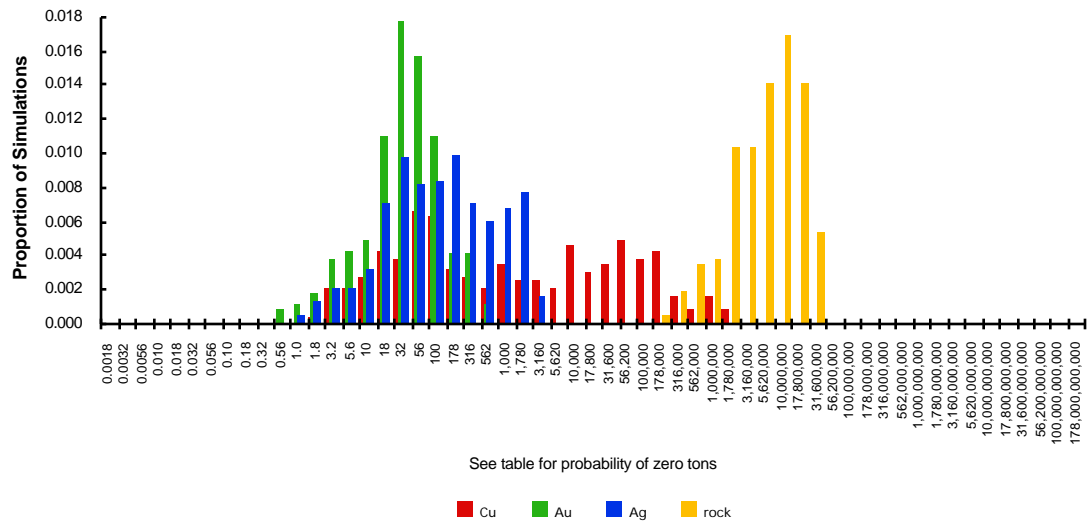
quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	63	20	45	3,200,000
mean	3,500	4	24	530,000
Probability of mean	0.03	0.07	0.06	0.08
Probability of zero	0.93	0.92	0.92	0.92

The tract ID is GB27

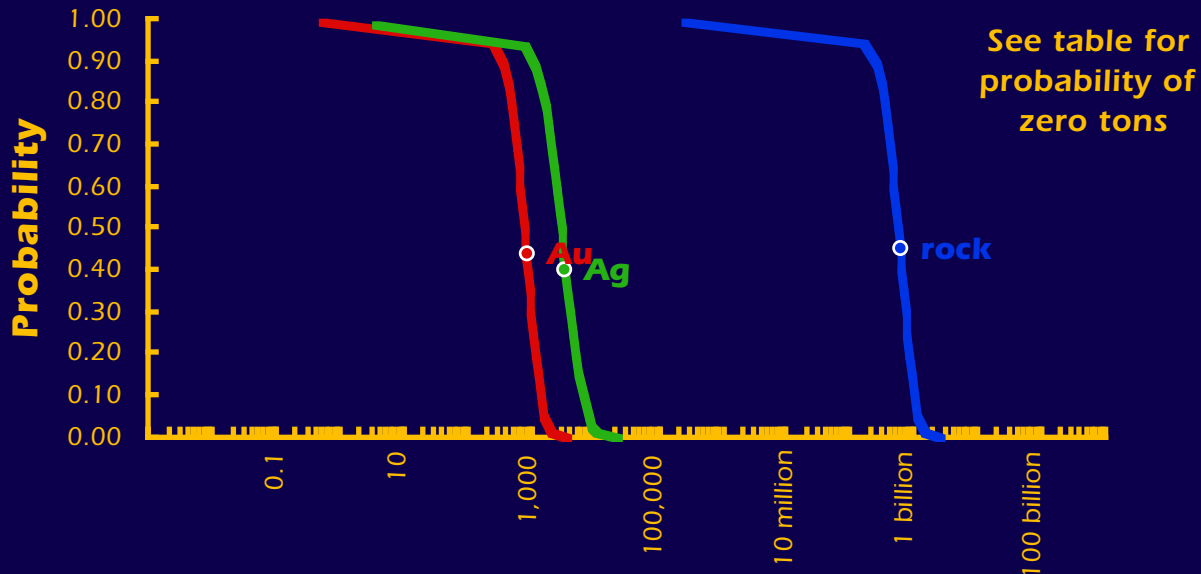
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

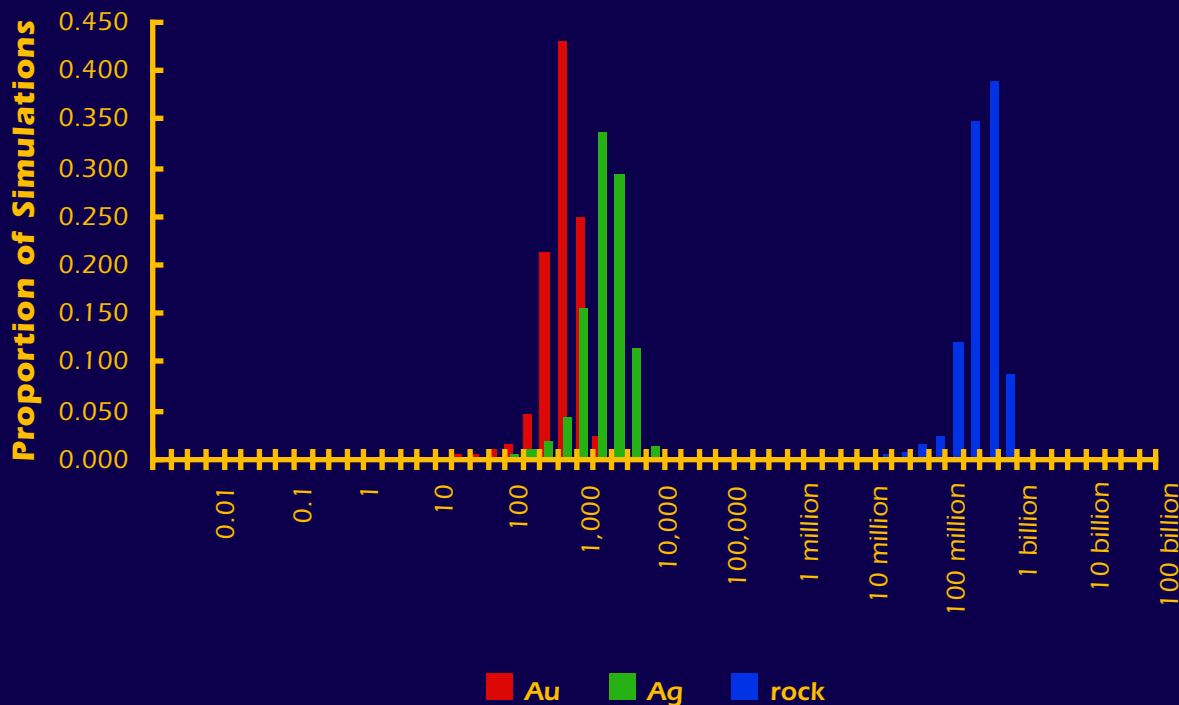


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GB28

The Mark3 Index is 45:

Hot spring Au-Ag

There is a 90% or greater chance of 13 or more deposits.

There is a 50% or greater chance of 18 or more deposits.

There is a 10% or greater chance of 21 or more deposits.

There is a 5% or greater chance of 25 or more deposits.

There is a 1% or greater chance of 29 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	220	610	150,000,000
0.90	340	1,100	240,000,000
0.50	740	2,800	540,000,000
0.10	1,300	6,100	980,000,000
0.05	1,600	7,400	1,100,000,000
mean	800	3,300	580,000,000
Probability of mean	0.44	0.40	0.45
Probability of zero	0.01	0.01	0.01

The tract ID is GB28The Mark3 Index is 45: **Hot spring Au-Ag**

There is a 90% or greater chance of 13 or more deposits.

There is a 50% or greater chance of 18 or more deposits.

There is a 10% or greater chance of 21 or more deposits.

There is a 5% or greater chance of 25 or more deposits.

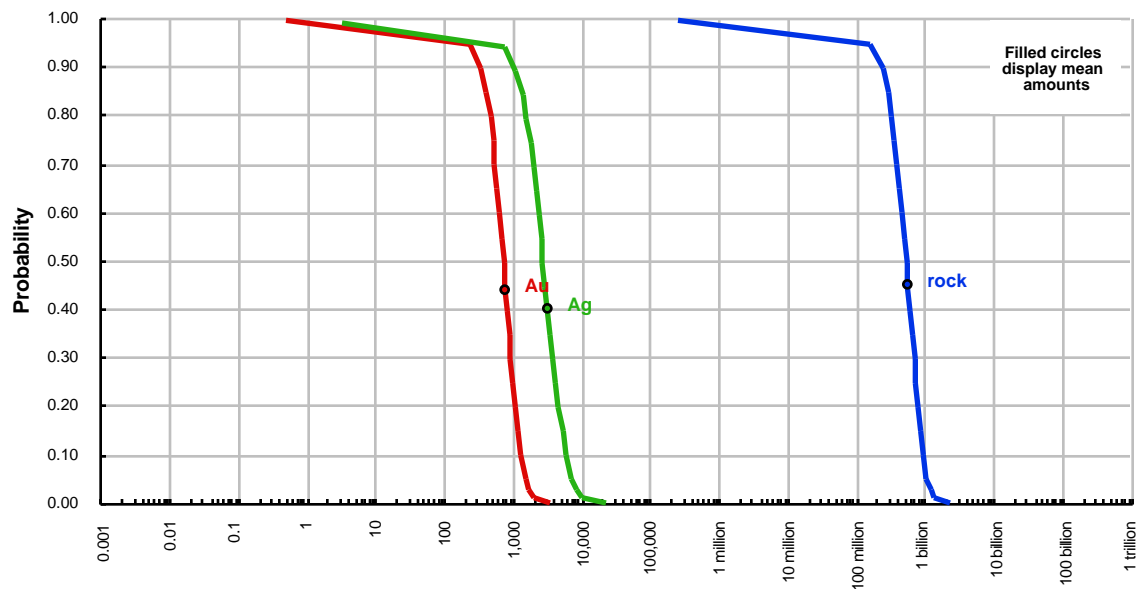
There is a 1% or greater chance of 29 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

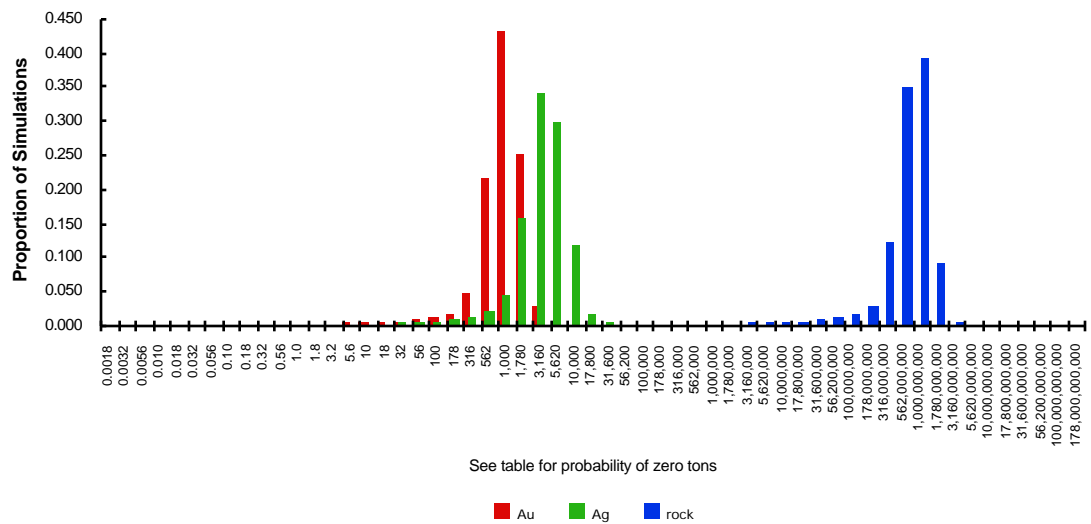
quantile	Au	Ag	rock
0.95	220	610	150,000,000
0.90	340	1,100	240,000,000
0.50	740	2,800	540,000,000
0.10	1,300	6,100	980,000,000
0.05	1,600	7,400	1,100,000,000
mean	800	3,300	580,000,000
Probability of mean	0.44	0.40	0.45
Probability of zero	0.01	0.01	0.01

The tract ID is GB28

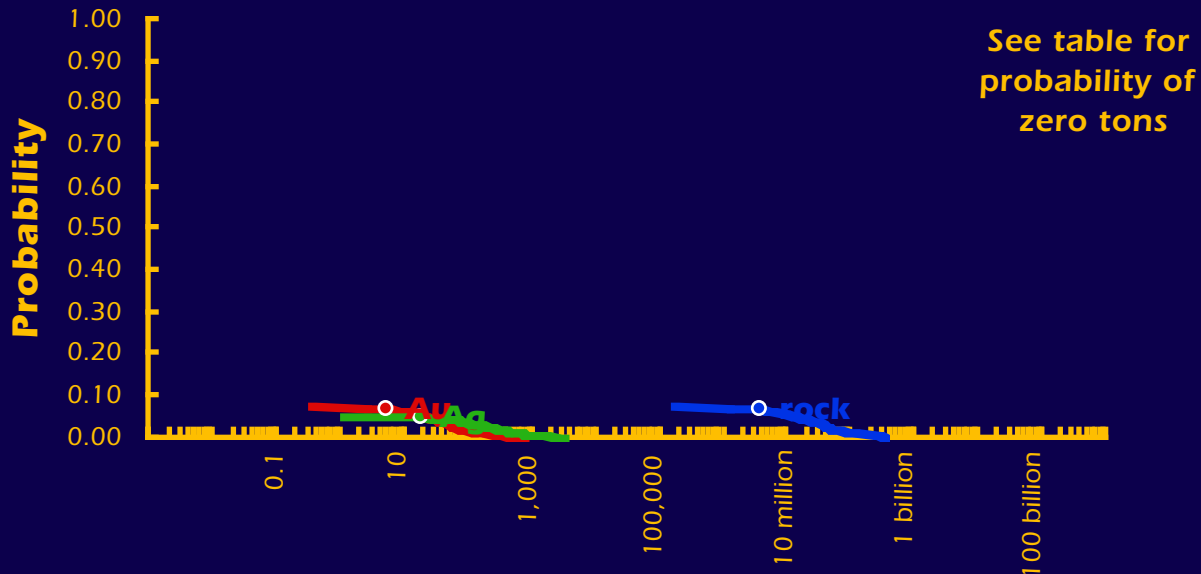
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

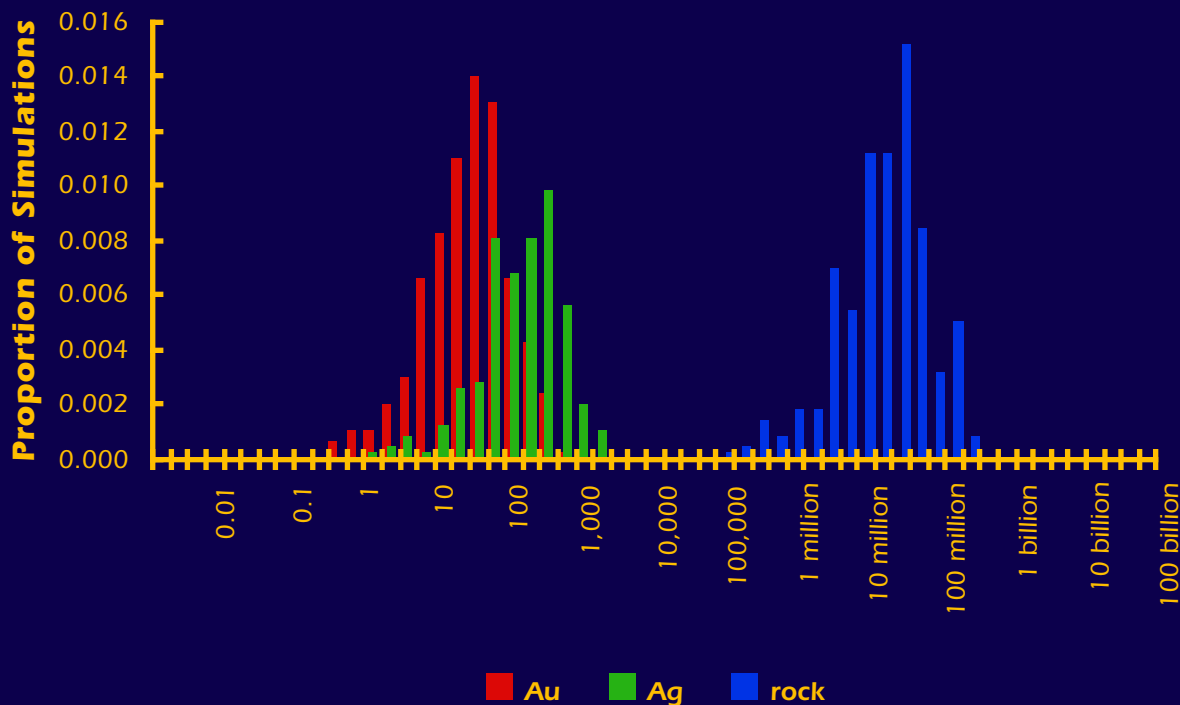


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GB29

The Mark3 Index is 45:

Hot spring Au-Ag

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	0	0
0.05	19	0	13,000,000
mean	5	17	3,700,000
Probability of mean	0.07	0.05	0.07
Probability of zero	0.93	0.95	0.93

The tract ID is GB29The Mark3 Index is 45: **Hot spring Au-Ag**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

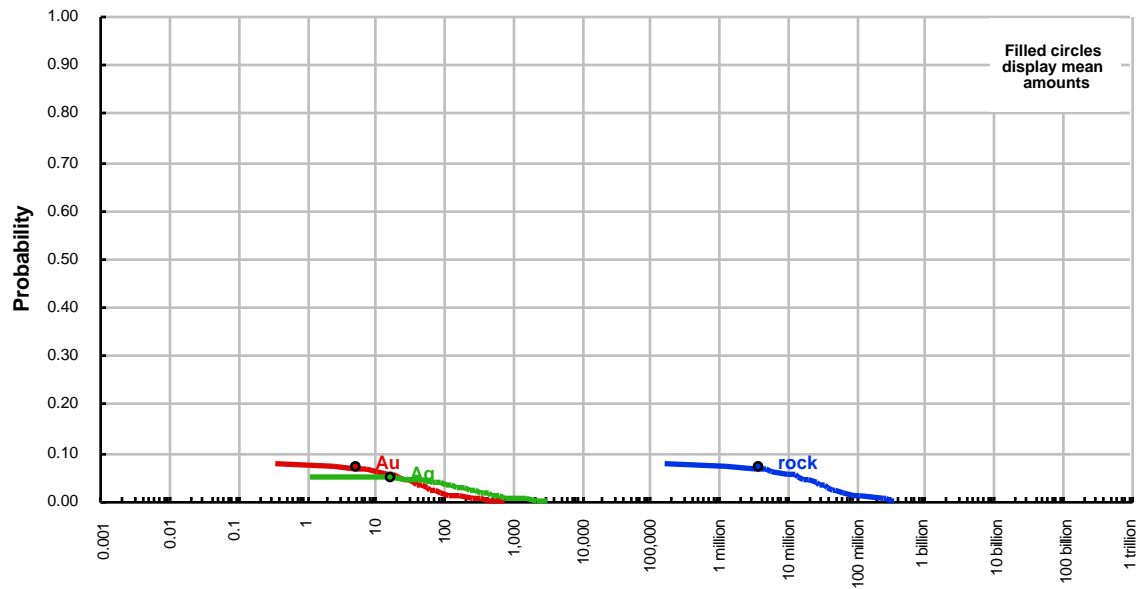
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

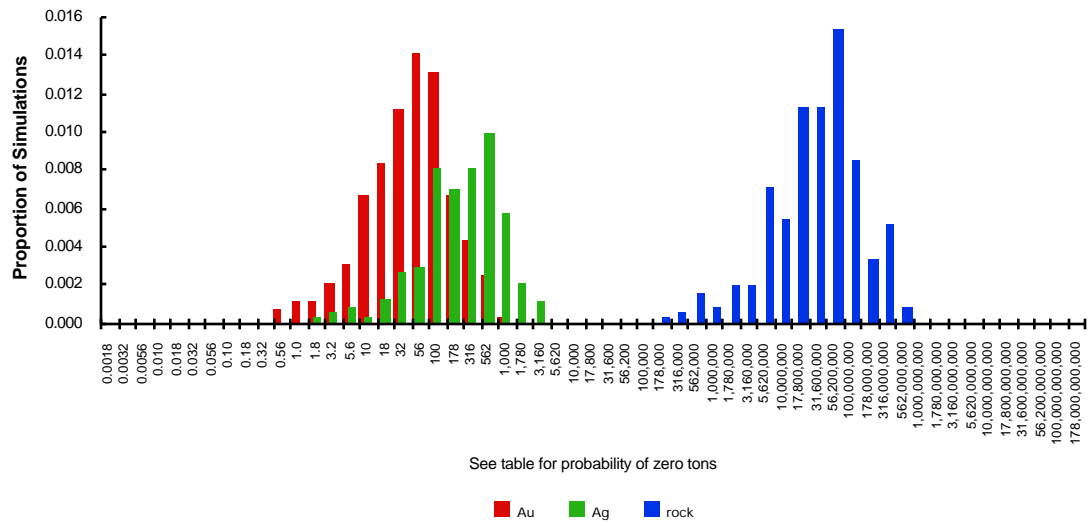
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	0	0
0.05	19	0	13,000,000
mean	5	17	3,700,000
Probability of mean	0.07	0.05	0.07
Probability of zero	0.93	0.95	0.93

The tract ID is GB29

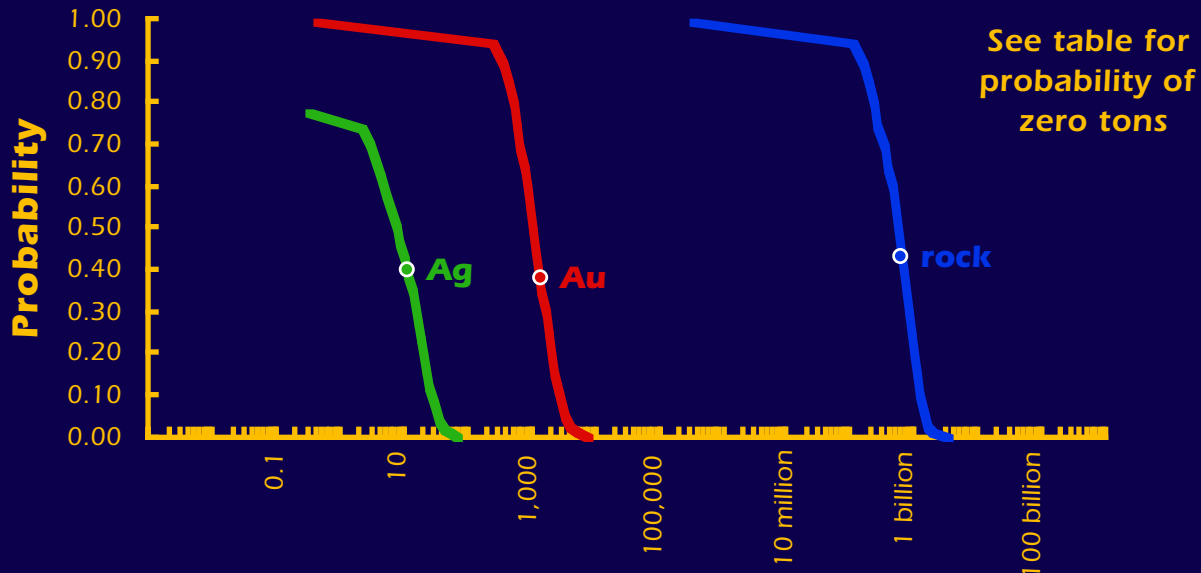
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

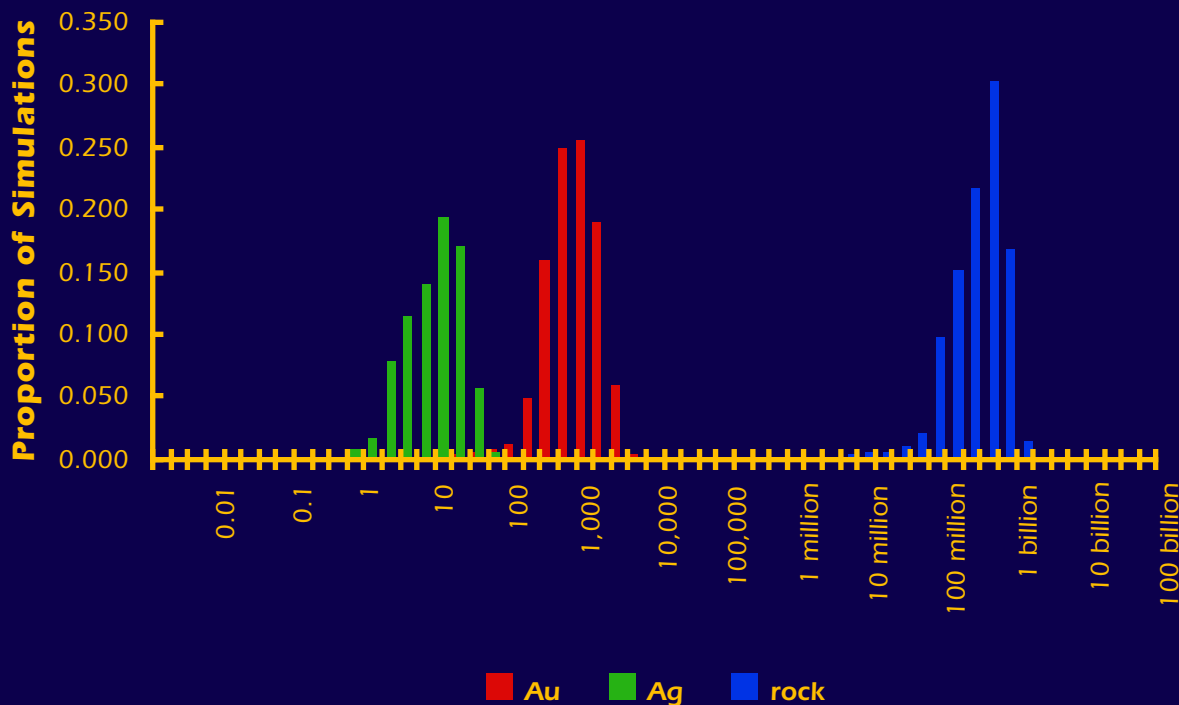


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GB30

The Mark3 Index is 17:

Sediment-hosted Au

There is a 90% or greater chance of 15 or more deposits.

There is a 50% or greater chance of 21 or more deposits.

There is a 10% or greater chance of 27 or more deposits.

There is a 5% or greater chance of 30 or more deposits.

There is a 1% or greater chance of 33 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	220	0	98,000,000
0.90	340	0	150,000,000
0.50	1,000	7	540,000,000
0.10	2,700	26	1,200,000,000
0.05	3,400	33	1,400,000,000
mean	1,300	11	610,000,000
Probability of mean	0.38	0.40	0.43
Probability of zero	0.01	0.22	0.01

The tract ID is GB30The Mark3 Index is 17: **Sediment-hosted Au**

There is a 90% or greater chance of 15 or more deposits.

There is a 50% or greater chance of 21 or more deposits.

There is a 10% or greater chance of 27 or more deposits.

There is a 5% or greater chance of 30 or more deposits.

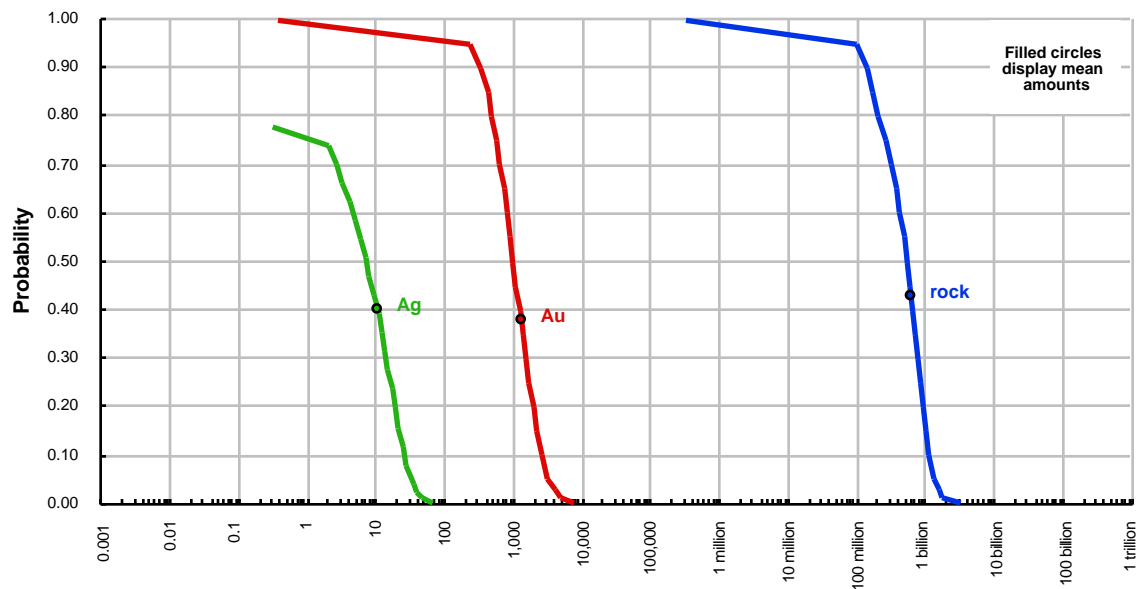
There is a 1% or greater chance of 33 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

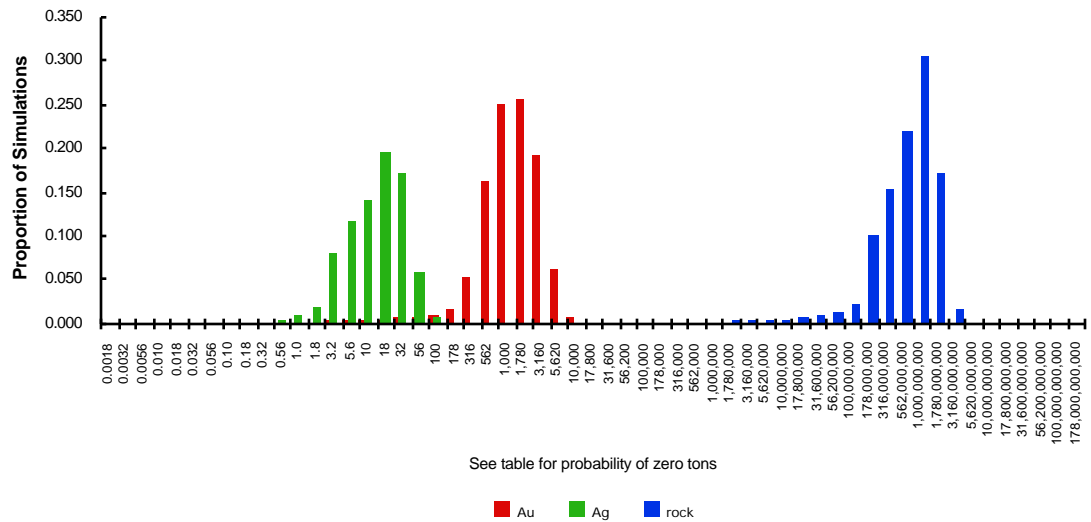
quantile	Au	Ag	rock
0.95	220	0	98,000,000
0.90	340	0	150,000,000
0.50	1,000	7	540,000,000
0.10	2,700	26	1,200,000,000
0.05	3,400	33	1,400,000,000
mean	1,300	11	610,000,000
Probability of mean	0.38	0.40	0.43
Probability of zero	0.01	0.22	0.01

The tract ID is GB30

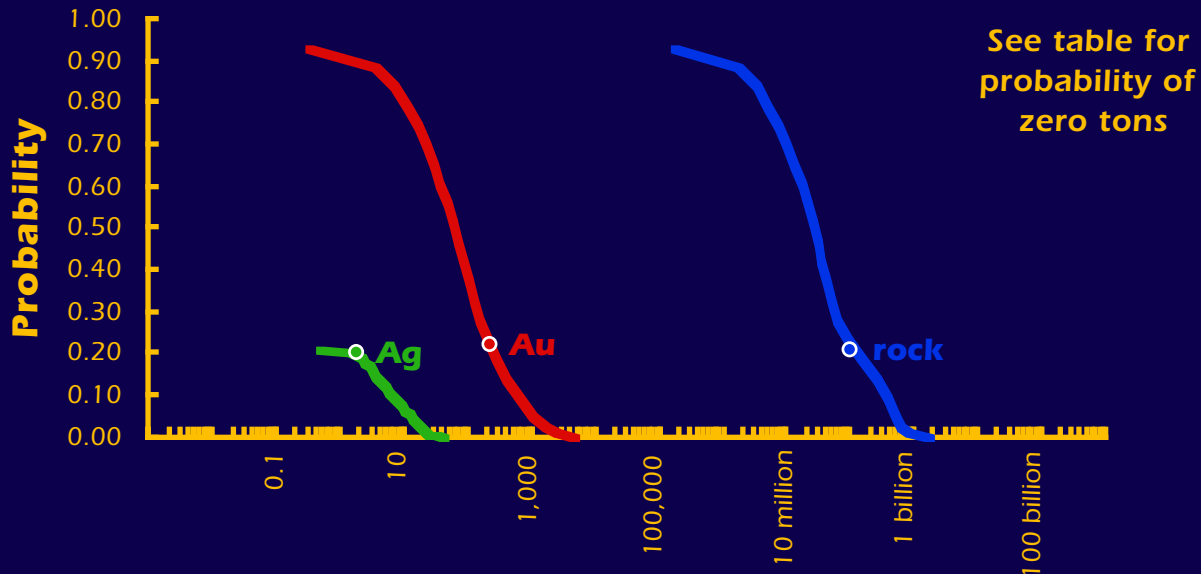
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

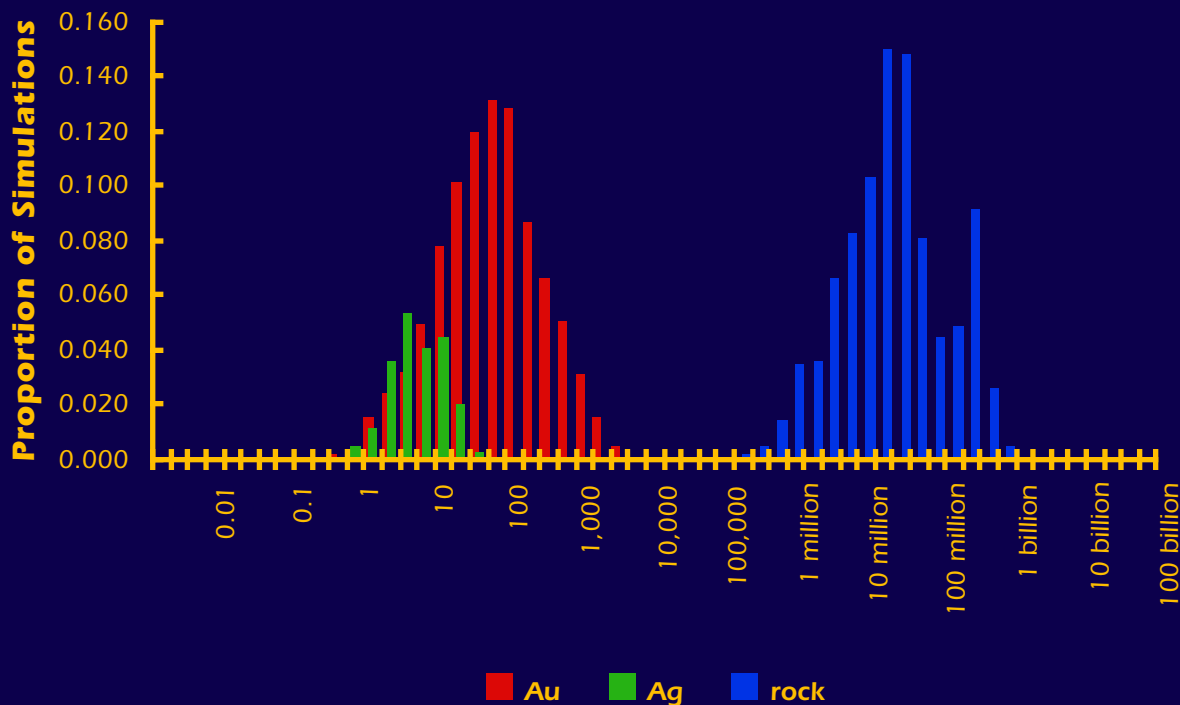


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GB31

The Mark3 Index is 17:
Sediment-hosted Au

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 9 or more deposits.

There is a 1% or greater chance of 16 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	3	0	1,300,000
0.50	59	0	26,000,000
0.10	570	6	375,000,000
0.05	1,000	13	500,000,000
mean	210	2	99,000,000
Probability of mean	0.22	0.20	0.21
Probability of zero	0.07	0.79	0.07

The tract ID is GB31The Mark3 Index is 17: **Sediment-hosted Au**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 9 or more deposits.

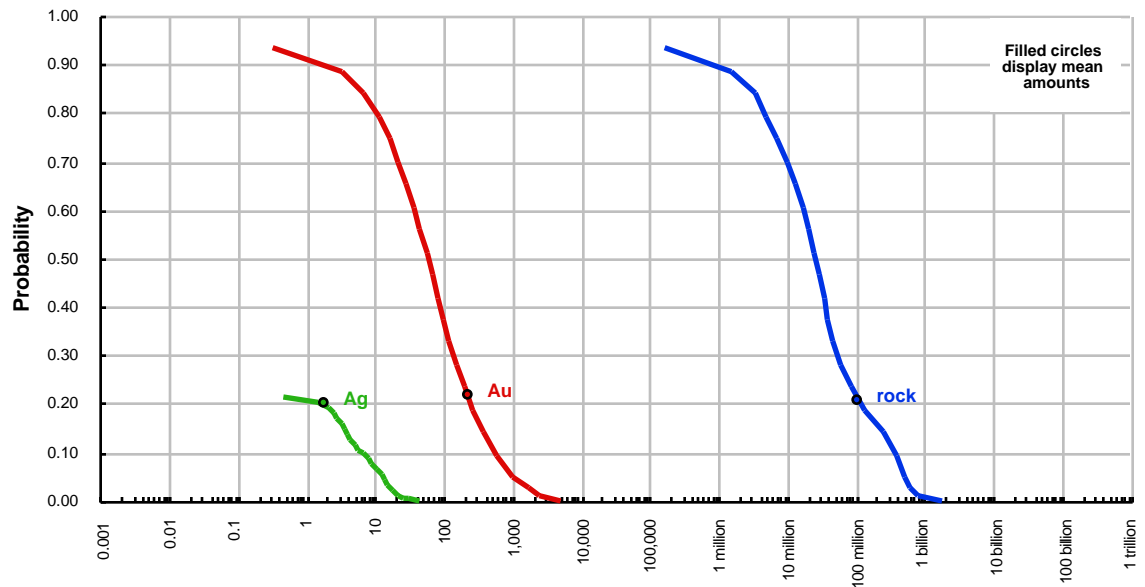
There is a 1% or greater chance of 16 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

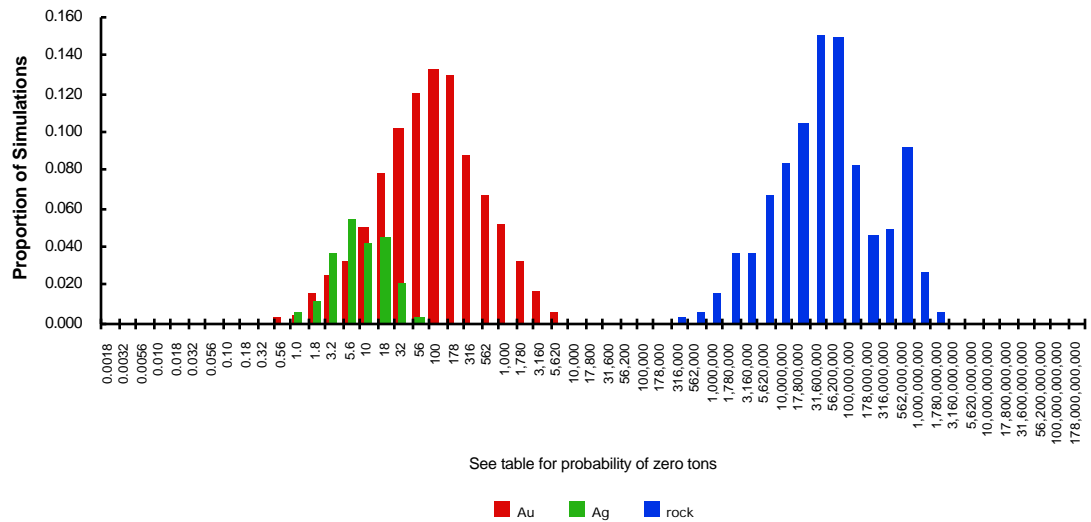
quantile	Au	Ag	rock
0.95	0	0	0
0.90	3	0	1,300,000
0.50	59	0	26,000,000
0.10	570	6	375,000,000
0.05	1,000	13	500,000,000
mean	210	2	99,000,000
Probability of mean	0.22	0.20	0.21
Probability of zero	0.07	0.79	0.07

The tract ID is GB31

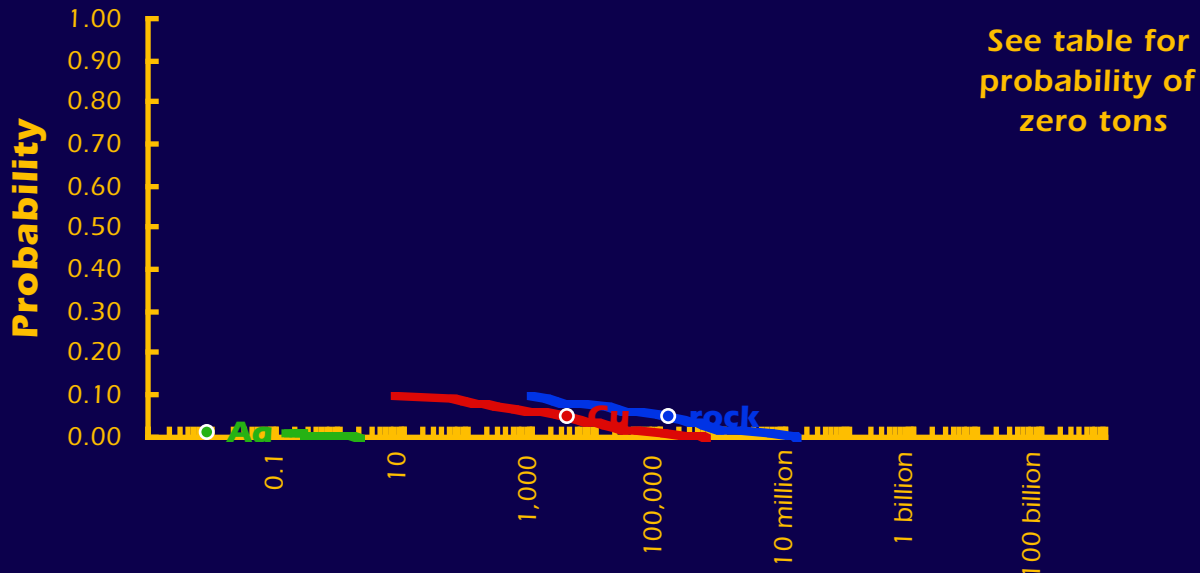
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

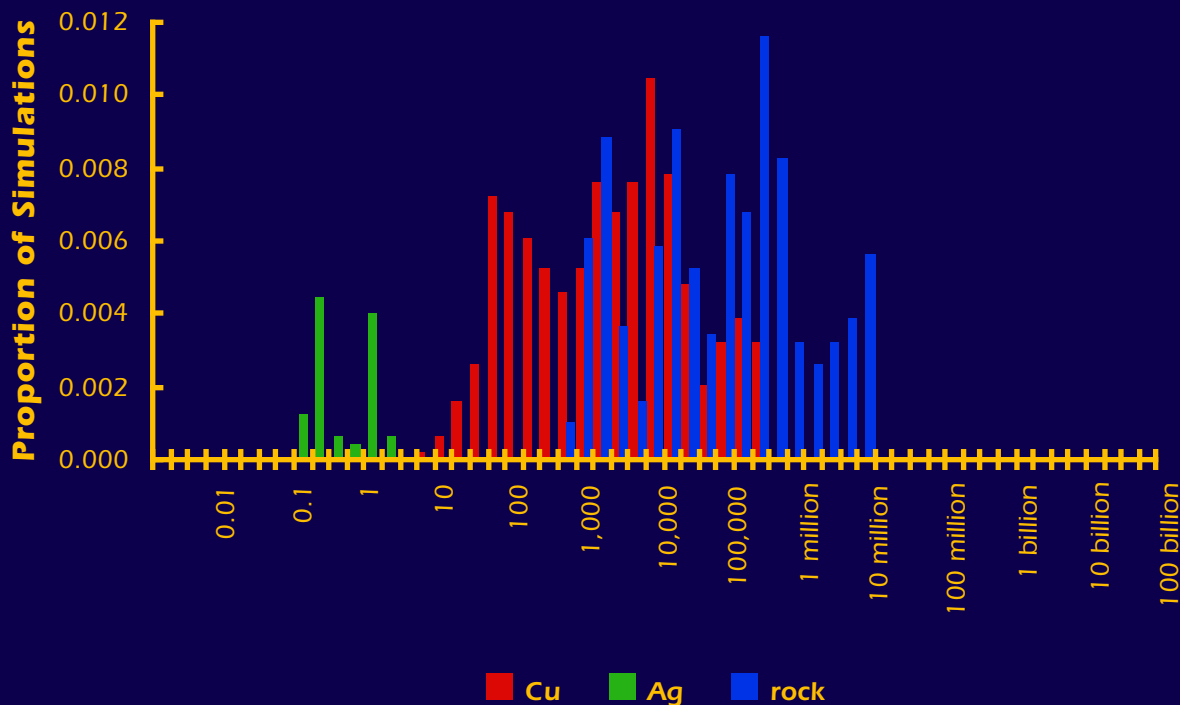


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GB32

The Mark3 Index is 97:

Sediment-hosted Cu, red-bed

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	0	0
0.05	3,100	0	120,000
mean	3,400	0	130,000
Probability of mean	0.05	0.01	0.05
Probability of zero	0.90	0.99	0.90

The tract ID is GB32The Mark3 Index is 97: **Sediment-hosted Cu, red-bed**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

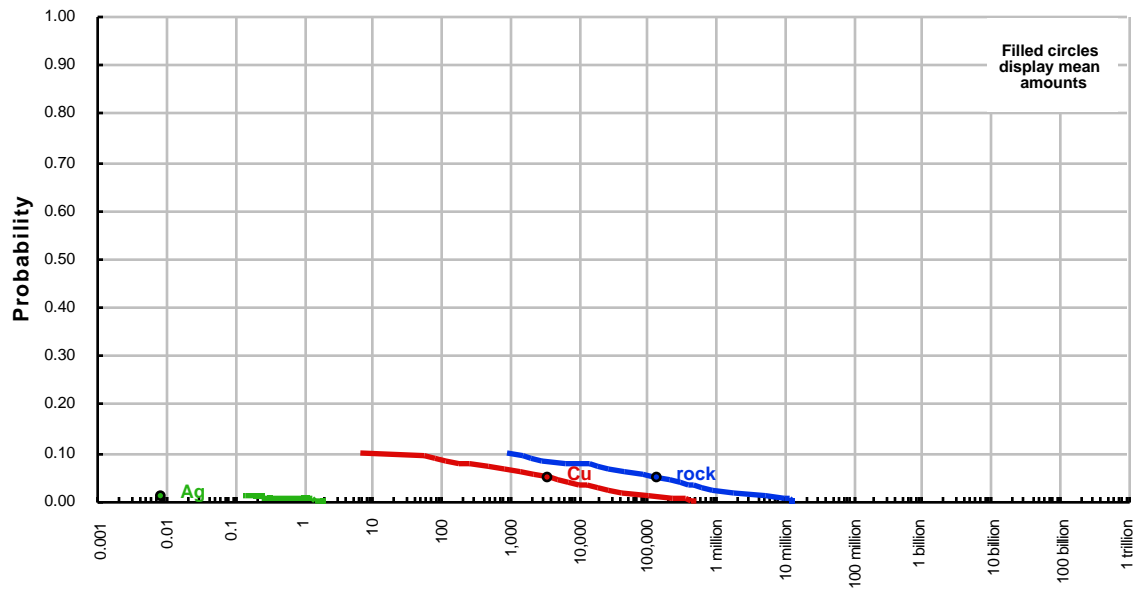
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

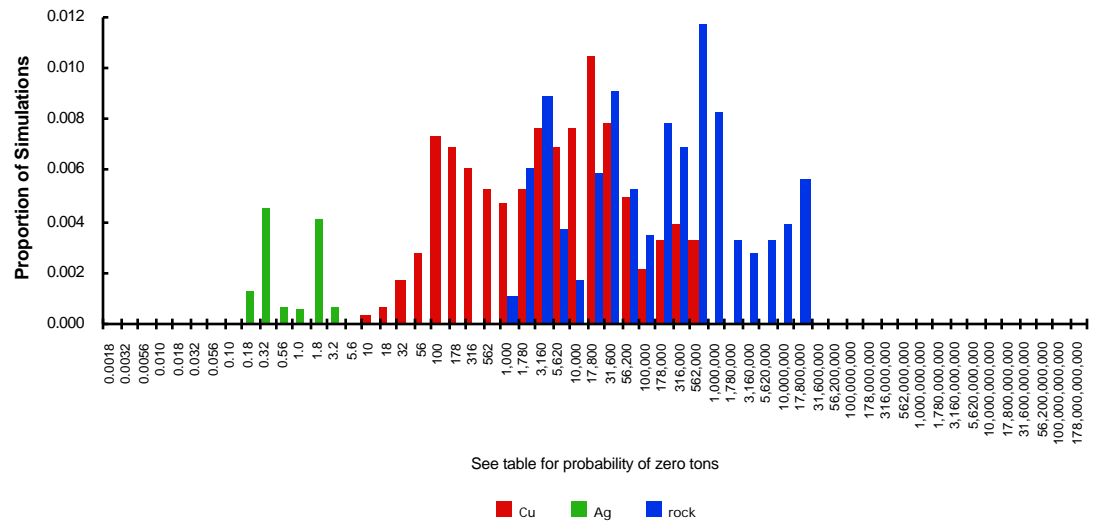
quantile	Cu	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	0	0
0.05	3,100	0	120,000
mean	3,400	0	130,000
Probability of mean	0.05	0.01	0.05
Probability of zero	0.90	0.99	0.90

The tract ID is GB32

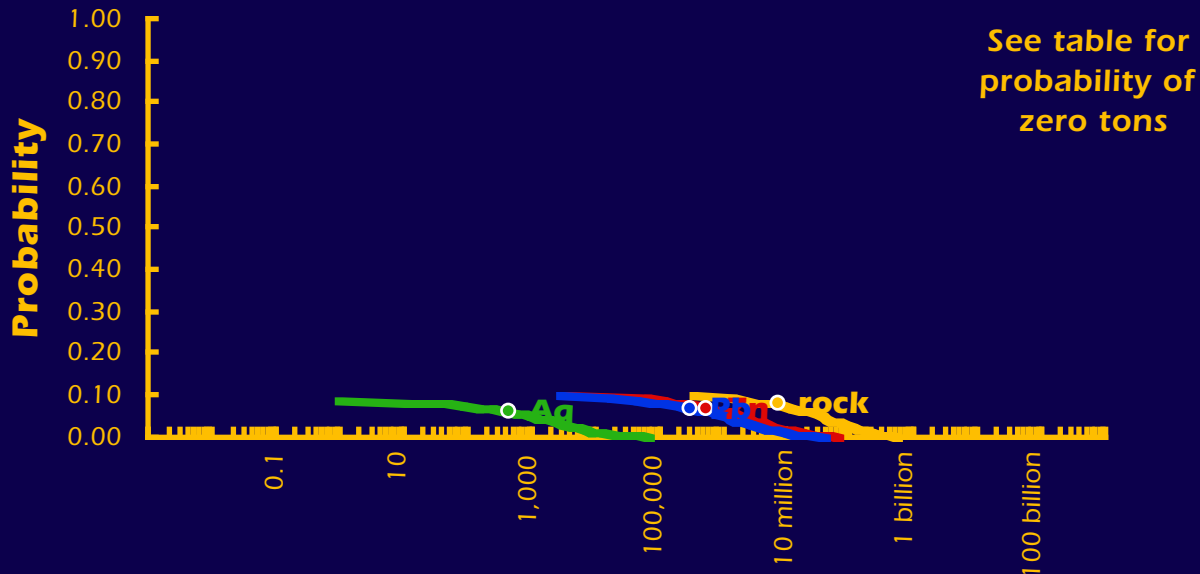
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

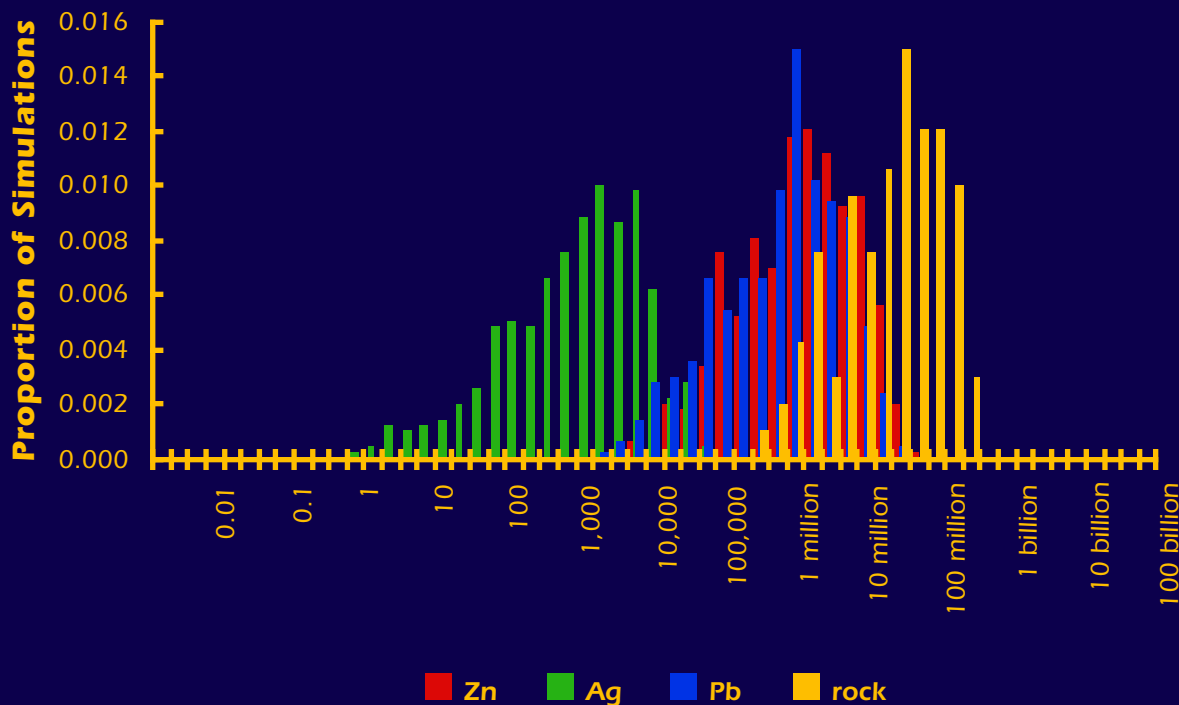


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GB33

The Mark3 Index is 13:

Sedimentary exhalative Zn-Pb

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Zn	Ag	Pb	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	1,800,000	960	1,100,000	34,000,000
mean	530,000	420	300,000	7,100,000
Probability of mean	0.07	0.06	0.07	0.08
Probability of zero	0.90	0.91	0.90	0.90

The tract ID is GB33The Mark3 Index is 13: **Sedimentary exhalative Zn-Pb**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

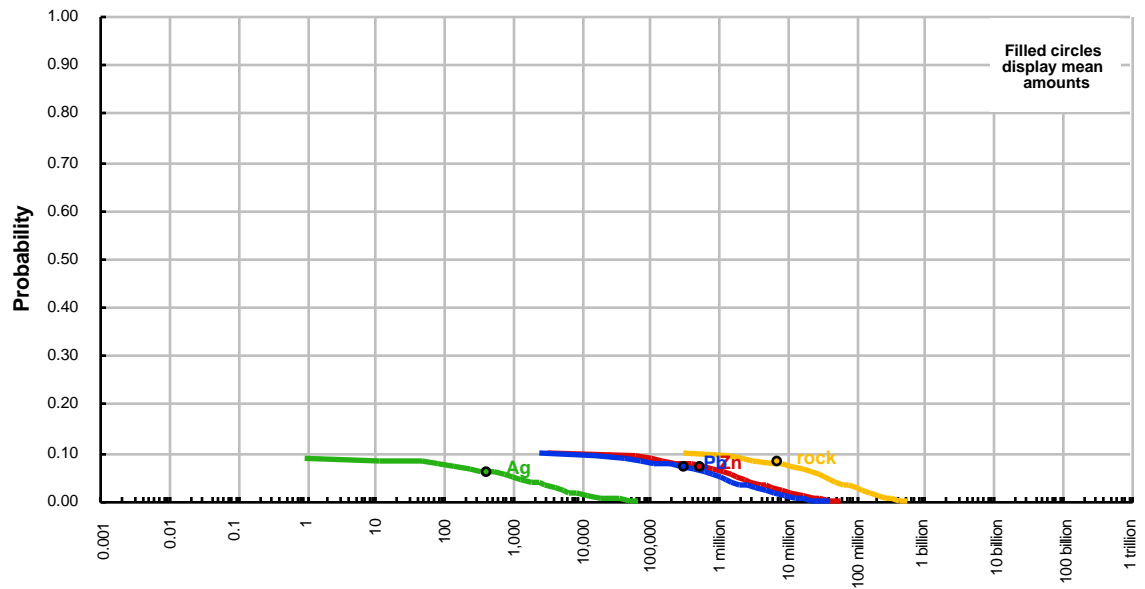
There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

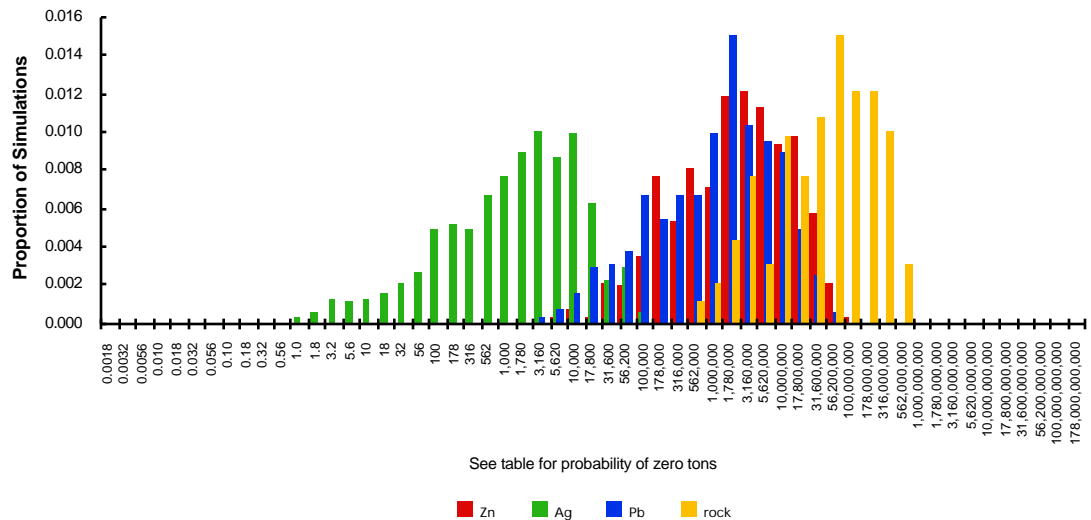
quantile	Zn	Ag	Pb	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	1,800,000	960	1,100,000	34,000,000
mean	530,000	420	300,000	7,100,000
Probability of mean	0.07	0.06	0.07	0.08
Probability of zero	0.90	0.91	0.90	0.90

The tract ID is GB33

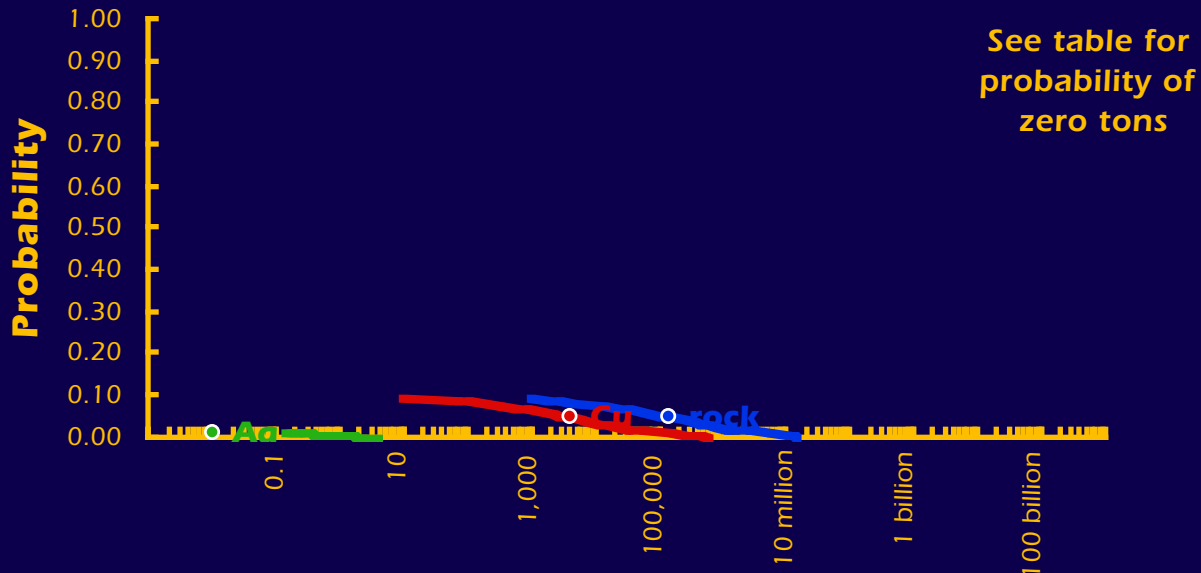
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

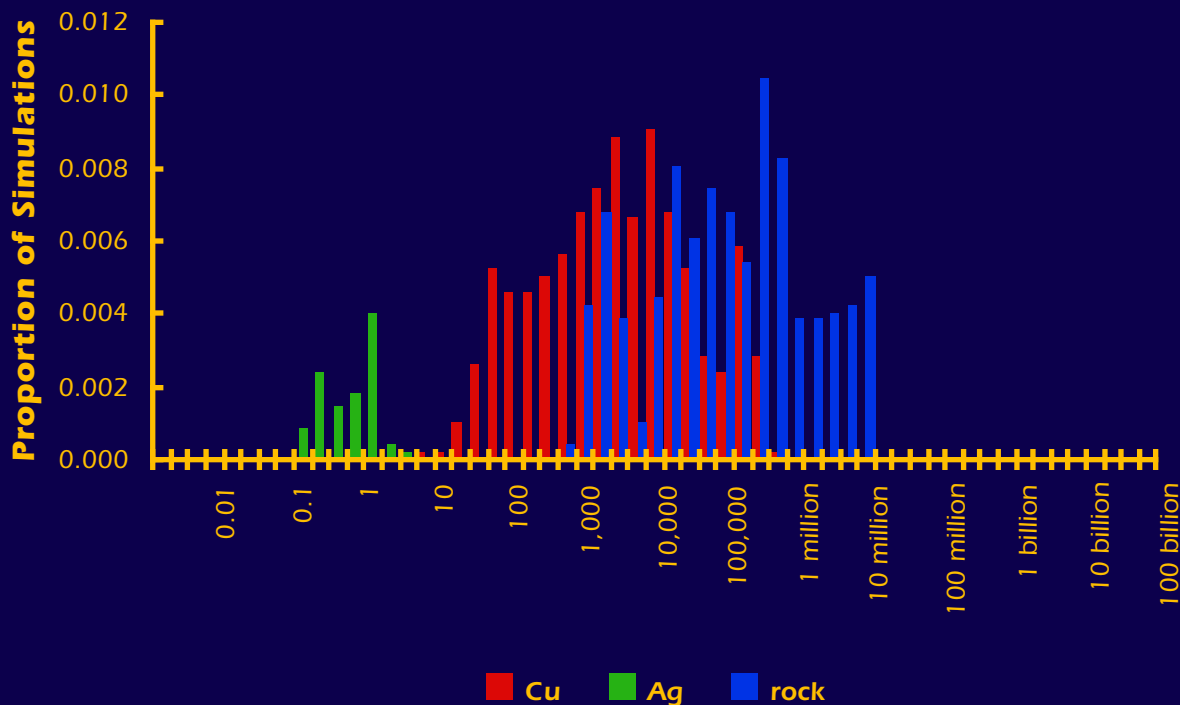


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GP01

The Mark3 Index is 97:

Sediment-hosted Cu, red-bed

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	0	0
0.05	3,500	0	110,000
mean	3,800	0	140,000
Probability of mean	0.05	0.01	0.05
Probability of zero	0.91	0.99	0.91

The tract ID is GP01The Mark3 Index is 97: **Sediment-hosted Cu, red-bed**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

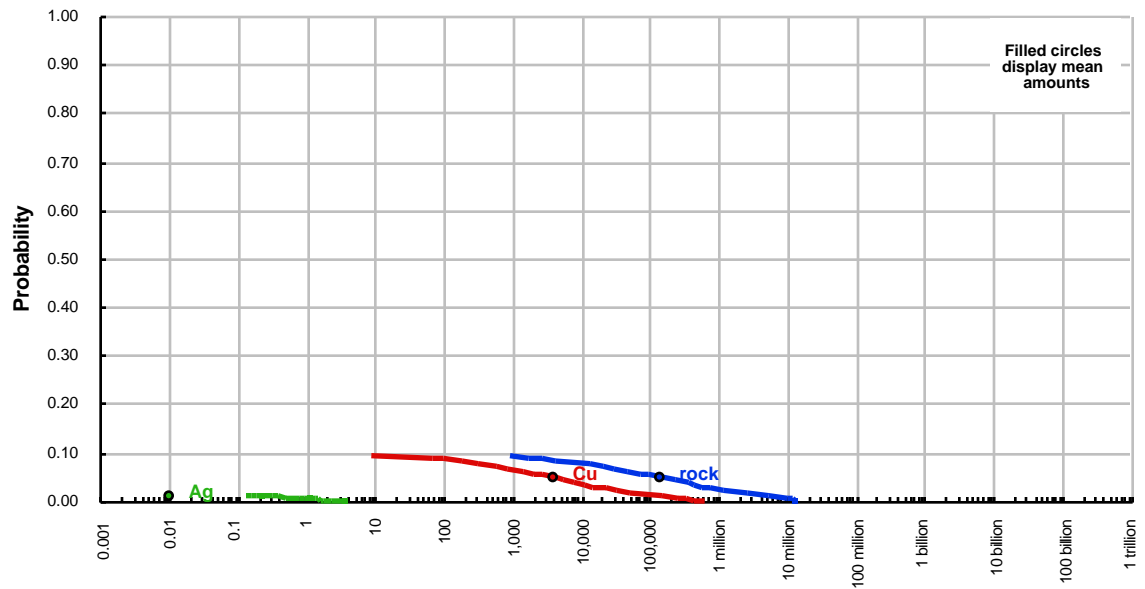
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

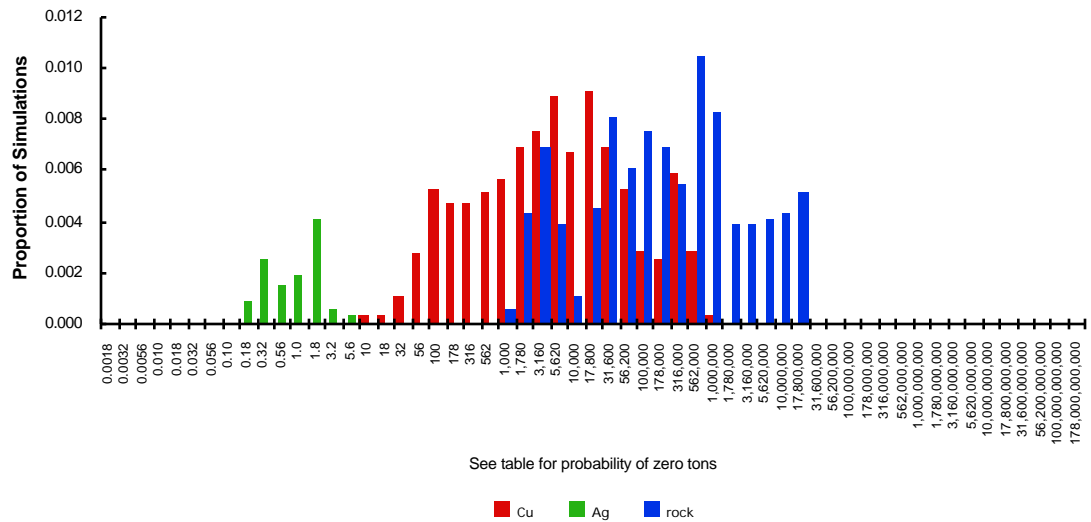
quantile	Cu	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	0	0
0.05	3,500	0	110,000
mean	3,800	0	140,000
Probability of mean	0.05	0.01	0.05
Probability of zero	0.91	0.99	0.91

The tract ID is GP01

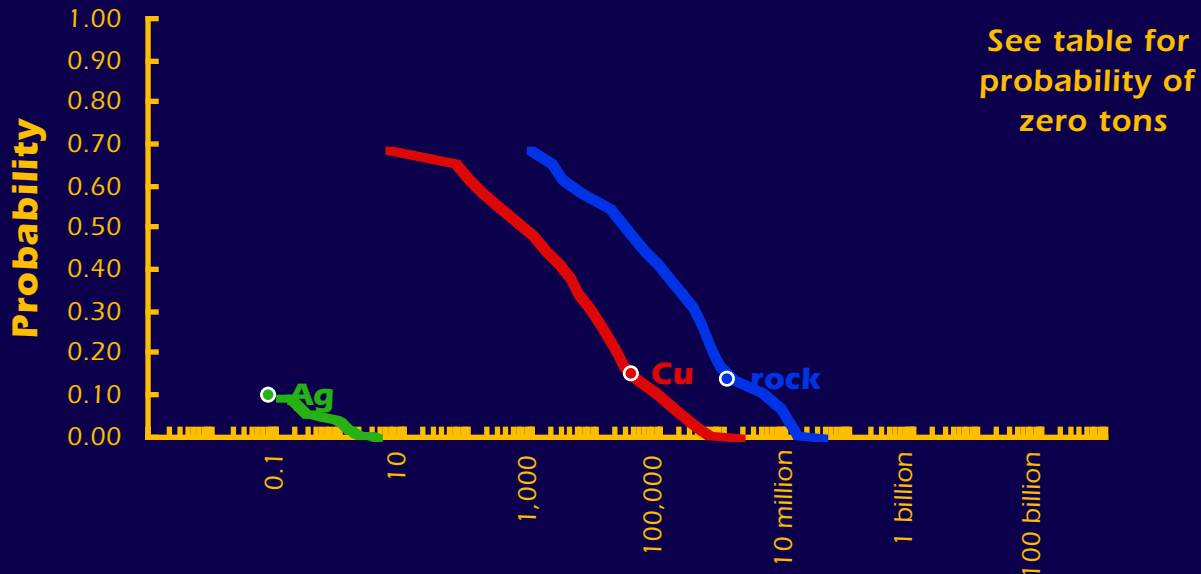
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

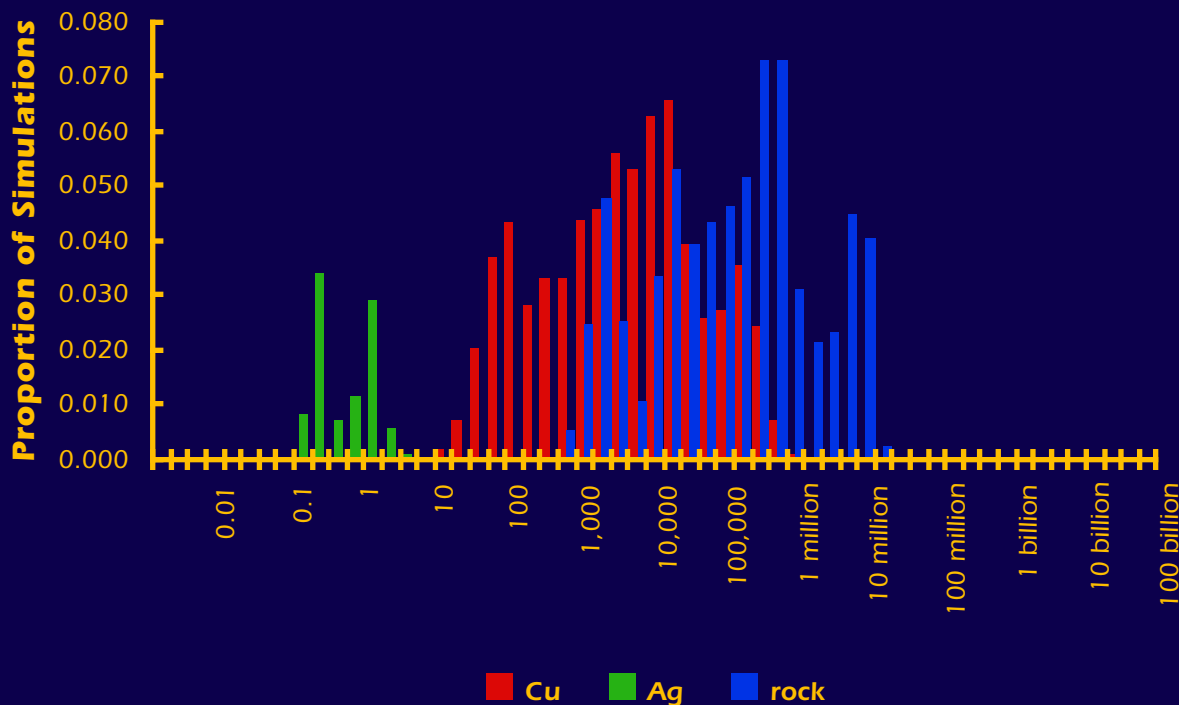


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GP02

The Mark3 Index is 97:

Sediment-hosted Cu, red-bed

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	770	0	27,000
0.10	89,000	0	4,410,000
0.05	230,000	0	9,300,000
mean	35,000	0	1,200,000
Probability of mean	0.15	0.10	0.14
Probability of zero	0.31	0.90	0.31

The tract ID is GP02The Mark3 Index is 97: **Sediment-hosted Cu, red-bed**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

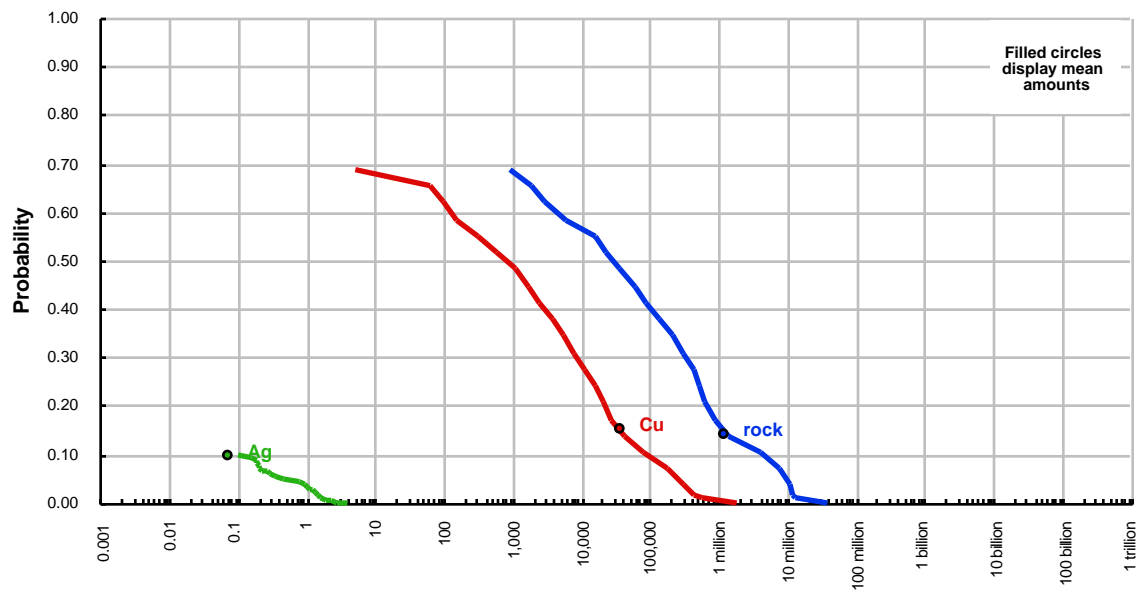
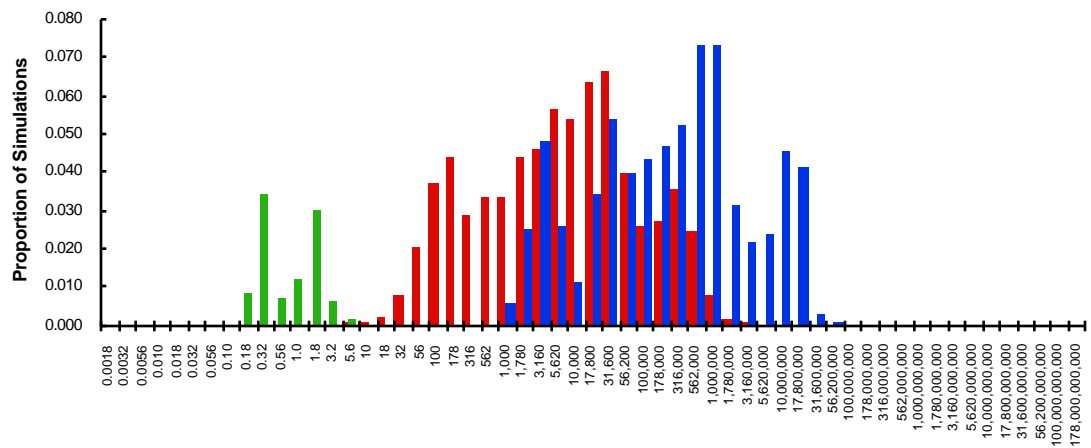
There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	770	0	27,000
0.10	89,000	0	4,410,000
0.05	230,000	0	9,300,000
mean	35,000	0	1,200,000
Probability of mean	0.15	0.10	0.14
Probability of zero	0.31	0.90	0.31

The tract ID is GP02

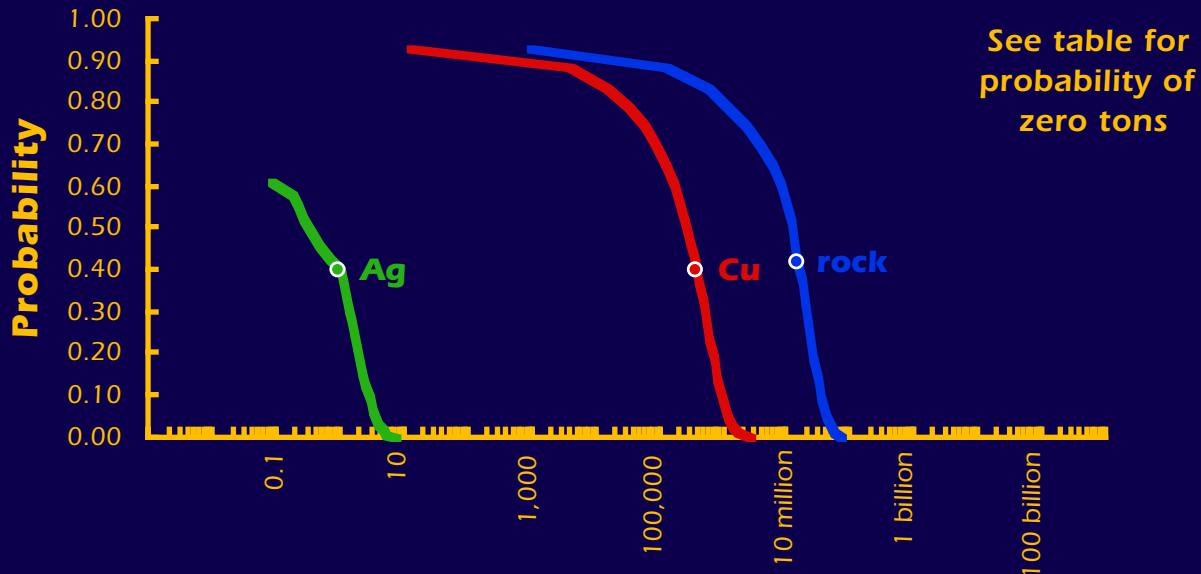
Cumulative Distributions of Contained Metal and Mineralized Rock

Histograms of Contained Metal and Mineralized Rock
(metric tons)

See table for probability of zero tons

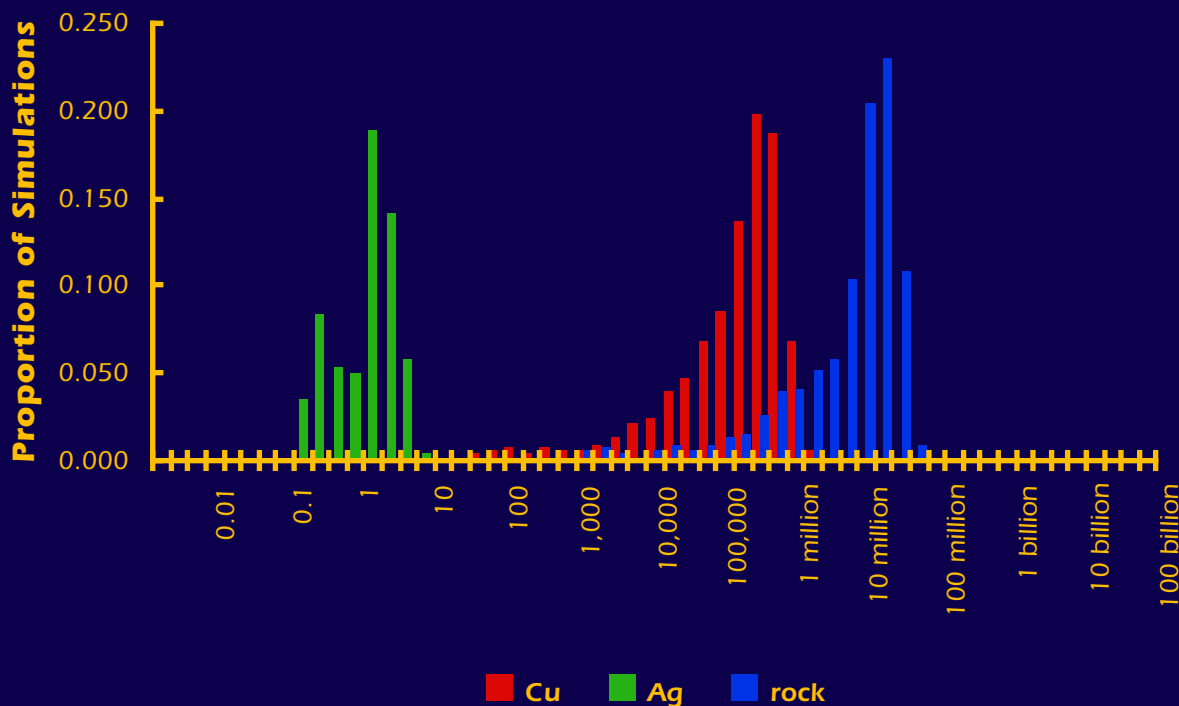
Cu Ag rock

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GP03

The Mark3 Index is 97:

Sediment-hosted Cu, red-bed

There is a 90% or greater chance of 1 or more deposits.
There is a 50% or greater chance of 10 or more deposits.
There is a 10% or greater chance of 20 or more deposits.
There is a 5% or greater chance of 20 or more deposits.
There is a 1% or greater chance of 20 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Ag	rock
0.95	0	0	0
0.90	1,200	0	45,000
0.50	270,000	0	12,000,000
0.10	910,000	3	33,400,000
0.05	1,100,000	3	40,000,000
mean	370,000	1	14,000,000
Probability of mean	0.40	0.40	0.42
Probability of zero	0.07	0.39	0.07

The tract ID is GP03The Mark3 Index is 97: **Sediment-hosted Cu, red-bed**

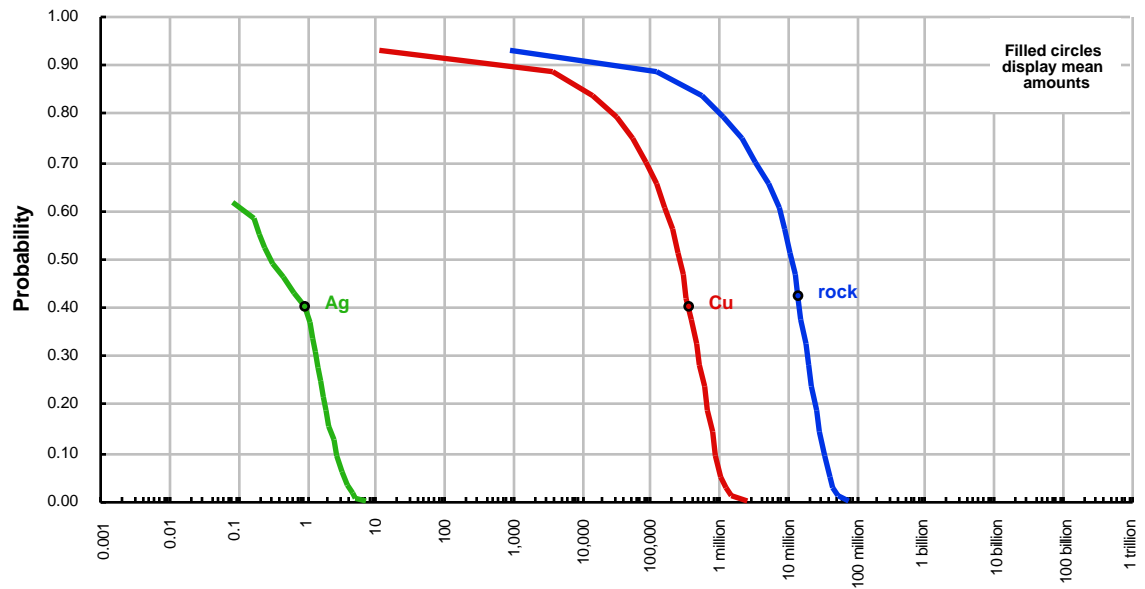
There is a 90% or greater chance of 1 or more deposits.
 There is a 50% or greater chance of 10 or more deposits.
 There is a 10% or greater chance of 20 or more deposits.
 There is a 5% or greater chance of 20 or more deposits.
 There is a 1% or greater chance of 20 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

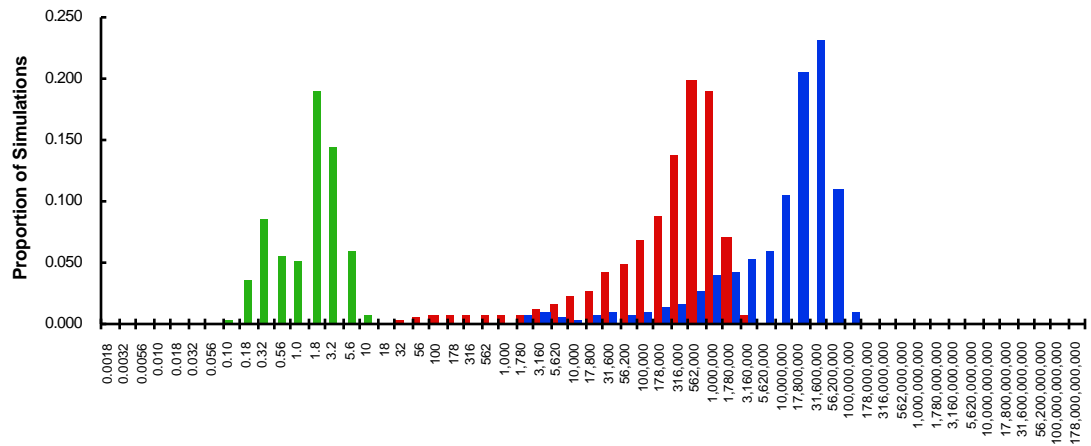
quantile	Cu	Ag	rock
0.95	0	0	0
0.90	1,200	0	45,000
0.50	270,000	0	12,000,000
0.10	910,000	3	33,400,000
0.05	1,100,000	3	40,000,000
mean	370,000	1	14,000,000
Probability of mean	0.40	0.40	0.42
Probability of zero	0.07	0.39	0.07

The tract ID is GP03

Cumulative Distributions of Contained Metal and Mineralized Rock



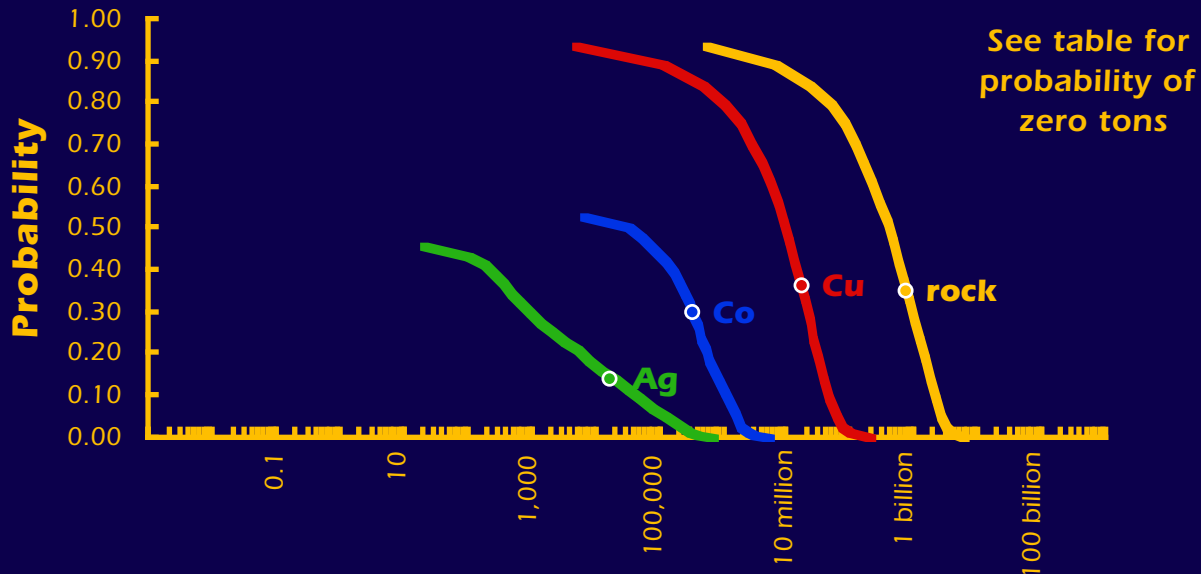
Histograms of Contained Metal and Mineralized Rock (metric tons)



See table for probability of zero tons

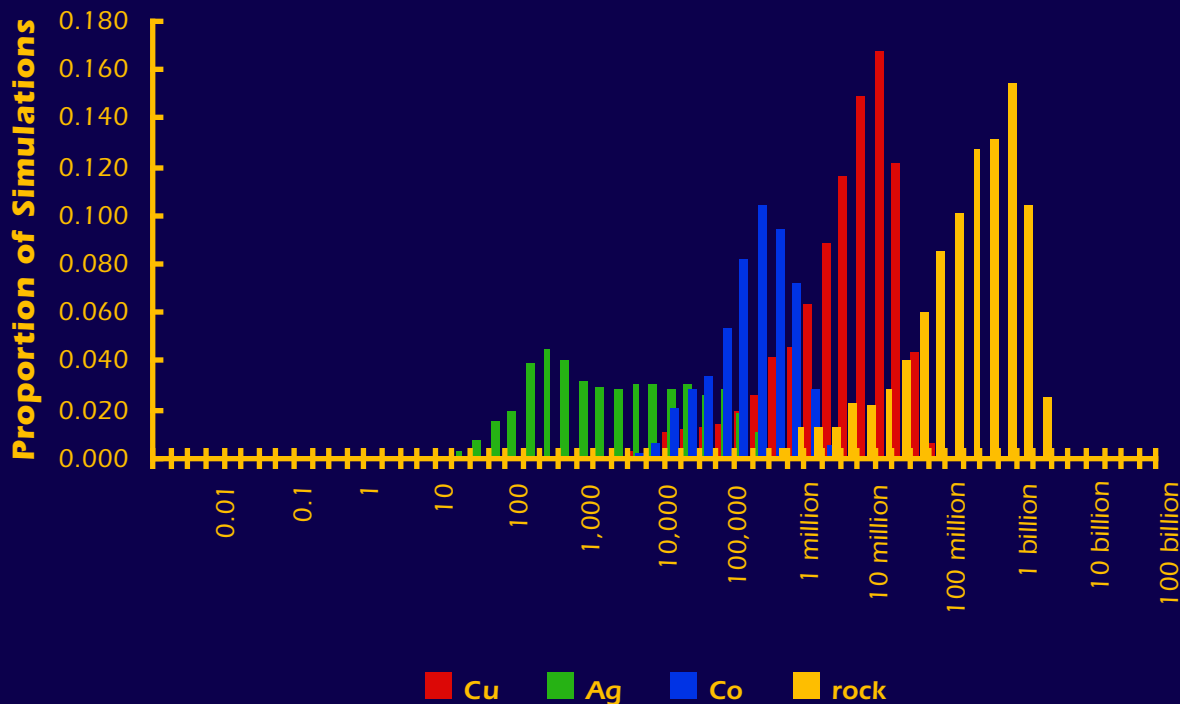
Cu Ag rock

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GP04

The Mark3 Index is 96:

Sediment-hosted Cu, reduced facies

There is a 90% or greater chance of 1 or more deposits.
There is a 50% or greater chance of 3 or more deposits.
There is a 10% or greater chance of 10 or more deposits.
There is a 5% or greater chance of 10 or more deposits.
There is a 1% or greater chance of 10 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Ag	Co	rock
0.95	0	0	0	0
0.90	90,000	0	0	5,100,000
0.50	9,400,000	0	31,000	390,000,000
0.10	43,000,000	41,000	1,030,000	2,000,000,000
0.05	56,000,000	110,000	1,500,000	2,500,000,000
mean	16,000,000	17,000	330,000	740,000,000
Probability of mean	0.36	0.14	0.30	0.35
Probability of zero	0.06	0.54	0.47	0.06

The tract ID is GP04The Mark3 Index is 96: **Sediment-hosted Cu, reduced facies**

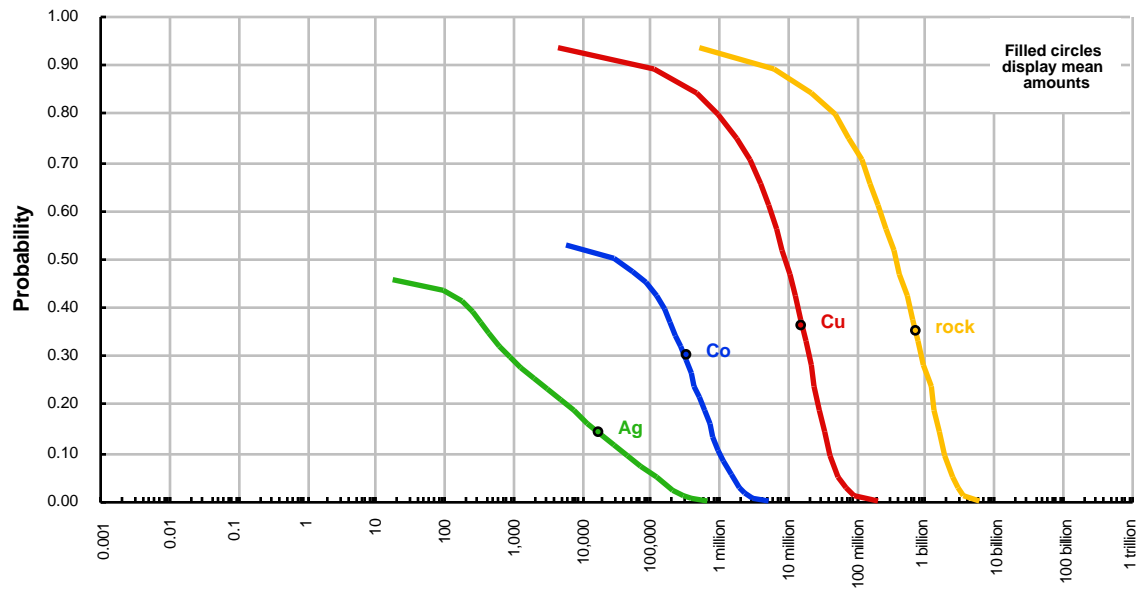
There is a 90% or greater chance of 1 or more deposits.
 There is a 50% or greater chance of 3 or more deposits.
 There is a 10% or greater chance of 10 or more deposits.
 There is a 5% or greater chance of 10 or more deposits.
 There is a 1% or greater chance of 10 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

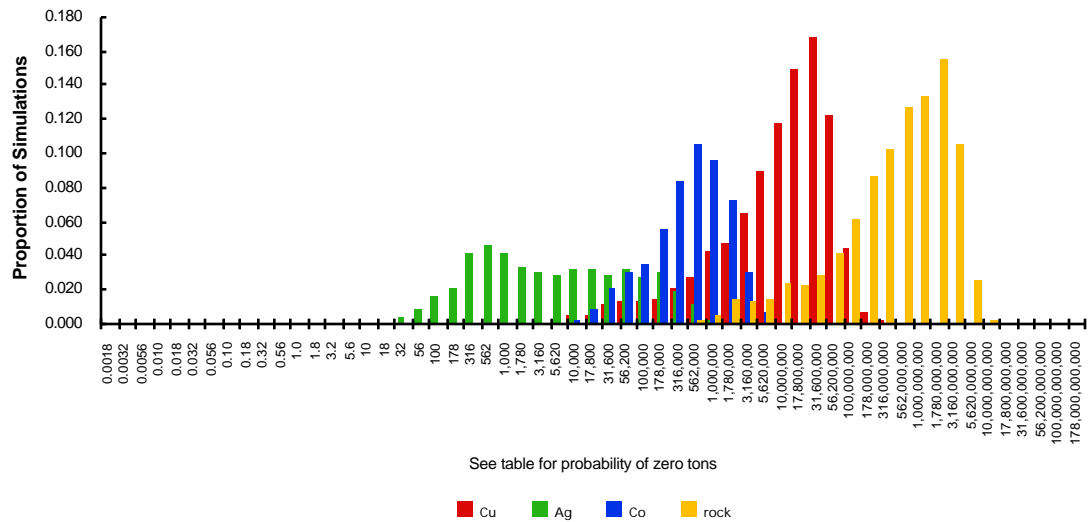
quantile	Cu	Ag	Co	rock
0.95	0	0	0	0
0.90	90,000	0	0	5,100,000
0.50	9,400,000	0	31,000	390,000,000
0.10	43,000,000	41,000	1,030,000	2,000,000,000
0.05	56,000,000	110,000	1,500,000	2,500,000,000
mean	16,000,000	17,000	330,000	740,000,000
Probability of mean	0.36	0.14	0.30	0.35
Probability of zero	0.06	0.54	0.47	0.06

The tract ID is GP04

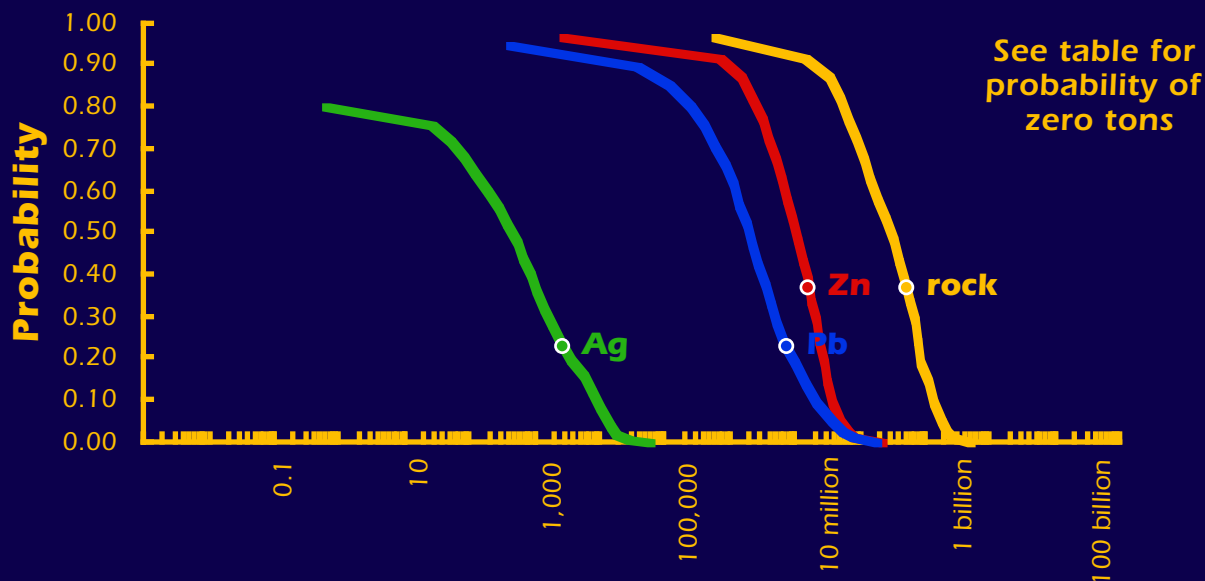
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

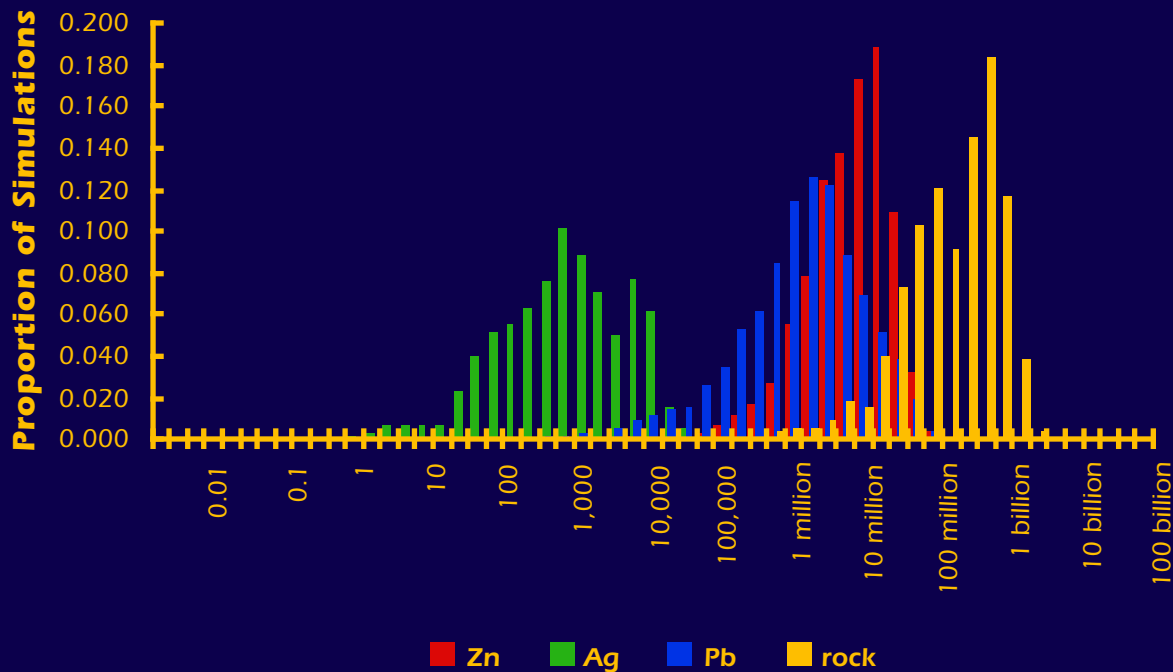


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is GP05

The Mark3 Index is 108:

Mississippi Valley

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Zn	Ag	Pb	rock
0.95	180,000	0	0	3,900,000
0.90	940,000	0	33,000	21,000,000
0.50	10,000,000	440	1,900,000	290,000,000
0.10	38,000,000	8,800	19,800,000	1,300,000,000
0.05	50,000,000	13,000	37,000,000	1,700,000,000
mean	16,000,000	2,600	7,300,000	500,000,000
Probability of mean	0.37	0.23	0.23	0.37
Probability of zero	0.04	0.20	0.06	0.04

The tract ID is GP05The Mark3 Index is 108: **Mississippi Valley**

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

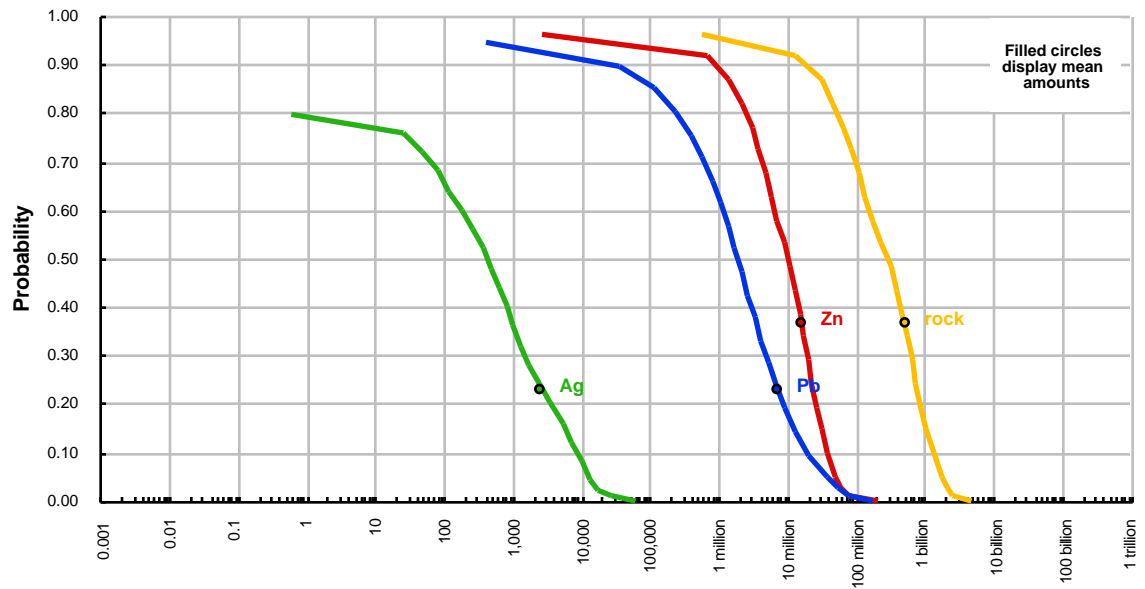
There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

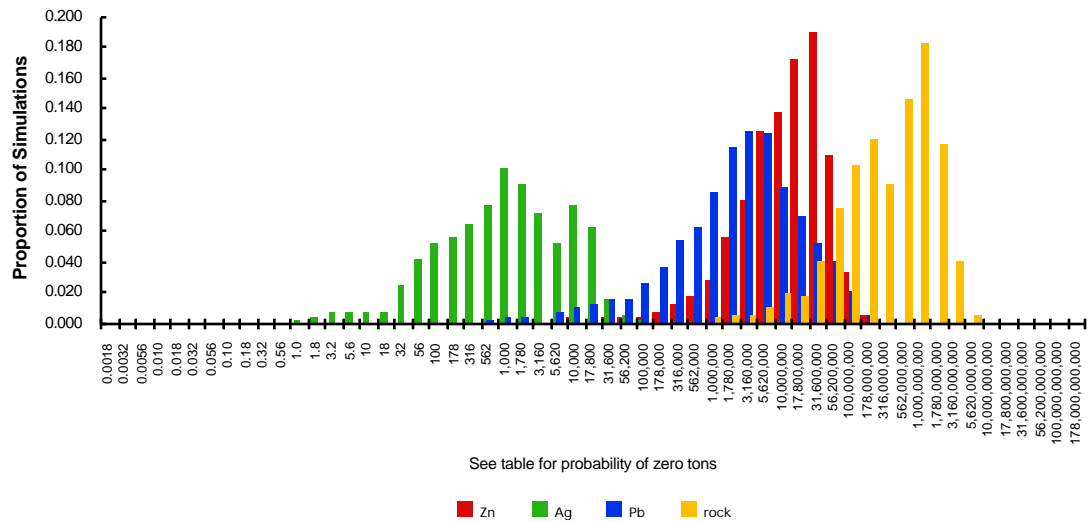
quantile	Zn	Ag	Pb	rock
0.95	180,000	0	0	3,900,000
0.90	940,000	0	33,000	21,000,000
0.50	10,000,000	440	1,900,000	290,000,000
0.10	38,000,000	8,800	19,800,000	1,300,000,000
0.05	50,000,000	13,000	37,000,000	1,700,000,000
mean	16,000,000	2,600	7,300,000	500,000,000
Probability of mean	0.37	0.23	0.23	0.37
Probability of zero	0.04	0.20	0.06	0.04

The tract ID is GP05

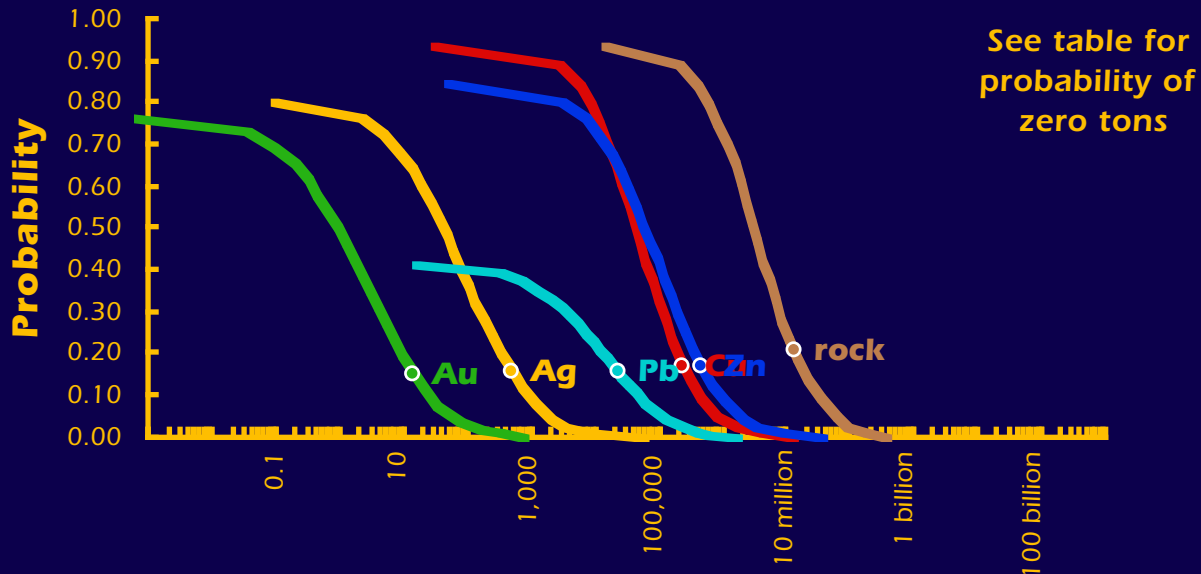
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

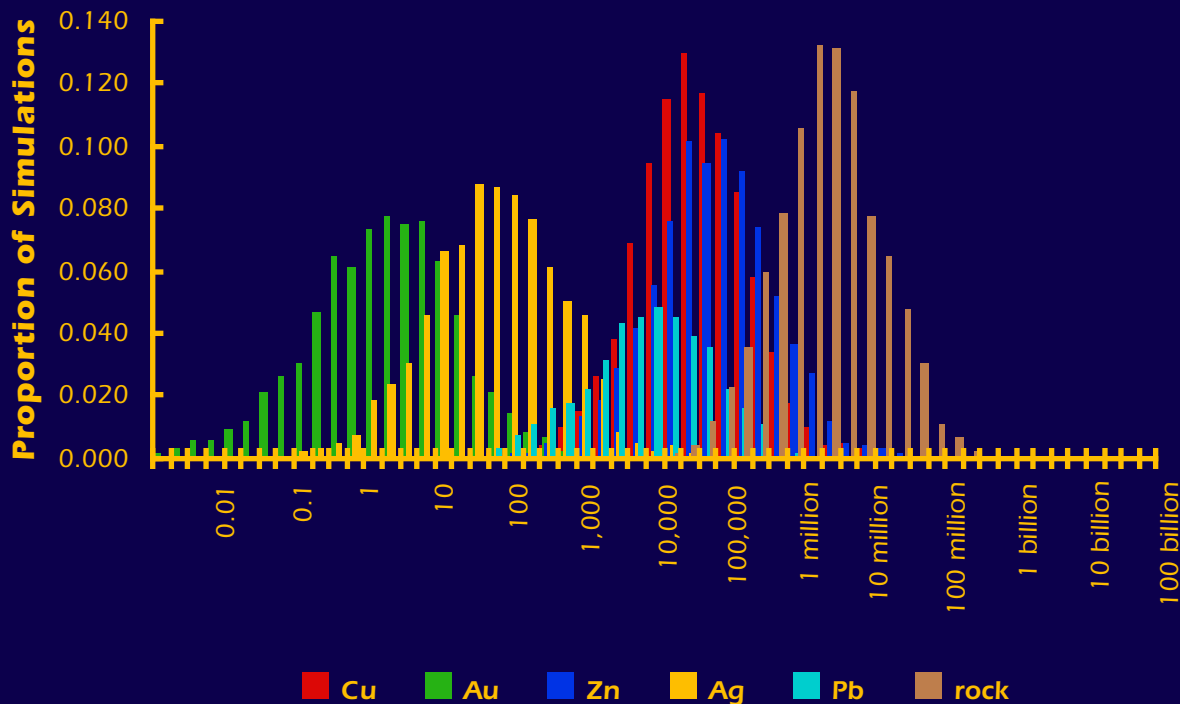


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is LS03

The Mark3 Index is 103:

Massive sulfide, kuroko (Precambrian)

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	2,100	0	0	0	0	170,000
0.50	43,000	1	56,000	40	0	3,000,000
0.10	420,000	24	841,000	910	45,000	31,000,000
0.05	790,000	58	1,800,000	1,700	110,000	57,000,000
mean	230,000	14	450,000	450	22,000	13,000,000
Probability of mean	0.17	0.15	0.17	0.16	0.16	0.21
Probability of zero	0.06	0.23	0.15	0.20	0.59	0.06

The tract ID is LS03

The Mark3 Index is 103: **Massive sulfide, kuroko (Precambrian)**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

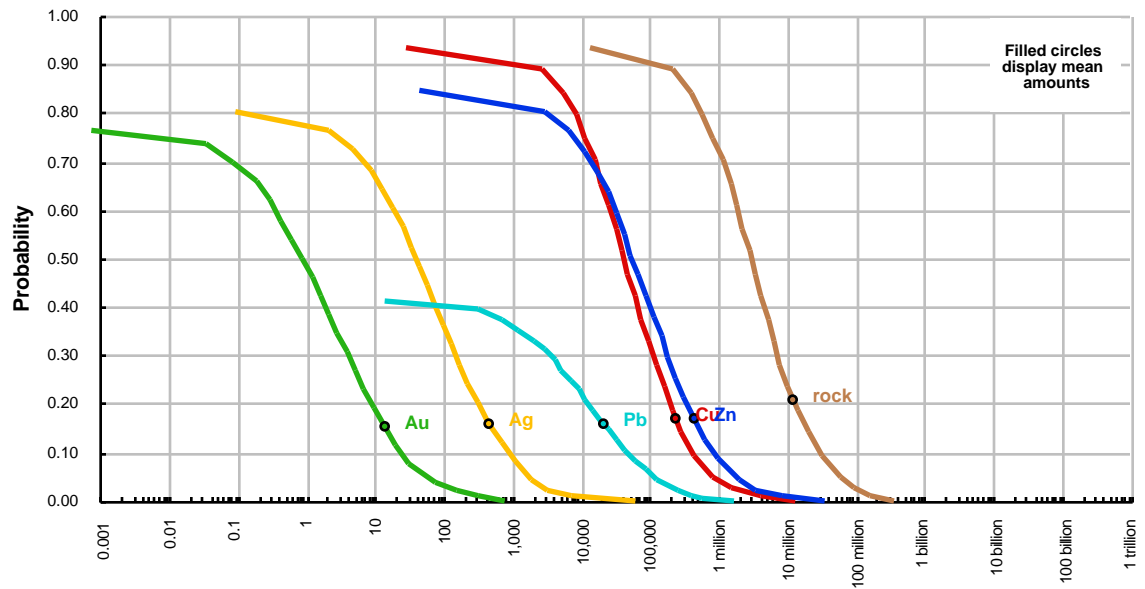
There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

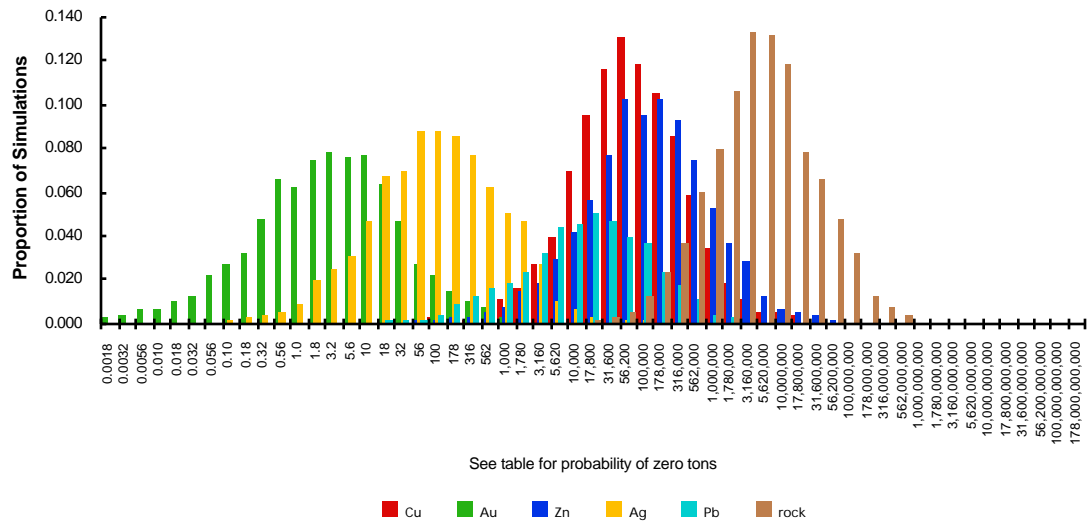
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	2,100	0	0	0	0	170,000
0.50	43,000	1	56,000	40	0	3,000,000
0.10	420,000	24	841,000	910	45,000	31,000,000
0.05	790,000	58	1,800,000	1,700	110,000	57,000,000
mean	230,000	14	450,000	450	22,000	13,000,000
Probability of mean	0.17	0.15	0.17	0.16	0.16	0.21
Probability of zero	0.06	0.23	0.15	0.20	0.59	0.06

The tract ID is LS03

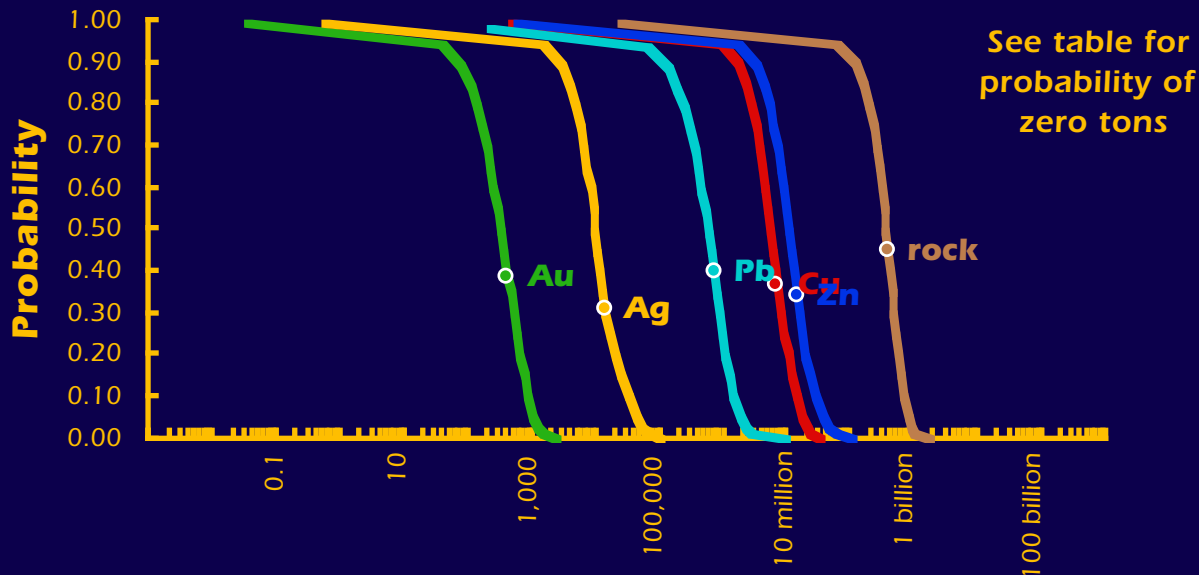
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

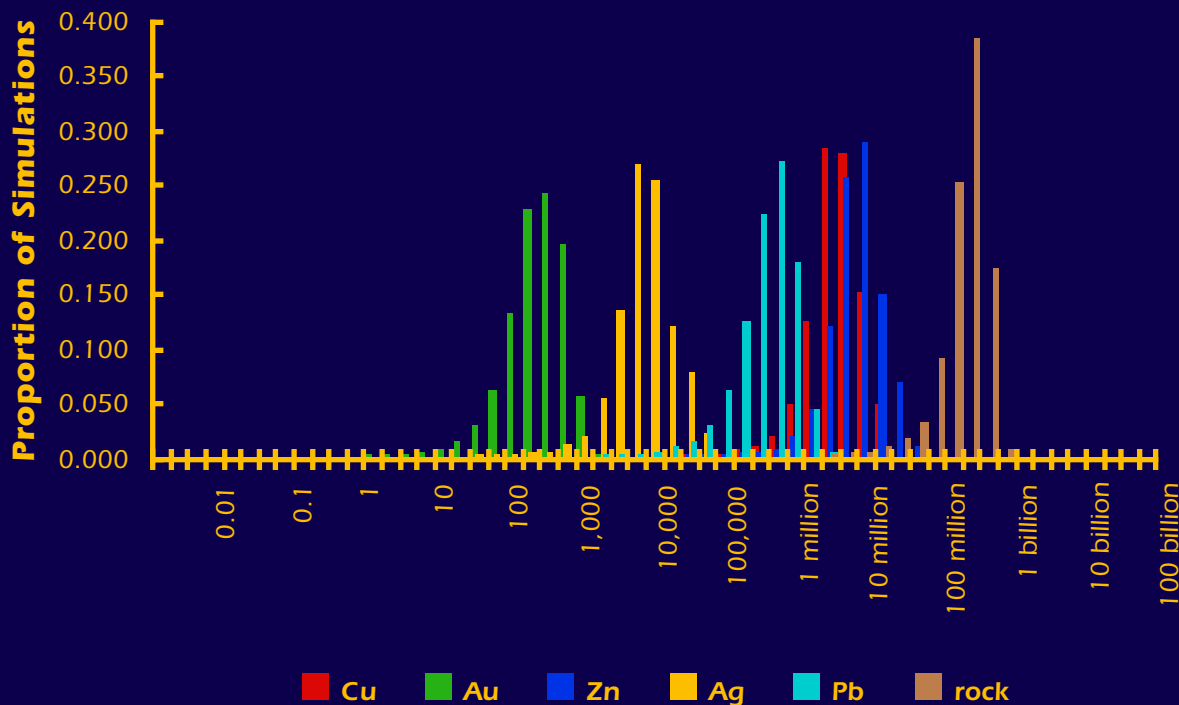


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is LS04

The Mark3 Index is 103:

Massive sulfide, kuroko (Precambrian)

There is a 90% or greater chance of 30 or more deposits.

There is a 50% or greater chance of 65 or more deposits.

There is a 10% or greater chance of 85 or more deposits.

There is a 5% or greater chance of 85 or more deposits.

There is a 1% or greater chance of 85 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	840,000	32	1,400,000	1,200	41,000	54,000,000
0.90	1,700,000	70	3,100,000	2,800	120,000	120,000,000
0.50	5,400,000	320	10,000,000	9,600	570,000	350,000,000
0.10	14,000,000	870	28,900,000	32,000	1,400,000	670,000,000
0.05	18,000,000	1,000	38,000,000	43,000	1,800,000	770,000,000
mean	6,800,000	410	14,000,000	14,000	700,000	380,000,000
Probability of mean	0.37	0.39	0.34	0.31	0.40	0.45
Probability of zero	0.00	0.01	0.01	0.01	0.01	0.00

The tract ID is LS04The Mark3 Index is 103: **Massive sulfide, kuroko (Precambrian)**

There is a 90% or greater chance of 30 or more deposits.

There is a 50% or greater chance of 65 or more deposits.

There is a 10% or greater chance of 85 or more deposits.

There is a 5% or greater chance of 85 or more deposits.

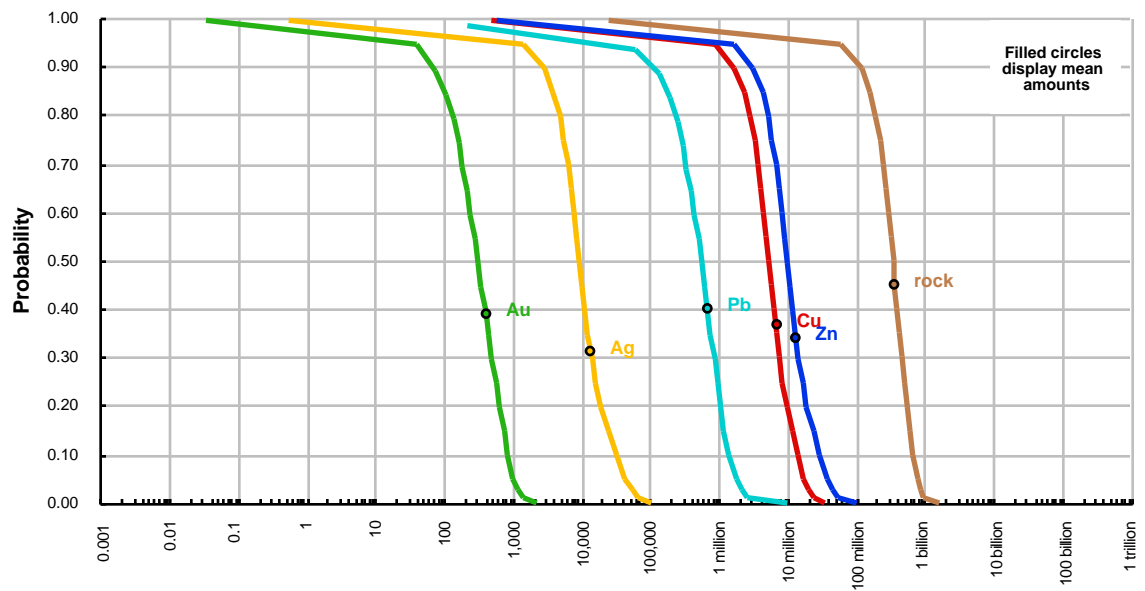
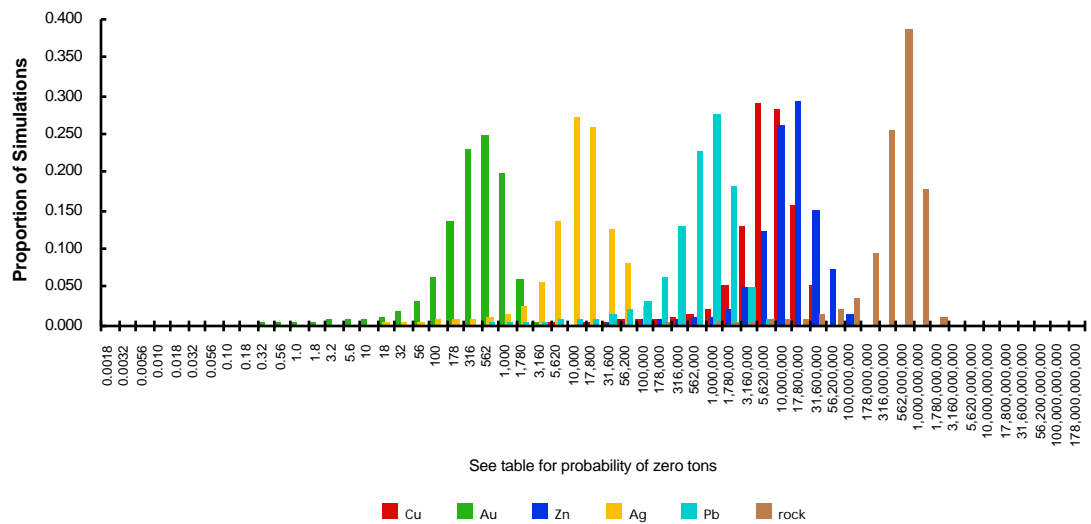
There is a 1% or greater chance of 85 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

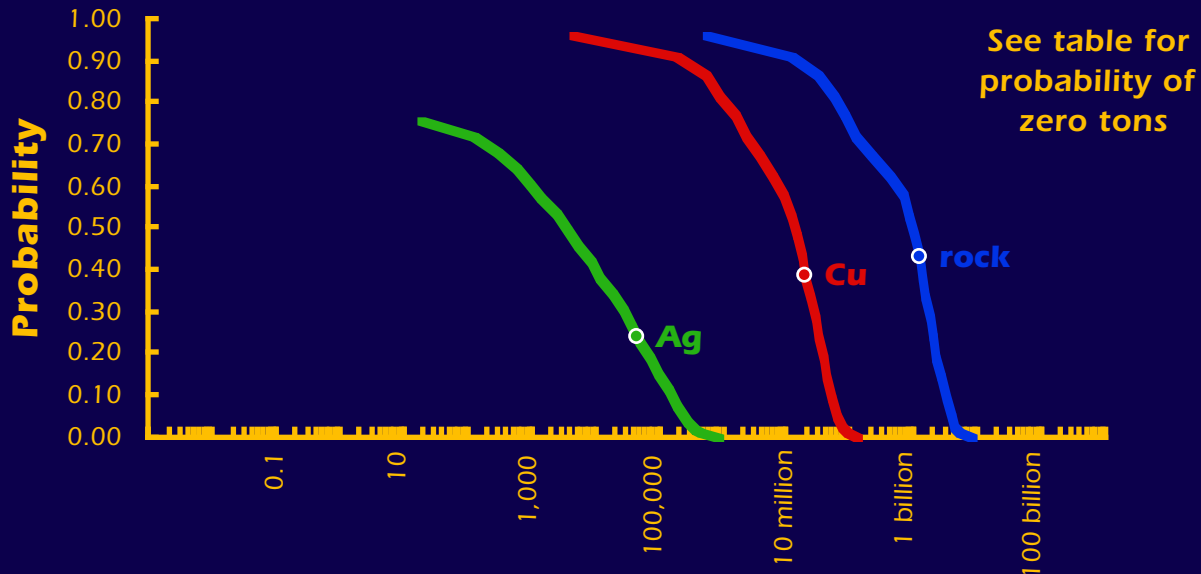
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	840,000	32	1,400,000	1,200	41,000	54,000,000
0.90	1,700,000	70	3,100,000	2,800	120,000	120,000,000
0.50	5,400,000	320	10,000,000	9,600	570,000	350,000,000
0.10	14,000,000	870	28,900,000	32,000	1,400,000	670,000,000
0.05	18,000,000	1,000	38,000,000	43,000	1,800,000	770,000,000
mean	6,800,000	410	14,000,000	14,000	700,000	380,000,000
Probability of mean	0.37	0.39	0.34	0.31	0.40	0.45
Probability of zero	0.00	0.01	0.01	0.01	0.01	0.00

The tract ID is LS04

Cumulative Distributions of Contained Metal and Mineralized Rock

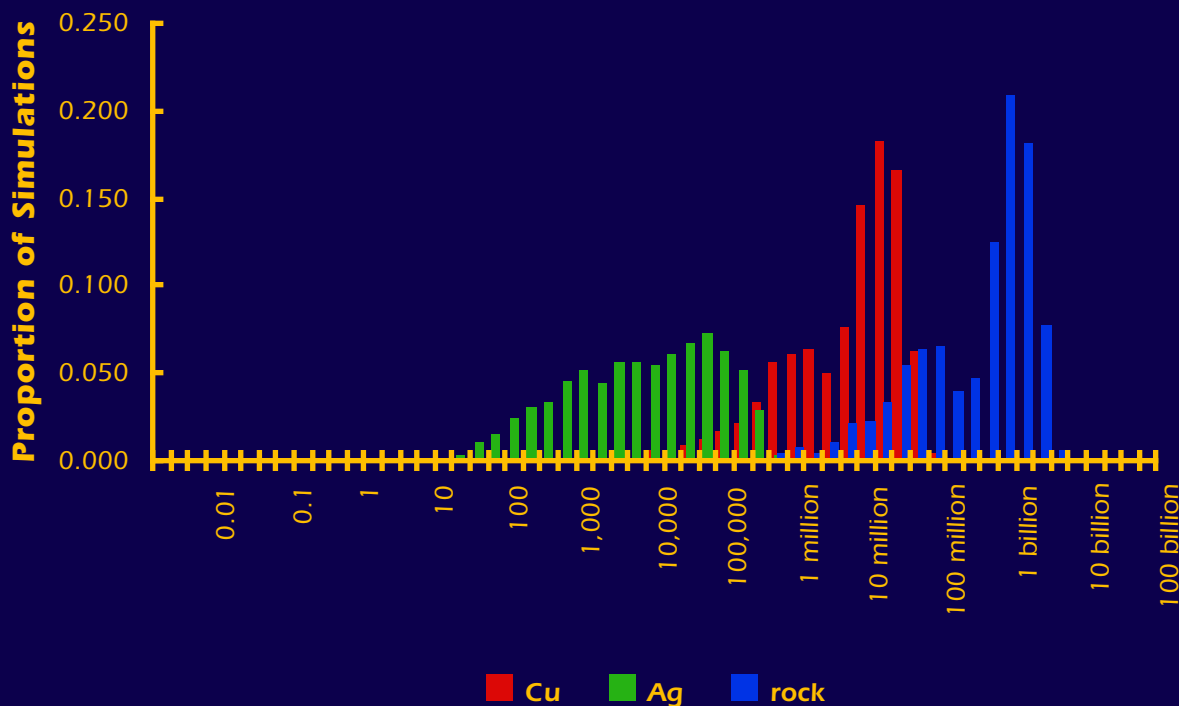
Histograms of Contained Metal and Mineralized Rock
(metric tons)

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is LS07

The Mark3 Index is 102:

Sediment-hosted Cu, reduced facies (modified)

There is a 90% or greater chance of 2 or more deposits.
There is a 50% or greater chance of 5 or more deposits.
There is a 10% or greater chance of 10 or more deposits.
There is a 5% or greater chance of 10 or more deposits.
There is a 1% or greater chance of 10 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Ag	rock
0.95	31,000	0	2,200,000
0.90	270,000	0	16,000,000
0.50	13,000,000	3,400	890,000,000
0.10	48,000,000	150,000	2,960,000,000
0.05	62,000,000	240,000	3,600,000,000
mean	19,000,000	44,000	1,200,000,000
Probability of mean	0.39	0.24	0.43
Probability of zero	0.04	0.24	0.04

The tract ID is LS07The Mark3 Index is 102: **Sediment-hosted Cu, reduced facies (modified)**

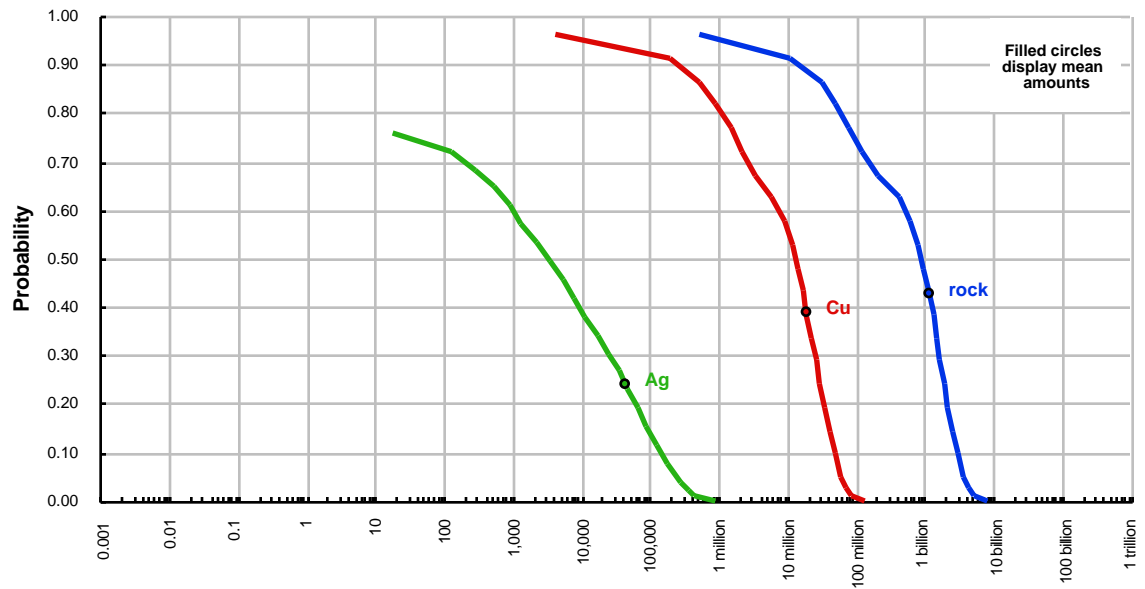
There is a 90% or greater chance of 2 or more deposits.
 There is a 50% or greater chance of 5 or more deposits.
 There is a 10% or greater chance of 10 or more deposits.
 There is a 5% or greater chance of 10 or more deposits.
 There is a 1% or greater chance of 10 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

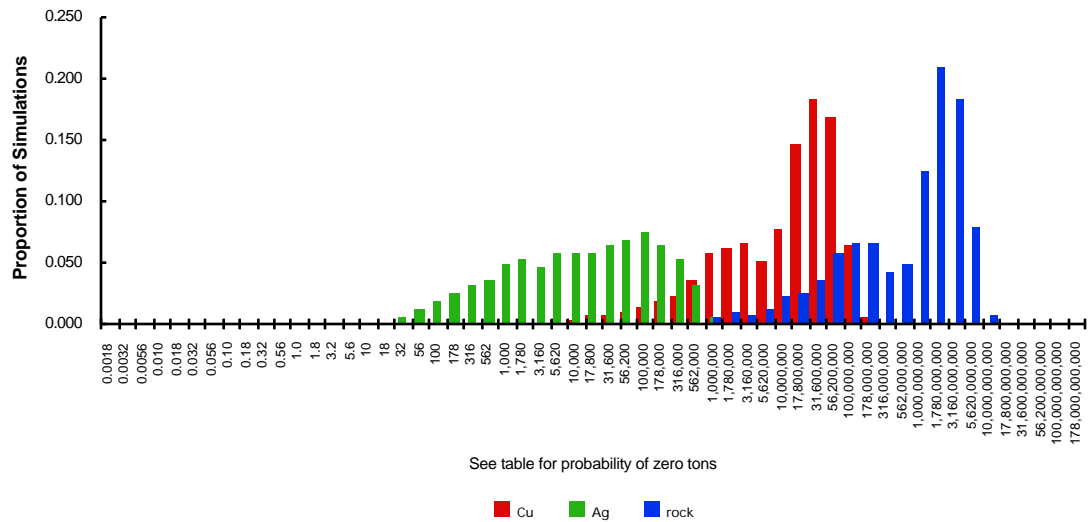
quantile	Cu	Ag	rock
0.95	31,000	0	2,200,000
0.90	270,000	0	16,000,000
0.50	13,000,000	3,400	890,000,000
0.10	48,000,000	150,000	2,960,000,000
0.05	62,000,000	240,000	3,600,000,000
mean	19,000,000	44,000	1,200,000,000
Probability of mean	0.39	0.24	0.43
Probability of zero	0.04	0.24	0.04

The tract ID is LS07

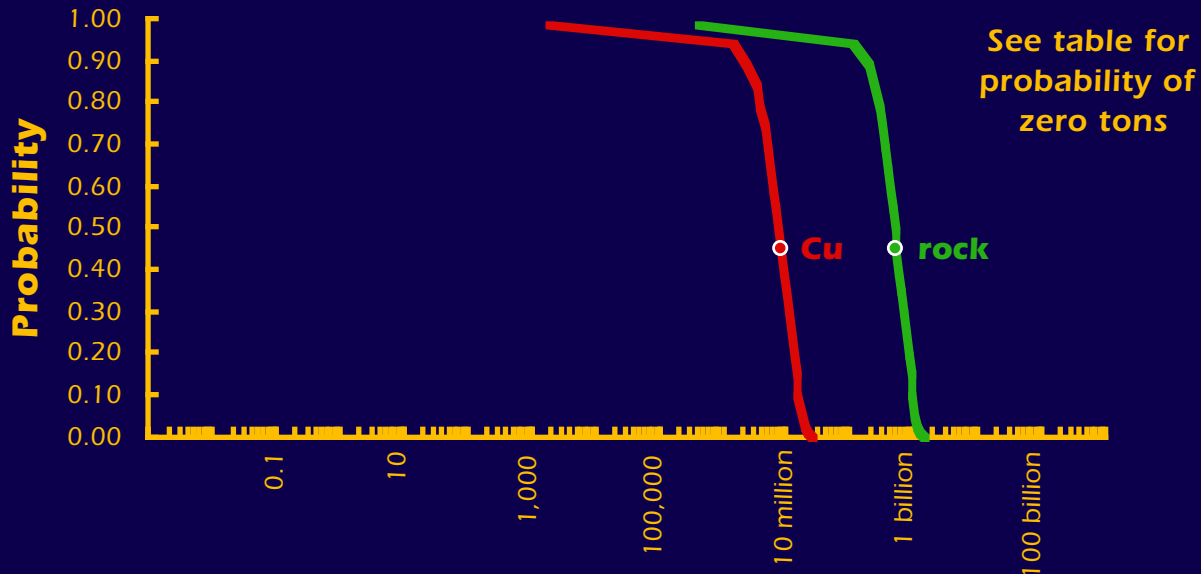
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

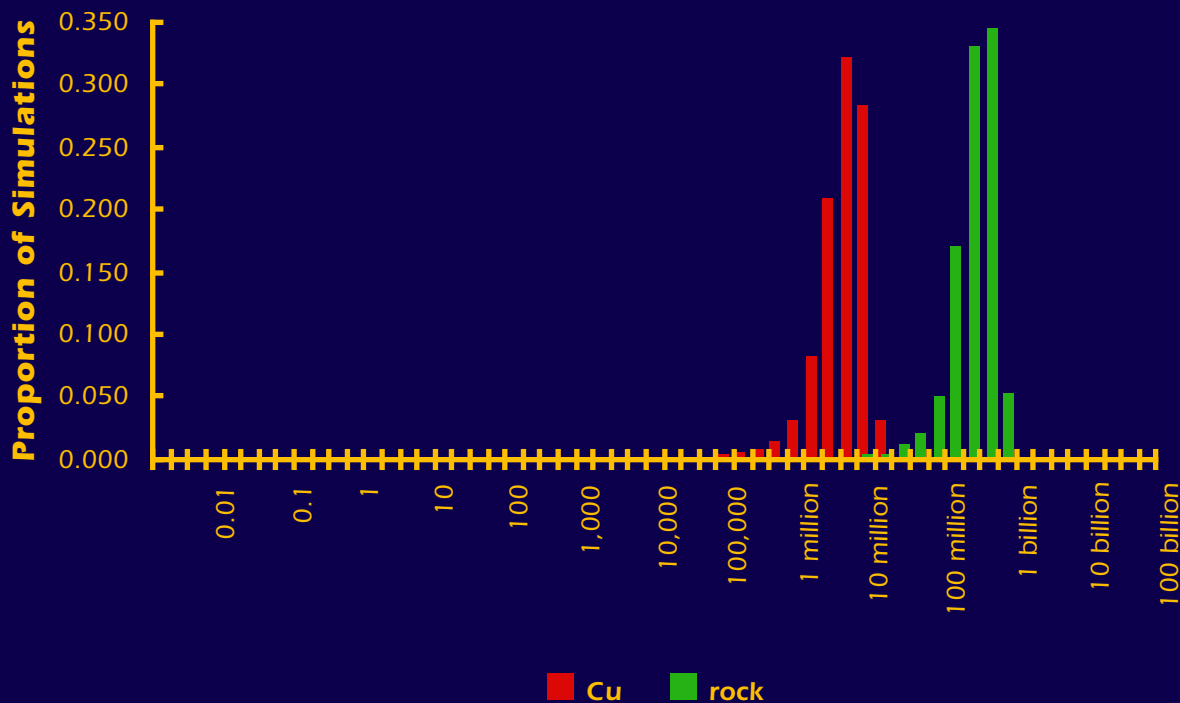


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is LS08

The Mark3 Index is 99:

Native Cu

There is a 90% or greater chance of 10 or more deposits.

There is a 50% or greater chance of 20 or more deposits.

There is a 10% or greater chance of 40 or more deposits.

There is a 5% or greater chance of 40 or more deposits.

There is a 1% or greater chance of 40 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	rock
0.95	1,100,000	90,000,000
0.90	2,200,000	170,000,000
0.50	7,200,000	470,000,000
0.10	15,000,000	910,000,000
0.05	17,000,000	1,000,000,000
mean	8,000,000	510,000,000
Probability of mean	0.45	0.45
Probability of zero	0.01	0.01

The tract ID is LS08The Mark3 Index is 99: **Native Cu**

There is a 90% or greater chance of 10 or more deposits.

There is a 50% or greater chance of 20 or more deposits.

There is a 10% or greater chance of 40 or more deposits.

There is a 5% or greater chance of 40 or more deposits.

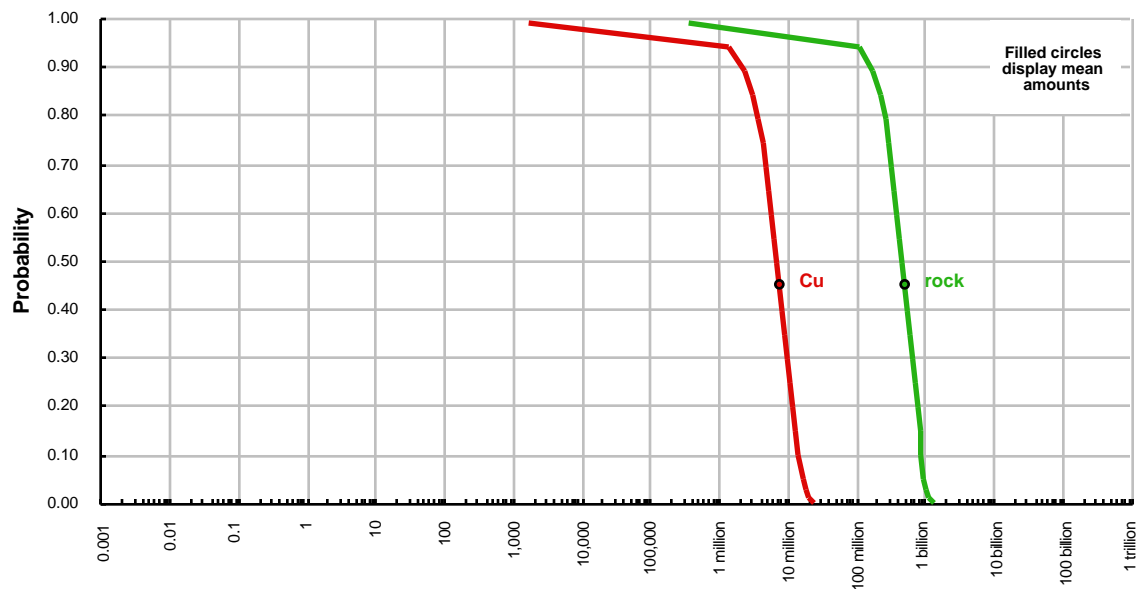
There is a 1% or greater chance of 40 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

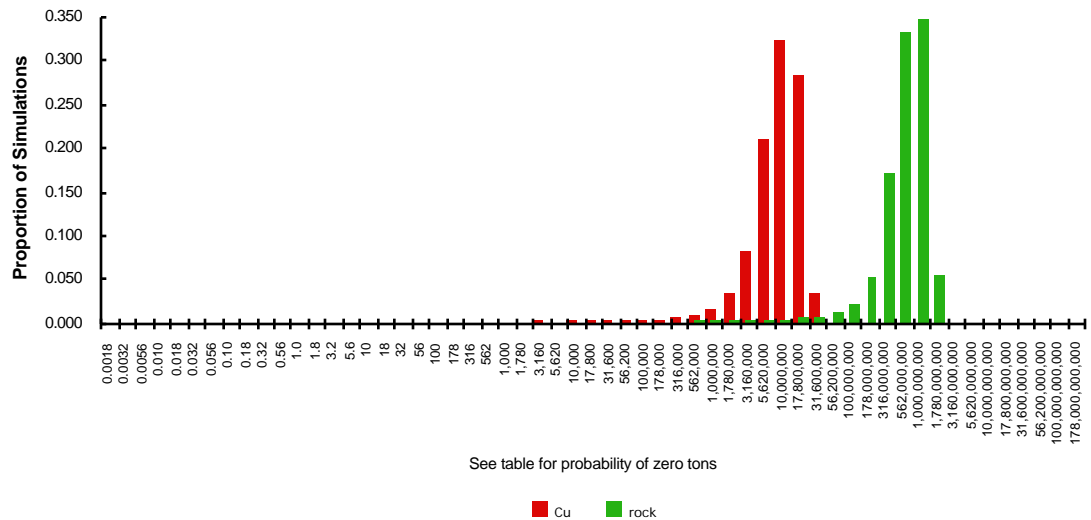
quantile	Cu	rock
0.95	1,100,000	90,000,000
0.90	2,200,000	170,000,000
0.50	7,200,000	470,000,000
0.10	15,000,000	910,000,000
0.05	17,000,000	1,000,000,000
mean	8,000,000	510,000,000
Probability of mean	0.45	0.45
Probability of zero	0.01	0.01

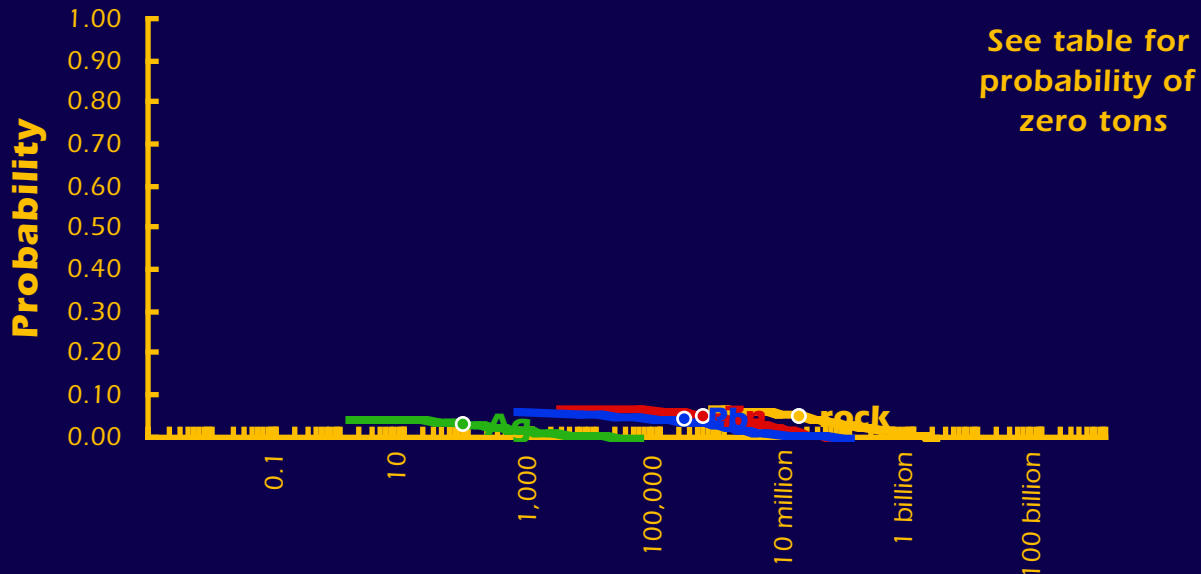
The tract ID is LS08

Cumulative Distributions of Contained Metal and Mineralized Rock



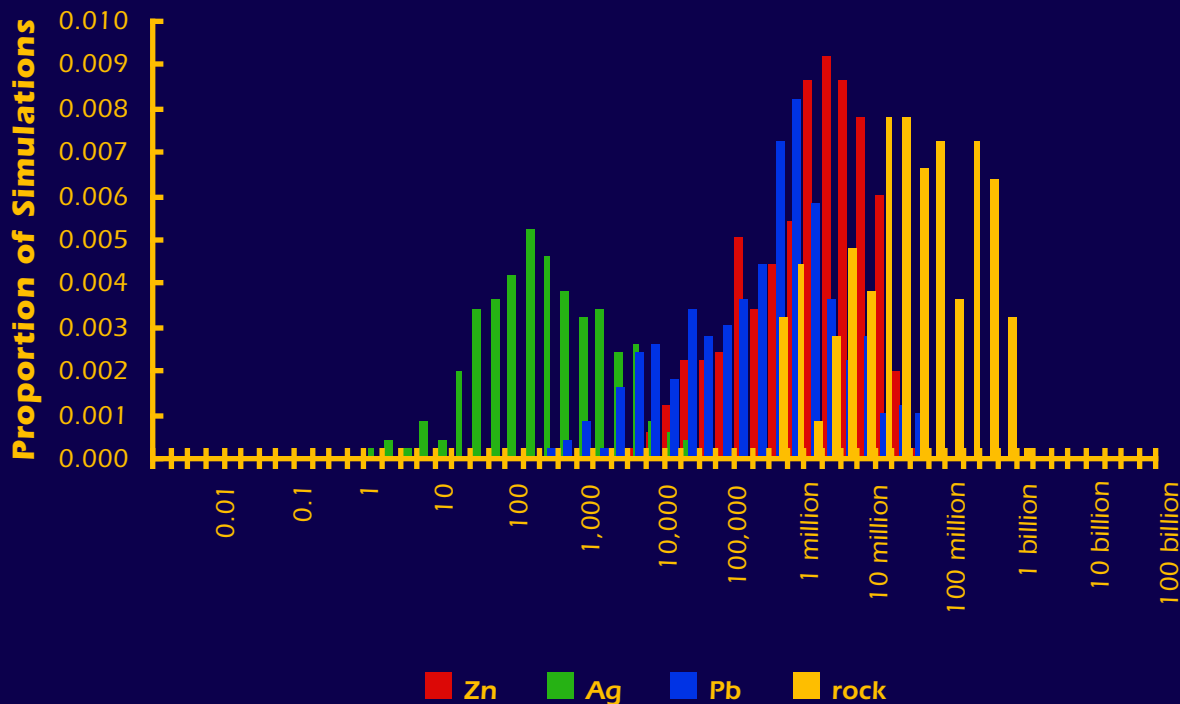
Histograms of Contained Metal and Mineralized Rock (metric tons)





Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is LS09

The Mark3 Index is 108:

Mississippi Valley

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Zn	Ag	Pb	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	710,000	0	32,000	19,000,000
mean	470,000	87	250,000	16,000,000
Probability of mean	0.05	0.03	0.04	0.05
Probability of zero	0.93	0.96	0.94	0.93

The tract ID is LS09The Mark3 Index is 108: **Mississippi Valley**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

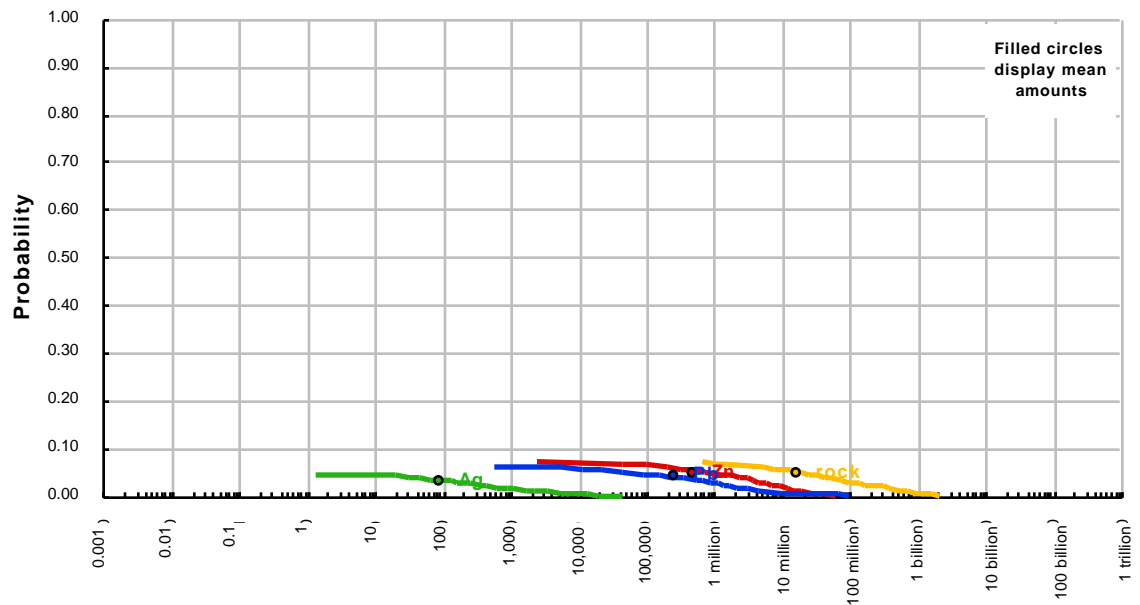
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

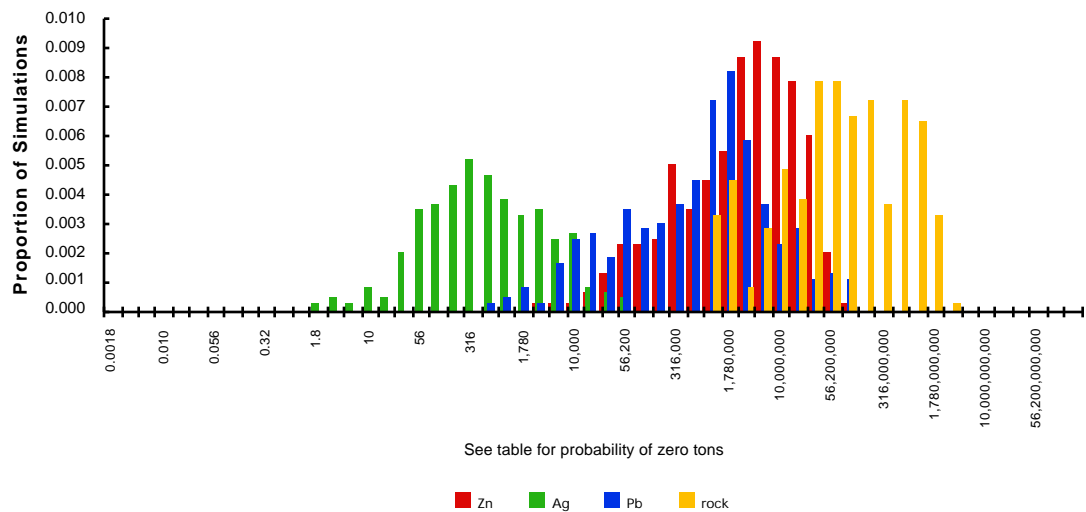
quantile	Zn	Ag	Pb	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	710,000	0	32,000	19,000,000
mean	470,000	87	250,000	16,000,000
Probability of mean	0.05	0.03	0.04	0.05
Probability of zero	0.93	0.96	0.94	0.93

The tract ID is LS09

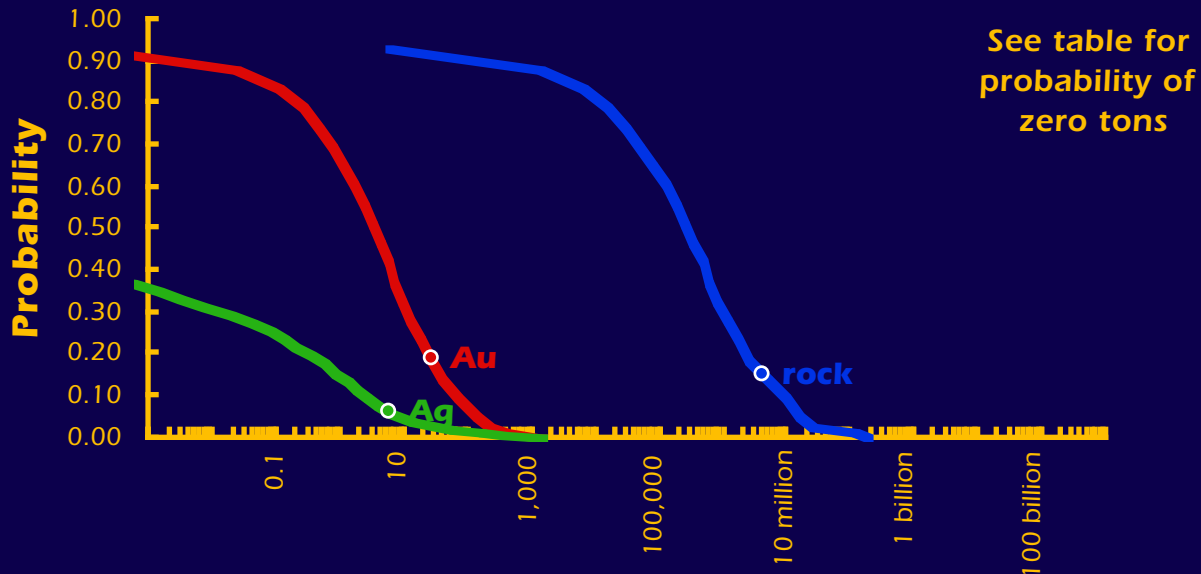
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

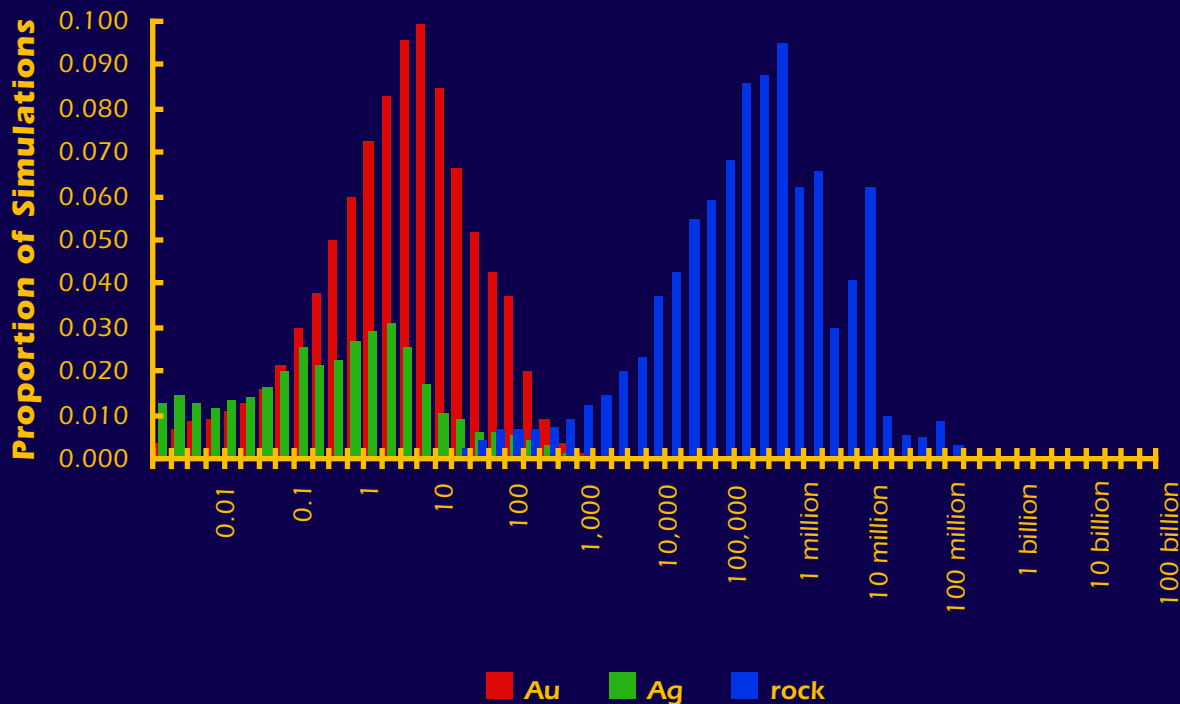


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is LS10

The Mark3 Index is 27:

Low sulfide Au-quartz vein

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

There is a 1% or greater chance of 6 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	400
0.50	3	0	260,000
0.10	64	3	8,880,000
0.05	130	8	14,000,000
mean	26	6	4,100,000
Probability of mean	0.19	0.06	0.15
Probability of zero	0.07	0.61	0.07

The tract ID is LS10The Mark3 Index is 27: **Low sulfide Au-quartz vein**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

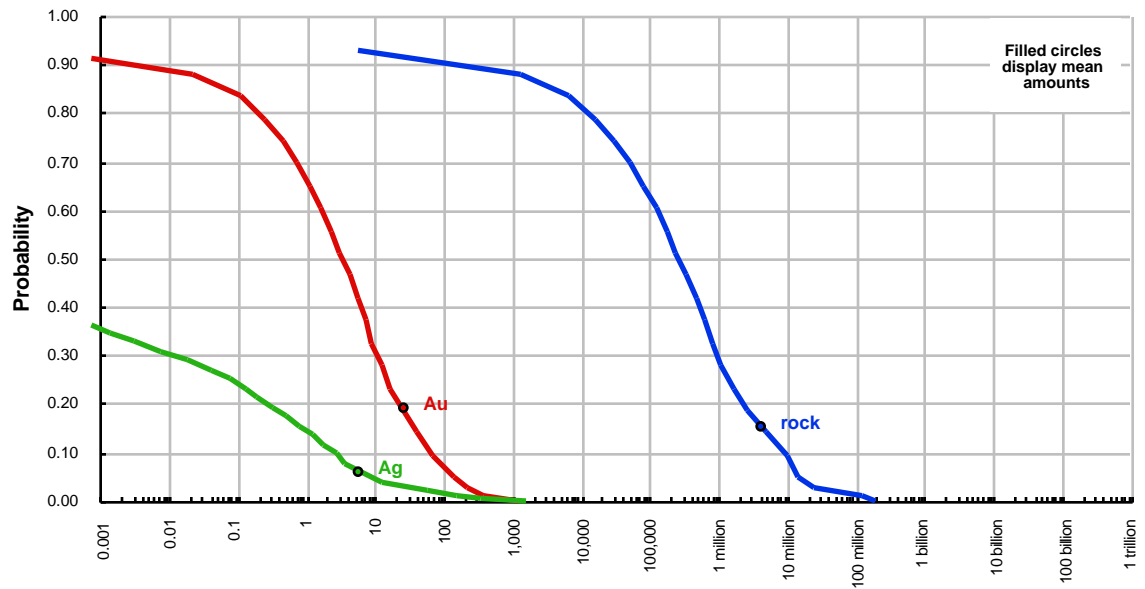
There is a 1% or greater chance of 6 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

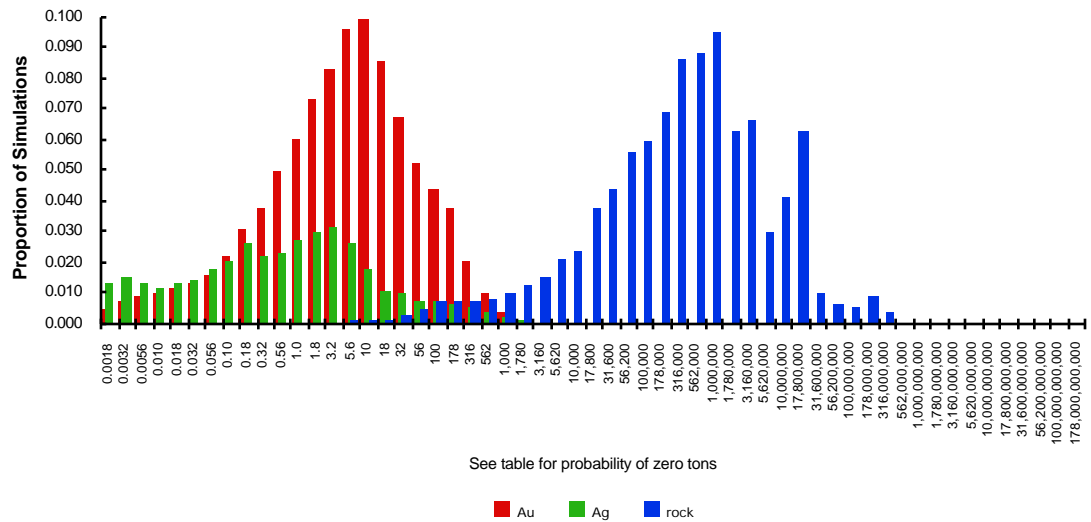
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	400
0.50	3	0	260,000
0.10	64	3	8,880,000
0.05	130	8	14,000,000
mean	26	6	4,100,000
Probability of mean	0.19	0.06	0.15
Probability of zero	0.07	0.61	0.07

The tract ID is LS10

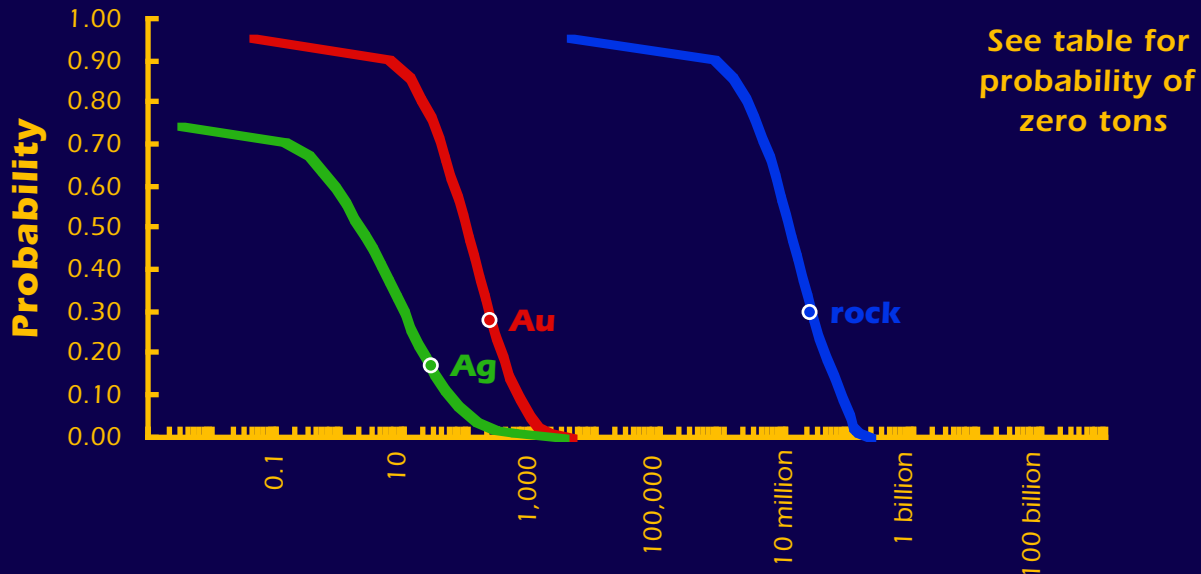
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

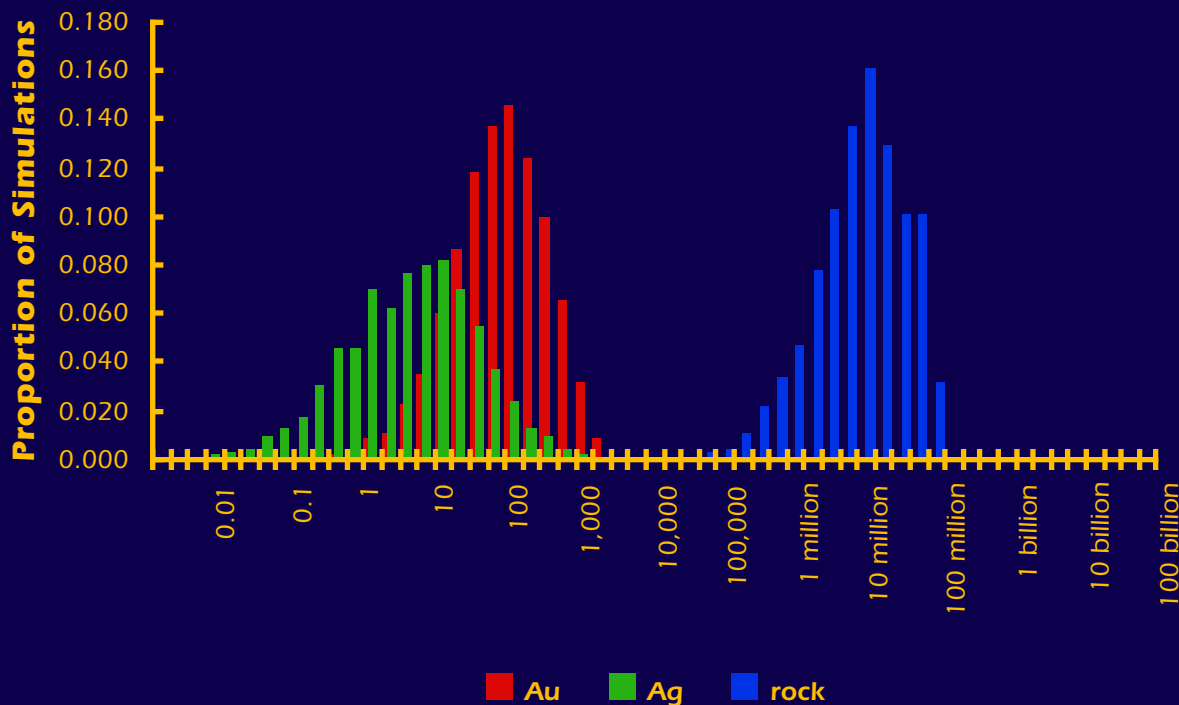


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is LS11

The Mark3 Index is 101:

Low-sulfide Au-quartz, Archean

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 4 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

There is a 1% or greater chance of 6 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	1	0	150,000
0.90	7	0	800,000
0.50	91	2	11,000,000
0.10	590	49	69,300,000
0.05	860	100	91,000,000
mean	220	25	23,000,000
Probability of mean	0.28	0.17	0.30
Probability of zero	0.04	0.25	0.04

The tract ID is LS11

The Mark3 Index is 101: **Low-sulfide Au-quartz, Archean**

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 4 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

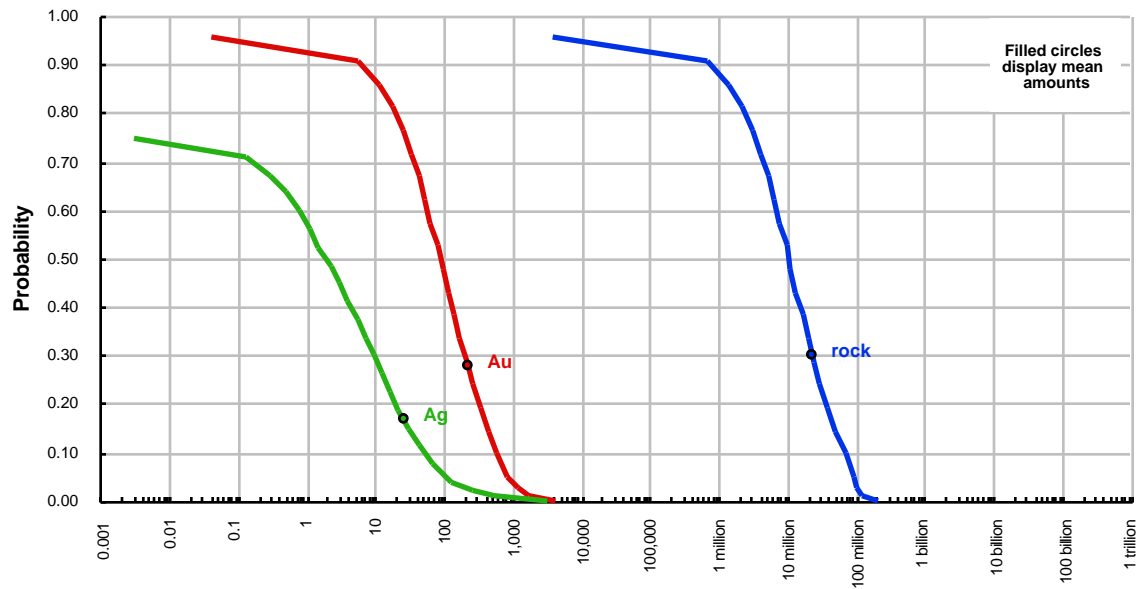
There is a 1% or greater chance of 6 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

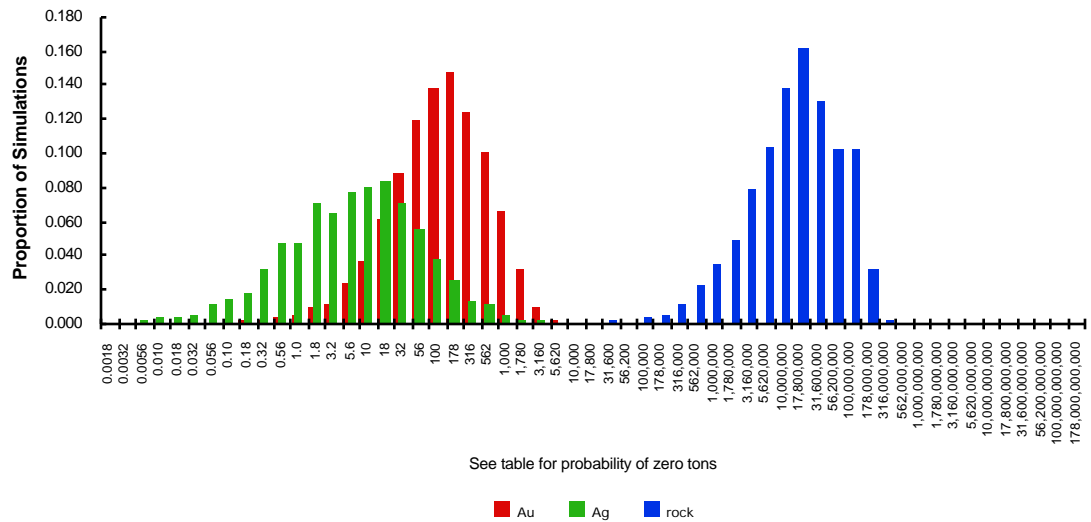
quantile	Au	Ag	rock
0.95	1	0	150,000
0.90	7	0	800,000
0.50	91	2	11,000,000
0.10	590	49	69,300,000
0.05	860	100	91,000,000
mean	220	25	23,000,000
Probability of mean	0.28	0.17	0.30
Probability of zero	0.04	0.25	0.04

The tract ID is LS11

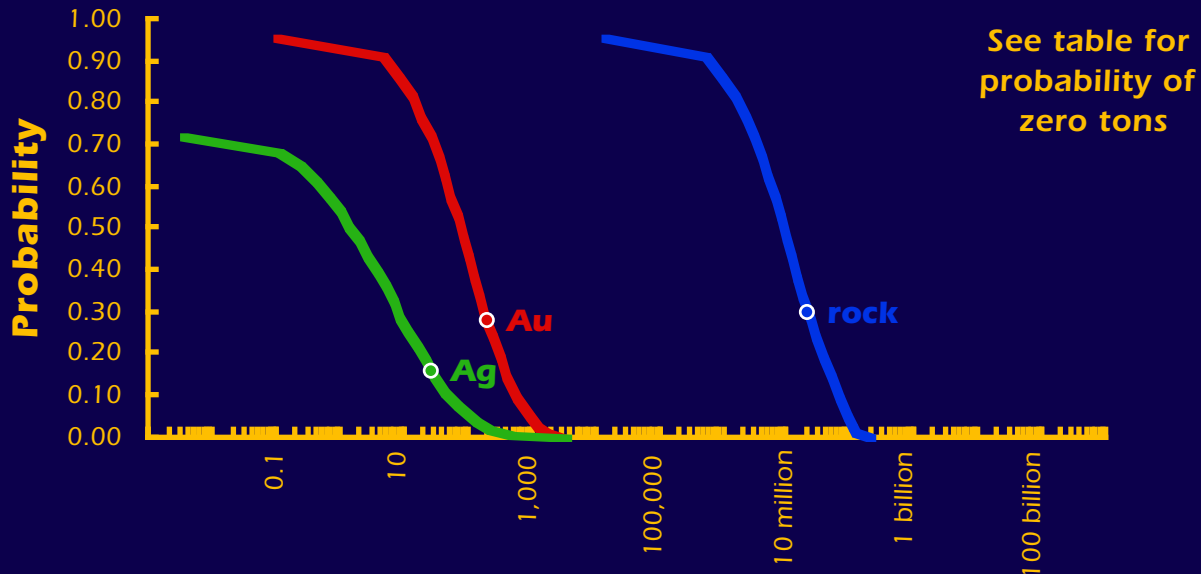
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

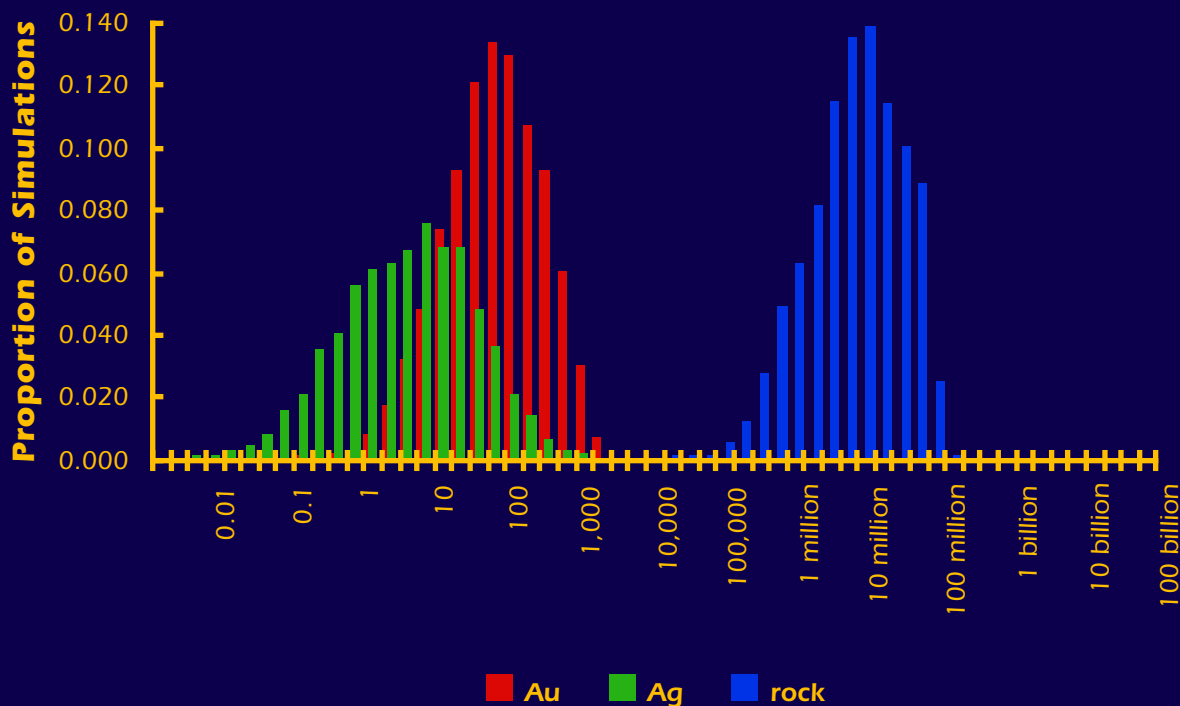


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is LS12

The Mark3 Index is 101:

Low-sulfide Au-quartz, Archean

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

There is a 1% or greater chance of 6 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	1	0	180,000
0.90	5	0	640,000
0.50	74	1	8,700,000
0.10	560	44	62,300,000
0.05	860	94	85,000,000
mean	200	25	21,000,000
Probability of mean	0.28	0.16	0.30
Probability of zero	0.04	0.28	0.04

The tract ID is LS12

The Mark3 Index is 101: **Low-sulfide Au-quartz, Archean**

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

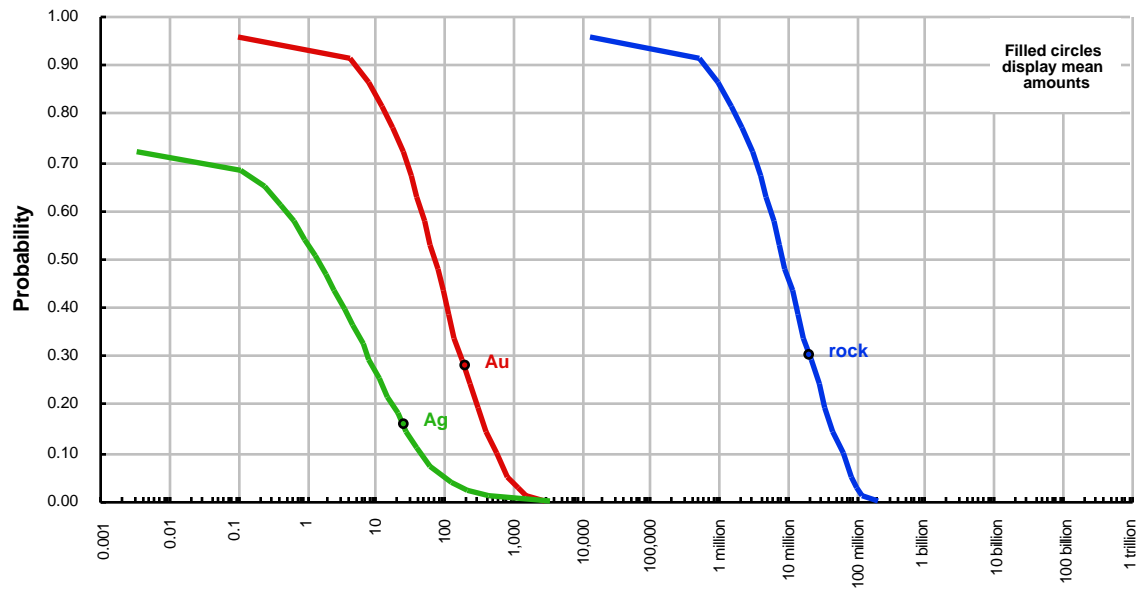
There is a 1% or greater chance of 6 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

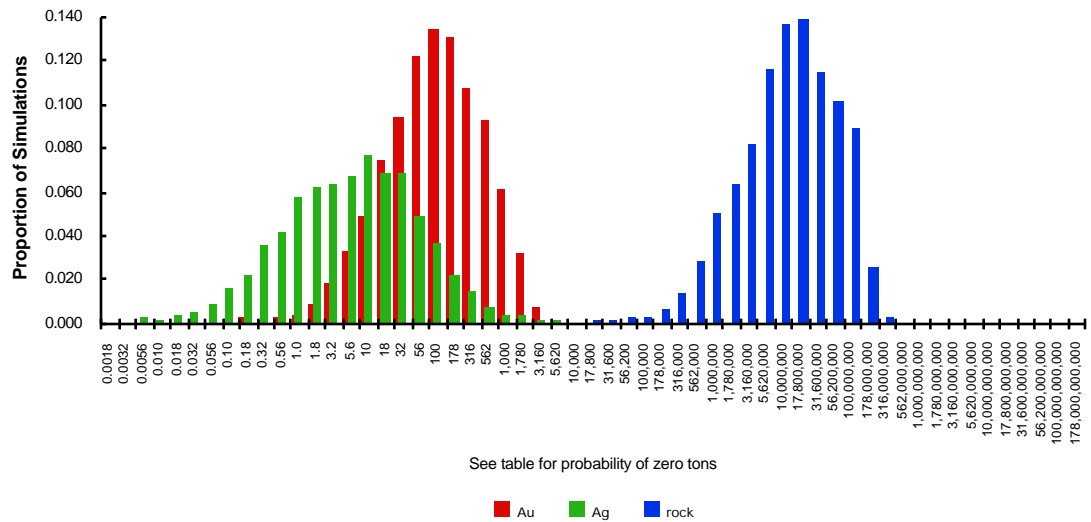
quantile	Au	Ag	rock
0.95	1	0	180,000
0.90	5	0	640,000
0.50	74	1	8,700,000
0.10	560	44	62,300,000
0.05	860	94	85,000,000
mean	200	25	21,000,000
Probability of mean	0.28	0.16	0.30
Probability of zero	0.04	0.28	0.04

The tract ID is LS12

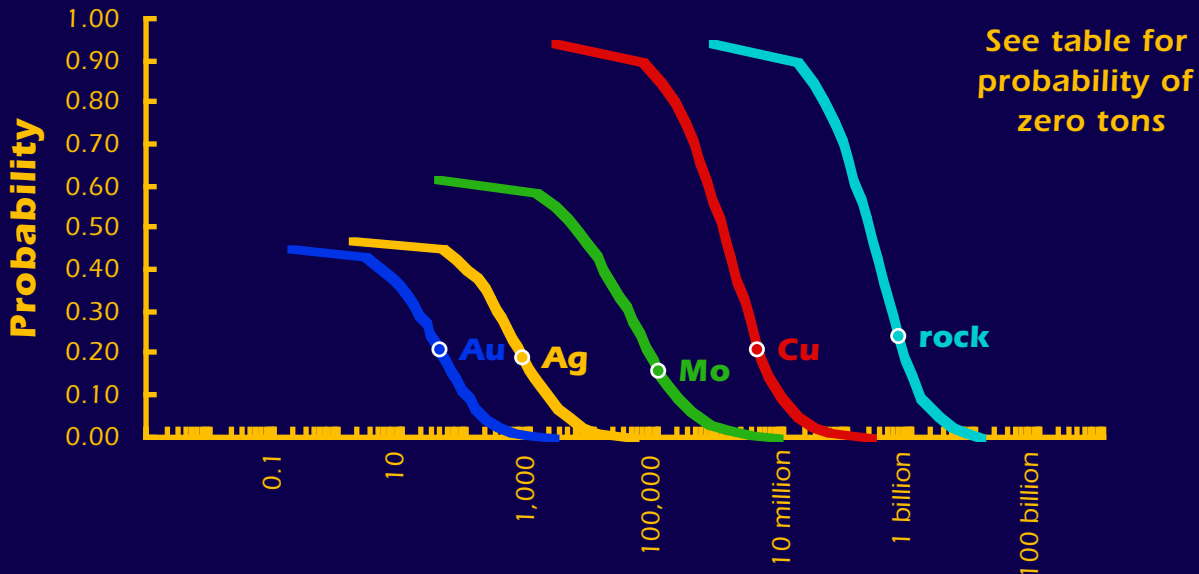
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

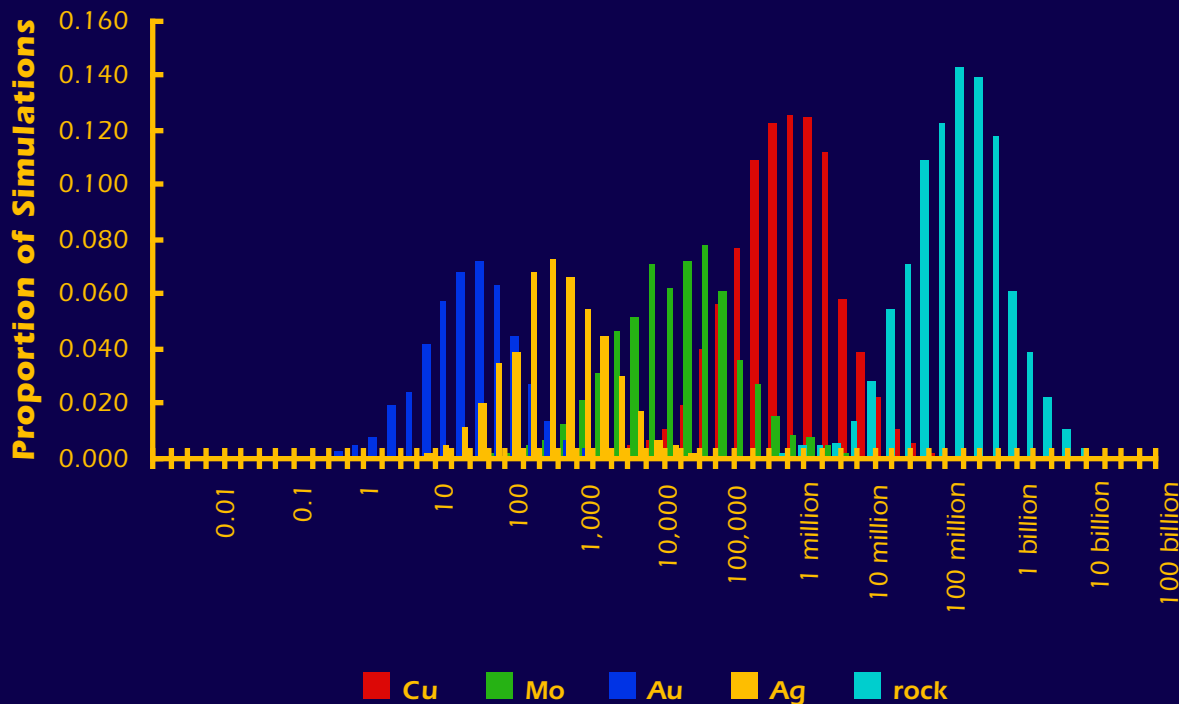


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NA02

The Mark3 Index is 4:

Porphyry Cu

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	57,000	0	0	0	15,000,000
0.50	990,000	5,300	0	0	200,000,000
0.10	7,800,000	180,000	95	1,900	1,300,000,000
0.05	15,000,000	410,000	180	3,600	2,500,000,000
mean	3,700,000	100,000	38	760	580,000,000
Probability of mean	0.21	0.16	0.21	0.19	0.24
Probability of zero	0.06	0.38	0.55	0.53	0.06

The tract ID is NA02The Mark3 Index is 4: **Porphyry Cu**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

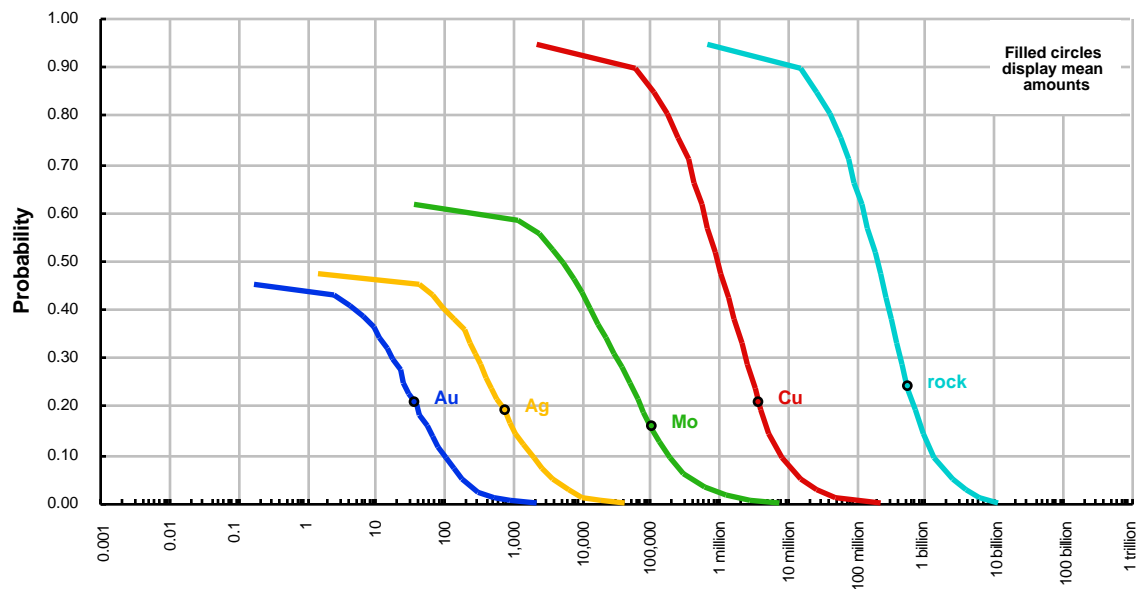
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

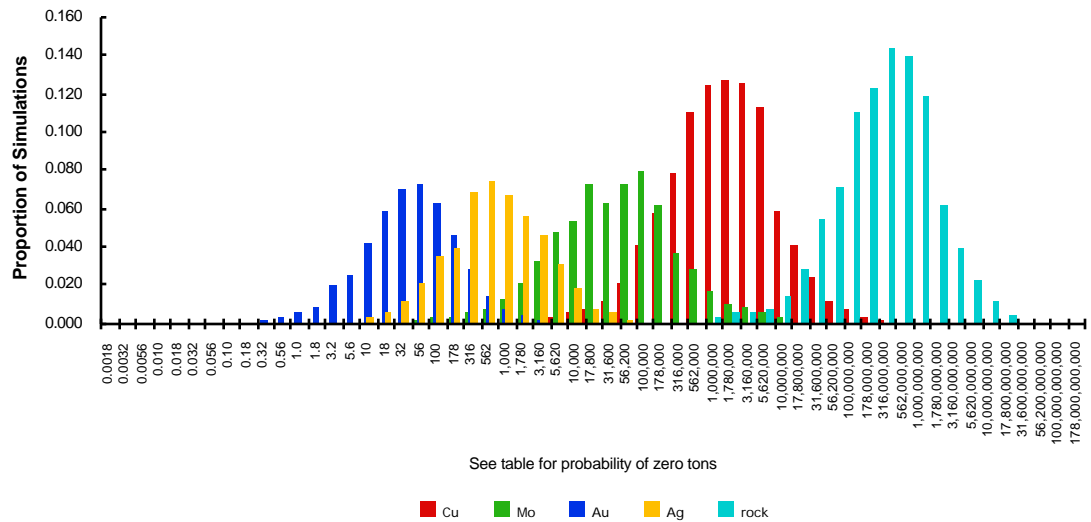
quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	57,000	0	0	0	15,000,000
0.50	990,000	5,300	0	0	200,000,000
0.10	7,800,000	180,000	95	1,900	1,300,000,000
0.05	15,000,000	410,000	180	3,600	2,500,000,000
mean	3,700,000	100,000	38	760	580,000,000
Probability of mean	0.21	0.16	0.21	0.19	0.24
Probability of zero	0.06	0.38	0.55	0.53	0.06

The tract ID is NA02

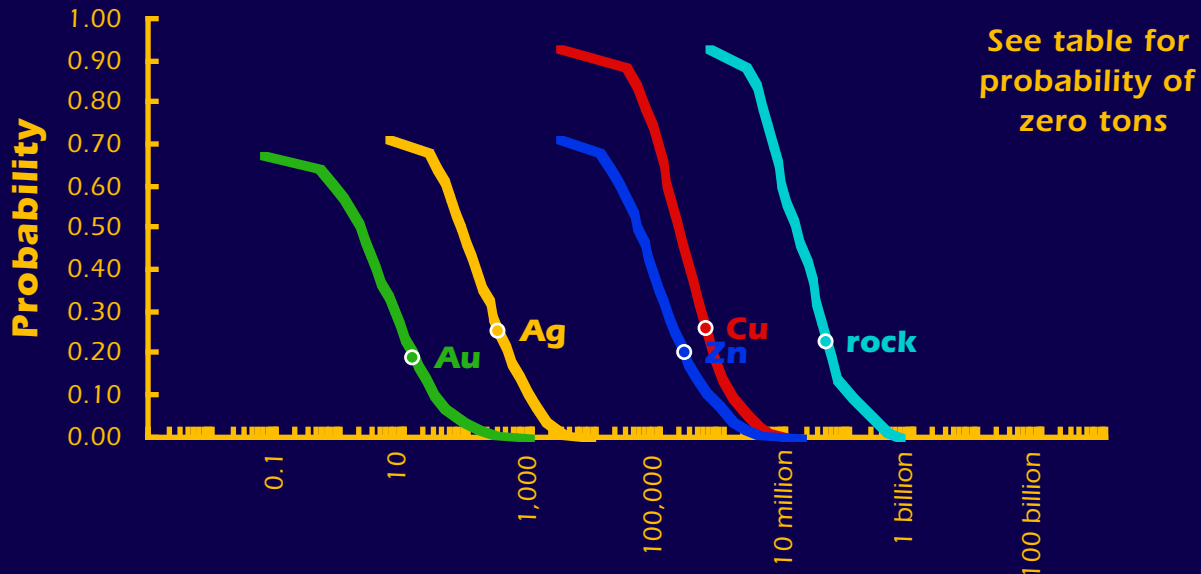
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

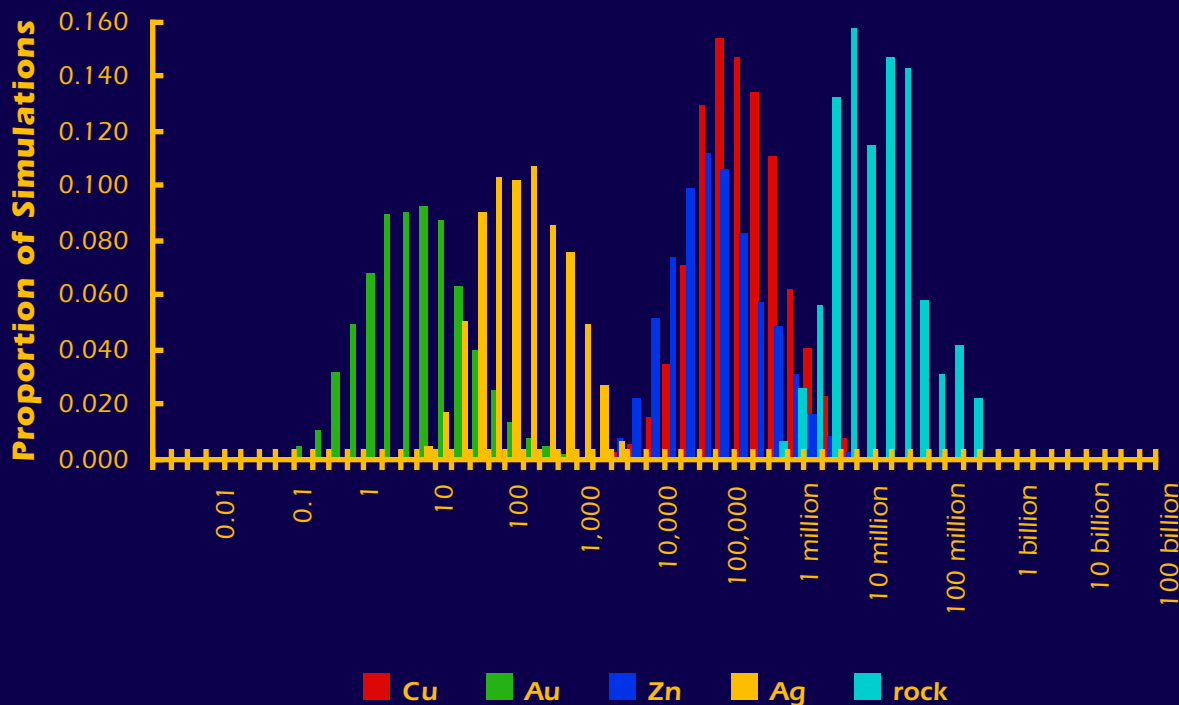


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NAO6

The Mark3 Index is 98:

Massive sulfide, Besshi

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	rock
0.95	0	0	0	0	0
0.90	22,000	0	0	0	1,800,000
0.50	200,000	2	46,000	76	13,000,000
0.10	1,300,000	30	604,000	860	94,000,000
0.05	2,300,000	57	1,100,000	1,400	210,000,000
mean	530,000	14	240,000	300	40,000,000
Probability of mean	0.26	0.19	0.20	0.25	0.23
Probability of zero	0.07	0.32	0.28	0.28	0.07

The tract ID is NA06The Mark3 Index is 98: **Massive sulfide, Besshi**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

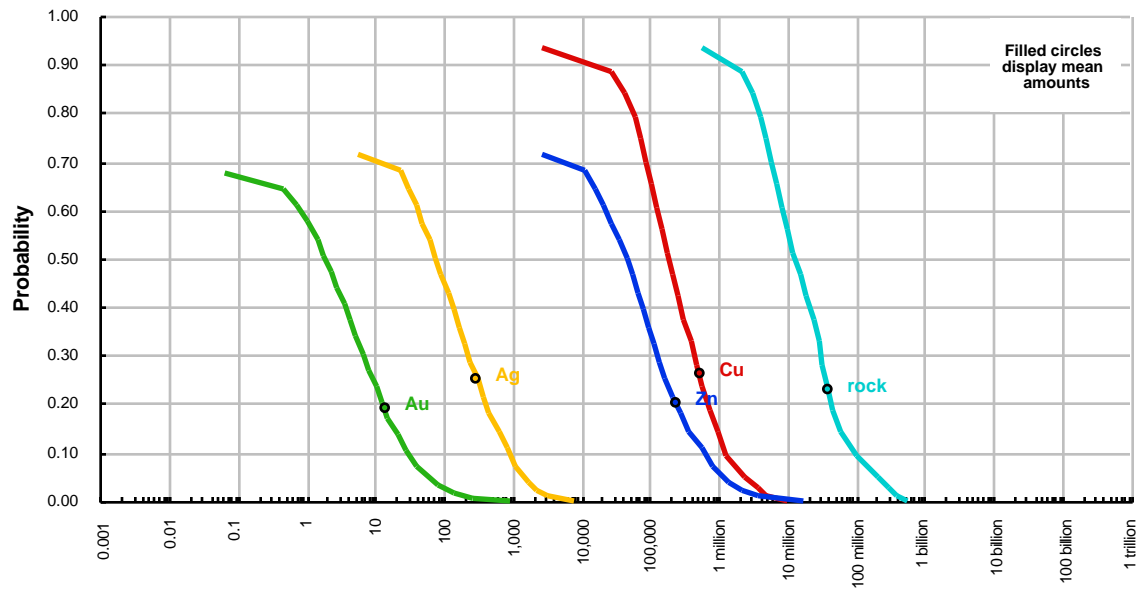
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

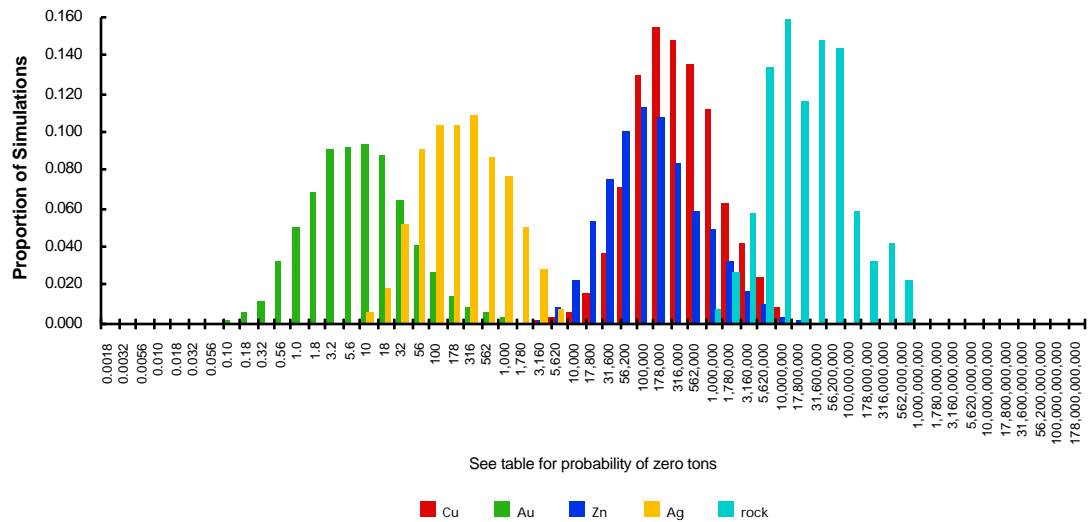
quantile	Cu	Au	Zn	Ag	rock
0.95	0	0	0	0	0
0.90	22,000	0	0	0	1,800,000
0.50	200,000	2	46,000	76	13,000,000
0.10	1,300,000	30	604,000	860	94,000,000
0.05	2,300,000	57	1,100,000	1,400	210,000,000
mean	530,000	14	240,000	300	40,000,000
Probability of mean	0.26	0.19	0.20	0.25	0.23
Probability of zero	0.07	0.32	0.28	0.28	0.07

The tract ID is NA06

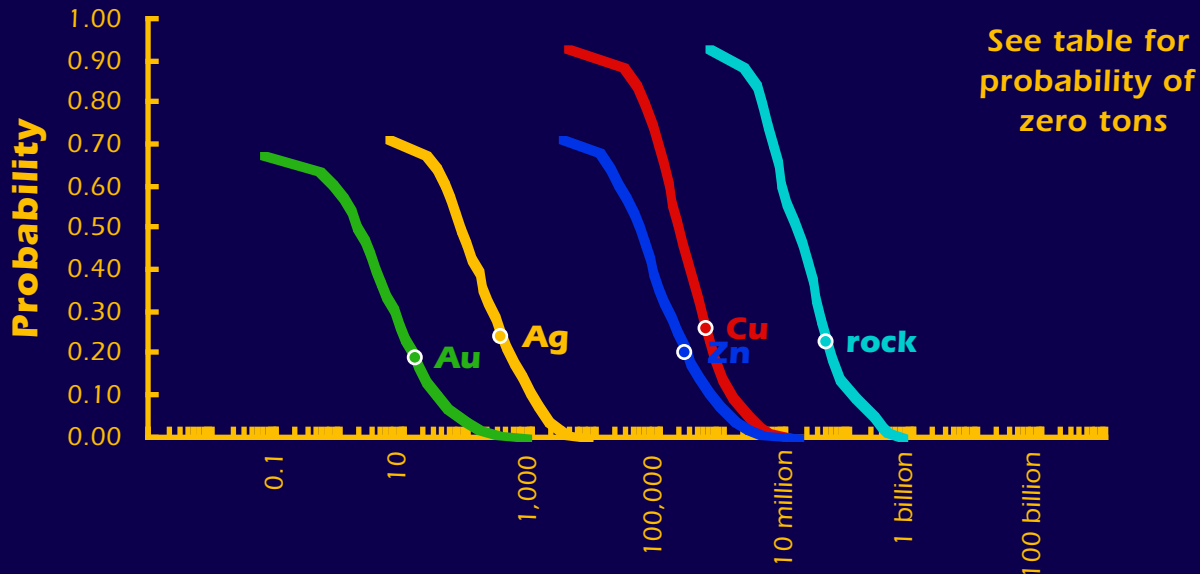
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

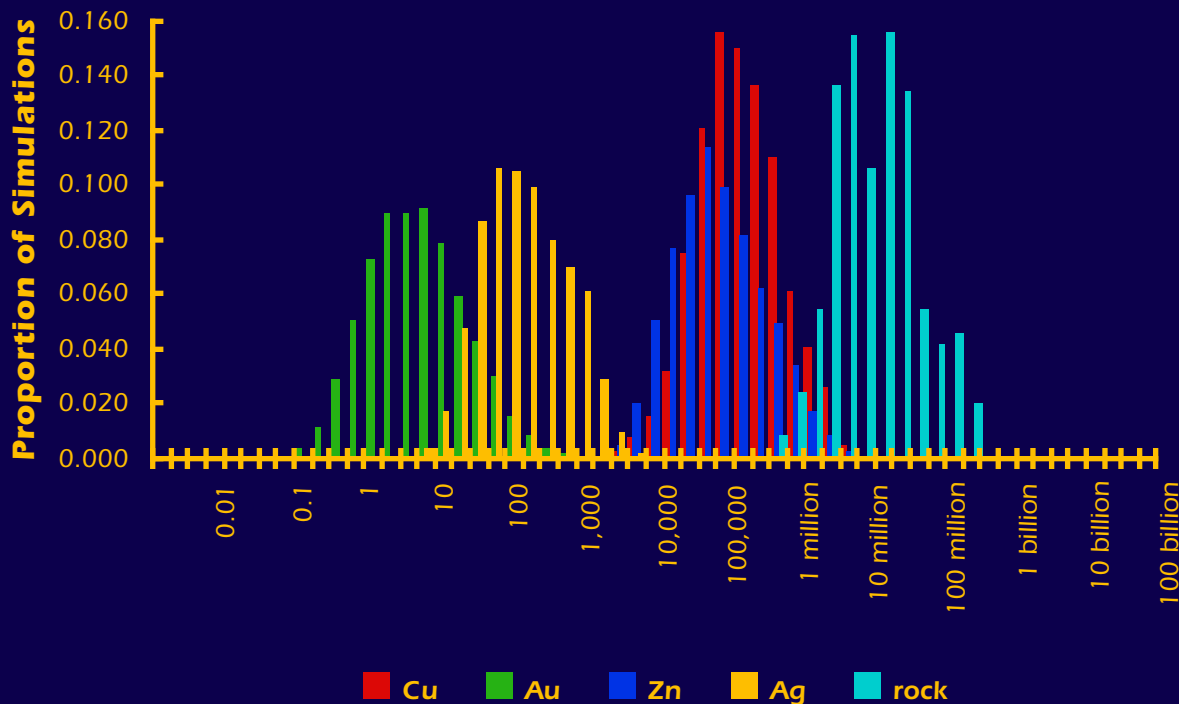


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NAO7

The Mark3 Index is 98:

Massive sulfide, Besshi

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	rock
0.95	0	0	0	0	0
0.90	22,000	0	0	0	1,800,000
0.50	200,000	2	46,000	77	13,000,000
0.10	1,300,000	32	632,000	1,000	110,000,000
0.05	2,400,000	63	1,200,000	1,600	220,000,000
mean	530,000	14	260,000	330	41,000,000
Probability of mean	0.26	0.19	0.20	0.24	0.23
Probability of zero	0.07	0.33	0.29	0.29	0.07

The tract ID is NA07The Mark3 Index is 98: **Massive sulfide, Besshi**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

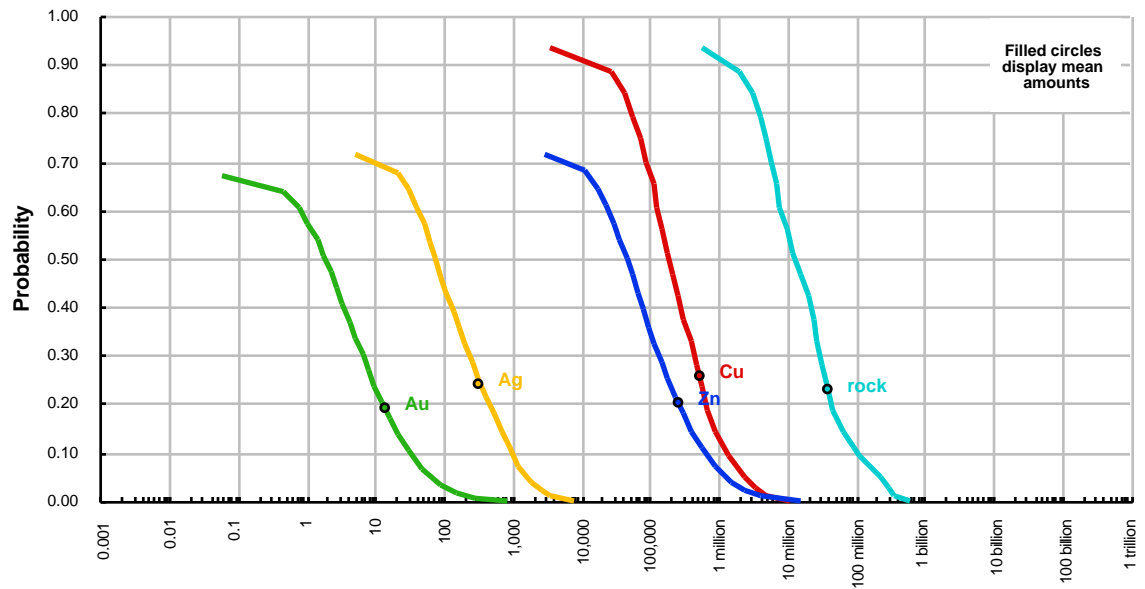
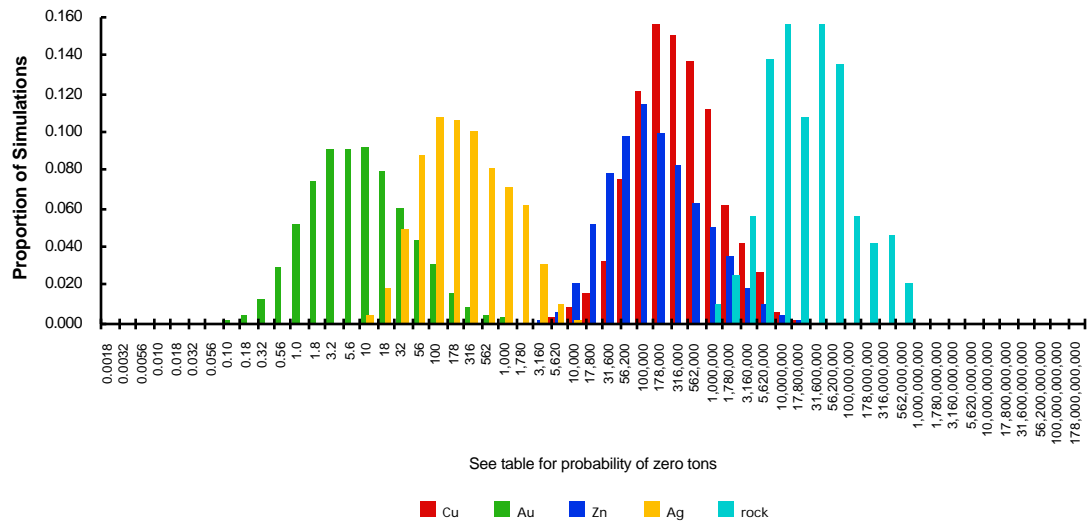
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

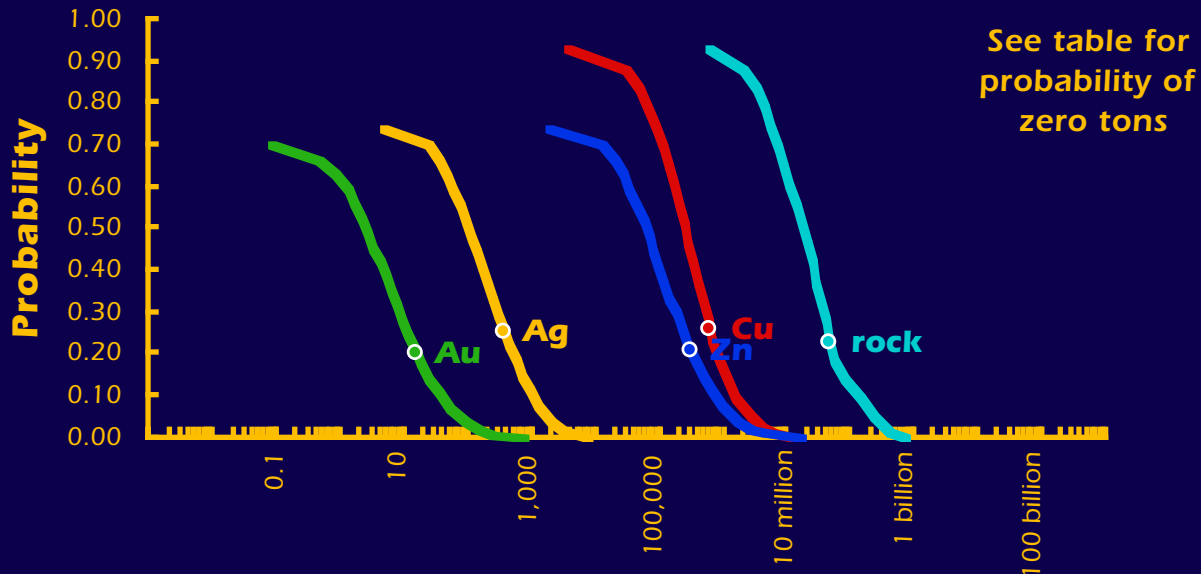
quantile	Cu	Au	Zn	Ag	rock
0.95	0	0	0	0	0
0.90	22,000	0	0	0	1,800,000
0.50	200,000	2	46,000	77	13,000,000
0.10	1,300,000	32	632,000	1,000	110,000,000
0.05	2,400,000	63	1,200,000	1,600	220,000,000
mean	530,000	14	260,000	330	41,000,000
Probability of mean	0.26	0.19	0.20	0.24	0.23
Probability of zero	0.07	0.33	0.29	0.29	0.07

The tract ID is NA07

Cumulative Distributions of Contained Metal and Mineralized Rock

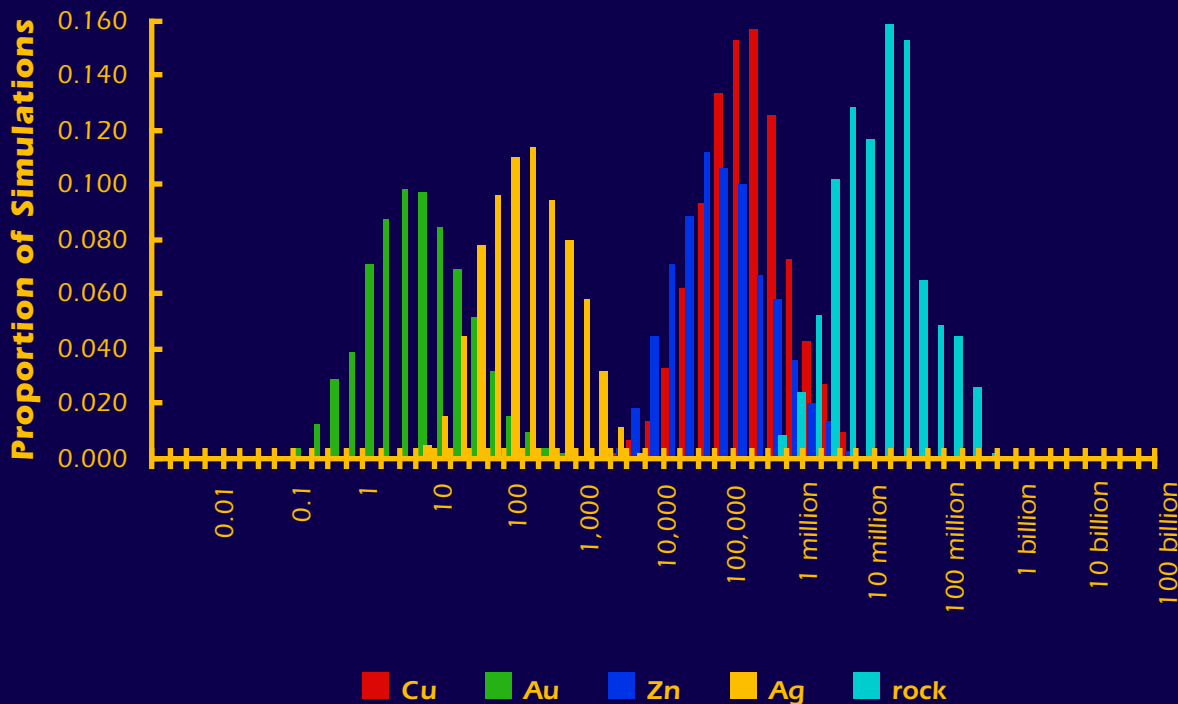
Histograms of Contained Metal and Mineralized Rock
(metric tons)

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NAO8

The Mark3 Index is 98:

Massive sulfide, Besshi

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	rock
0.95	0	0	0	0	0
0.90	21,000	0	0	0	1,700,000
0.50	240,000	2	61,000	100	18,000,000
0.10	1,500,000	36	744,000	1,000	130,000,000
0.05	2,700,000	65	1,400,000	1,600	230,000,000
mean	610,000	15	300,000	360	46,000,000
Probability of mean	0.26	0.20	0.21	0.25	0.23
Probability of zero	0.07	0.30	0.26	0.26	0.07

The tract ID is NA08The Mark3 Index is 98: **Massive sulfide, Besshi**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

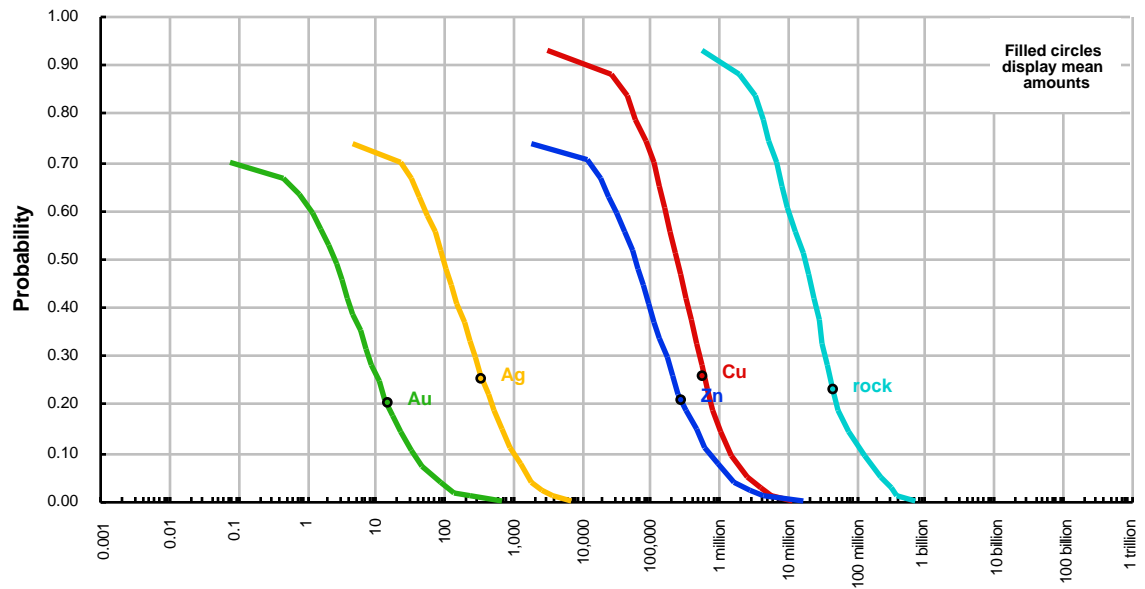
There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

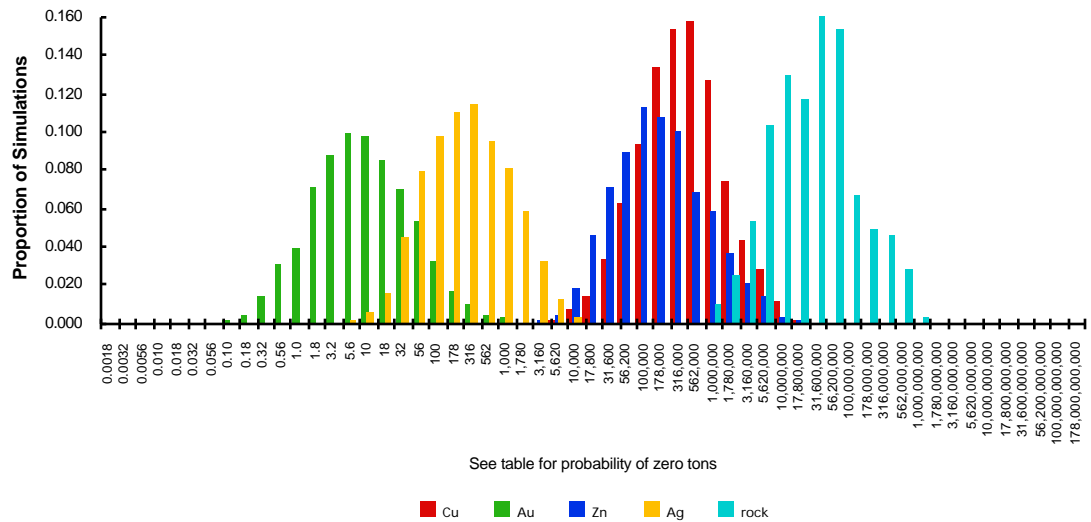
quantile	Cu	Au	Zn	Ag	rock
0.95	0	0	0	0	0
0.90	21,000	0	0	0	1,700,000
0.50	240,000	2	61,000	100	18,000,000
0.10	1,500,000	36	744,000	1,000	130,000,000
0.05	2,700,000	65	1,400,000	1,600	230,000,000
mean	610,000	15	300,000	360	46,000,000
Probability of mean	0.26	0.20	0.21	0.25	0.23
Probability of zero	0.07	0.30	0.26	0.26	0.07

The tract ID is NA08

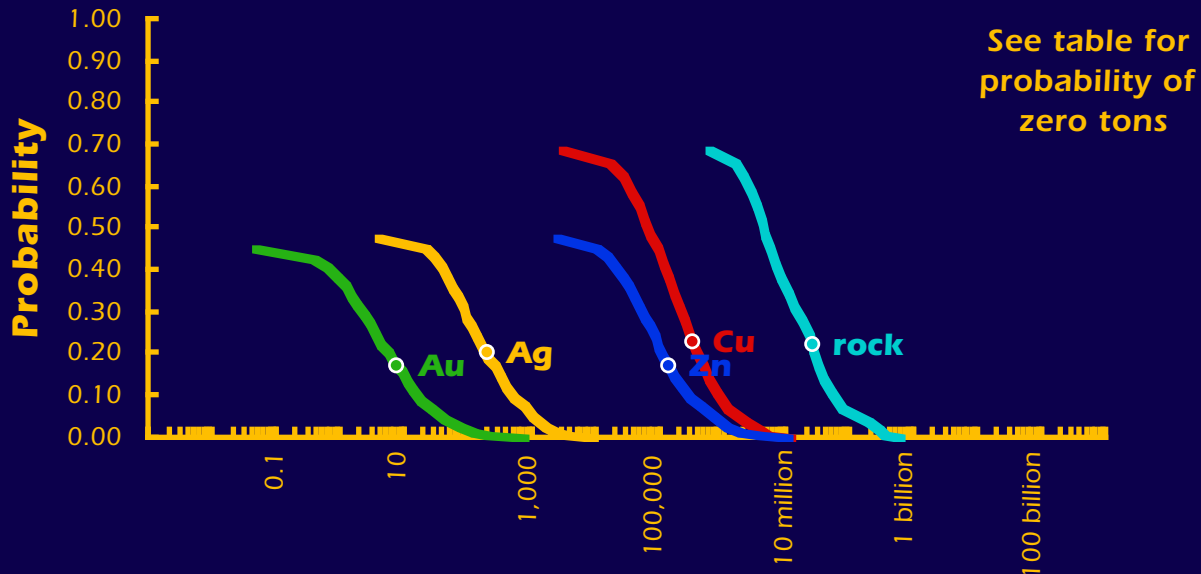
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

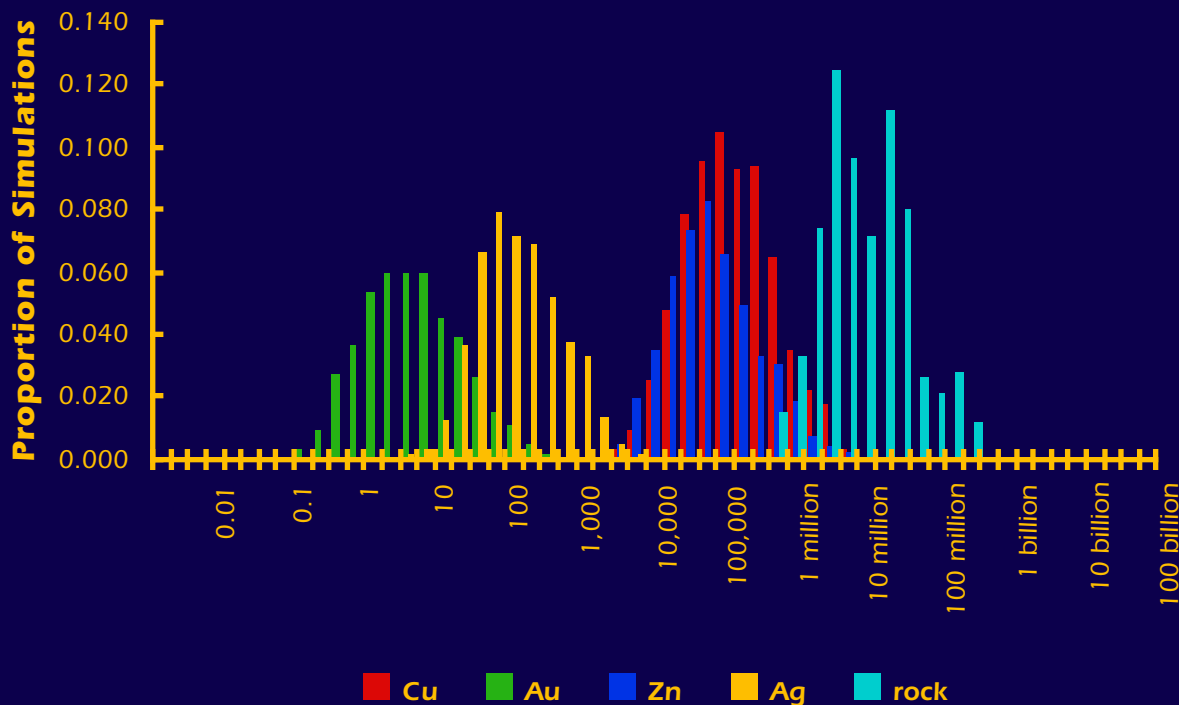


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NAO9

The Mark3 Index is 98:

Massive sulfide, Besshi

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	67,000	0	0	0	4,400,000
0.10	790,000	17	287,000	490	50,000,000
0.05	1,600,000	37	680,000	1,000	130,000,000
mean	330,000	8	140,000	190	24,000,000
Probability of mean	0.23	0.17	0.17	0.20	0.22
Probability of zero	0.31	0.55	0.52	0.52	0.31

The tract ID is NA09The Mark3 Index is 98: **Massive sulfide, Besshi**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

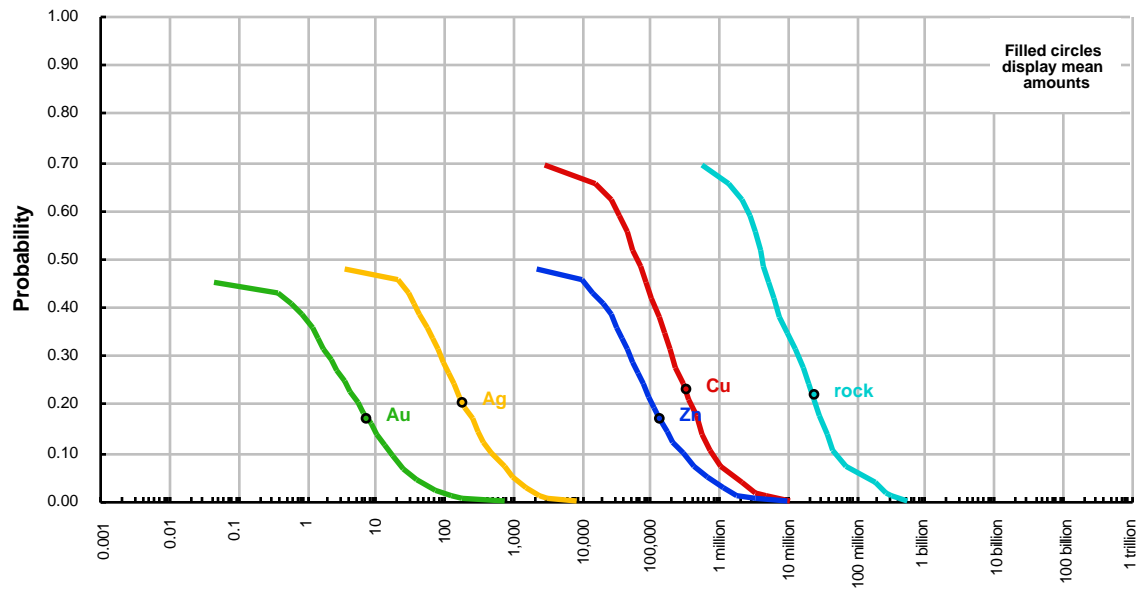
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

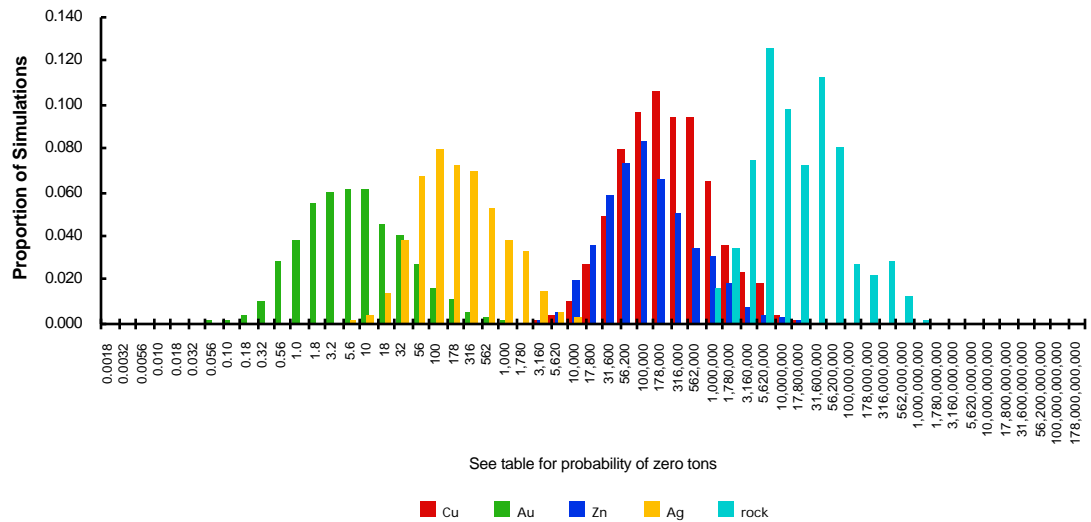
quantile	Cu	Au	Zn	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	67,000	0	0	0	4,400,000
0.10	790,000	17	287,000	490	50,000,000
0.05	1,600,000	37	680,000	1,000	130,000,000
mean	330,000	8	140,000	190	24,000,000
Probability of mean	0.23	0.17	0.17	0.20	0.22
Probability of zero	0.31	0.55	0.52	0.52	0.31

The tract ID is NA09

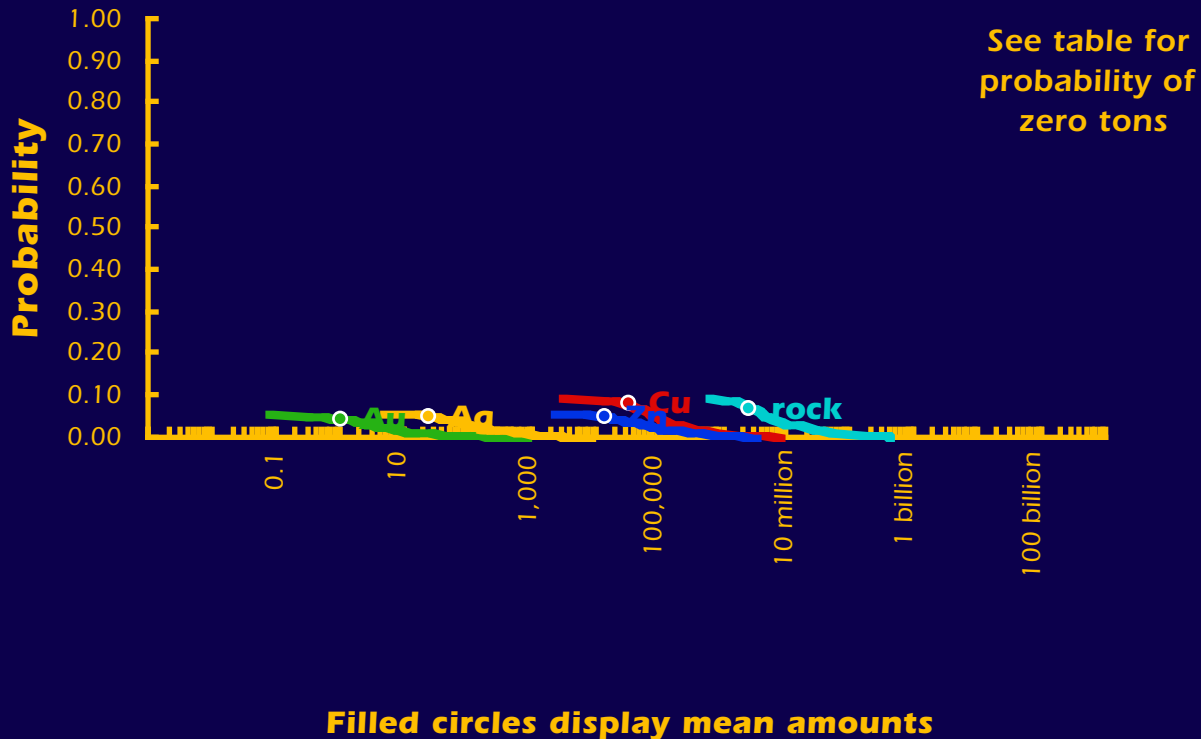
Cumulative Distributions of Contained Metal and Mineralized Rock



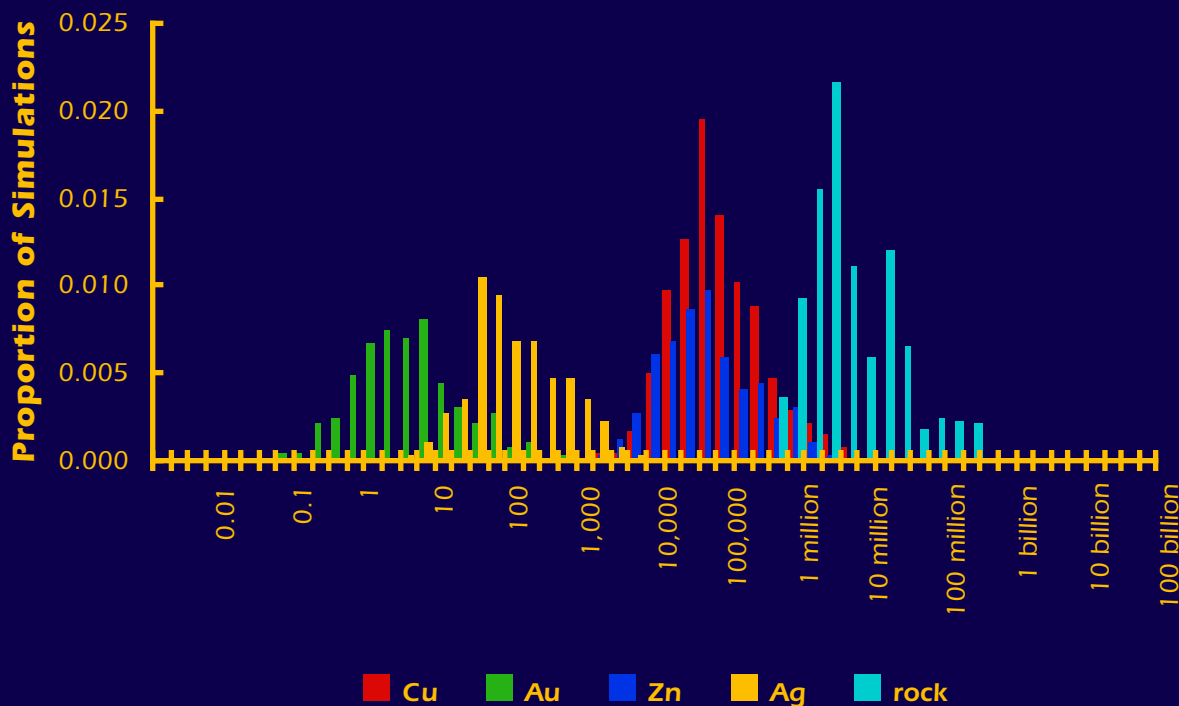
Histograms of Contained Metal and Mineralized Rock (metric tons)



Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NA10

The Mark3 Index is 98:

Massive sulfide, Besshi

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	83,000	0	13,000	29	4,600,000
mean	32,000	1	14,000	23	2,600,000
Probability of mean	0.08	0.04	0.05	0.05	0.07
Probability of zero	0.91	0.95	0.94	0.94	0.91

The tract ID is NA10The Mark3 Index is 98: **Massive sulfide, Besshi**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

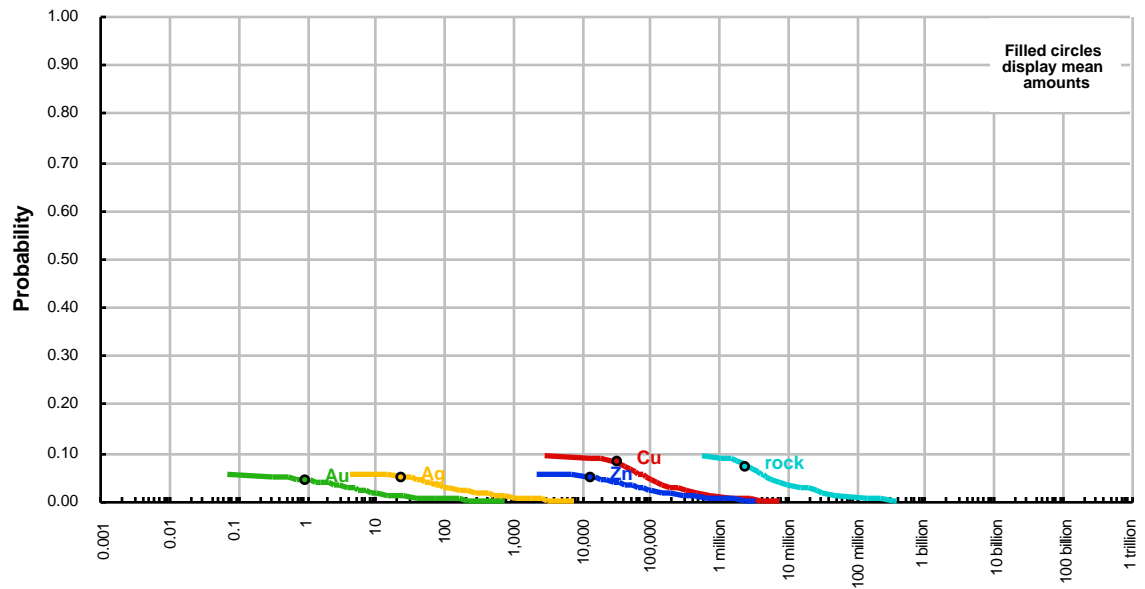
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

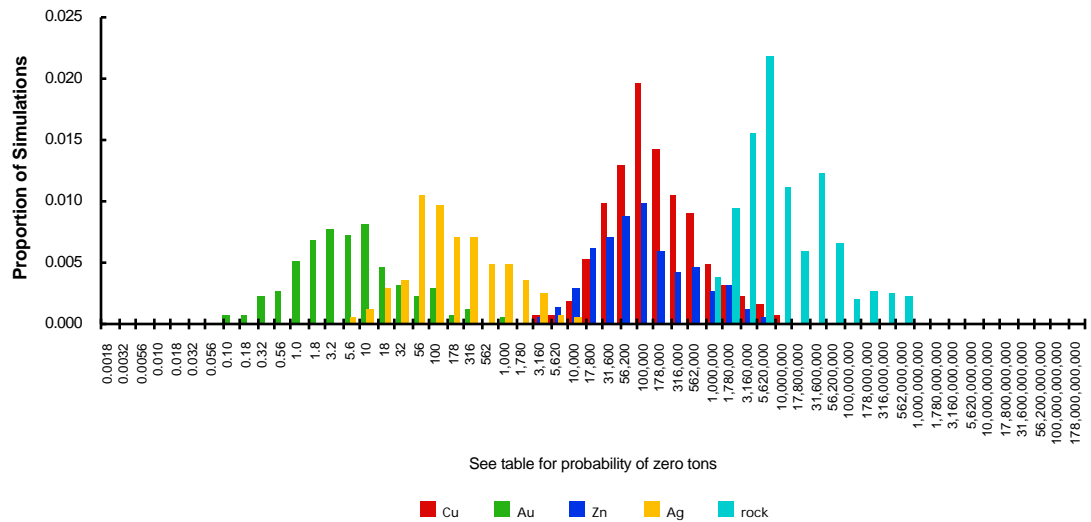
quantile	Cu	Au	Zn	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	83,000	0	13,000	29	4,600,000
mean	32,000	1	14,000	23	2,600,000
Probability of mean	0.08	0.04	0.05	0.05	0.07
Probability of zero	0.91	0.95	0.94	0.94	0.91

The tract ID is NA10

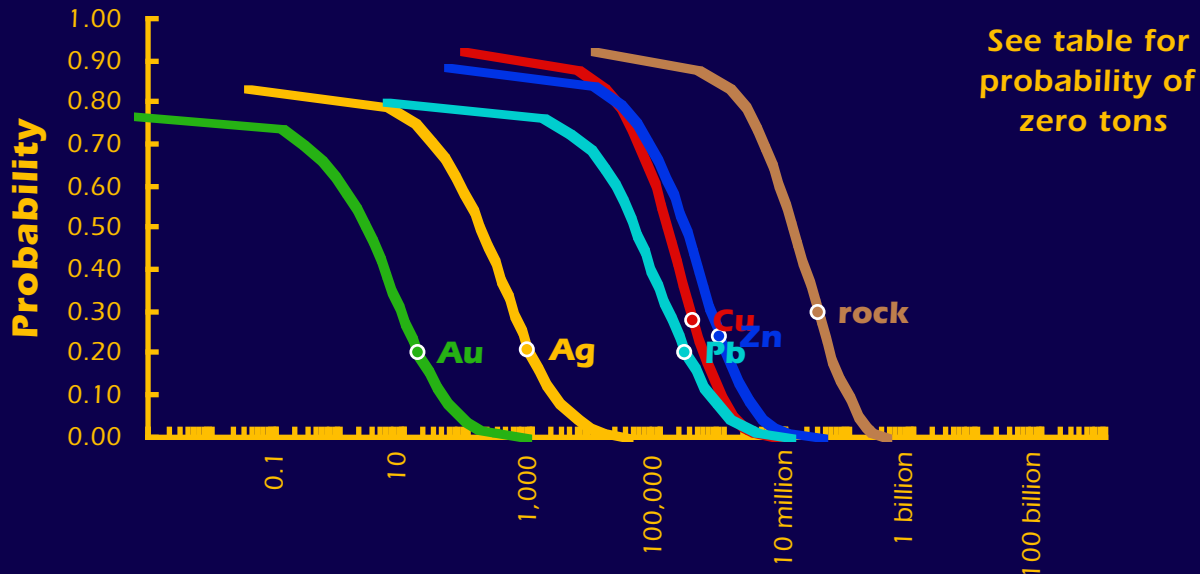
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

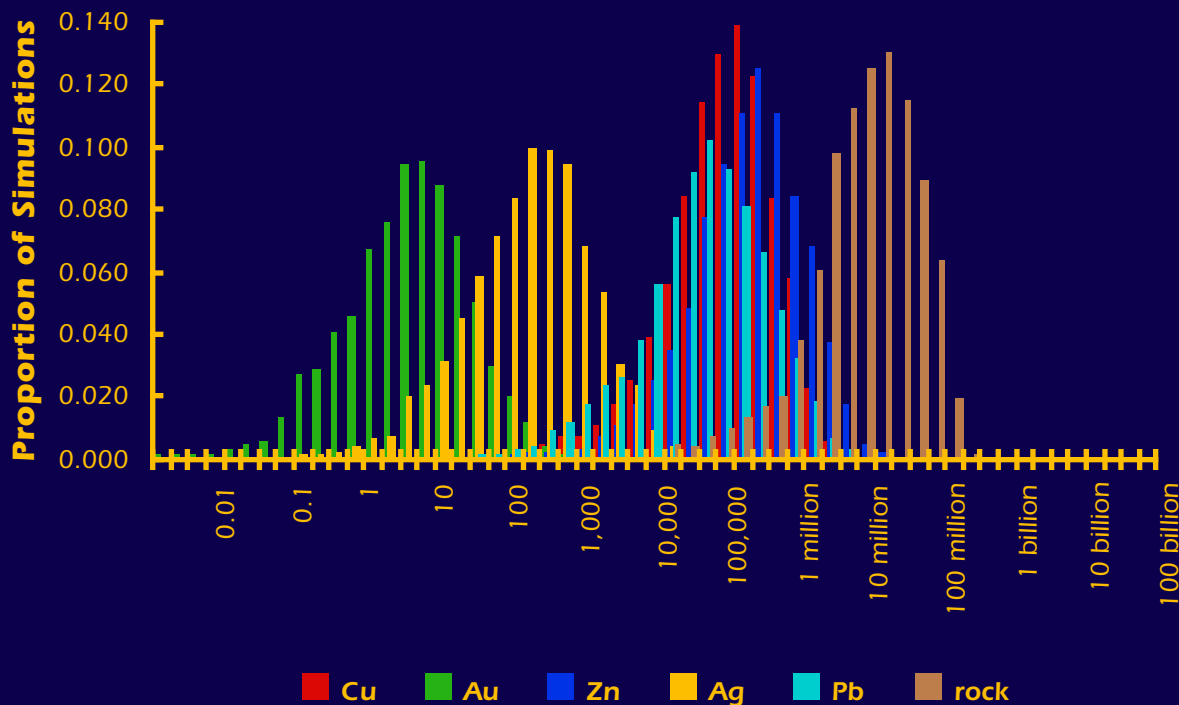


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NA11

The Mark3 Index is 104:

Massive sulfide, kuroko (Phanerozoic)

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	2,600	0	0	0	0	180,000
0.50	130,000	2	240,000	160	41,000	12,000,000
0.10	890,000	38	2,230,000	2,200	610,000	89,000,000
0.05	1,400,000	73	3,900,000	4,100	1,200,000	130,000,000
mean	330,000	16	870,000	870	250,000	30,000,000
Probability of mean	0.28	0.20	0.24	0.21	0.20	0.30
Probability of zero	0.07	0.22	0.11	0.17	0.19	0.07

The tract ID is NA11The Mark3 Index is 104: **Massive sulfide, kuroko (Phanerozoic)**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

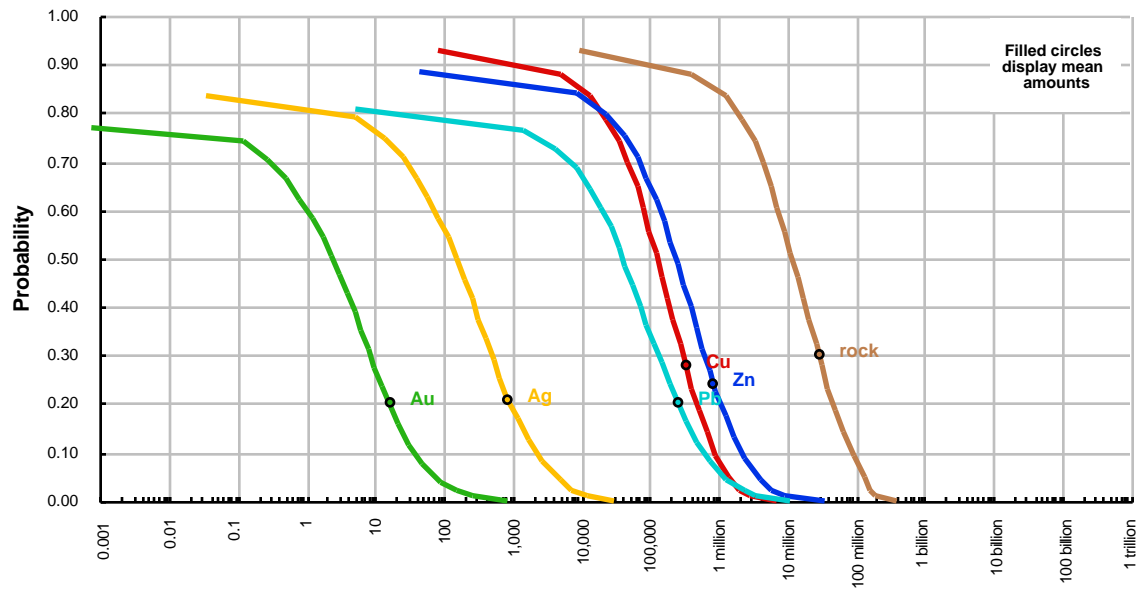
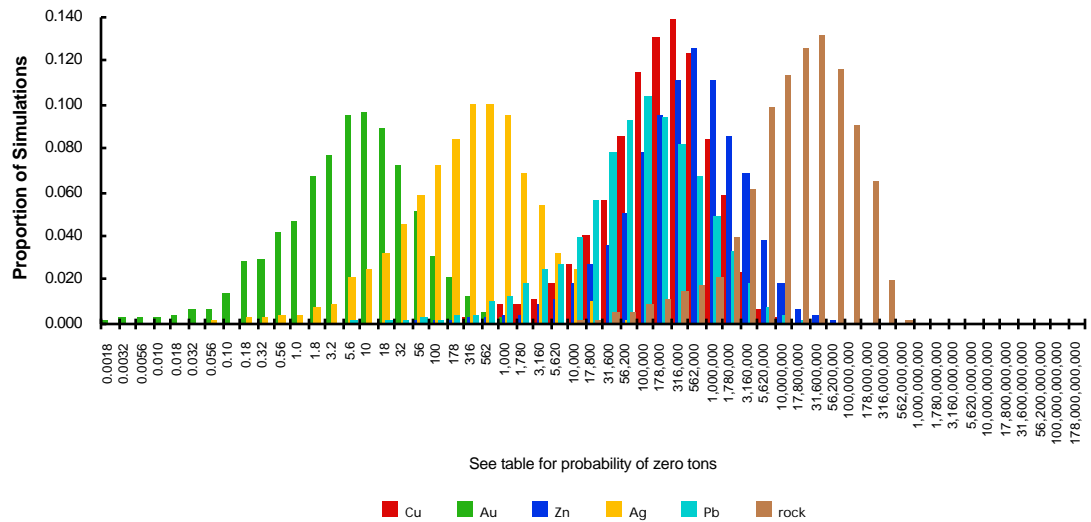
There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

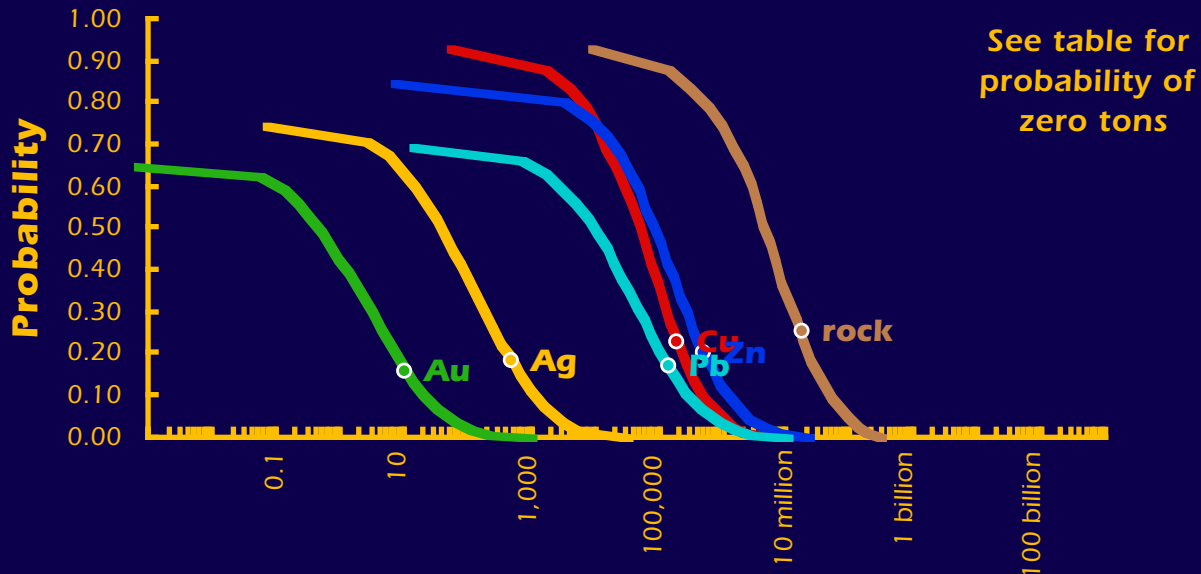
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	2,600	0	0	0	0	180,000
0.50	130,000	2	240,000	160	41,000	12,000,000
0.10	890,000	38	2,230,000	2,200	610,000	89,000,000
0.05	1,400,000	73	3,900,000	4,100	1,200,000	130,000,000
mean	330,000	16	870,000	870	250,000	30,000,000
Probability of mean	0.28	0.20	0.24	0.21	0.20	0.30
Probability of zero	0.07	0.22	0.11	0.17	0.19	0.07

The tract ID is NA11

Cumulative Distributions of Contained Metal and Mineralized Rock

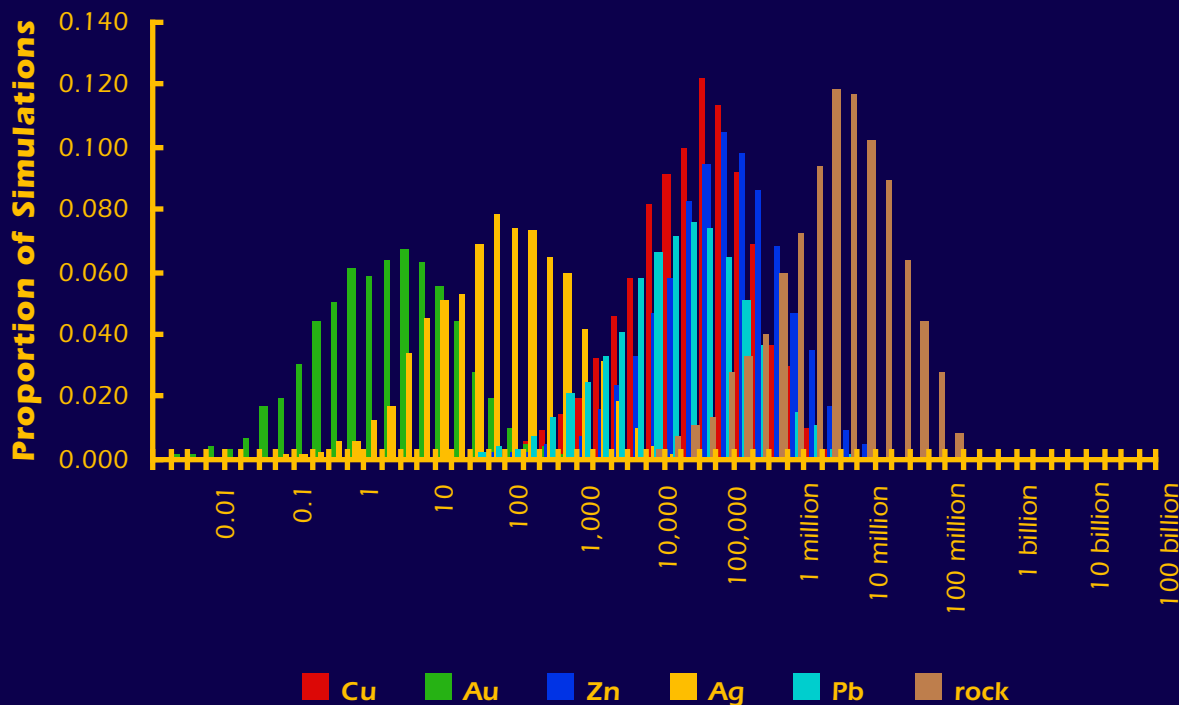
Histograms of Contained Metal and Mineralized Rock
(metric tons)

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NA12

The Mark3 Index is 104:

Massive sulfide, kuroko (Phanerozoic)

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	1,000	0	0	0	0	73,000
0.50	49,000	0	82,000	39	9,200	4,400,000
0.10	450,000	20	1,130,000	1,100	270,000	45,000,000
0.05	890,000	40	2,300,000	2,300	610,000	82,000,000
mean	180,000	10	490,000	460	140,000	16,000,000
Probability of mean	0.23	0.16	0.20	0.18	0.17	0.25
Probability of zero	0.07	0.34	0.15	0.25	0.30	0.07

The tract ID is NA12

The Mark3 Index is 104: **Massive sulfide, kuroko (Phanerozoic)**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

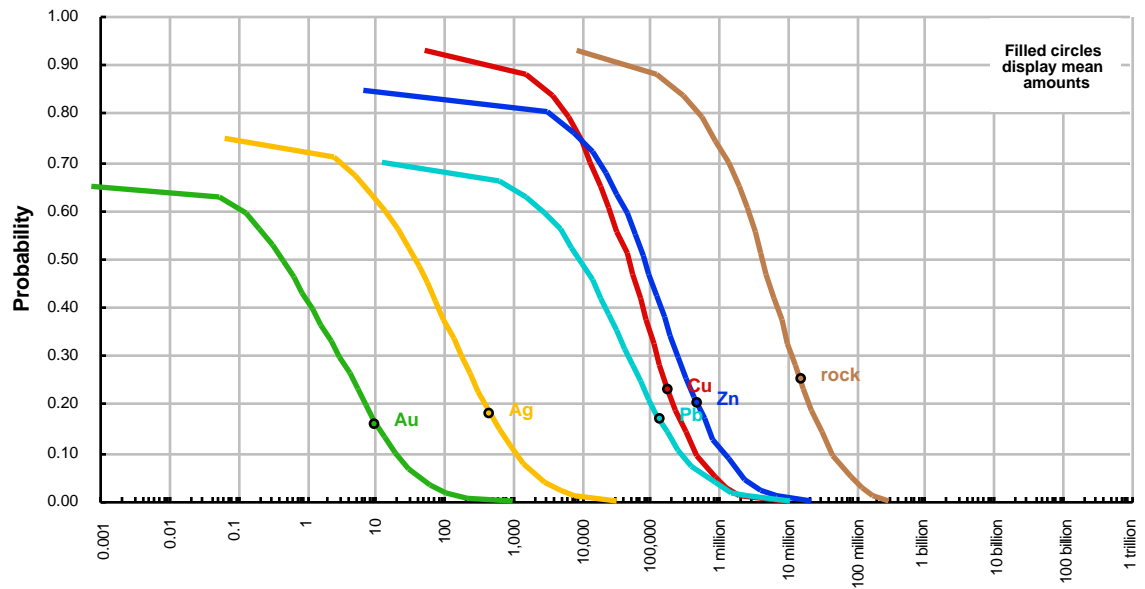
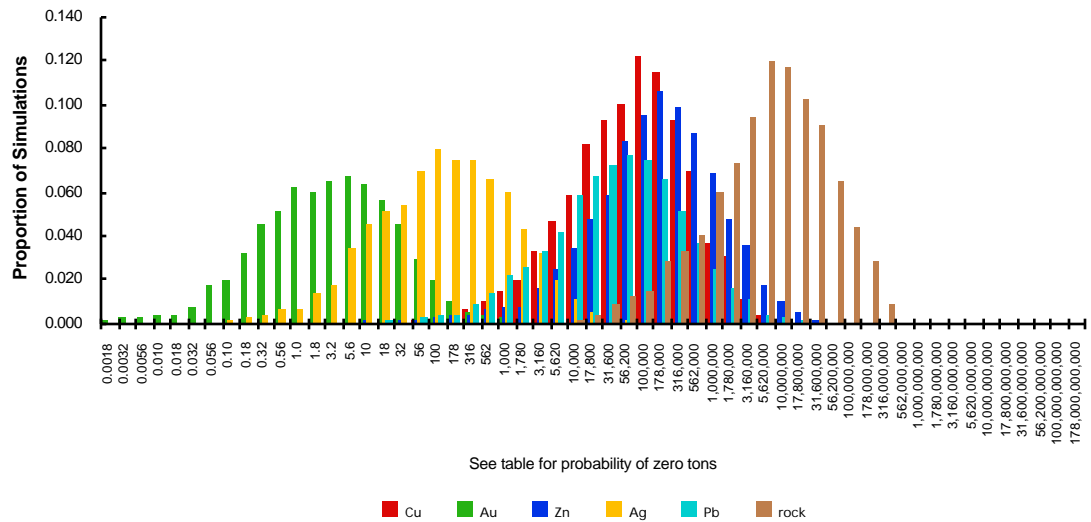
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

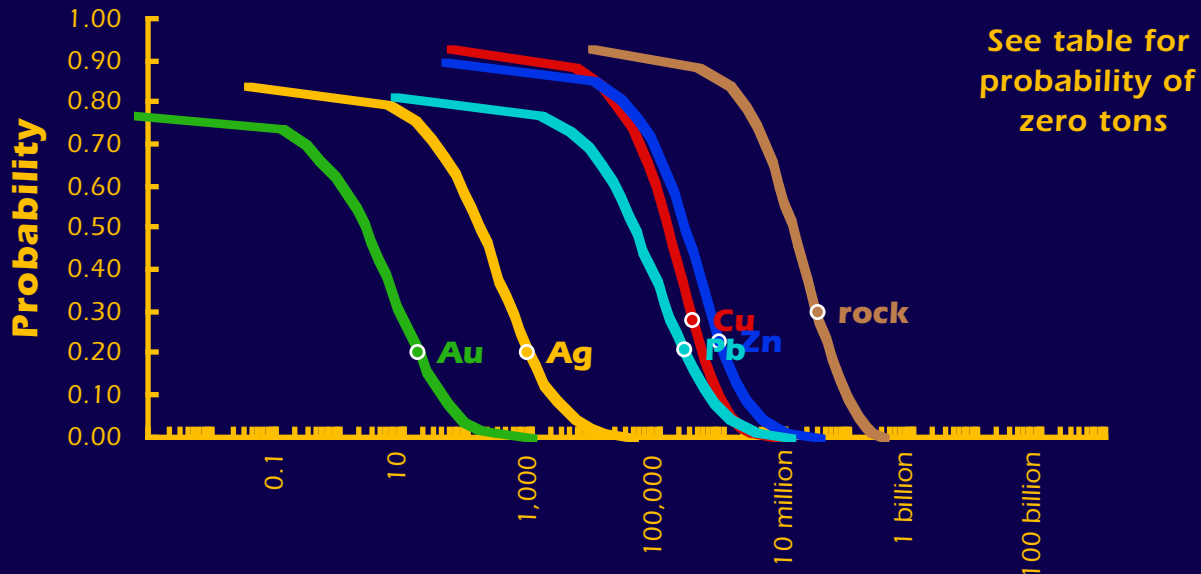
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	1,000	0	0	0	0	73,000
0.50	49,000	0	82,000	39	9,200	4,400,000
0.10	450,000	20	1,130,000	1,100	270,000	45,000,000
0.05	890,000	40	2,300,000	2,300	610,000	82,000,000
mean	180,000	10	490,000	460	140,000	16,000,000
Probability of mean	0.23	0.16	0.20	0.18	0.17	0.25
Probability of zero	0.07	0.34	0.15	0.25	0.30	0.07

The tract ID is NA12

Cumulative Distributions of Contained Metal and Mineralized Rock

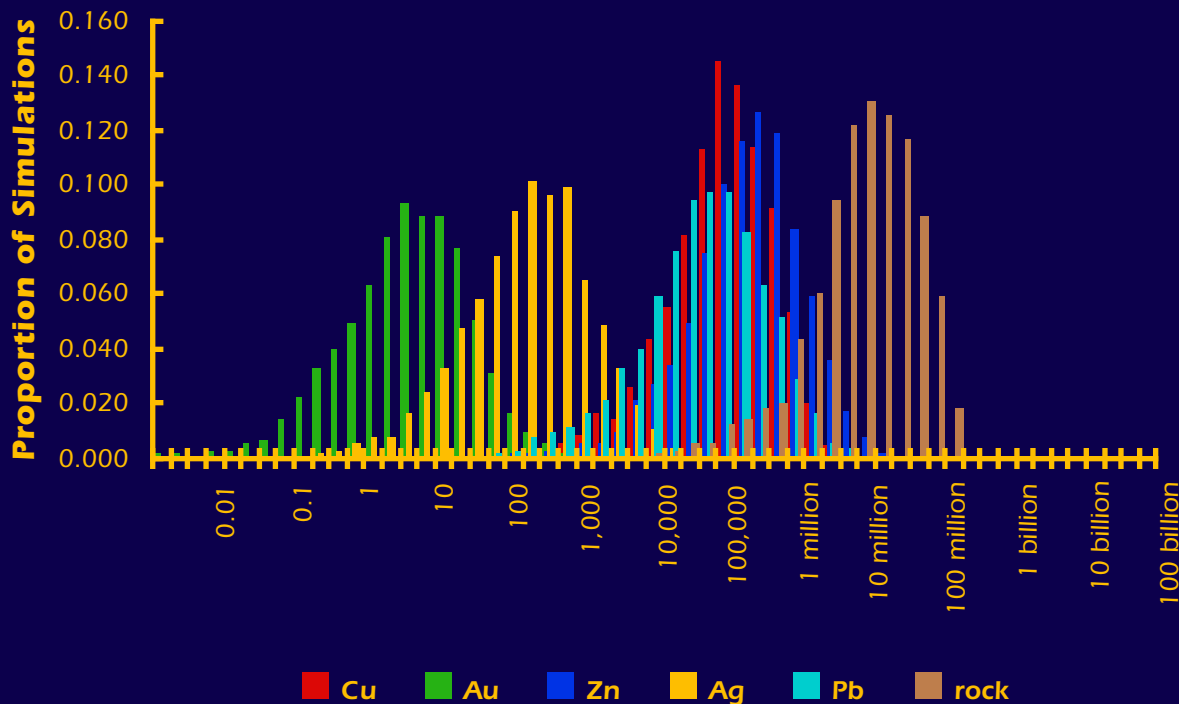
Histograms of Contained Metal and Mineralized Rock
(metric tons)

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NA13

The Mark3 Index is 104:

Massive sulfide, kuroko (Phanerozoic)

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	2,800	0	0	0	0	250,000
0.50	130,000	2	240,000	150	40,000	12,000,000
0.10	850,000	36	2,100,000	2,000	590,000	83,000,000
0.05	1,300,000	69	3,700,000	4,000	1,100,000	130,000,000
mean	320,000	16	840,000	860	240,000	29,000,000
Probability of mean	0.28	0.20	0.23	0.20	0.21	0.30
Probability of zero	0.07	0.22	0.10	0.16	0.19	0.07

The tract ID is NA13The Mark3 Index is 104: **Massive sulfide, kuroko (Phanerozoic)**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

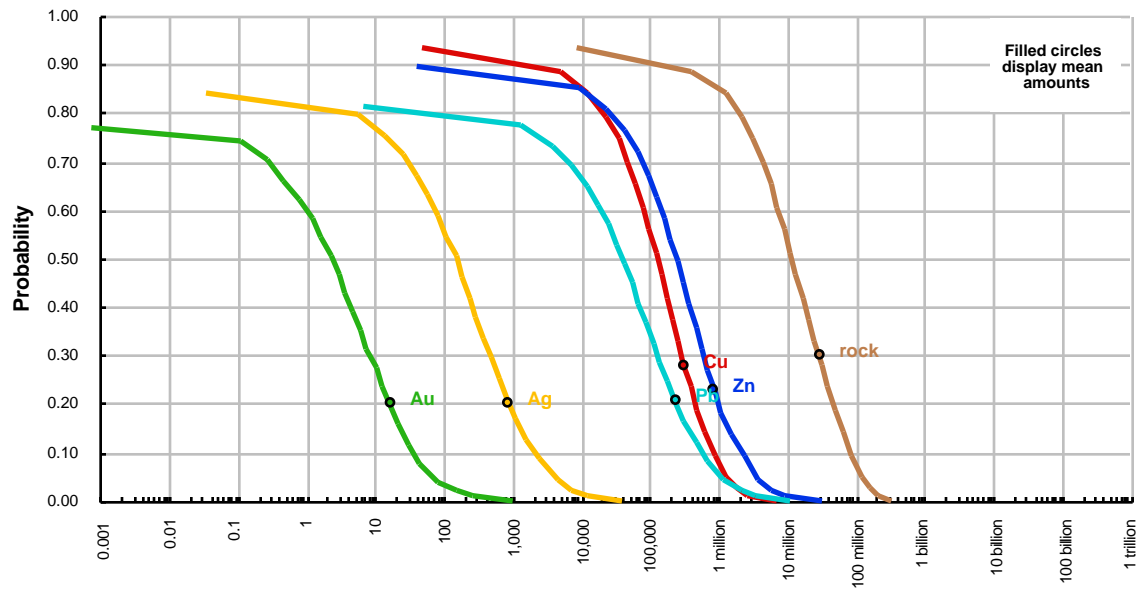
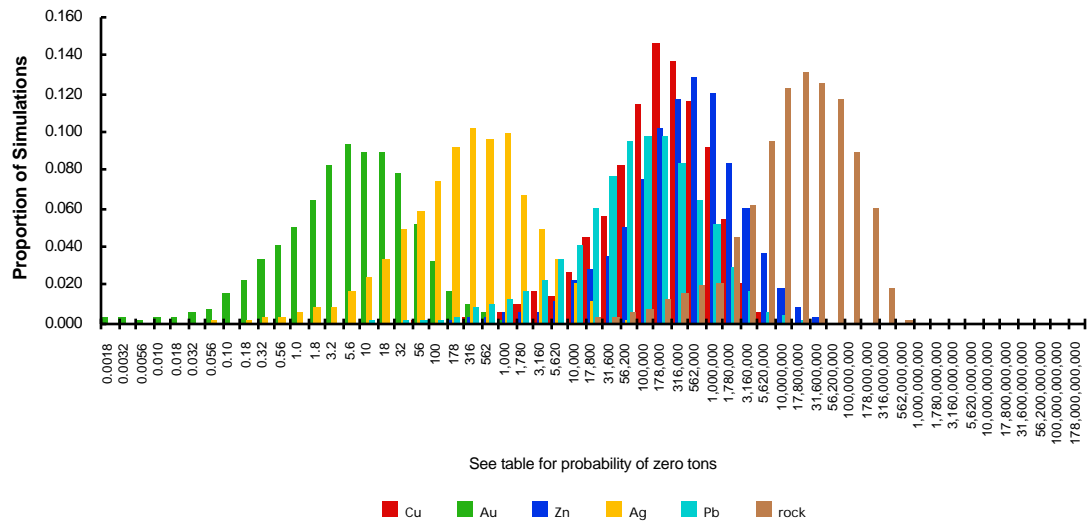
There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

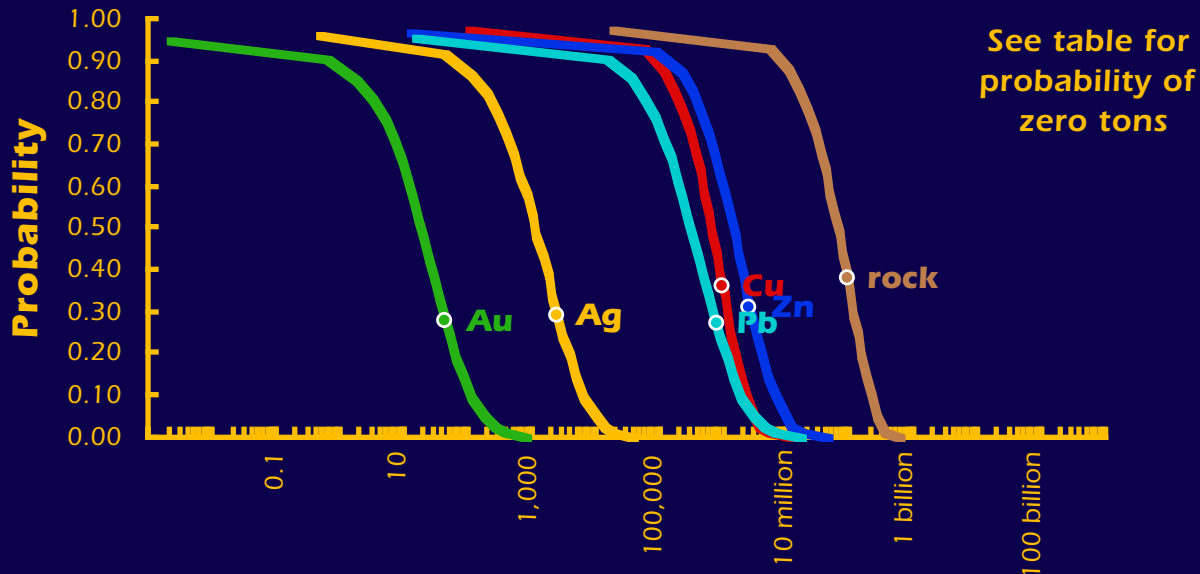
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	2,800	0	0	0	0	250,000
0.50	130,000	2	240,000	150	40,000	12,000,000
0.10	850,000	36	2,100,000	2,000	590,000	83,000,000
0.05	1,300,000	69	3,700,000	4,000	1,100,000	130,000,000
mean	320,000	16	840,000	860	240,000	29,000,000
Probability of mean	0.28	0.20	0.23	0.20	0.21	0.30
Probability of zero	0.07	0.22	0.10	0.16	0.19	0.07

The tract ID is NA13

Cumulative Distributions of Contained Metal and Mineralized Rock

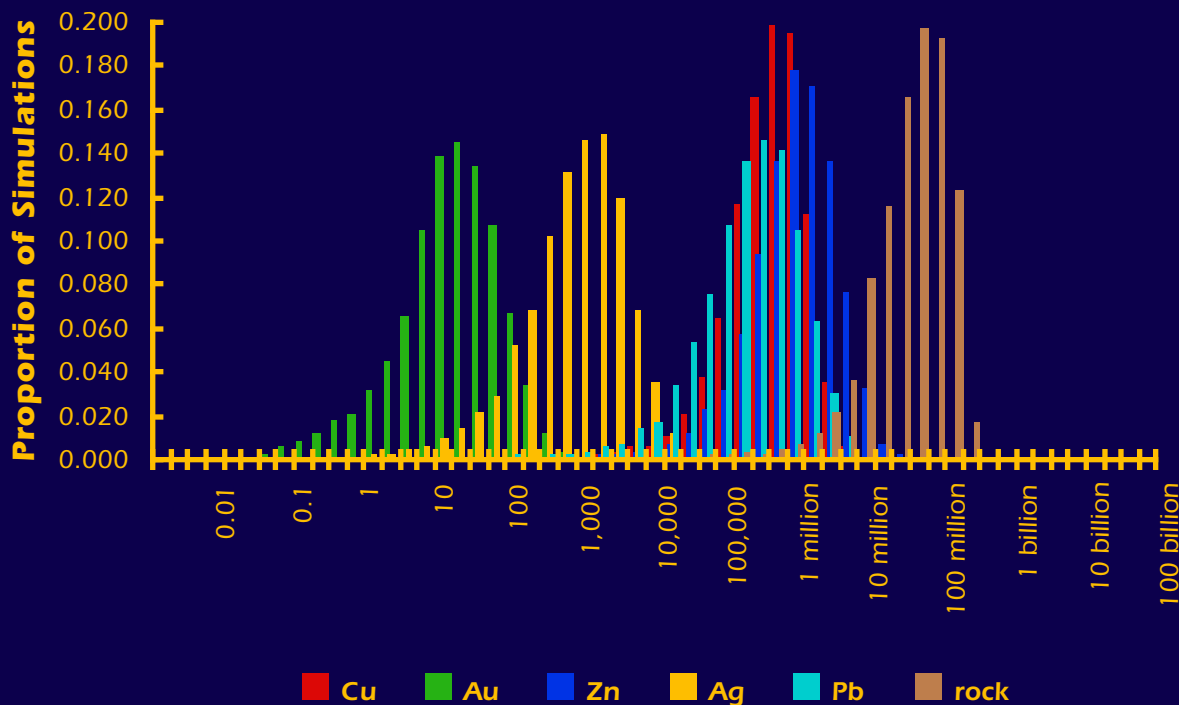
Histograms of Contained Metal and Mineralized Rock
(metric tons)

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NA14

The Mark3 Index is 104:

Massive sulfide, kuroko (Phanerozoic)

There is a 90% or greater chance of 4 or more deposits.
 There is a 50% or greater chance of 8 or more deposits.
 There is a 10% or greater chance of 15 or more deposits.
 There is a 5% or greater chance of 15 or more deposits.
 There is a 1% or greater chance of 15 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	31,000	0	36,000	11	470	2,900,000
0.90	90,000	1	150,000	65	19,000	8,700,000
0.50	640,000	18	1,400,000	1,100	310,000	61,000,000
0.10	2,200,000	110	6,180,000	6,300	1,900,000	200,000,000
0.05	2,900,000	180	9,000,000	9,700	2,900,000	250,000,000
mean	960,000	44	2,600,000	2,400	750,000	86,000,000
Probability of mean	0.36	0.28	0.31	0.29	0.27	0.38
Probability of zero	0.02	0.05	0.03	0.04	0.05	0.02

The tract ID is NA14The Mark3 Index is 104: **Massive sulfide, kuroko (Phanerozoic)**

There is a 90% or greater chance of 4 or more deposits.

There is a 50% or greater chance of 8 or more deposits.

There is a 10% or greater chance of 15 or more deposits.

There is a 5% or greater chance of 15 or more deposits.

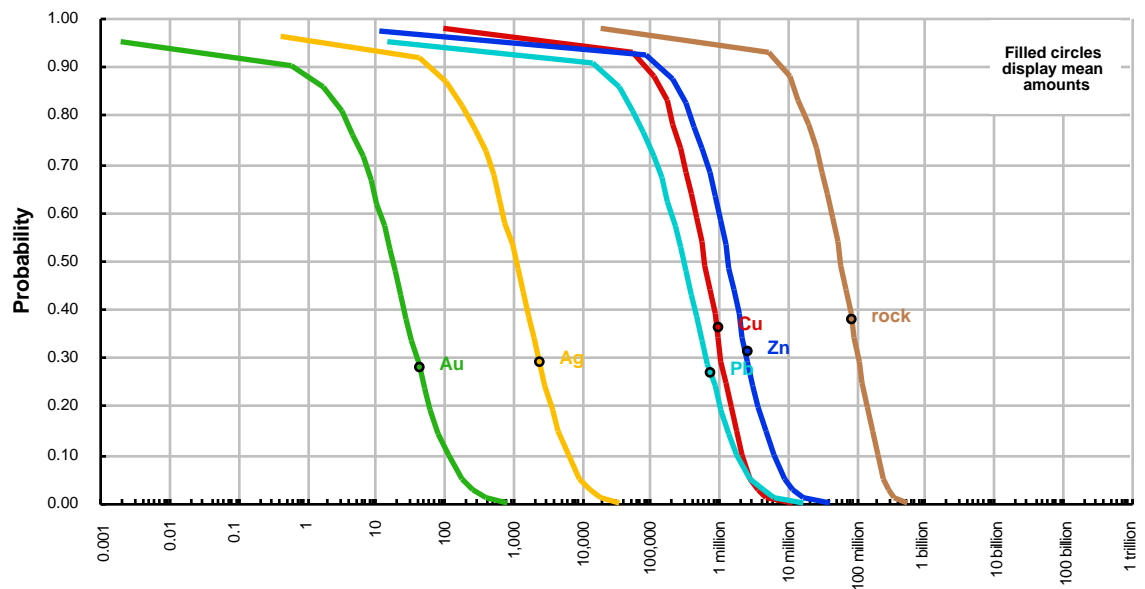
There is a 1% or greater chance of 15 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

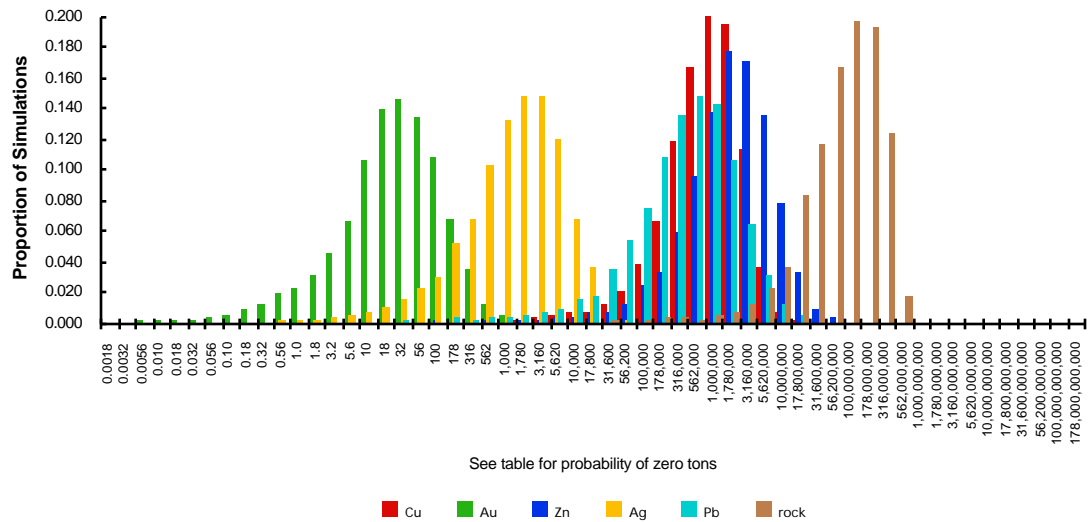
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	31,000	0	36,000	11	470	2,900,000
0.90	90,000	1	150,000	65	19,000	8,700,000
0.50	640,000	18	1,400,000	1,100	310,000	61,000,000
0.10	2,200,000	110	6,180,000	6,300	1,900,000	200,000,000
0.05	2,900,000	180	9,000,000	9,700	2,900,000	250,000,000
mean	960,000	44	2,600,000	2,400	750,000	86,000,000
Probability of mean	0.36	0.28	0.31	0.29	0.27	0.38
Probability of zero	0.02	0.05	0.03	0.04	0.05	0.02

The tract ID is NA14

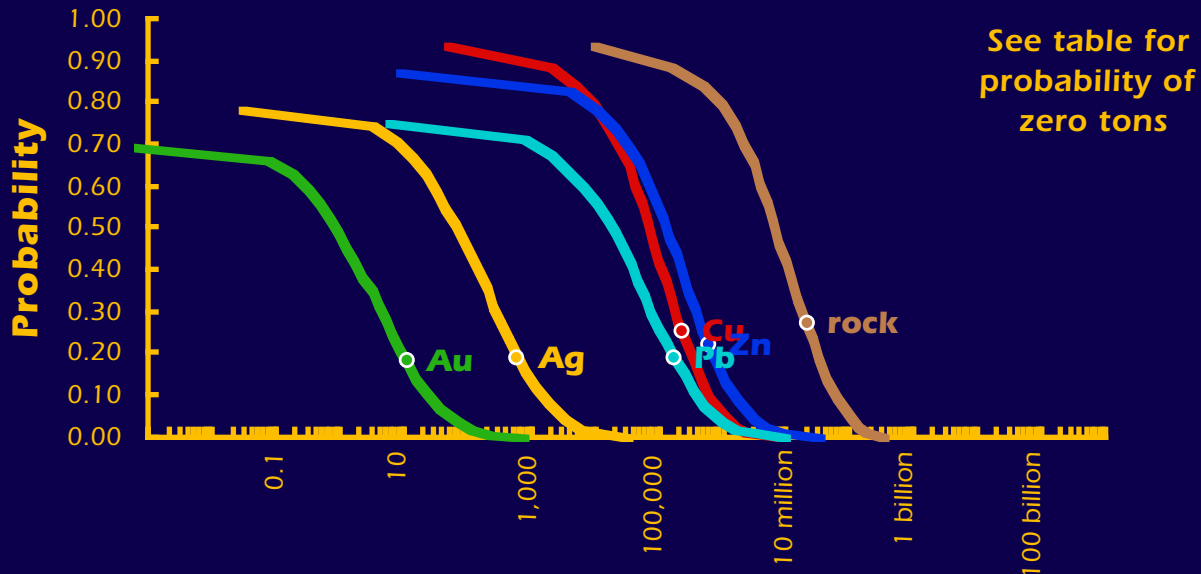
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

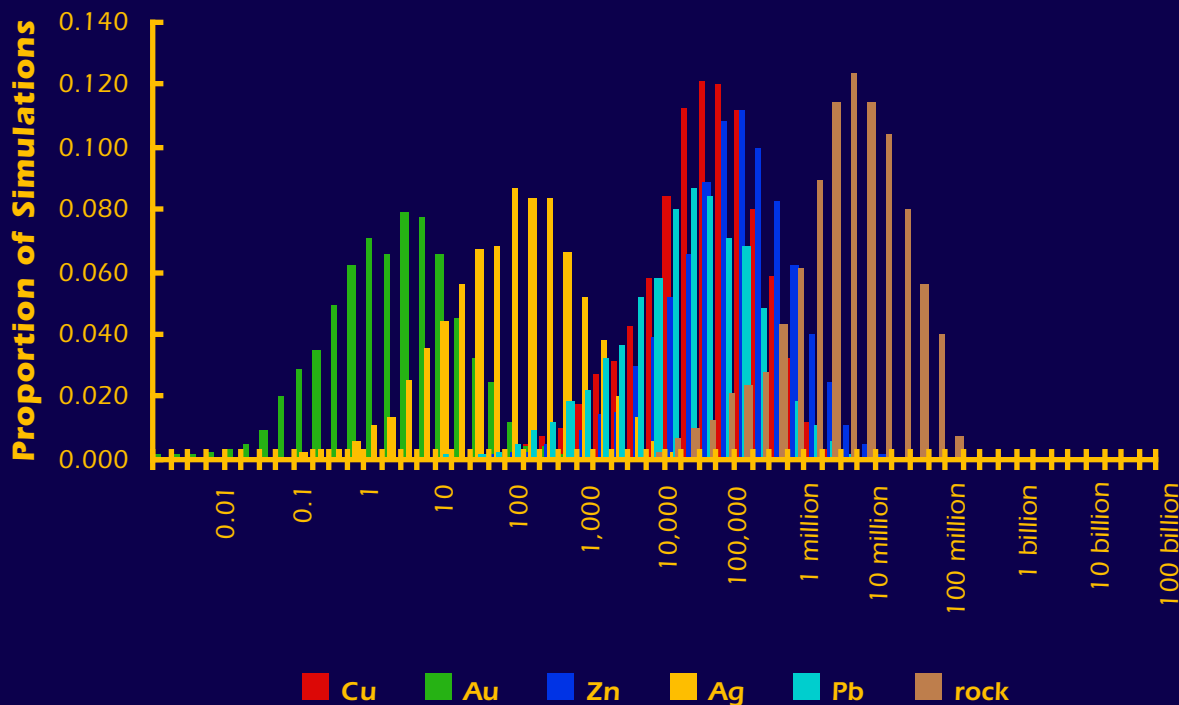


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NA16

The Mark3 Index is 104:

Massive sulfide, kuroko (Phanerozoic)

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	1,500	0	0	0	0	110,000
0.50	67,000	1	130,000	65	18,000	6,200,000
0.10	580,000	23	1,470,000	1,400	370,000	58,000,000
0.05	970,000	50	2,600,000	2,700	760,000	96,000,000
mean	220,000	11	580,000	590	160,000	20,000,000
Probability of mean	0.25	0.18	0.22	0.19	0.19	0.27
Probability of zero	0.07	0.30	0.13	0.22	0.25	0.07

The tract ID is NA16The Mark3 Index is 104: **Massive sulfide, kuroko (Phanerozoic)**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

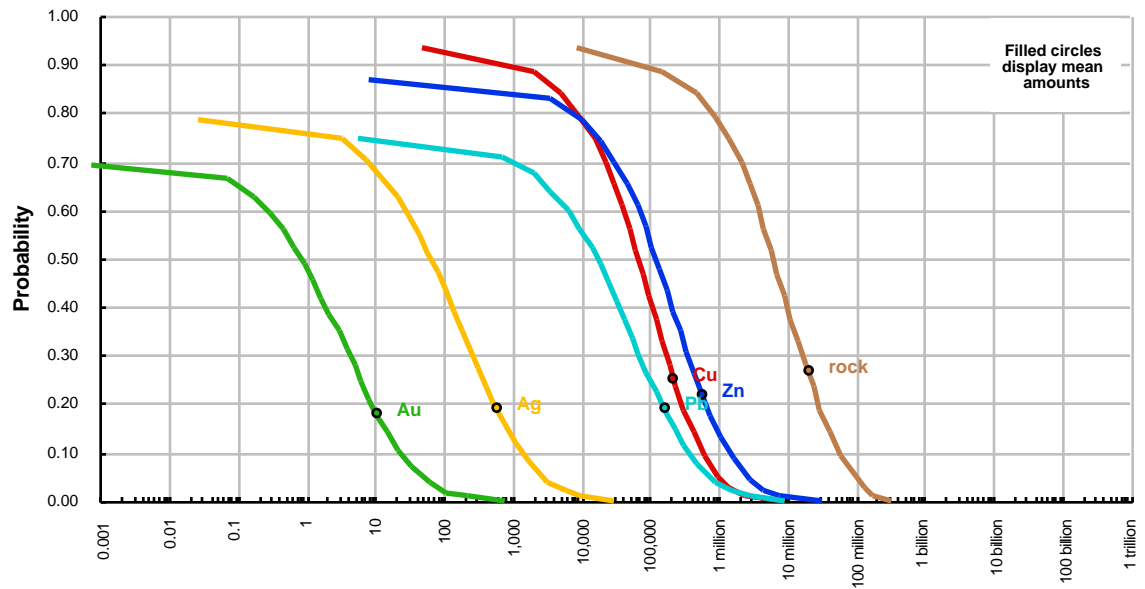
There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

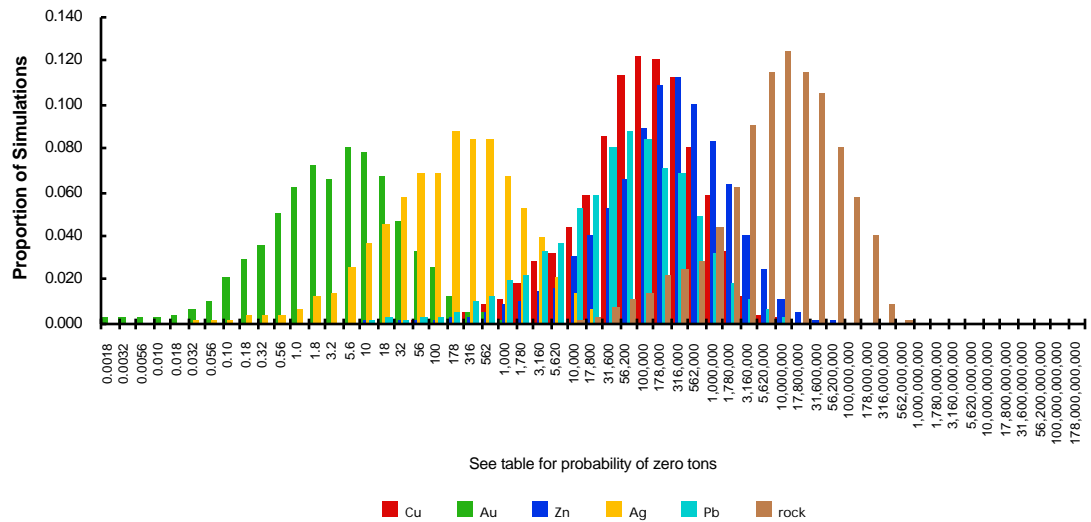
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	1,500	0	0	0	0	110,000
0.50	67,000	1	130,000	65	18,000	6,200,000
0.10	580,000	23	1,470,000	1,400	370,000	58,000,000
0.05	970,000	50	2,600,000	2,700	760,000	96,000,000
mean	220,000	11	580,000	590	160,000	20,000,000
Probability of mean	0.25	0.18	0.22	0.19	0.19	0.27
Probability of zero	0.07	0.30	0.13	0.22	0.25	0.07

The tract ID is NA16

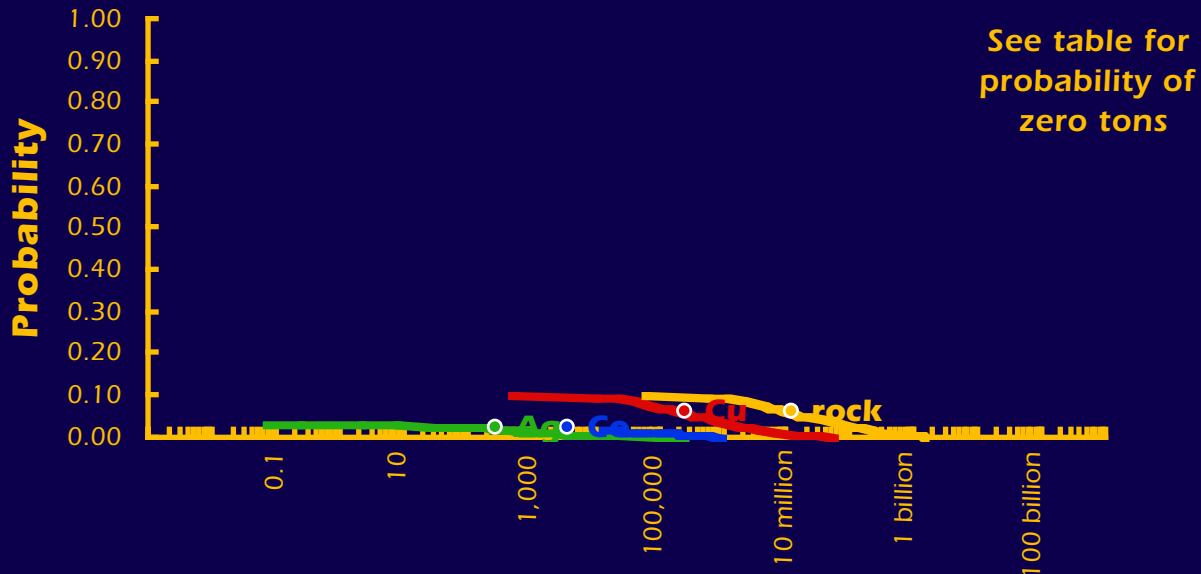
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

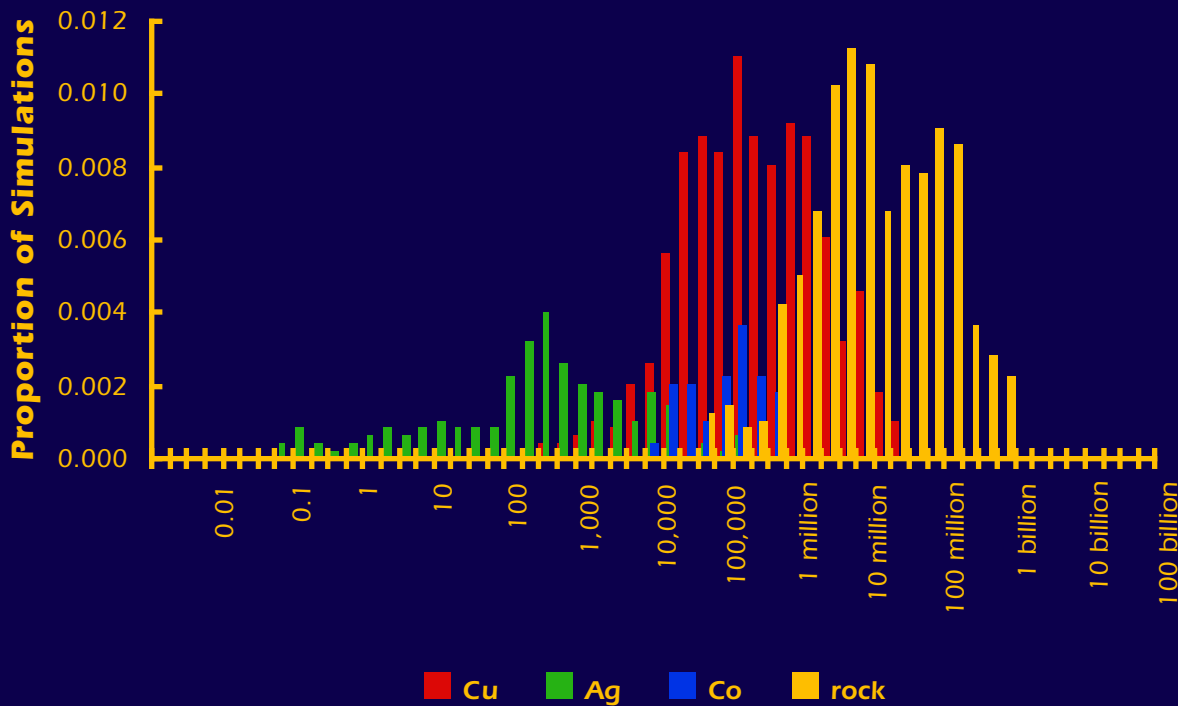


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NA19

The Mark3 Index is 63:

Sediment-hosted Cu

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Ag	Co	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	2,000	0	0	100,000
0.05	360,000	0	0	16,000,000
mean	250,000	270	3,600	11,000,000
Probability of mean	0.06	0.02	0.02	0.06
Probability of zero	0.90	0.97	0.98	0.90

The tract ID is NA19The Mark3 Index is 63: **Sediment-hosted Cu**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

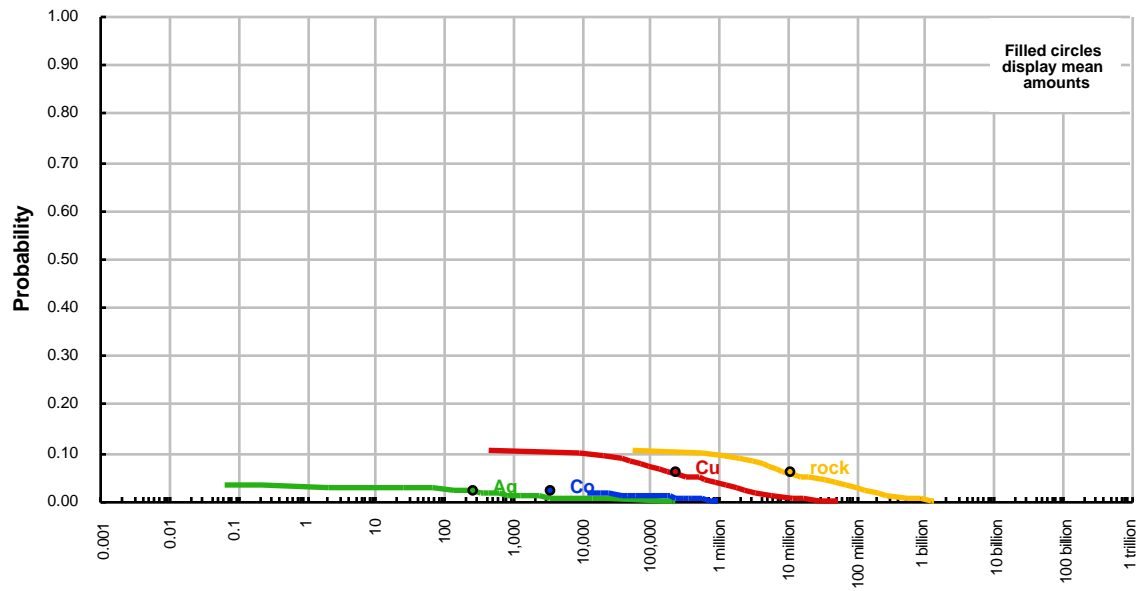
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

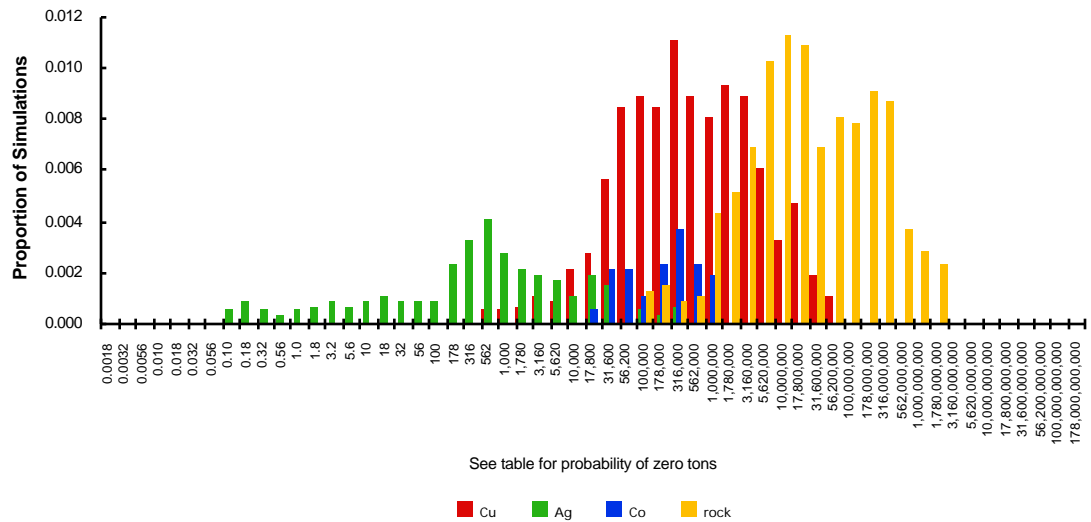
quantile	Cu	Ag	Co	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	2,000	0	0	100,000
0.05	360,000	0	0	16,000,000
mean	250,000	270	3,600	11,000,000
Probability of mean	0.06	0.02	0.02	0.06
Probability of zero	0.90	0.97	0.98	0.90

The tract ID is NA19

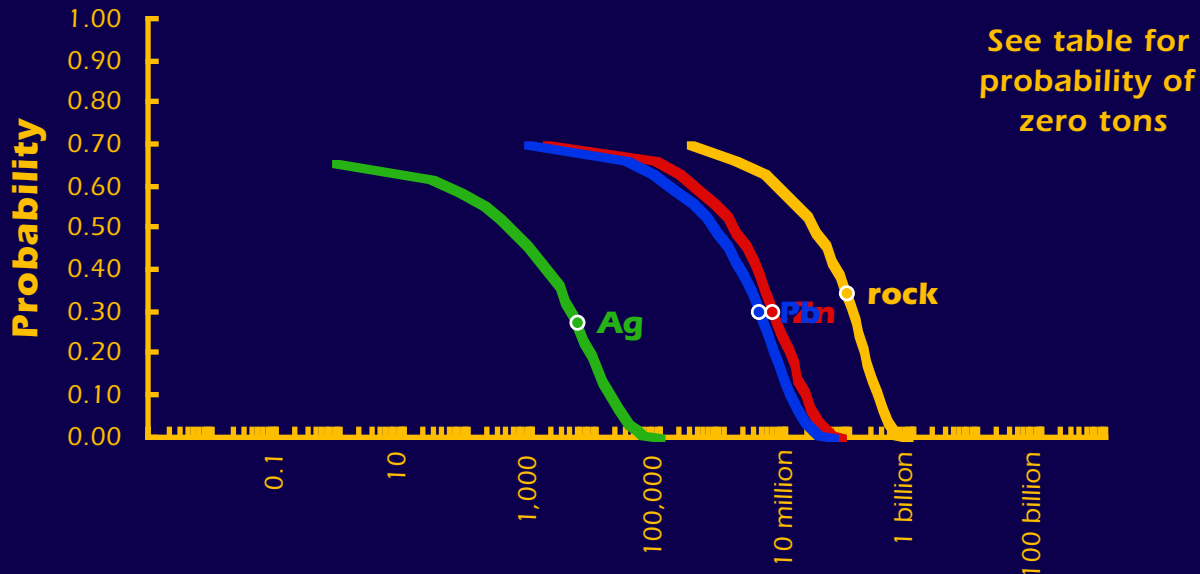
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

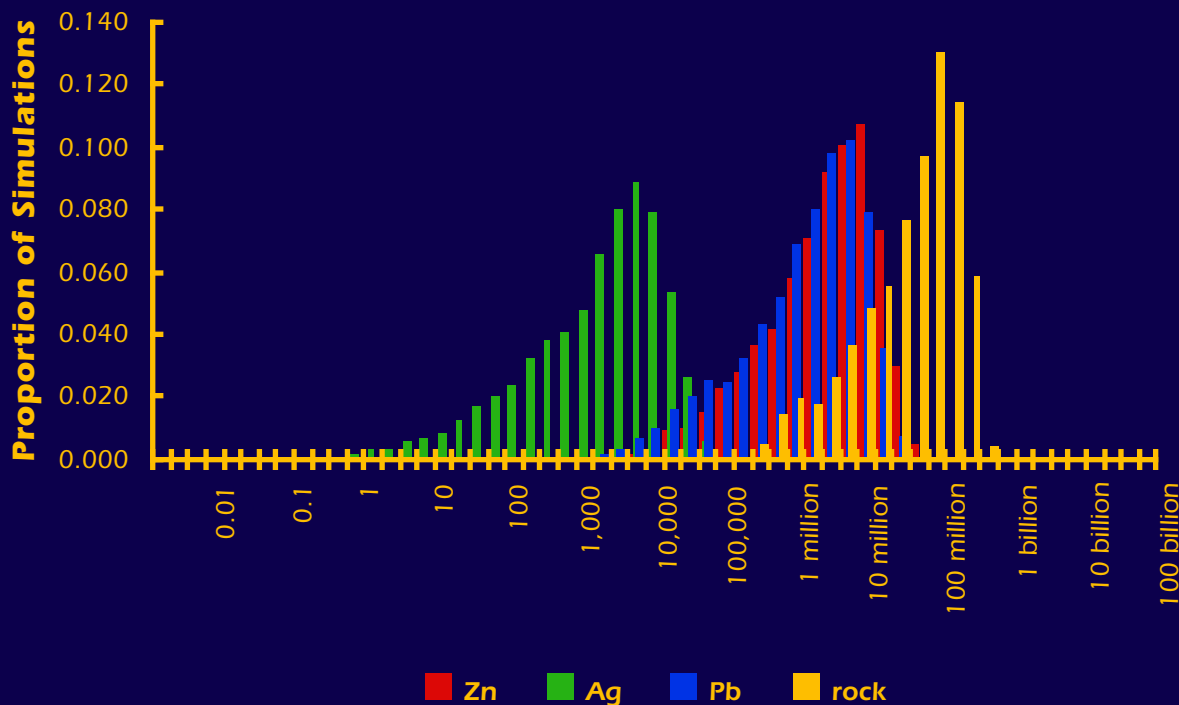


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NA20

The Mark3 Index is 13:

Sedimentary exhalative Zn-Pb

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Zn	Ag	Pb	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	1,500,000	460	730,000	26,000,000
0.10	19,000,000	16,000	11,400,000	260,000,000
0.05	27,000,000	25,000	17,000,000	340,000,000
mean	6,000,000	5,100	3,600,000	84,000,000
Probability of mean	0.30	0.27	0.30	0.34
Probability of zero	0.30	0.35	0.30	0.30

The tract ID is NA20The Mark3 Index is 13: **Sedimentary exhalative Zn-Pb**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

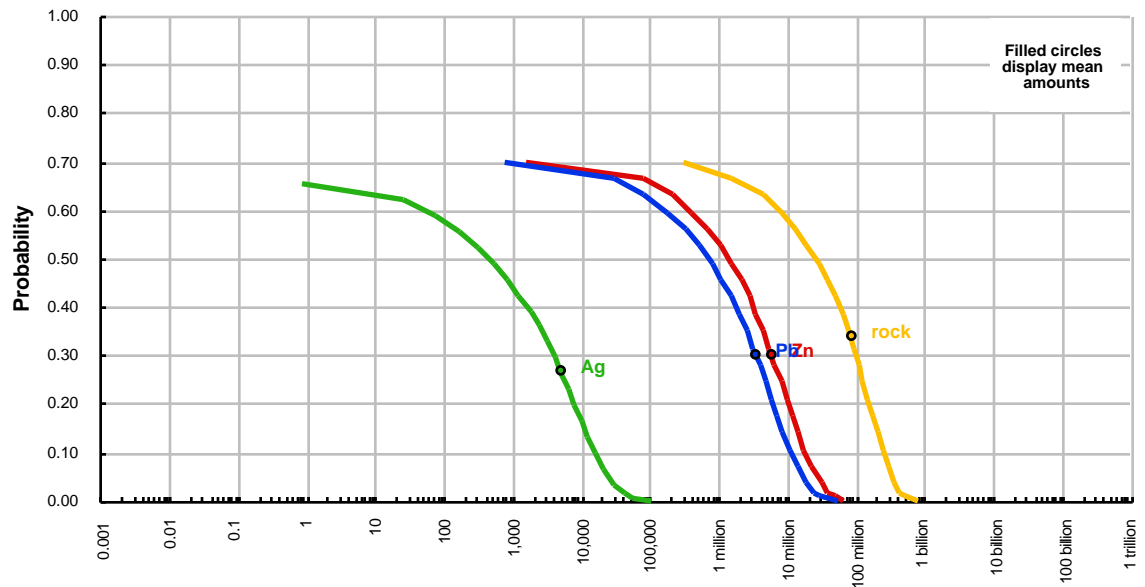
There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

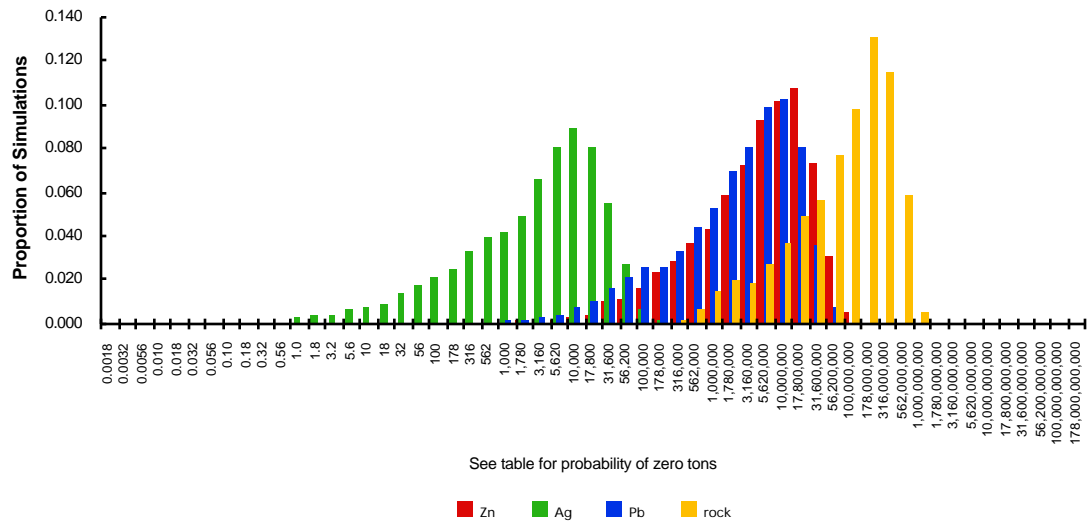
quantile	Zn	Ag	Pb	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	1,500,000	460	730,000	26,000,000
0.10	19,000,000	16,000	11,400,000	260,000,000
0.05	27,000,000	25,000	17,000,000	340,000,000
mean	6,000,000	5,100	3,600,000	84,000,000
Probability of mean	0.30	0.27	0.30	0.34
Probability of zero	0.30	0.35	0.30	0.30

The tract ID is NA20

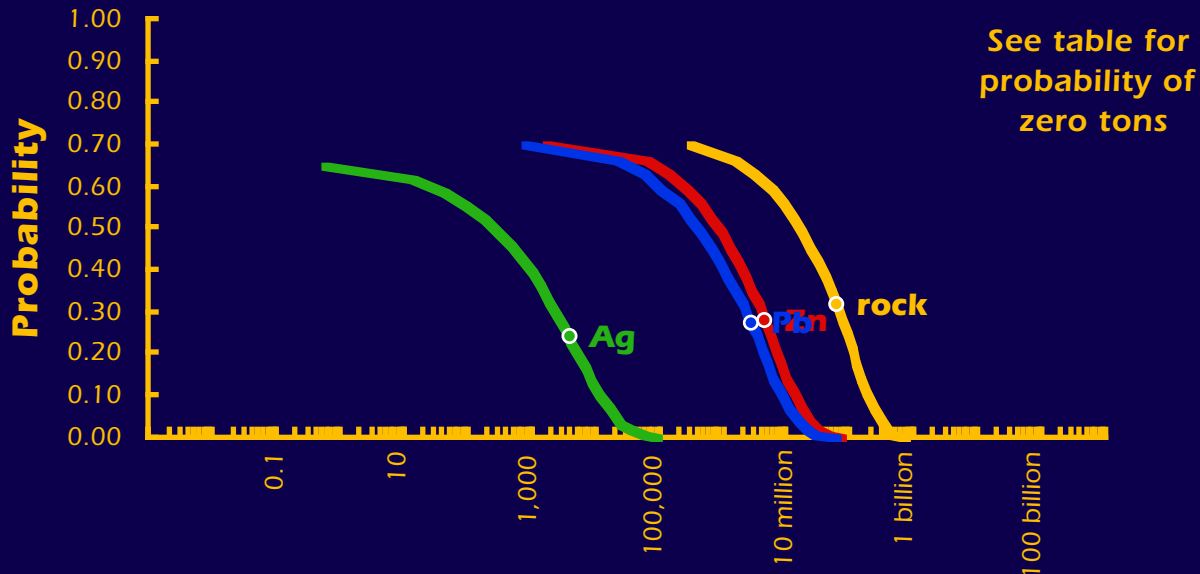
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

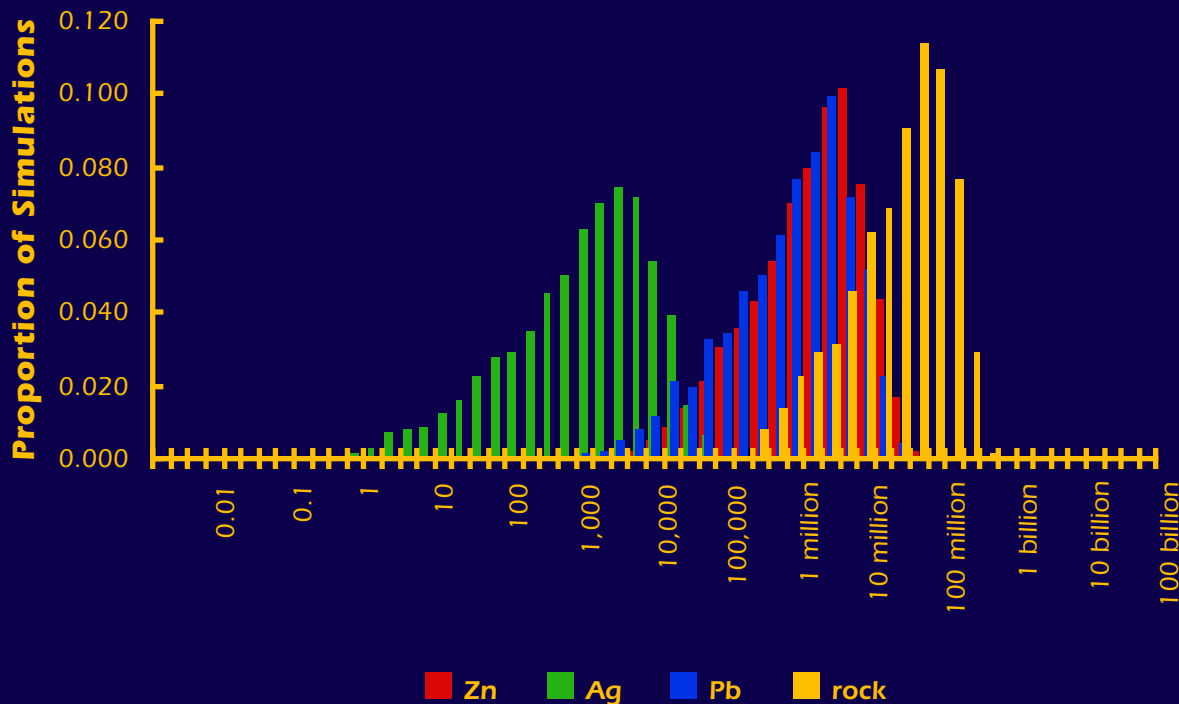


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NA21

The Mark3 Index is 13:

Sedimentary exhalative Zn-Pb

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Zn	Ag	Pb	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	830,000	250	390,000	16,000,000
0.10	13,000,000	11,000	8,050,000	180,000,000
0.05	20,000,000	20,000	13,000,000	270,000,000
mean	4,300,000	3,800	2,700,000	60,000,000
Probability of mean	0.28	0.24	0.27	0.32
Probability of zero	0.30	0.35	0.30	0.30

The tract ID is NA21The Mark3 Index is 13: **Sedimentary exhalative Zn-Pb**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

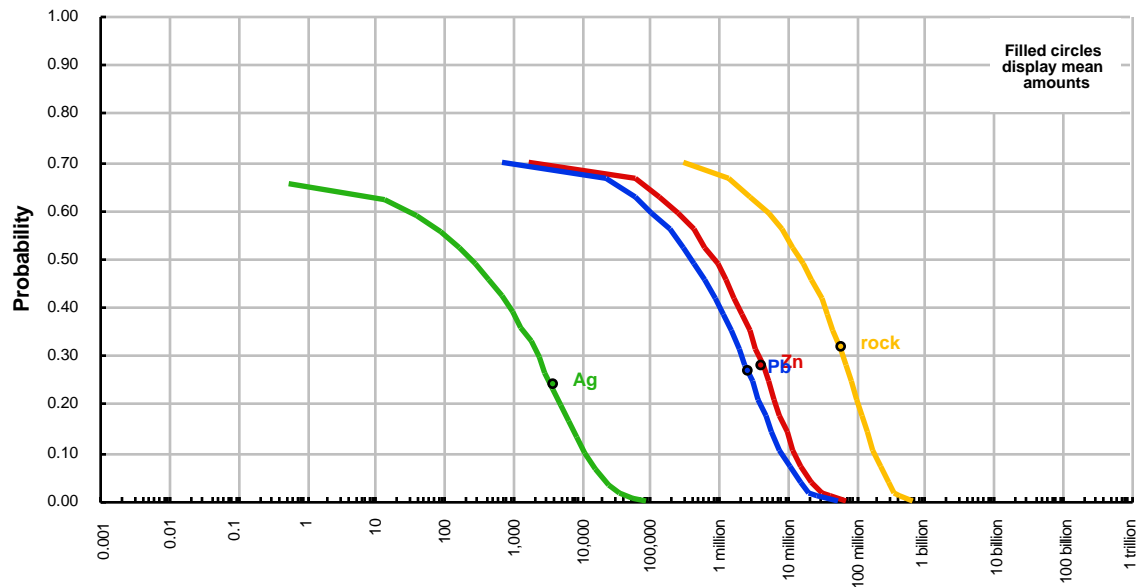
There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

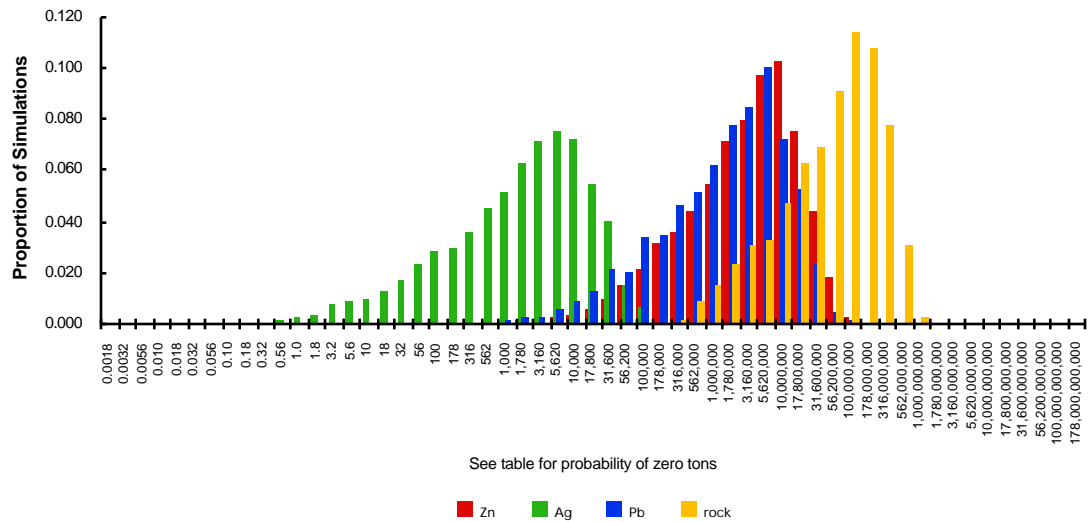
quantile	Zn	Ag	Pb	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	830,000	250	390,000	16,000,000
0.10	13,000,000	11,000	8,050,000	180,000,000
0.05	20,000,000	20,000	13,000,000	270,000,000
mean	4,300,000	3,800	2,700,000	60,000,000
Probability of mean	0.28	0.24	0.27	0.32
Probability of zero	0.30	0.35	0.30	0.30

The tract ID is NA21

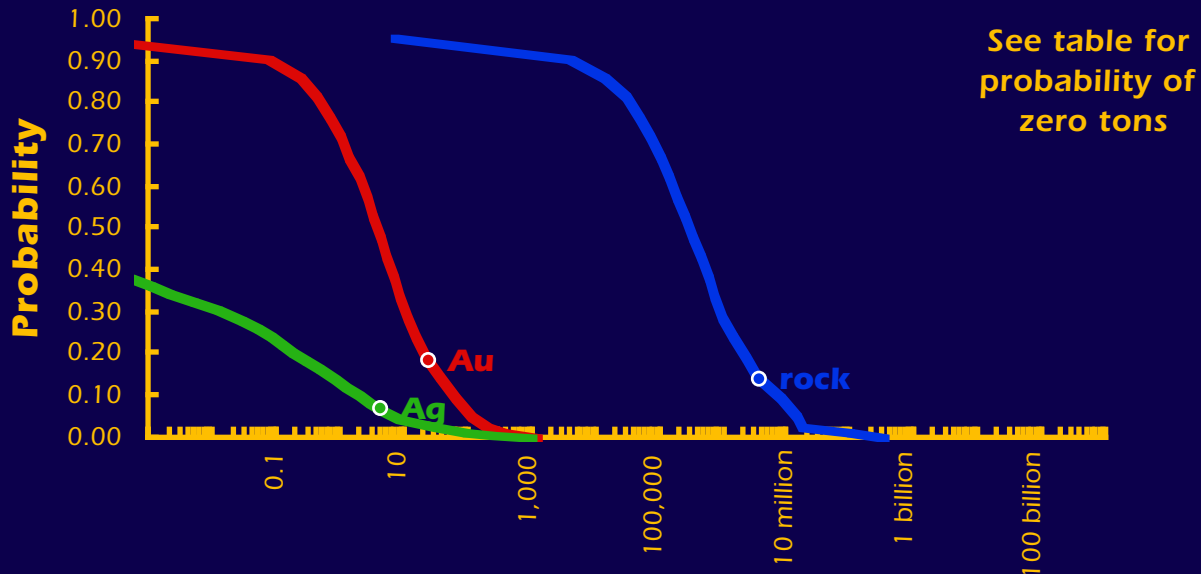
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

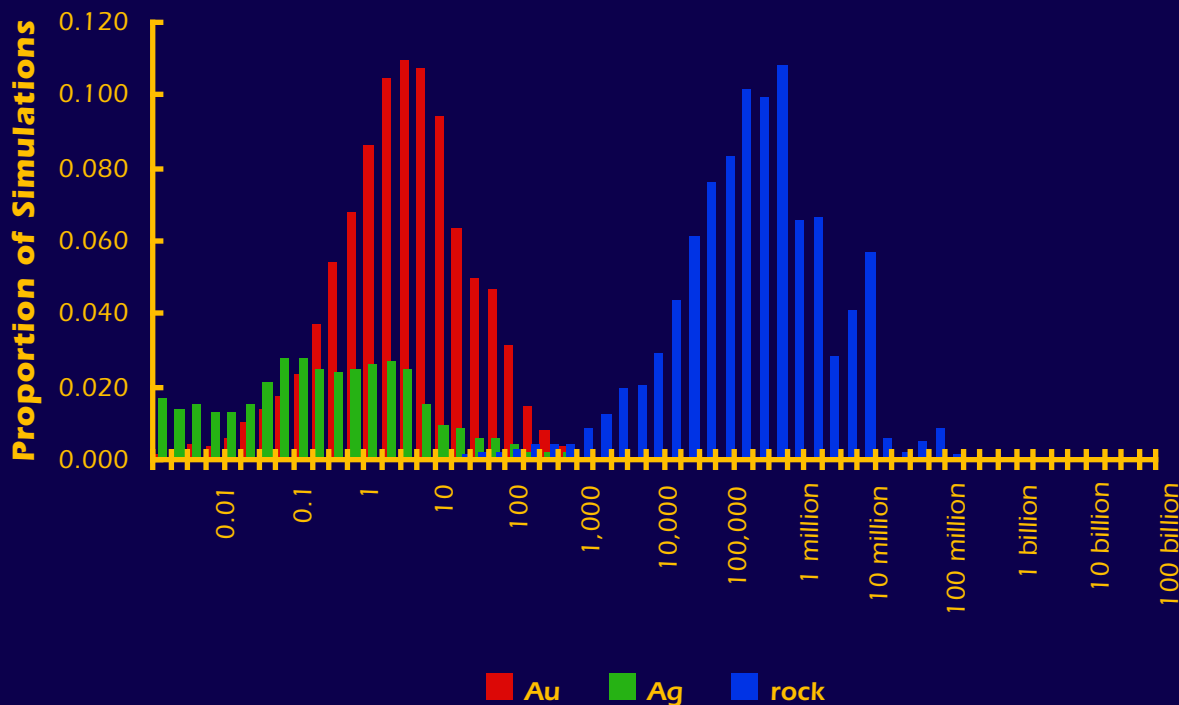


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NA23

The Mark3 Index is 27:

Low sulfide Au-quartz vein

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	150
0.90	0	0	5,200
0.50	4	0	290,000
0.10	60	2	7,390,000
0.05	110	6	13,000,000
mean	23	4	3,500,000
Probability of mean	0.18	0.07	0.14
Probability of zero	0.04	0.60	0.04

The tract ID is NA23The Mark3 Index is 27: **Low sulfide Au-quartz vein**

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

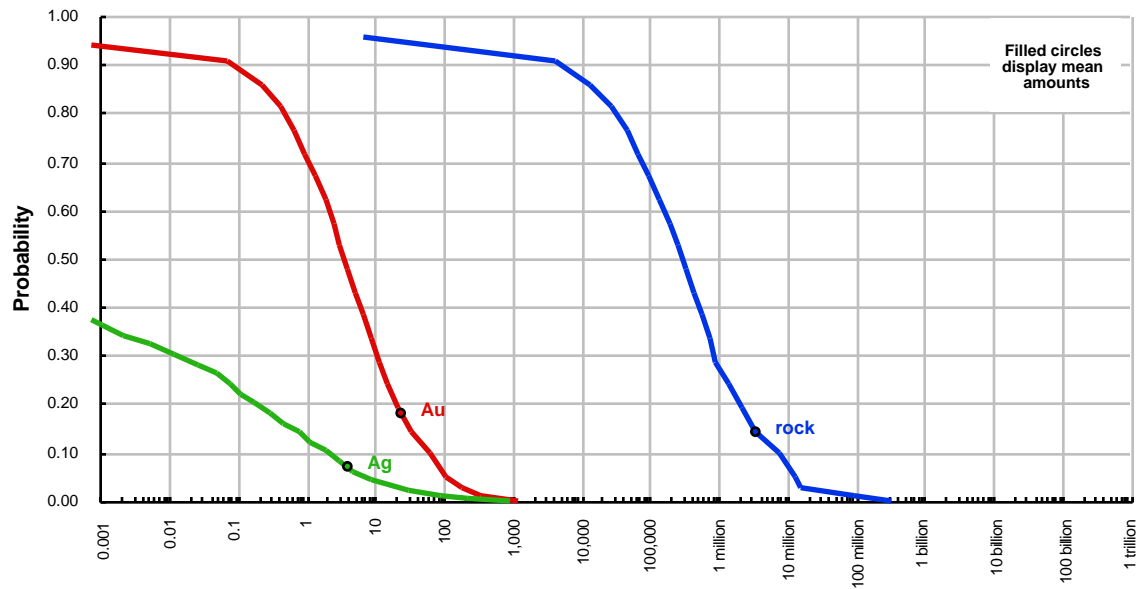
There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

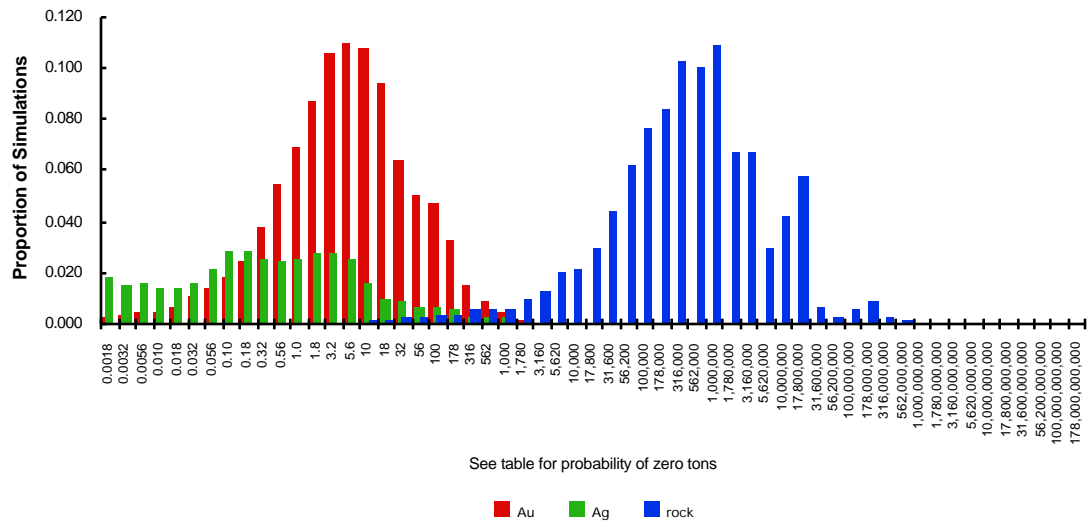
quantile	Au	Ag	rock
0.95	0	0	150
0.90	0	0	5,200
0.50	4	0	290,000
0.10	60	2	7,390,000
0.05	110	6	13,000,000
mean	23	4	3,500,000
Probability of mean	0.18	0.07	0.14
Probability of zero	0.04	0.60	0.04

The tract ID is NA23

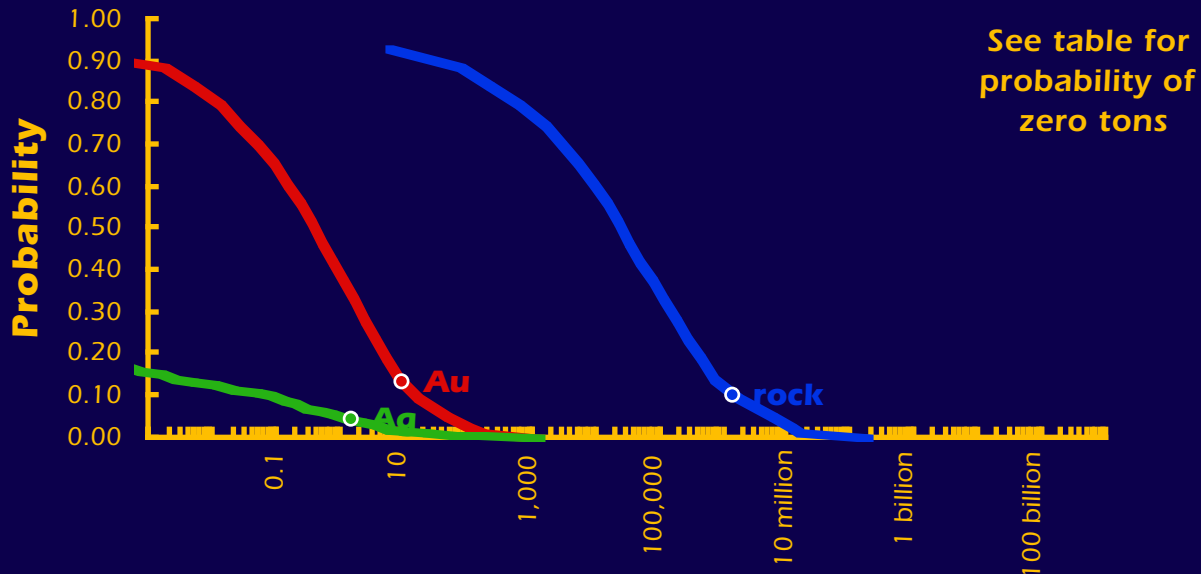
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

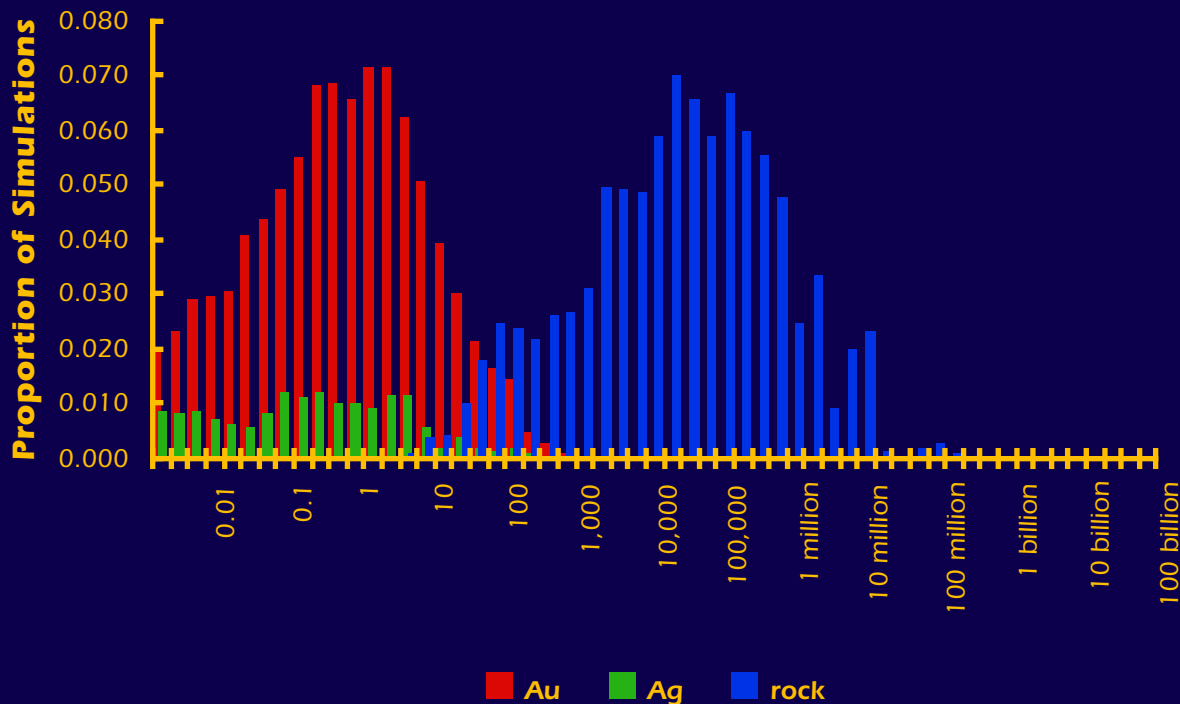


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NA24

The Mark3 Index is 27:

Low sulfide Au-quartz vein

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	54
0.50	0	0	25,000
0.10	15	0	1,400,000
0.05	43	1	5,300,000
mean	9	1	1,300,000
Probability of mean	0.13	0.04	0.10
Probability of zero	0.07	0.82	0.07

The tract ID is NA24The Mark3 Index is 27: **Low sulfide Au-quartz vein**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

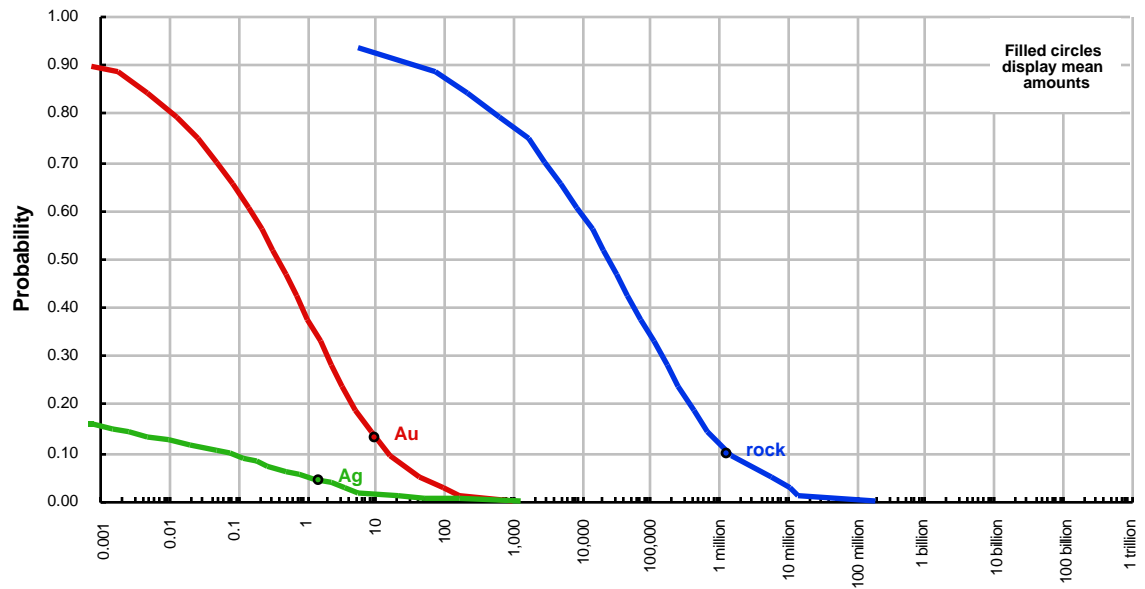
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

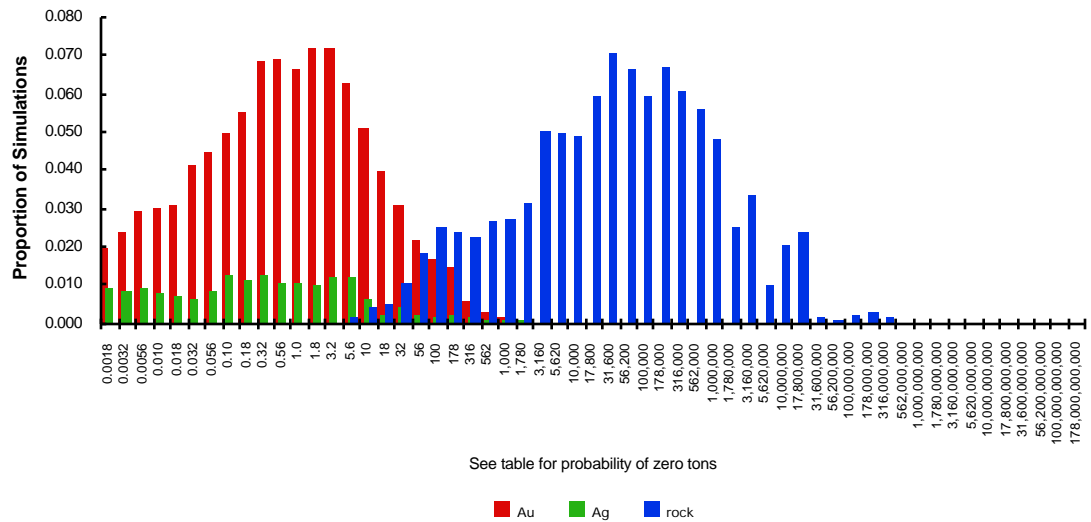
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	54
0.50	0	0	25,000
0.10	15	0	1,400,000
0.05	43	1	5,300,000
mean	9	1	1,300,000
Probability of mean	0.13	0.04	0.10
Probability of zero	0.07	0.82	0.07

The tract ID is NA24

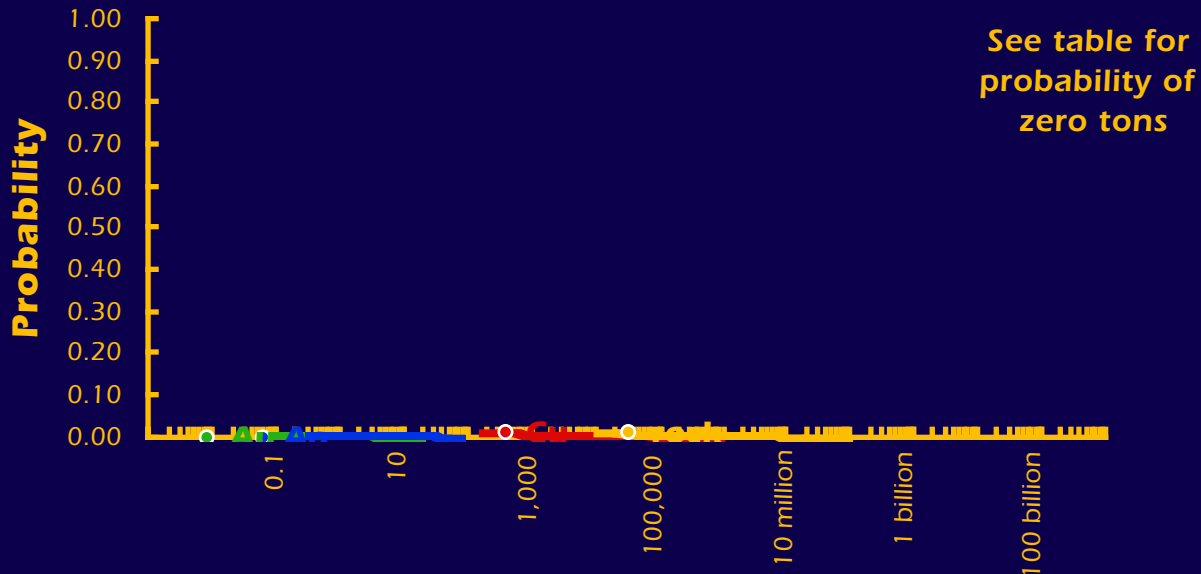
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

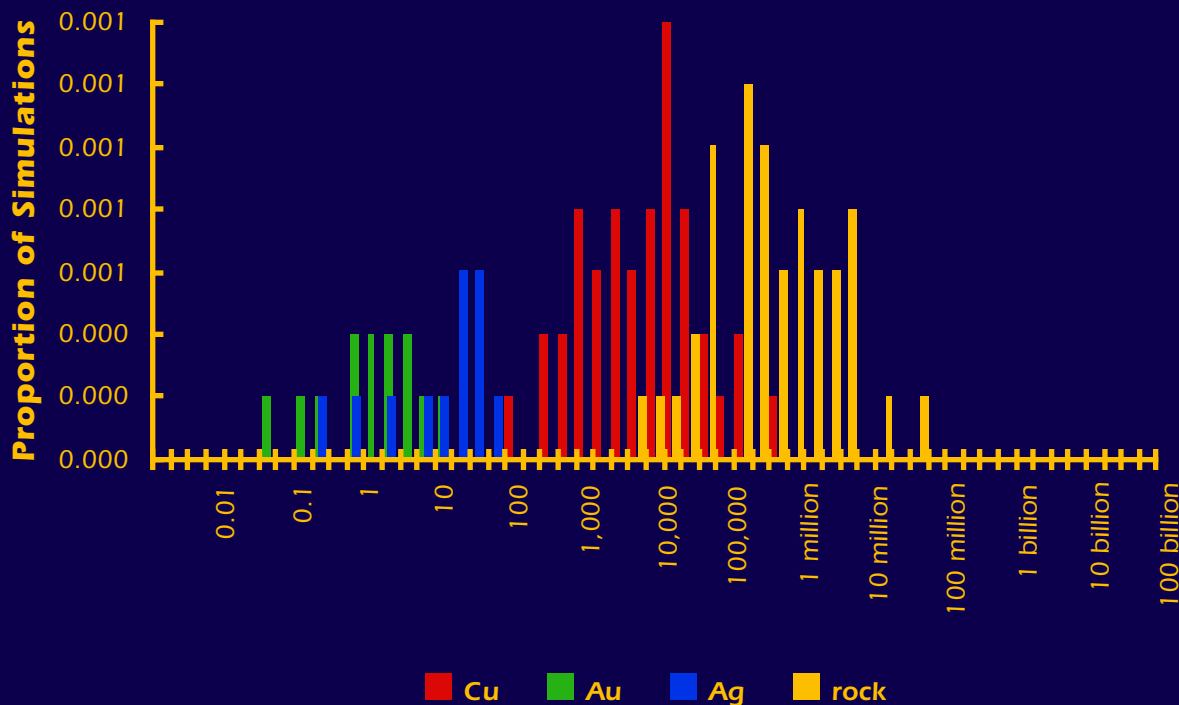


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR01

The Mark3 Index is 8:

Skarn Cu

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	0	0	0	0
mean	390	0	0	34,000
Probability of mean	0.01	0.00	0.00	0.01
Probability of zero	0.99	1.00	1.00	0.99

The tract ID is NR01The Mark3 Index is 8: **Skarn Cu**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

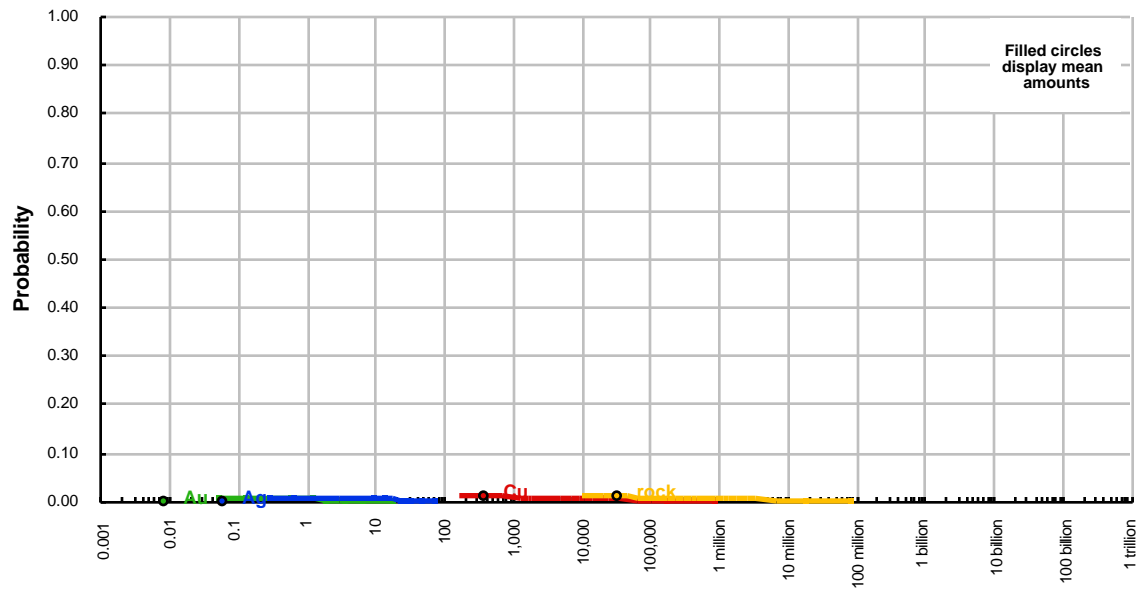
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

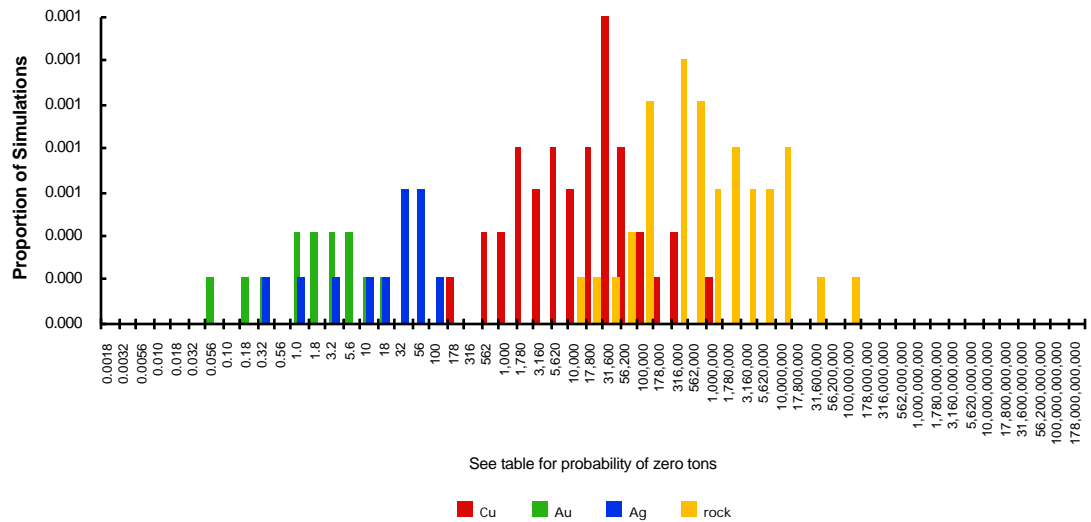
quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	0	0	0	0
mean	390	0	0	34,000
Probability of mean	0.01	0.00	0.00	0.01
Probability of zero	0.99	1.00	1.00	0.99

The tract ID is NR01

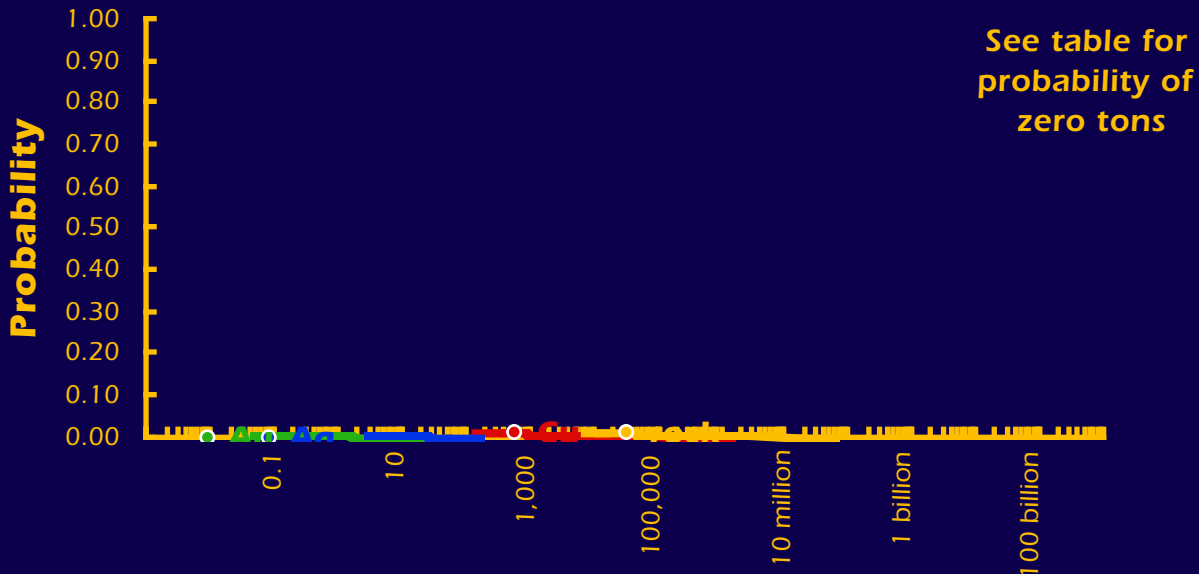
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

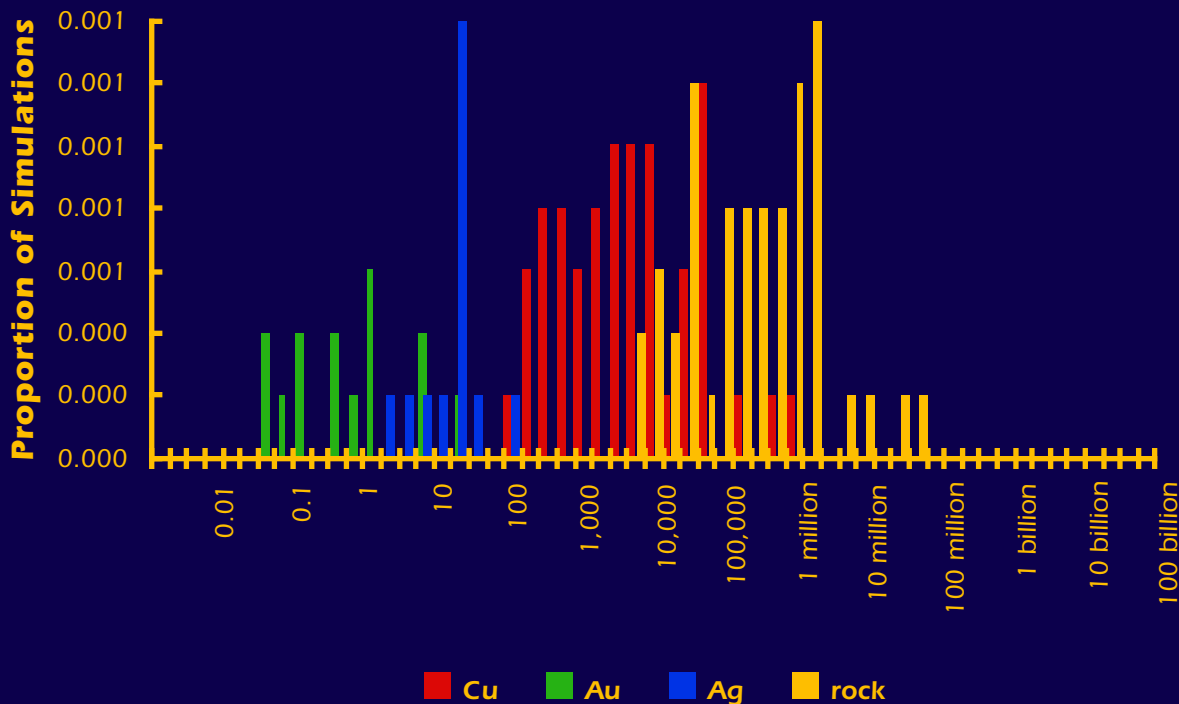


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR02

The Mark3 Index is 8:

Skarn Cu

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	0	0	0	0
mean	600	0	0	33,000
Probability of mean	0.01	0.00	0.00	0.01
Probability of zero	0.99	1.00	1.00	0.99

The tract ID is NR02The Mark3 Index is 8: **Skarn Cu**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

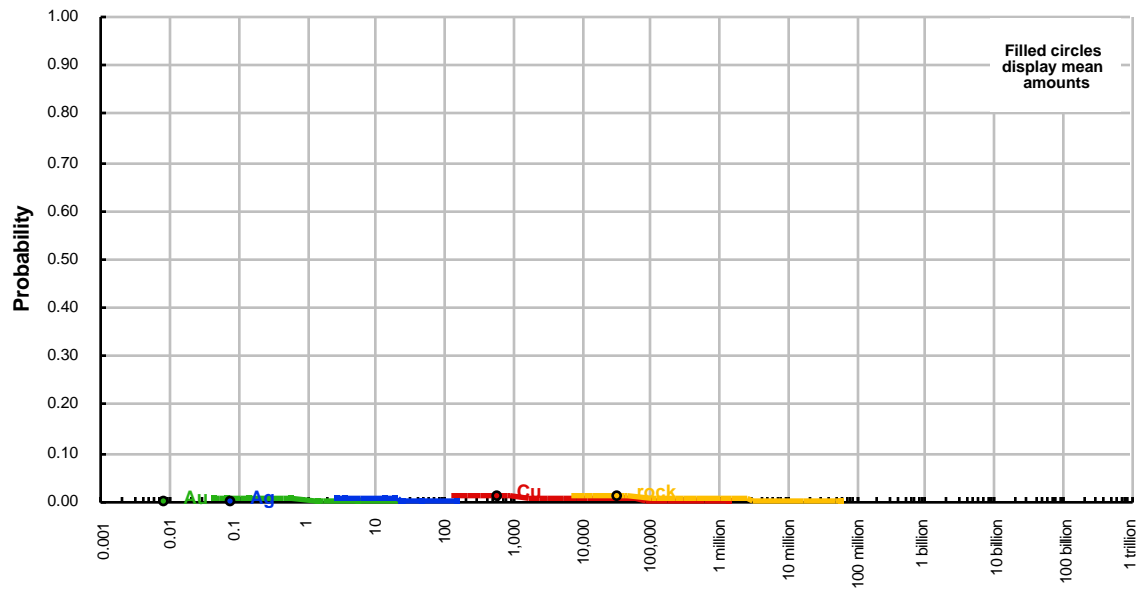
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

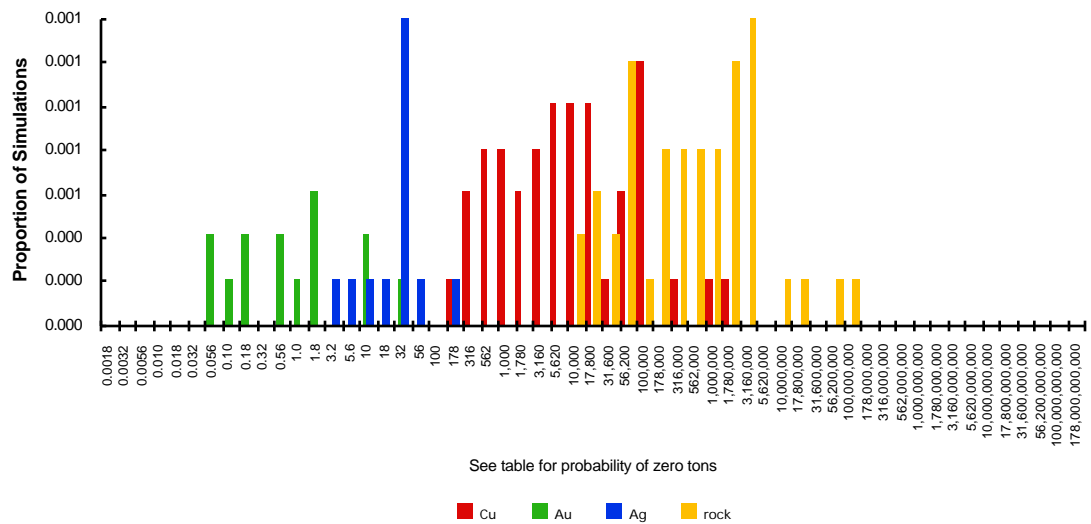
quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	0	0	0	0
mean	600	0	0	33,000
Probability of mean	0.01	0.00	0.00	0.01
Probability of zero	0.99	1.00	1.00	0.99

The tract ID is NR02

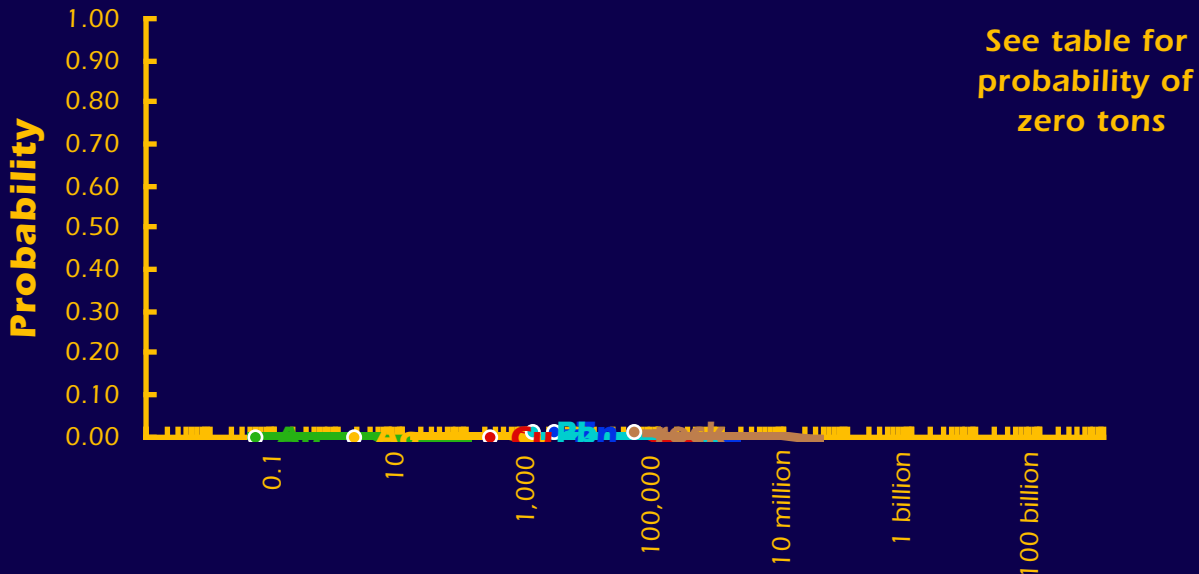
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

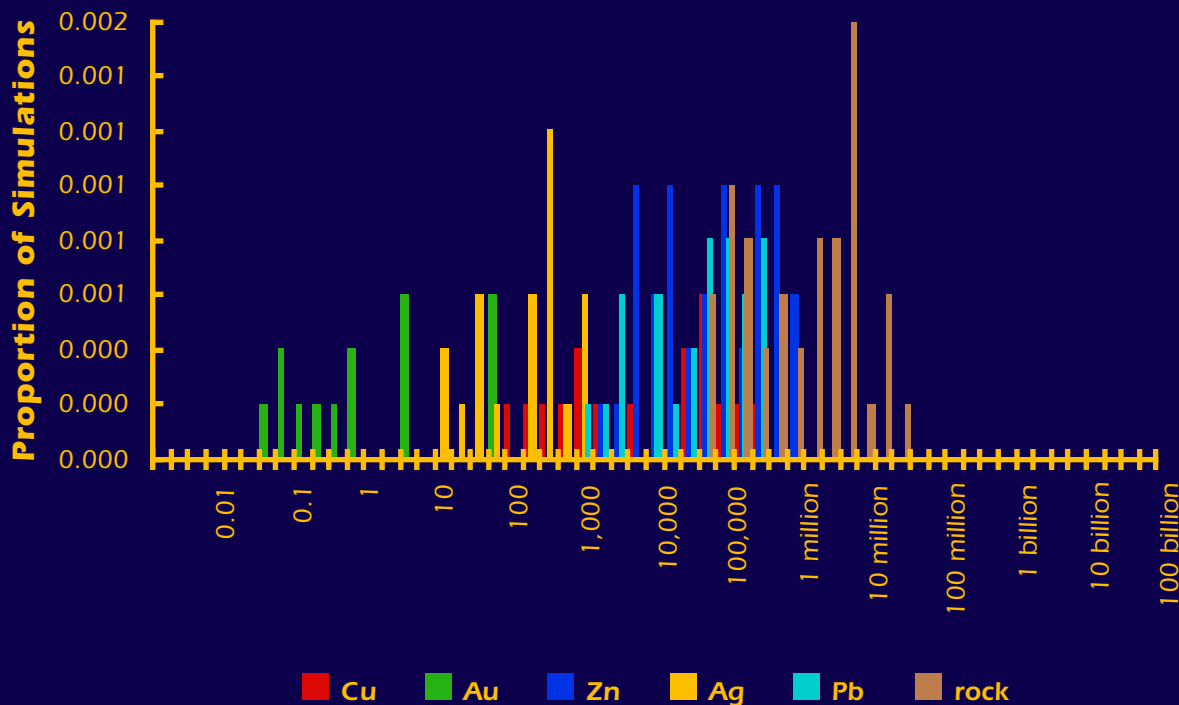


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR03

The Mark3 Index is 22:

Skarn Zn-Pb

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	230	0	2,400	2	1,200	42,000
Probability of mean	0.00	0.00	0.01	0.00	0.01	0.01
Probability of zero	1.00	1.00	0.99	1.00	0.99	0.99

The tract ID is NR03The Mark3 Index is 22: **Skarn Zn-Pb**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

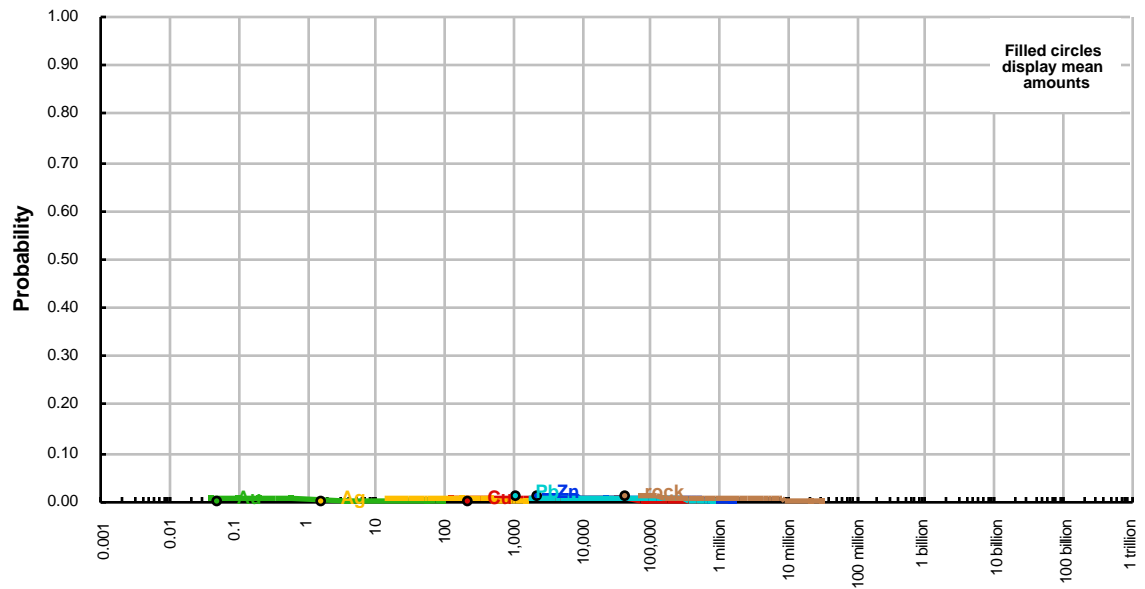
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

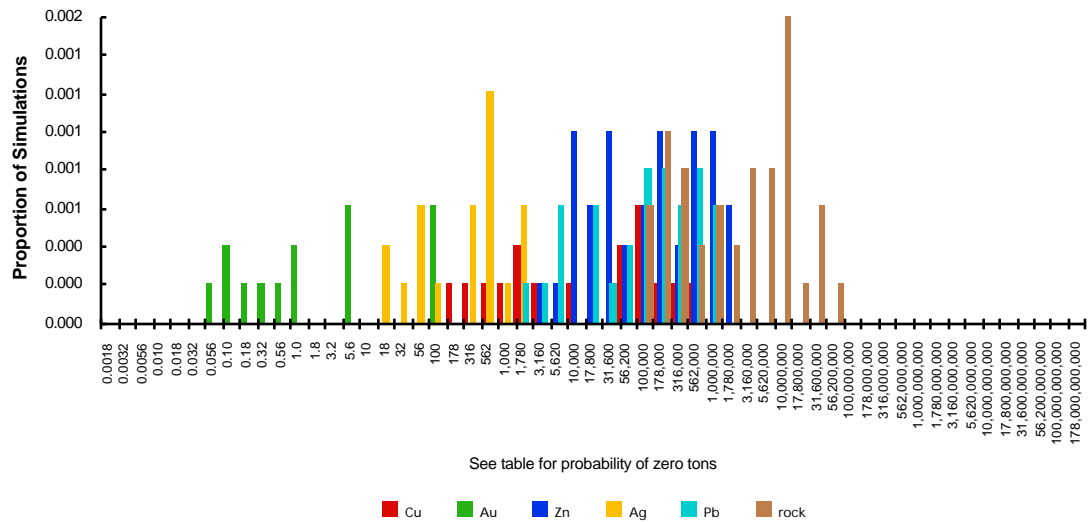
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	230	0	2,400	2	1,200	42,000
Probability of mean	0.00	0.00	0.01	0.00	0.01	0.01
Probability of zero	1.00	1.00	0.99	1.00	0.99	0.99

The tract ID is NR03

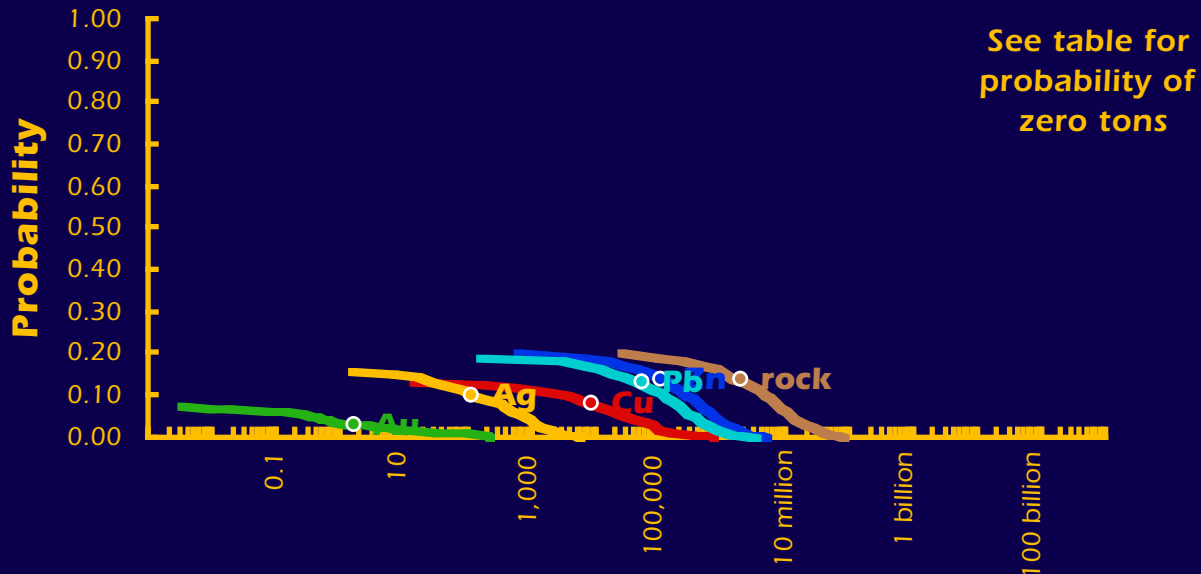
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

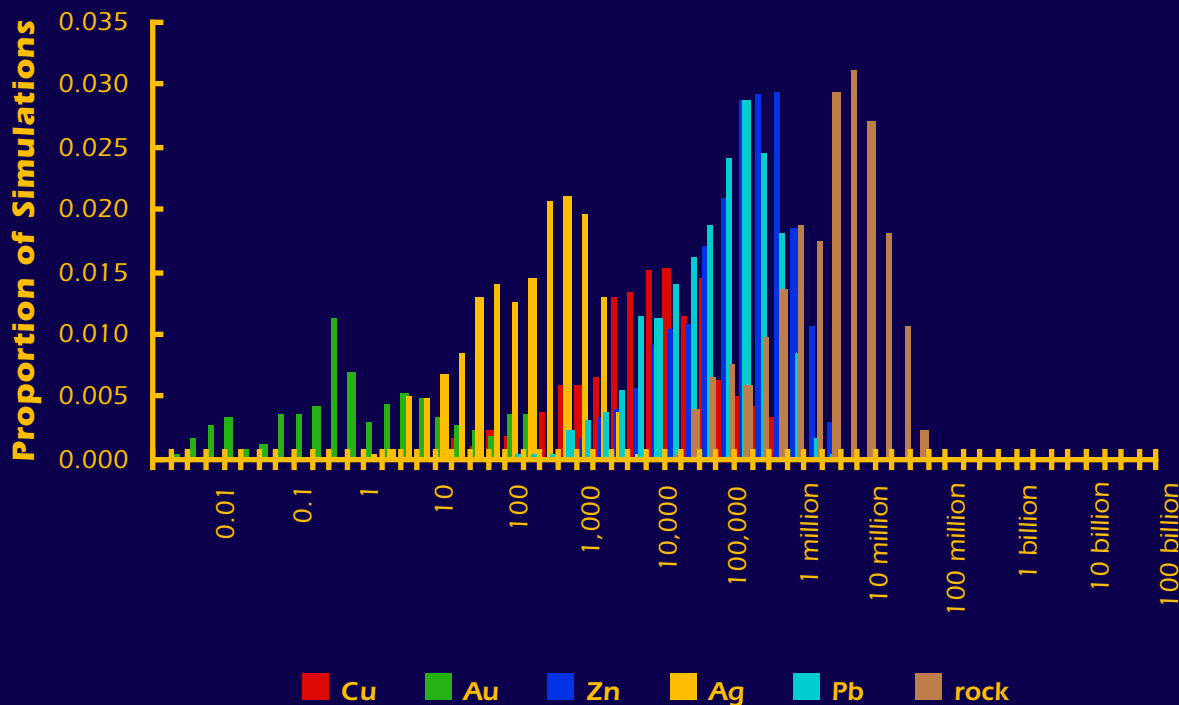


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NRO4

The Mark3 Index is 22:

Skarn Zn-Pb

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

There is a 1% or greater chance of 6 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	3,500	0	263,000	130	110,000	4,700,000
0.05	25,000	0	680,000	710	340,000	11,000,000
mean	8,200	2	110,000	110	52,000	1,800,000
Probability of mean	0.08	0.03	0.14	0.10	0.13	0.14
Probability of zero	0.87	0.93	0.80	0.84	0.81	0.80

The tract ID is NR04The Mark3 Index is 22: **Skarn Zn-Pb**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

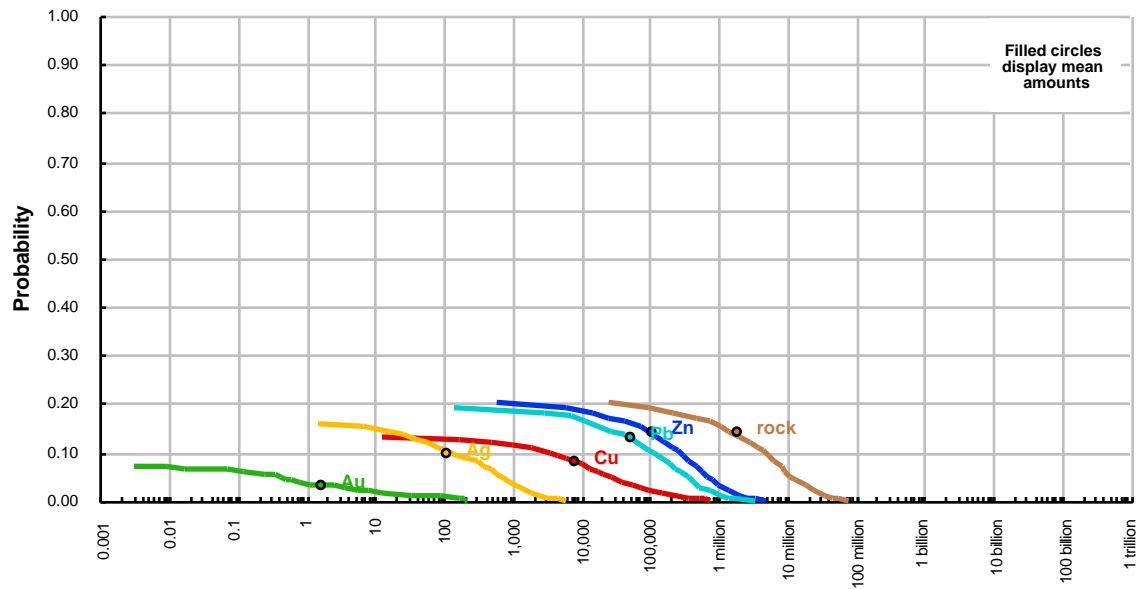
There is a 1% or greater chance of 6 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

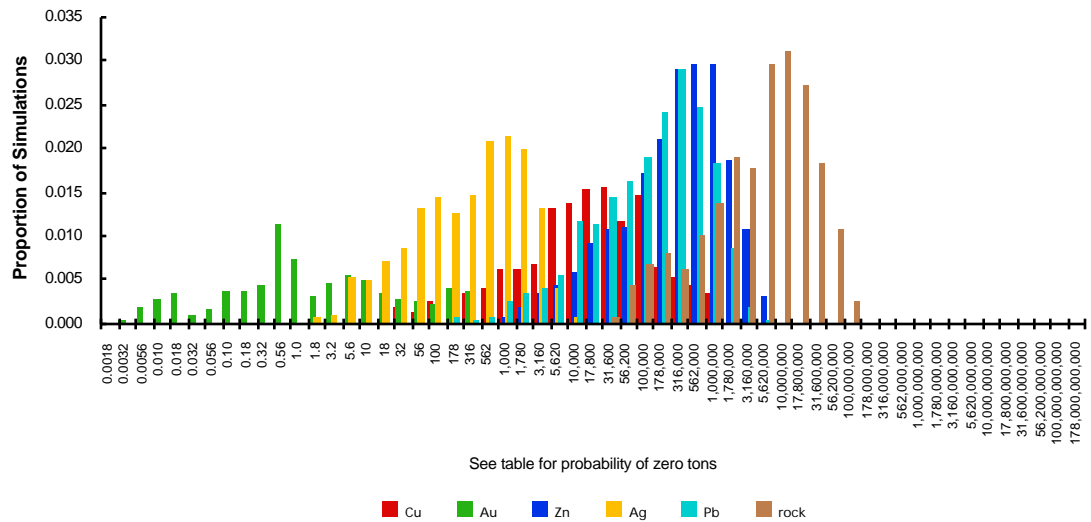
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	3,500	0	263,000	130	110,000	4,700,000
0.05	25,000	0	680,000	710	340,000	11,000,000
mean	8,200	2	110,000	110	52,000	1,800,000
Probability of mean	0.08	0.03	0.14	0.10	0.13	0.14
Probability of zero	0.87	0.93	0.80	0.84	0.81	0.80

The tract ID is NR04

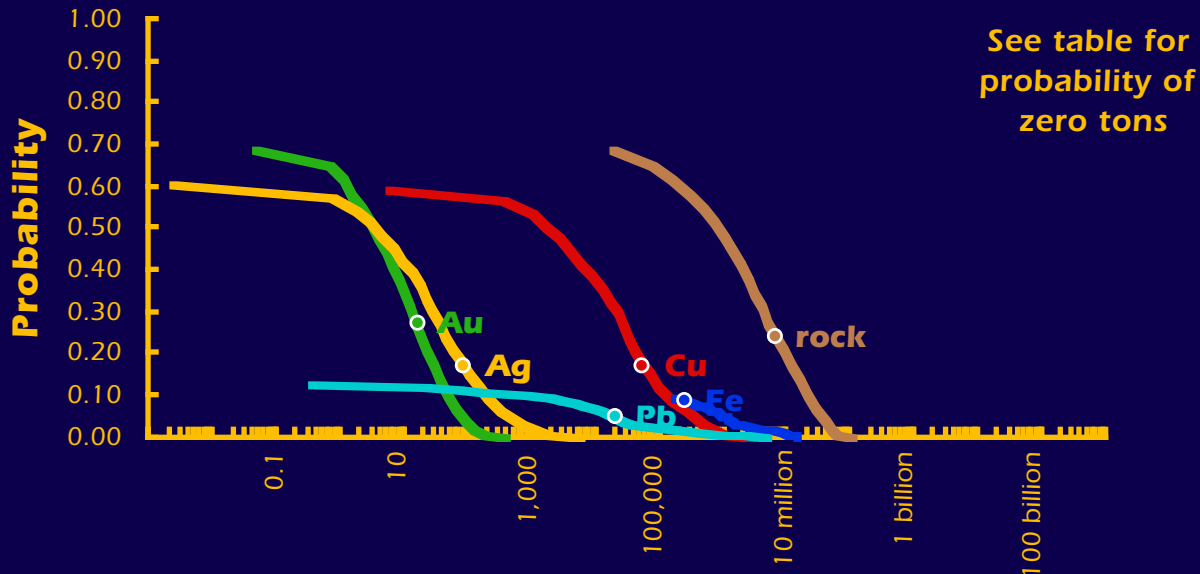
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

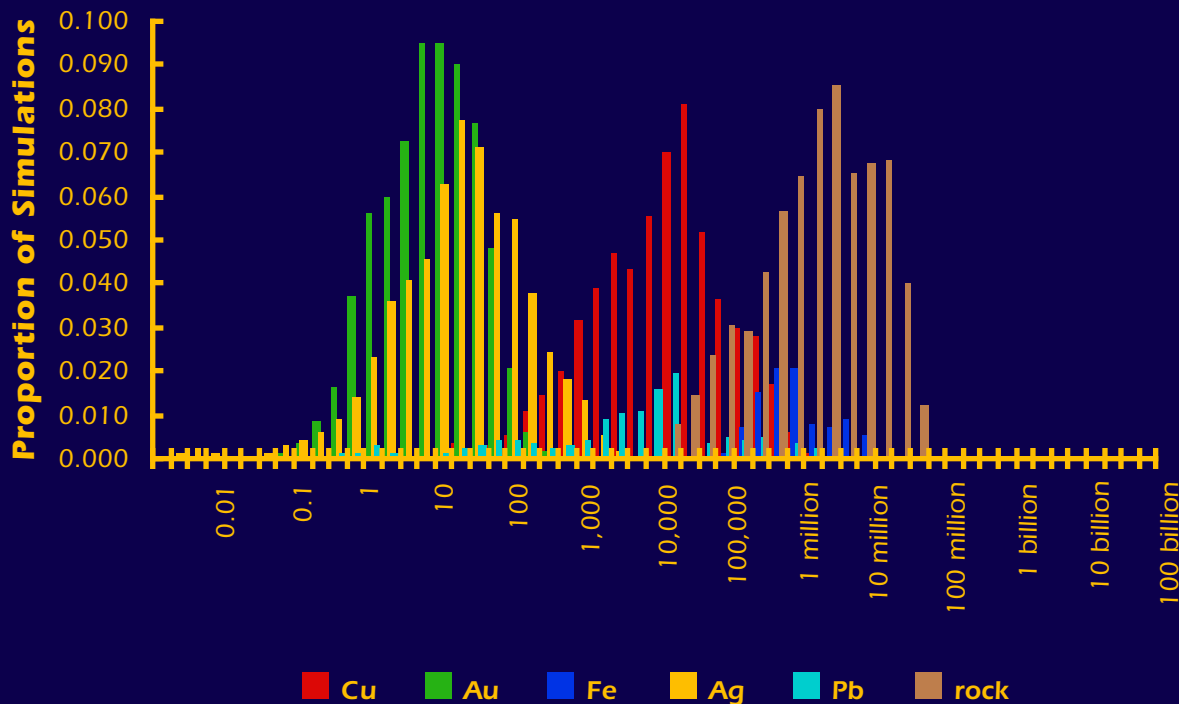


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR05

The Mark3 Index is 105:

Skarn Au, truncated

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

There is a 1% or greater chance of 7 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Fe	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	1,800	3	0	3	0	840,000
0.10	130,000	46	0	180	1,400	21,000,000
0.05	320,000	74	990,000	420	19,000	33,000,000
mean	55,000	16	240,000	86	19,000	6,200,000
Probability of mean	0.17	0.27	0.09	0.17	0.05	0.24
Probability of zero	0.41	0.31	0.91	0.40	0.87	0.31

The tract ID is NR05The Mark3 Index is 105: **Skarn Au, truncated**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

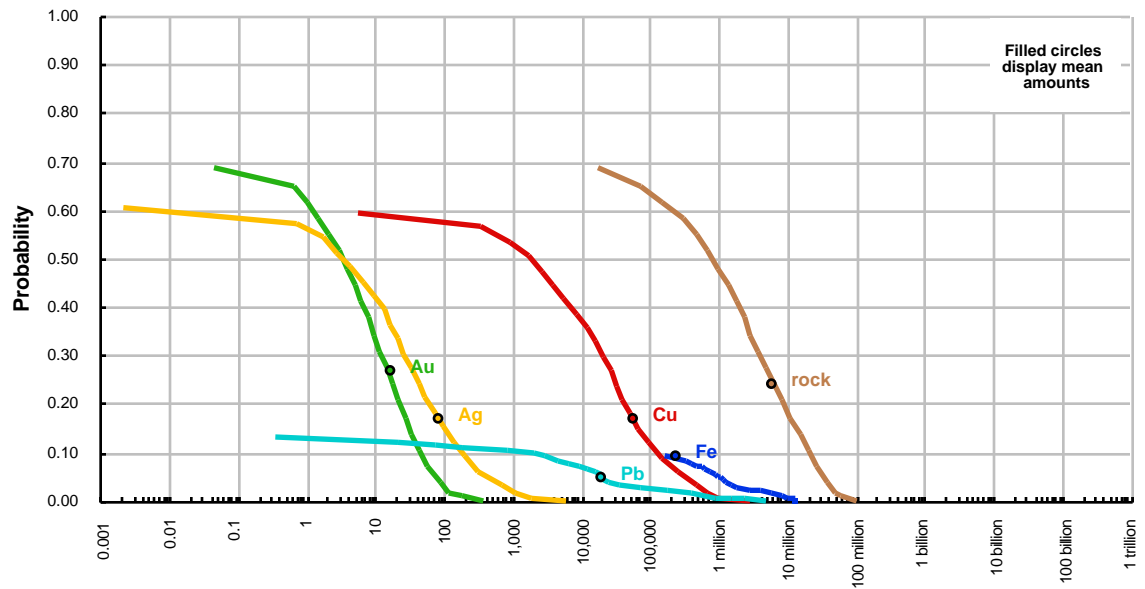
There is a 1% or greater chance of 7 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

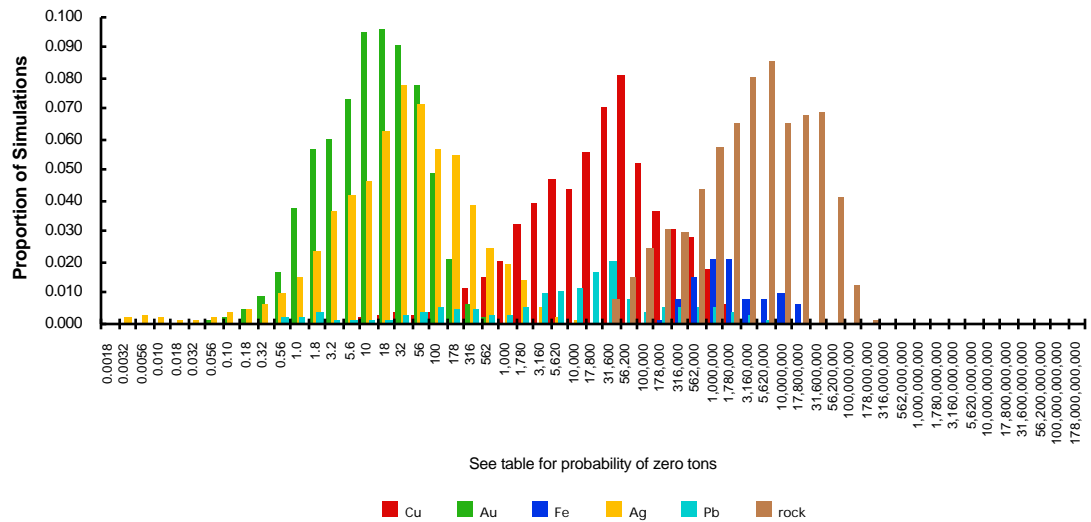
quantile	Cu	Au	Fe	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	1,800	3	0	3	0	840,000
0.10	130,000	46	0	180	1,400	21,000,000
0.05	320,000	74	990,000	420	19,000	33,000,000
mean	55,000	16	240,000	86	19,000	6,200,000
Probability of mean	0.17	0.27	0.09	0.17	0.05	0.24
Probability of zero	0.41	0.31	0.91	0.40	0.87	0.31

The tract ID is NR05

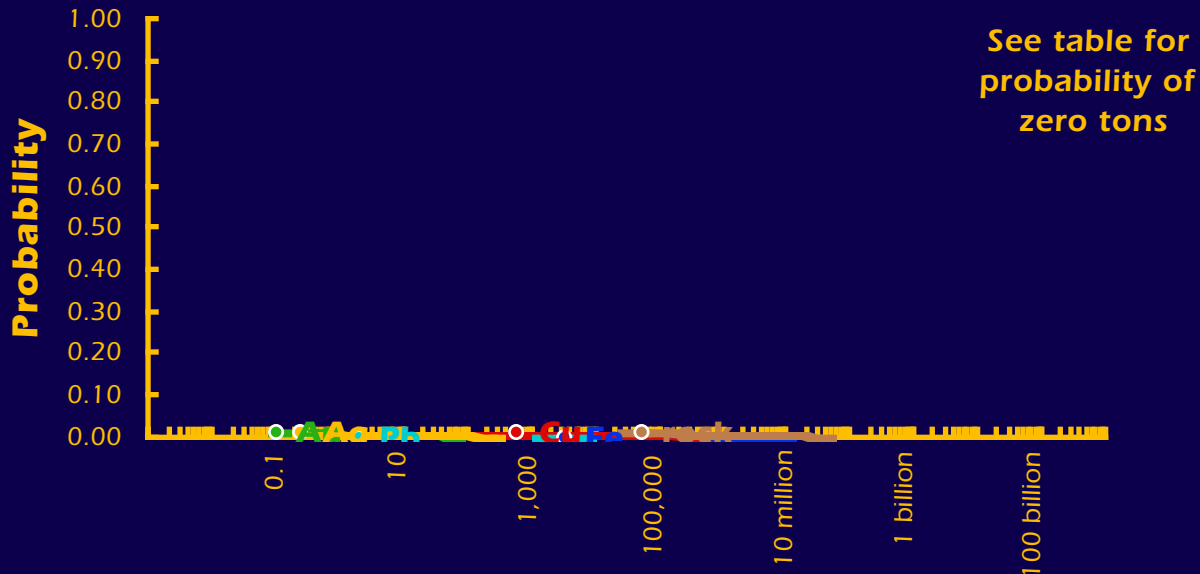
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

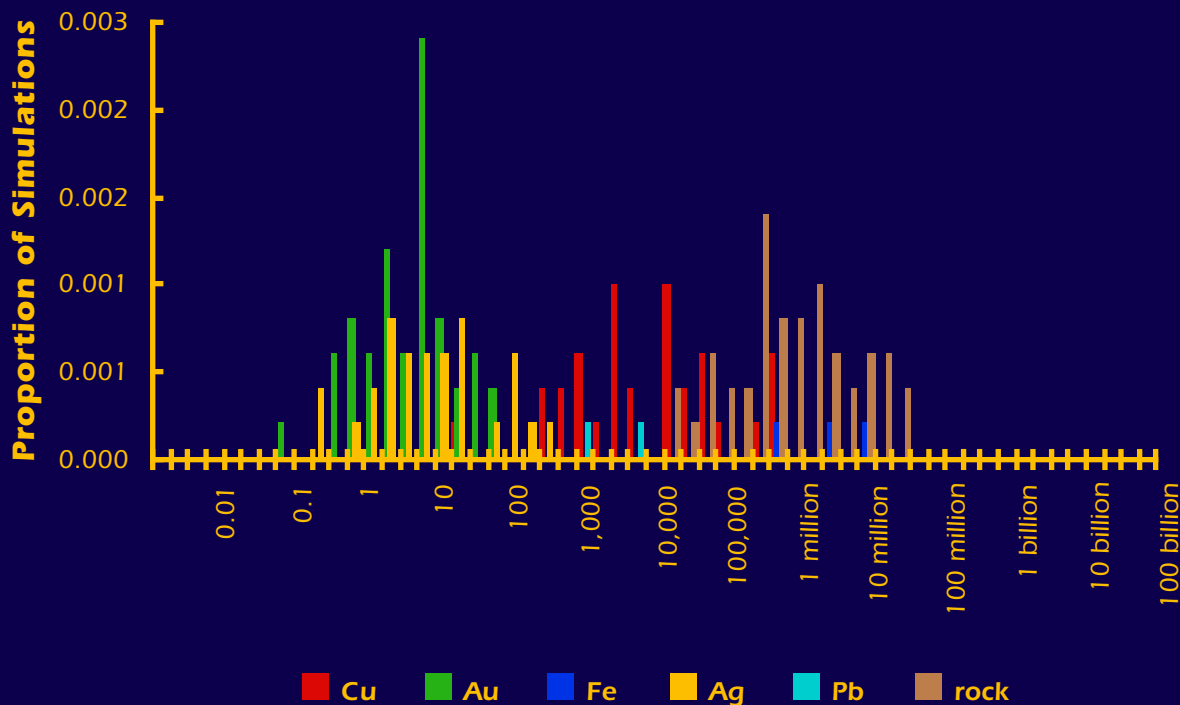


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR06

The Mark3 Index is 105:

Skarn Au, truncated

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Fe	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	590	0	3,200	0	2	52,000
Probability of mean	0.01	0.01	0.00	0.01	0.00	0.01
Probability of zero	0.99	0.99	1.00	0.99	1.00	0.99

The tract ID is NR06The Mark3 Index is 105: **Skarn Au, truncated**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

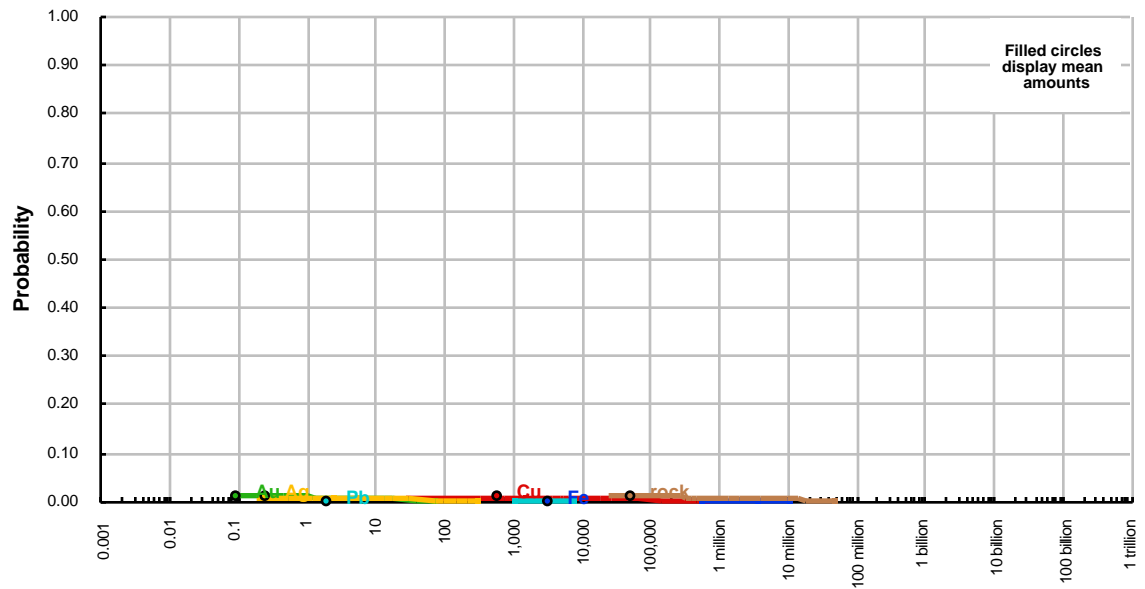
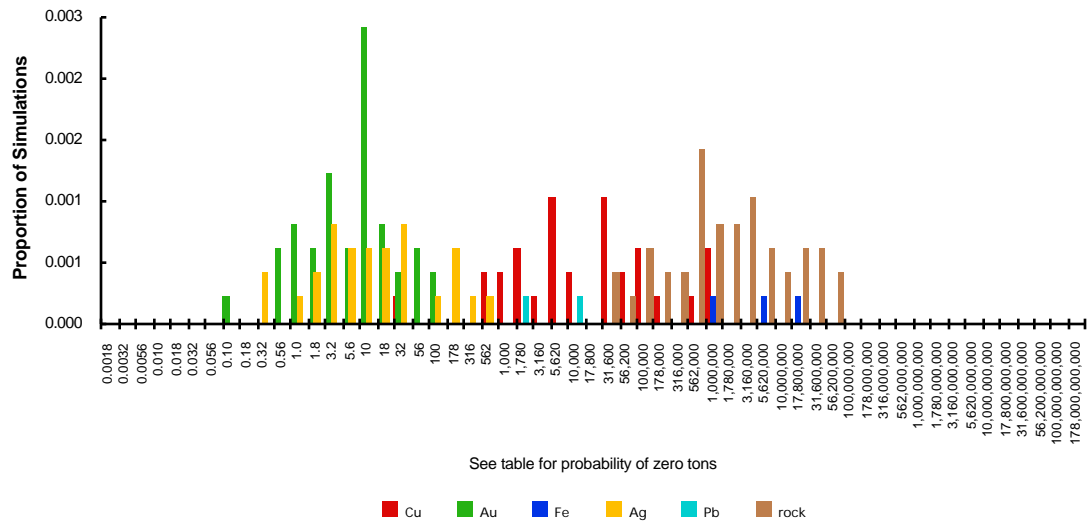
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

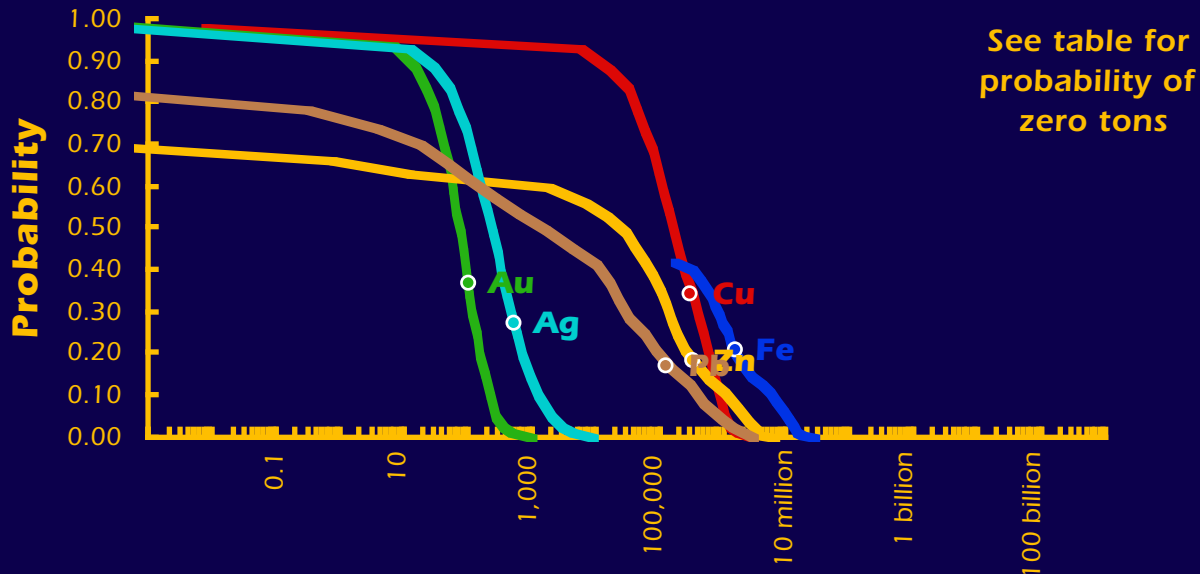
quantile	Cu	Au	Fe	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	590	0	3,200	0	2	52,000
Probability of mean	0.01	0.01	0.00	0.01	0.00	0.01
Probability of zero	0.99	0.99	1.00	0.99	1.00	0.99

The tract ID is NR06

Cumulative Distributions of Contained Metal and Mineralized Rock

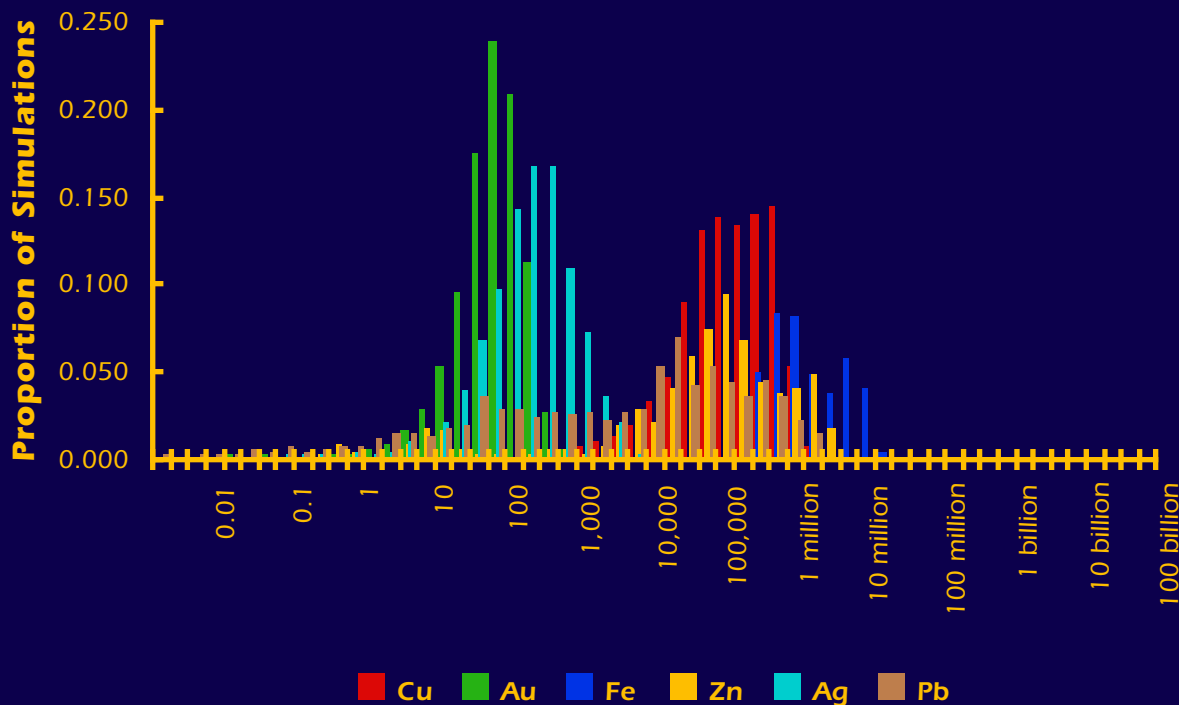
Histograms of Contained Metal and Mineralized Rock
(metric tons)

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR07

The Mark3 Index is 82:

Skorn Au

There is a 90% or greater chance of 5 or more deposits.
 There is a 50% or greater chance of 12 or more deposits.
 There is a 10% or greater chance of 20 or more deposits.
 There is a 5% or greater chance of 28 or more deposits.
 There is a 1% or greater chance of 36 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Fe	Zn	Ag	Pb
0.95	2,100	5	0	0	6	0
0.90	14,000	12	0	0	24	0
0.50	160,000	71	0	25,000	230	1,400
0.10	820,000	210	5,730,000	1,100,000	1,200	400,000
0.05	1,100,000	270	9,400,000	2,200,000	2,000	750,000
mean	310,000	97	1,500,000	330,000	490	130,000
Probability of mean	0.34	0.37	0.21	0.18	0.27	0.17
Probability of zero	0.02	0.01	0.58	0.30	0.02	0.18

The tract ID is NR07The Mark3 Index is 82: **Skarn Au**

There is a 90% or greater chance of 5 or more deposits.

There is a 50% or greater chance of 12 or more deposits.

There is a 10% or greater chance of 20 or more deposits.

There is a 5% or greater chance of 28 or more deposits.

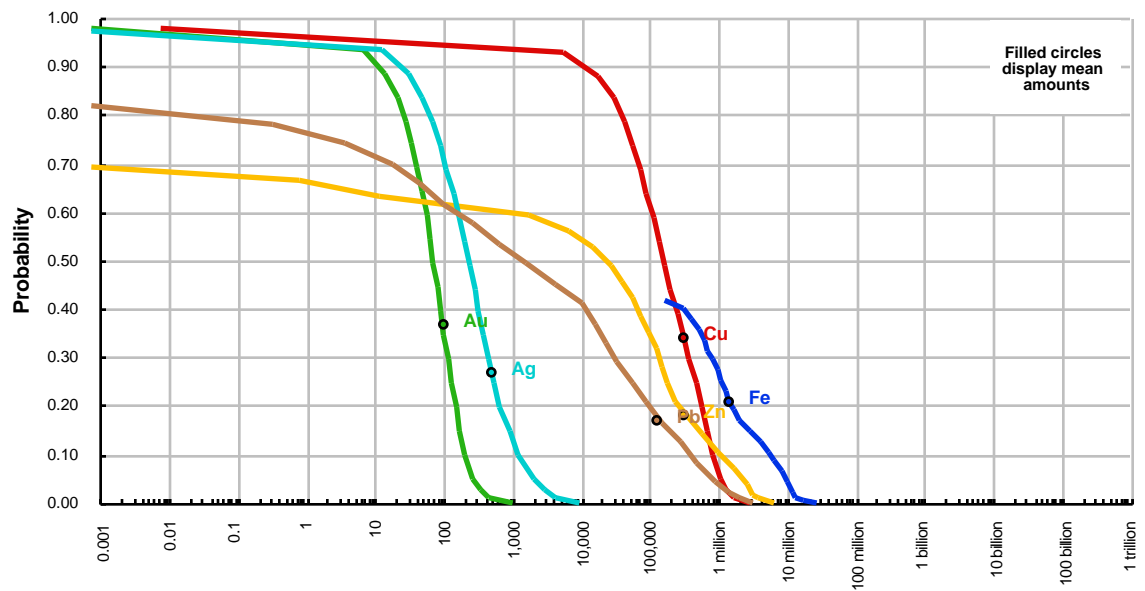
There is a 1% or greater chance of 36 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

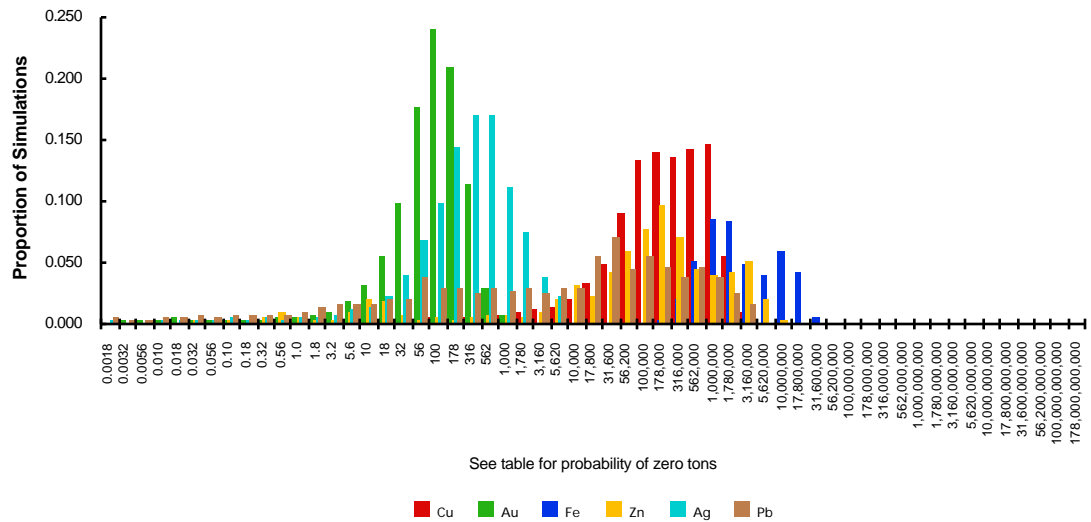
quantile	Cu	Au	Fe	Zn	Ag	Pb
0.95	2,100	5	0	0	6	0
0.90	14,000	12	0	0	24	0
0.50	160,000	71	0	25,000	230	1,400
0.10	820,000	210	5,730,000	1,100,000	1,200	400,000
0.05	1,100,000	270	9,400,000	2,200,000	2,000	750,000
mean	310,000	97	1,500,000	330,000	490	130,000
Probability of mean	0.34	0.37	0.21	0.18	0.27	0.17
Probability of zero	0.02	0.01	0.58	0.30	0.02	0.18

The tract ID is NR07

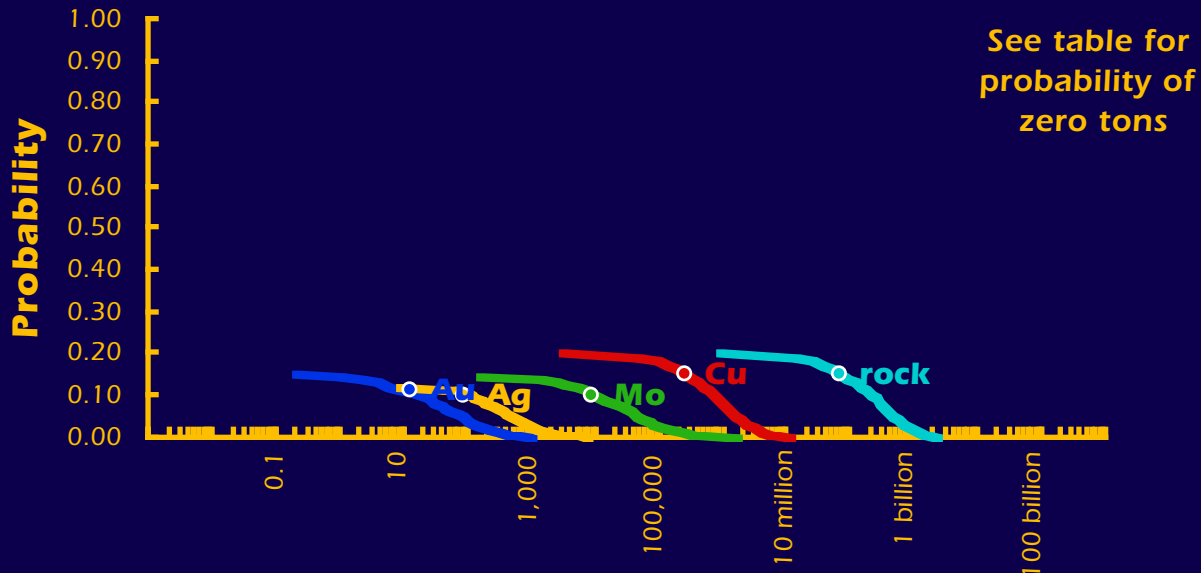
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

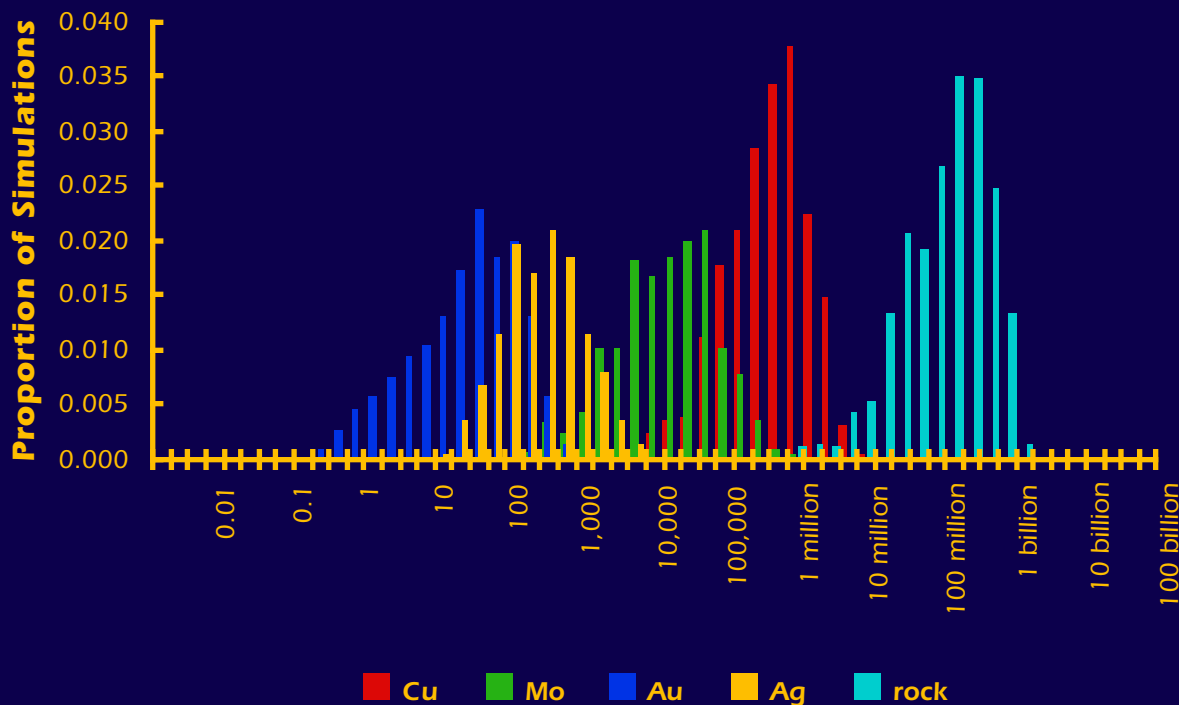


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR08

The Mark3 Index is 89:

Porphry Cu (BC-AK)

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	700,000	9,500	17	98	210,000,000
0.05	1,500,000	47,000	73	440	460,000,000
mean	240,000	8,800	12	86	67,000,000
Probability of mean	0.15	0.10	0.11	0.10	0.15
Probability of zero	0.80	0.85	0.85	0.88	0.80

The tract ID is NR08The Mark3 Index is 89: **Porphyry Cu (BC-AK)**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

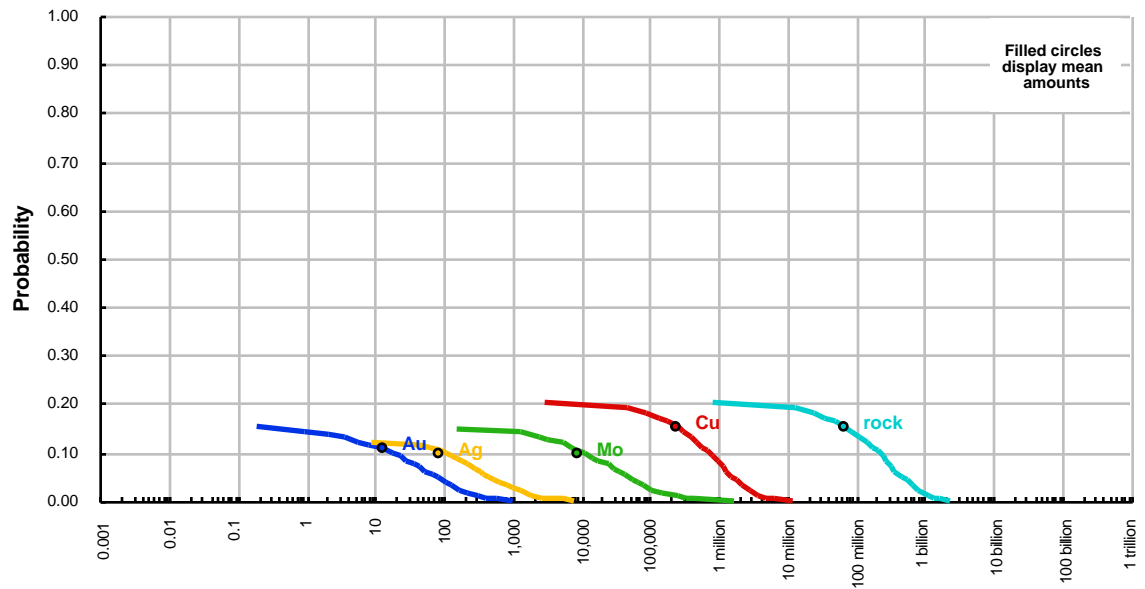
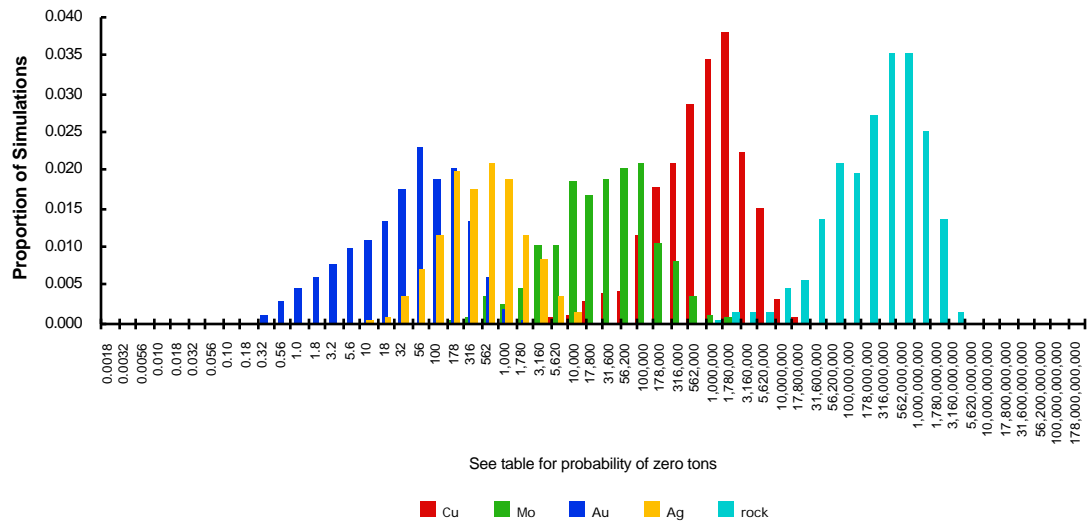
There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

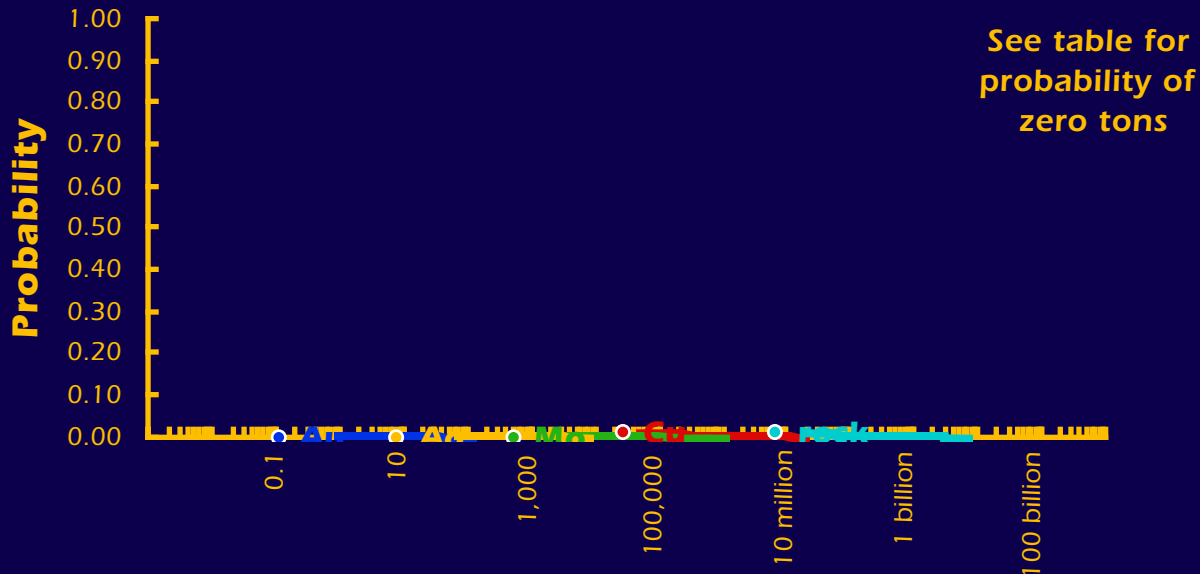
quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	700,000	9,500	17	98	210,000,000
0.05	1,500,000	47,000	73	440	460,000,000
mean	240,000	8,800	12	86	67,000,000
Probability of mean	0.15	0.10	0.11	0.10	0.15
Probability of zero	0.80	0.85	0.85	0.88	0.80

The tract ID is NR08

Cumulative Distributions of Contained Metal and Mineralized Rock

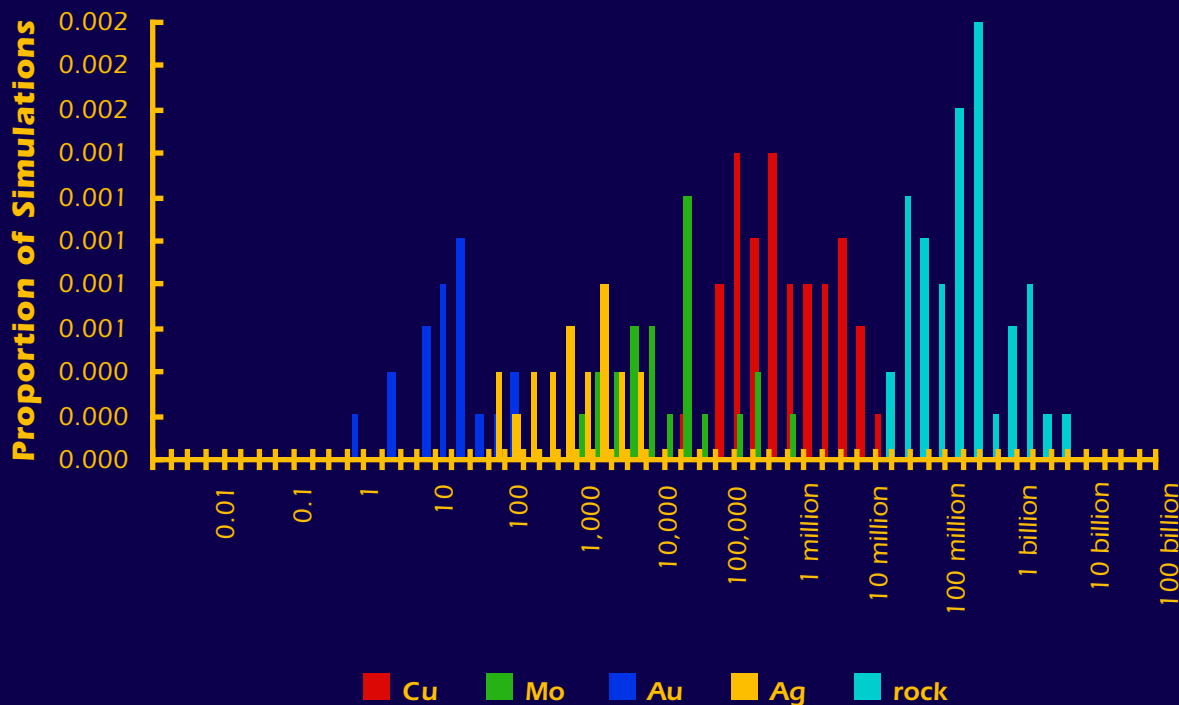
Histograms of Contained Metal and Mineralized Rock
(metric tons)

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR09

The Mark3 Index is 81:

Porphyry Cu (North America)

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock	0
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	28,000	520	0	8	6,700,000	0
Probability of mean	0.01	0.00	0.00	0.00	0.01	0.00
Probability of zero	0.99	1.00	1.00	1.00	0.99	0.00

The tract ID is NR09The Mark3 Index is 81: **Porphyry Cu (North America)**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

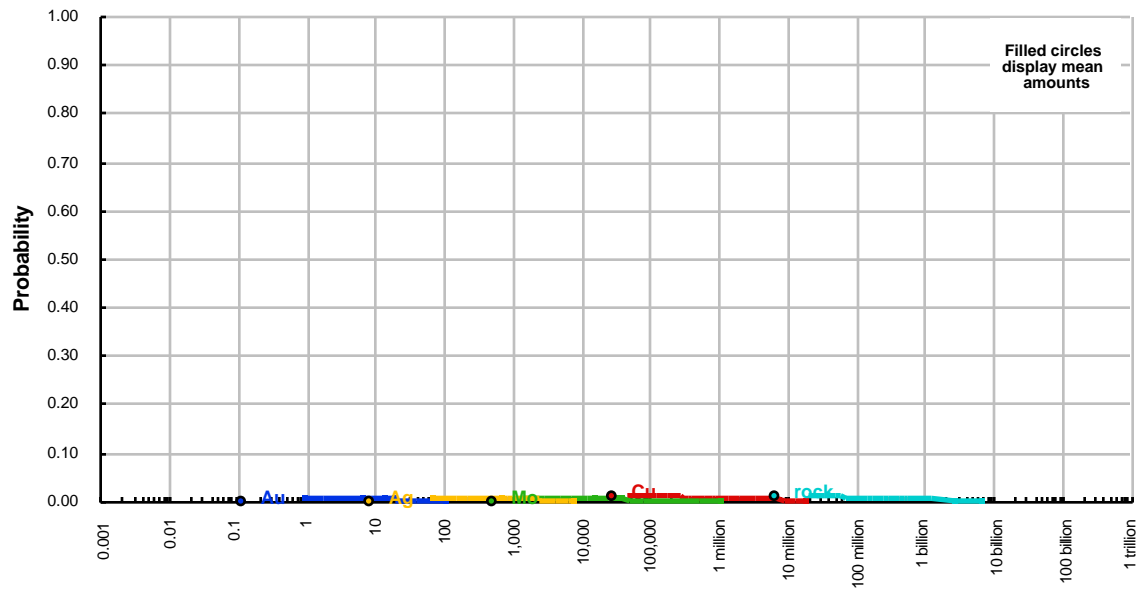
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

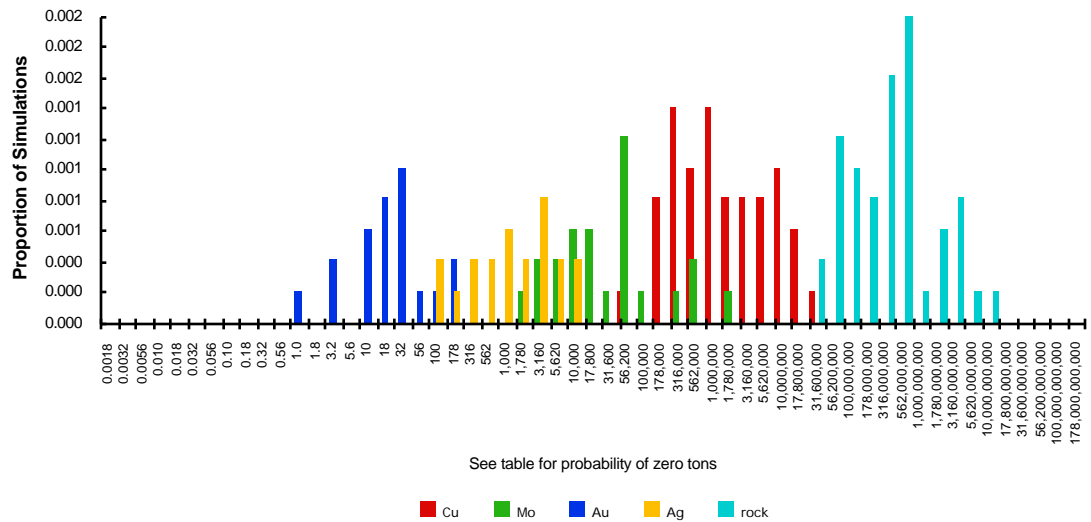
quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	0	0	0	0	0
mean	28,000	520	0	8	6,700,000
Probability of mean	0.01	0.00	0.00	0.00	0.01
Probability of zero	0.99	1.00	1.00	1.00	0.99

The tract ID is NR09

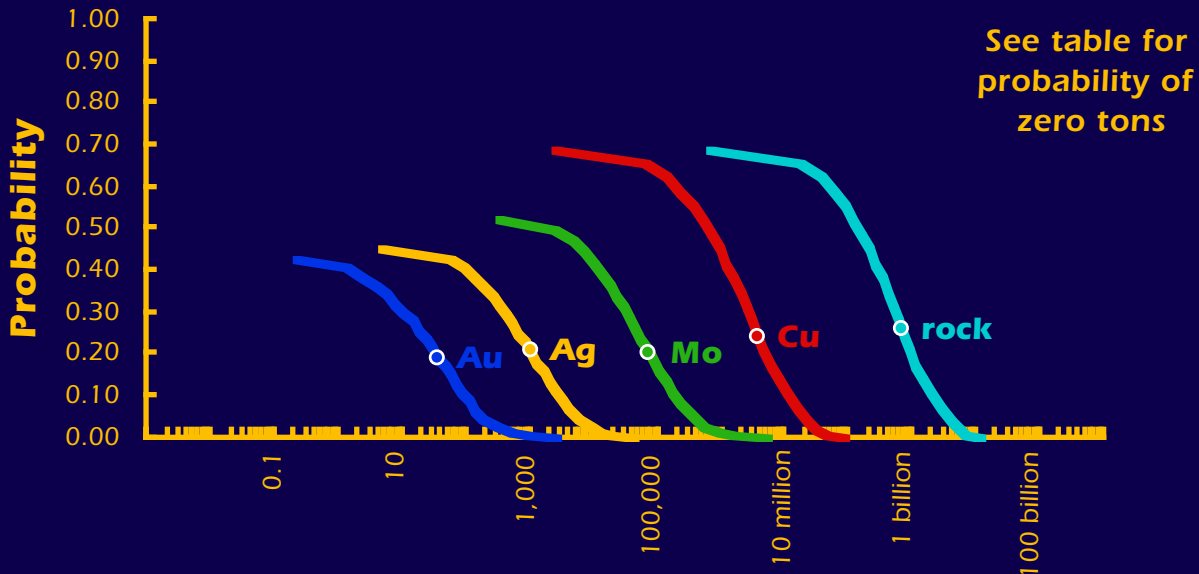
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

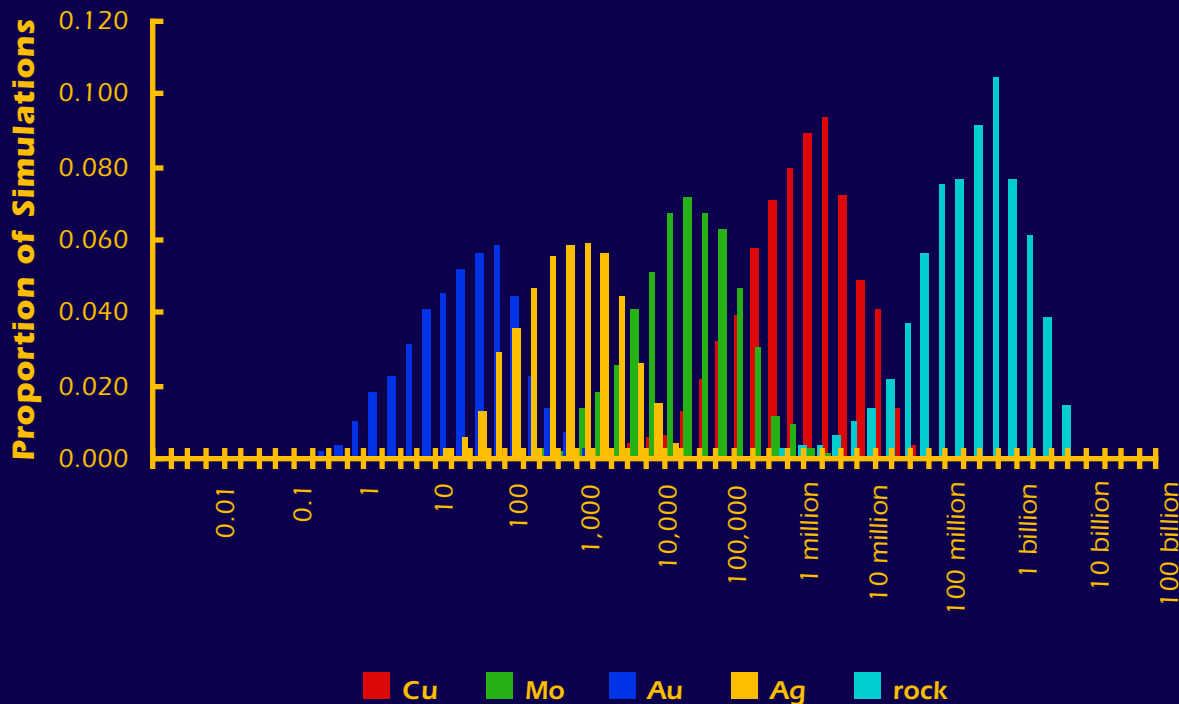


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR10

The Mark3 Index is 81:

Porphyry Cu (North America)

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

There is a 1% or greater chance of 7 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	610,000	1,900	0	0	130,000,000
0.10	11,000,000	180,000	88	2,900	2,000,000,000
0.05	19,000,000	340,000	170	5,300	3,300,000,000
mean	3,700,000	73,000	35	980	660,000,000
Probability of mean	0.24	0.20	0.19	0.21	0.26
Probability of zero	0.31	0.48	0.57	0.55	0.31

The tract ID is NR10The Mark3 Index is 81: **Porphyry Cu (North America)**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

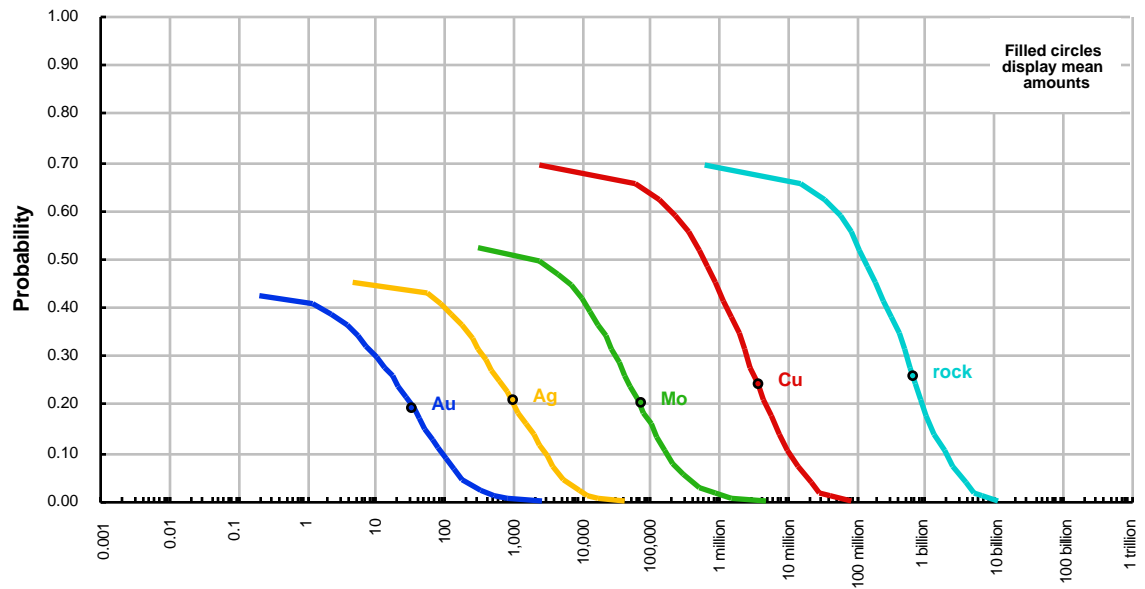
There is a 1% or greater chance of 7 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

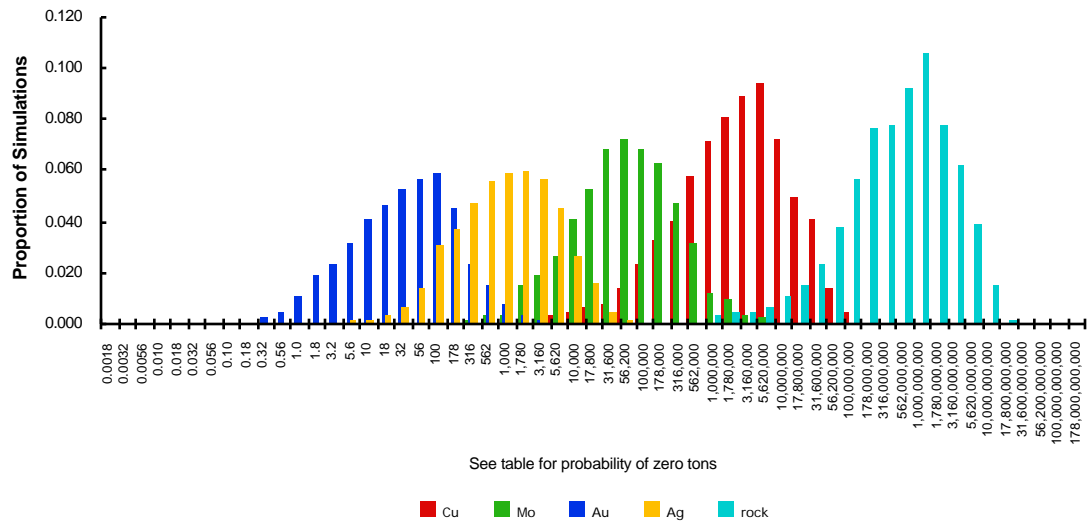
quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	610,000	1,900	0	0	130,000,000
0.10	11,000,000	180,000	88	2,900	2,000,000,000
0.05	19,000,000	340,000	170	5,300	3,300,000,000
mean	3,700,000	73,000	35	980	660,000,000
Probability of mean	0.24	0.20	0.19	0.21	0.26
Probability of zero	0.31	0.48	0.57	0.55	0.31

The tract ID is NR10

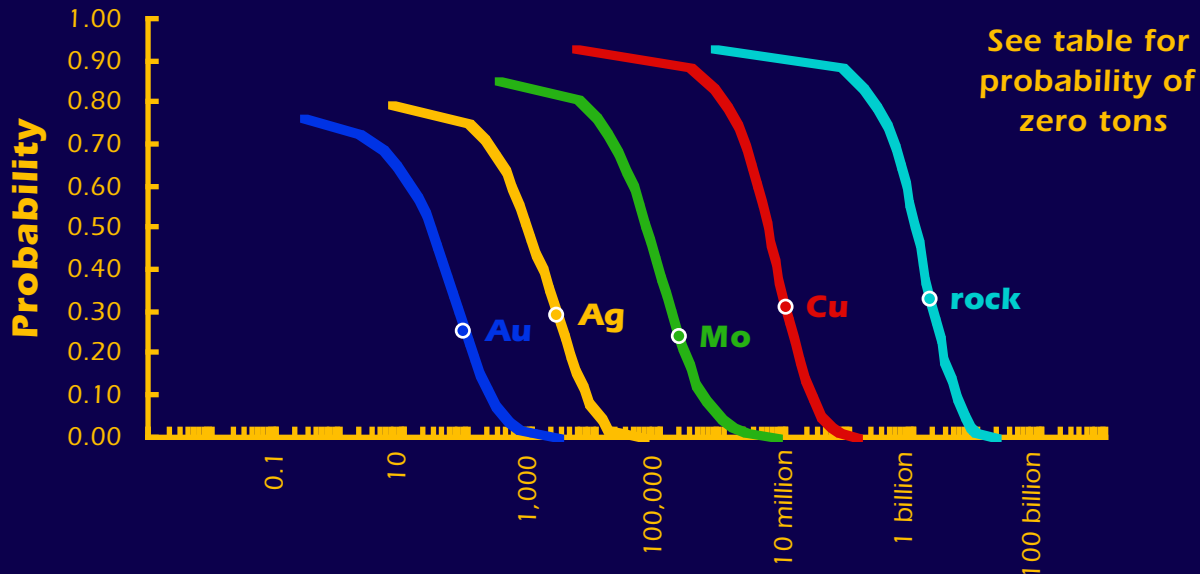
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

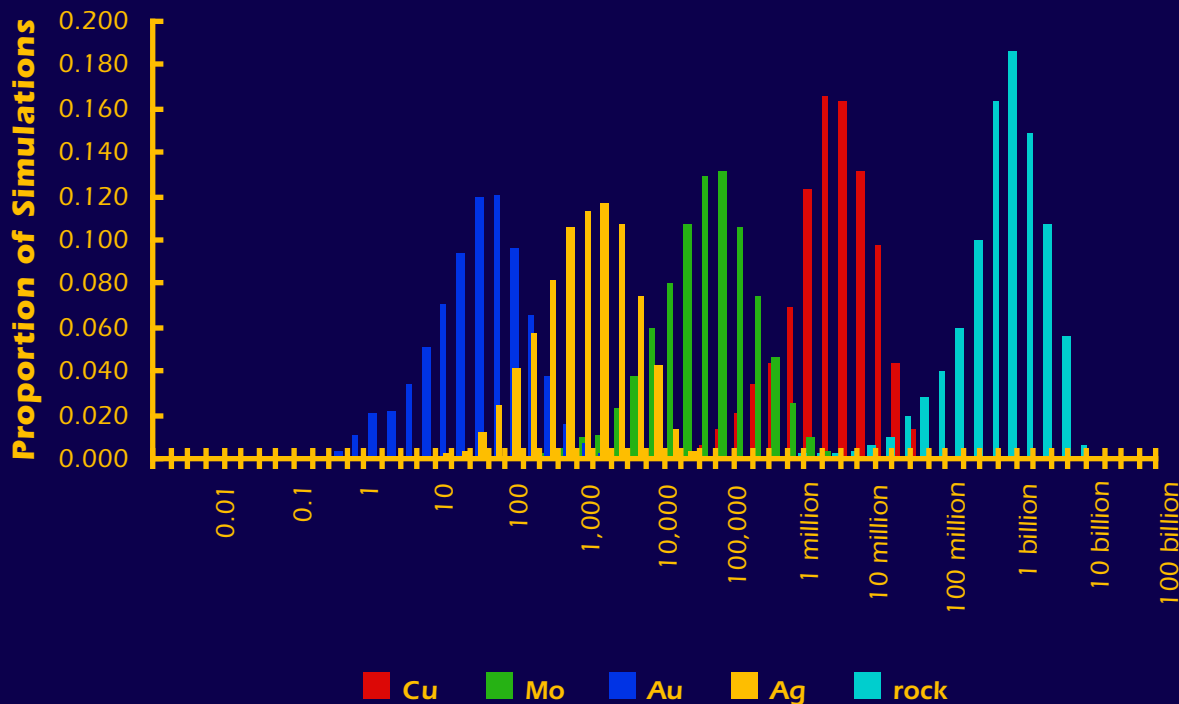


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR11

The Mark3 Index is 81:

Porphyry Cu (North America)

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 4 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 7 or more deposits.

There is a 1% or greater chance of 9 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	190,000	0	0	0	42,000,000
0.50	4,800,000	63,000	26	860	1,000,000,000
0.10	24,000,000	480,000	218	6,900	4,300,000,000
0.05	34,000,000	840,000	370	11,000	6,200,000,000
mean	9,200,000	200,000	85	2,500	1,700,000,000
Probability of mean	0.31	0.24	0.25	0.29	0.33
Probability of zero	0.07	0.15	0.24	0.21	0.07

The tract ID is NR11The Mark3 Index is 81: **Porphyry Cu (North America)**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 4 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 7 or more deposits.

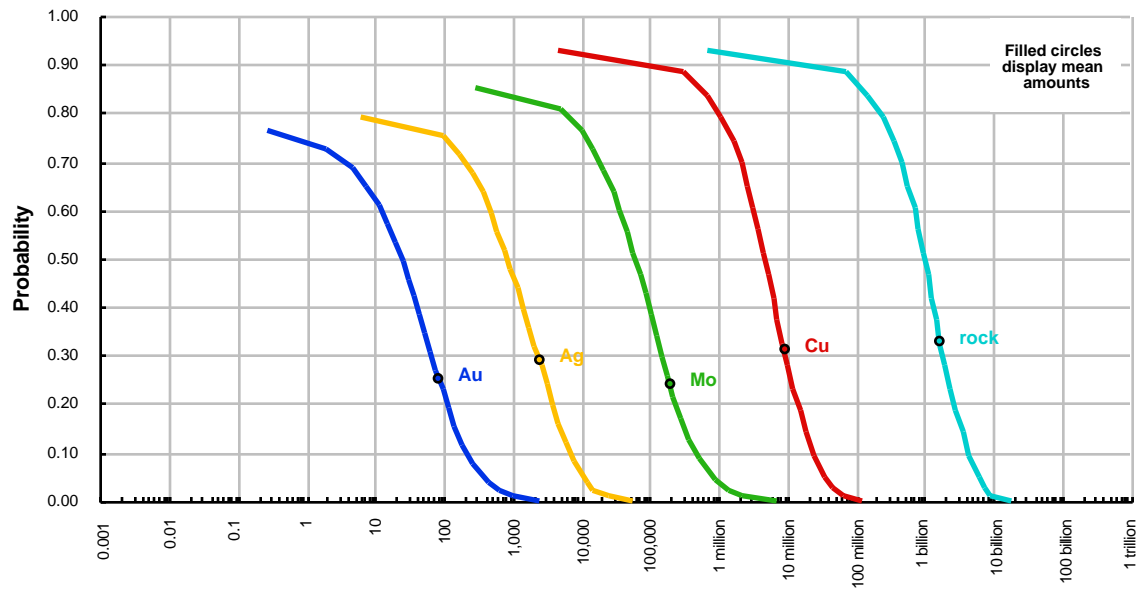
There is a 1% or greater chance of 9 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

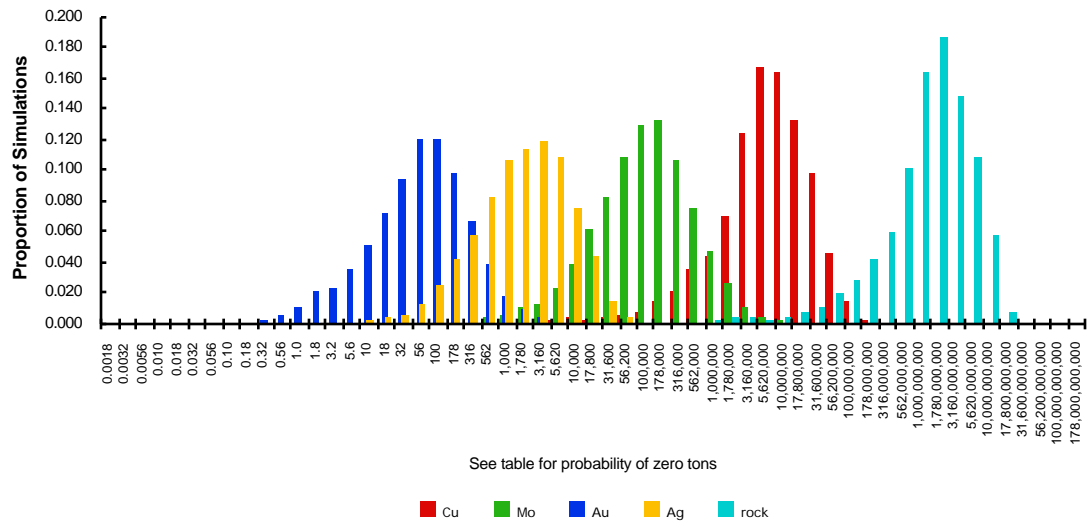
quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	190,000	0	0	0	42,000,000
0.50	4,800,000	63,000	26	860	1,000,000,000
0.10	24,000,000	480,000	218	6,900	4,300,000,000
0.05	34,000,000	840,000	370	11,000	6,200,000,000
mean	9,200,000	200,000	85	2,500	1,700,000,000
Probability of mean	0.31	0.24	0.25	0.29	0.33
Probability of zero	0.07	0.15	0.24	0.21	0.07

The tract ID is NR11

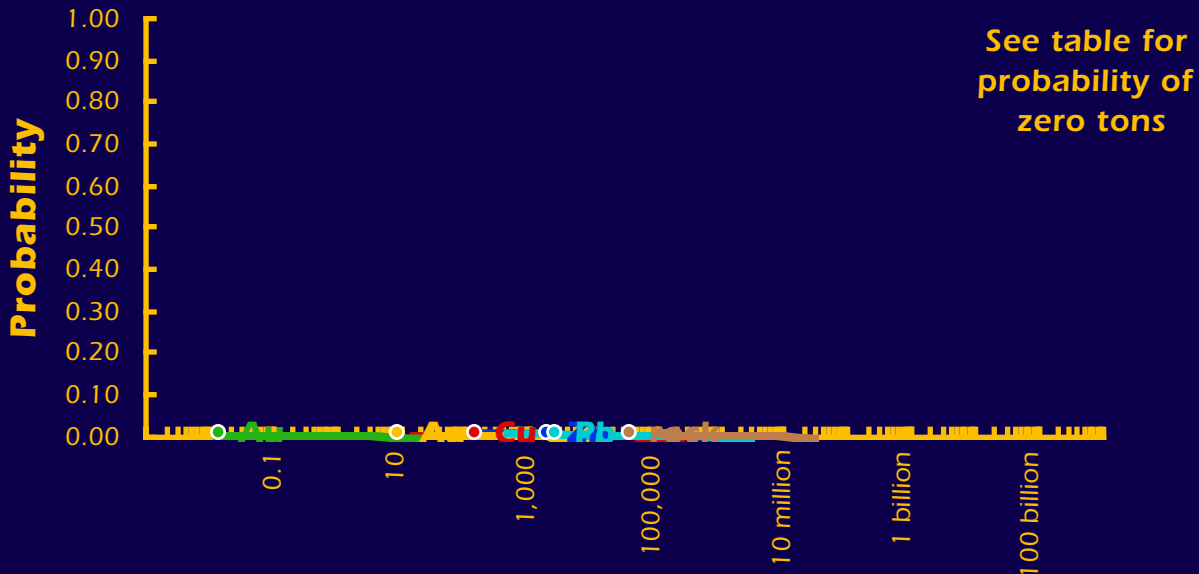
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

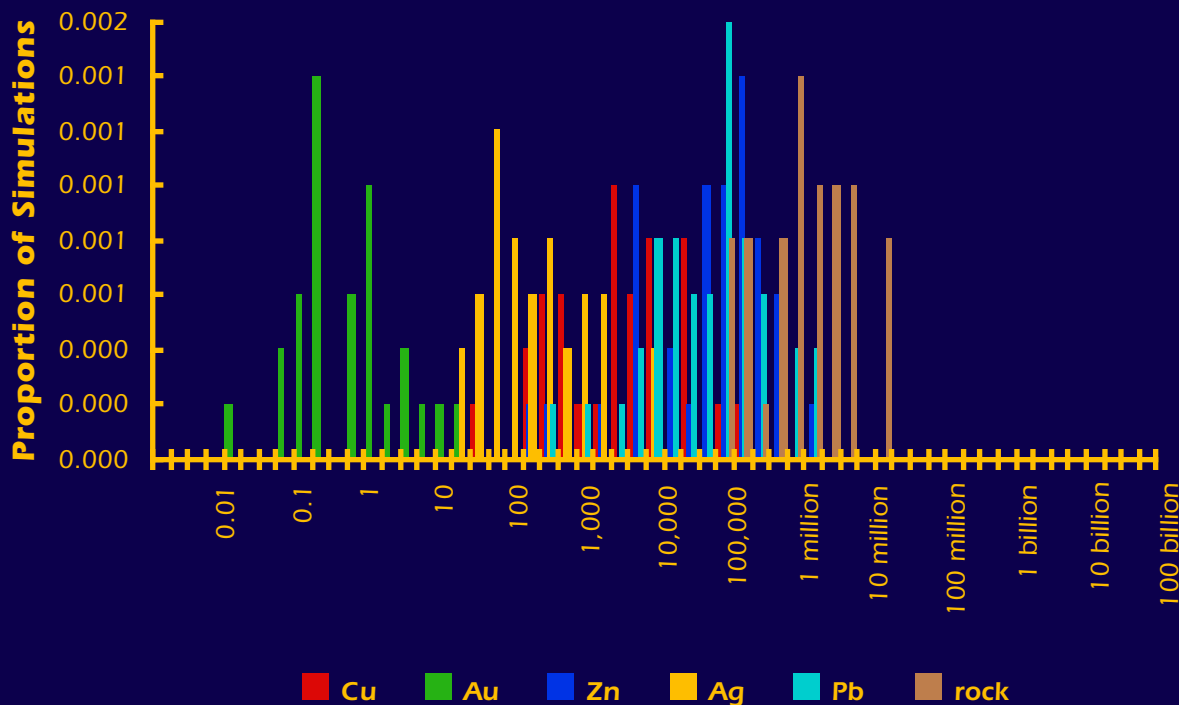


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR12

The Mark3 Index is 47:

Polymetallic replacement

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	130	0	1,800	9	2,300	35,000
Probability of mean	0.01	0.01	0.01	0.01	0.01	0.01
Probability of zero	0.99	0.99	0.99	0.99	0.99	0.99

The tract ID is NR12The Mark3 Index is 47: **Polymetallic replacement**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

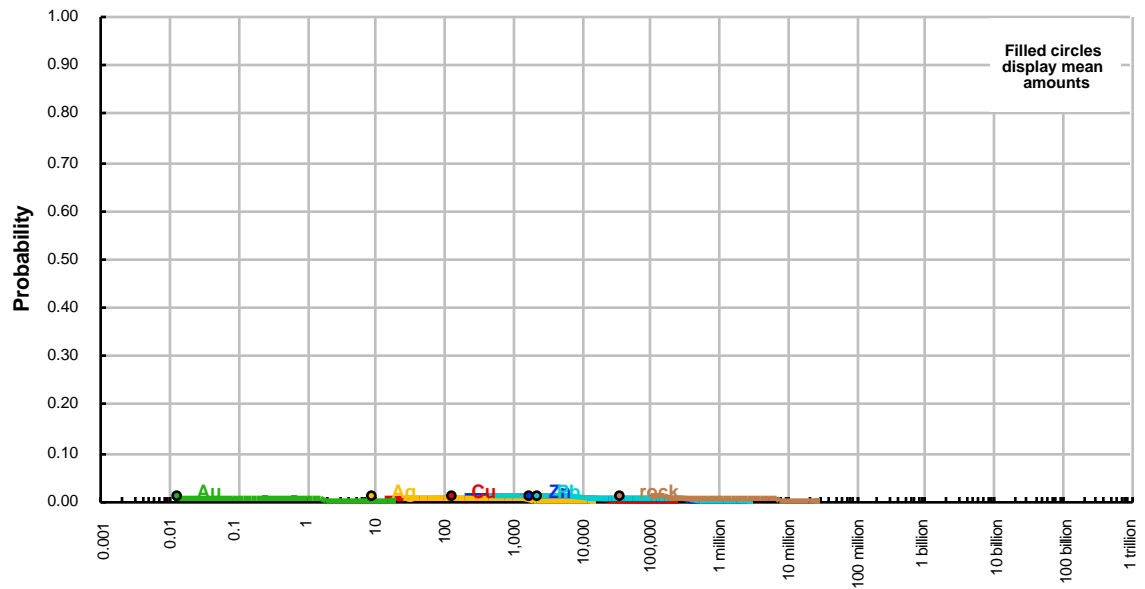
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

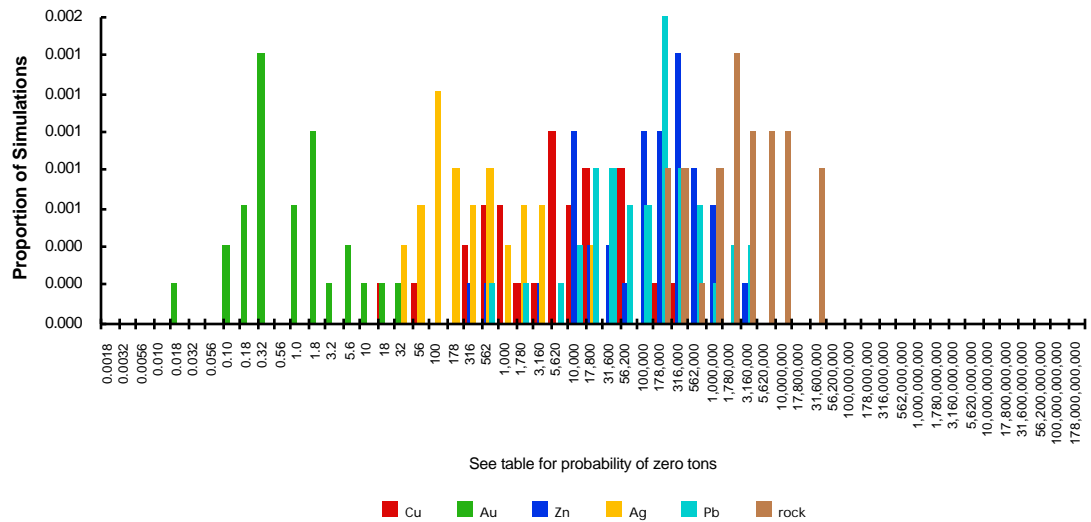
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	130	0	1,800	9	2,300	35,000
Probability of mean	0.01	0.01	0.01	0.01	0.01	0.01
Probability of zero	0.99	0.99	0.99	0.99	0.99	0.99

The tract ID is NR12

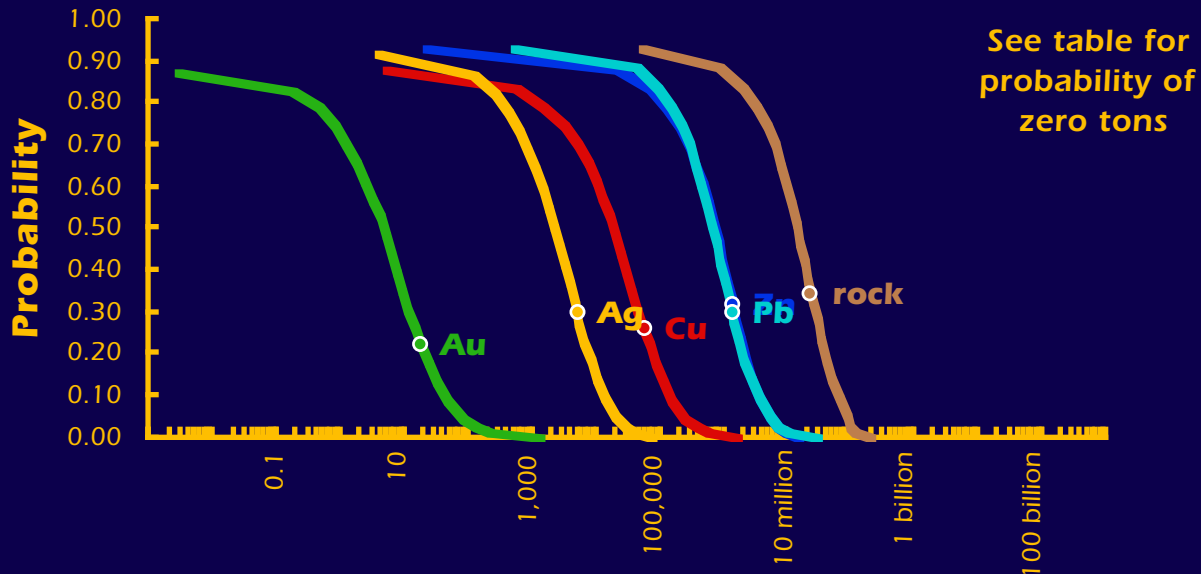
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

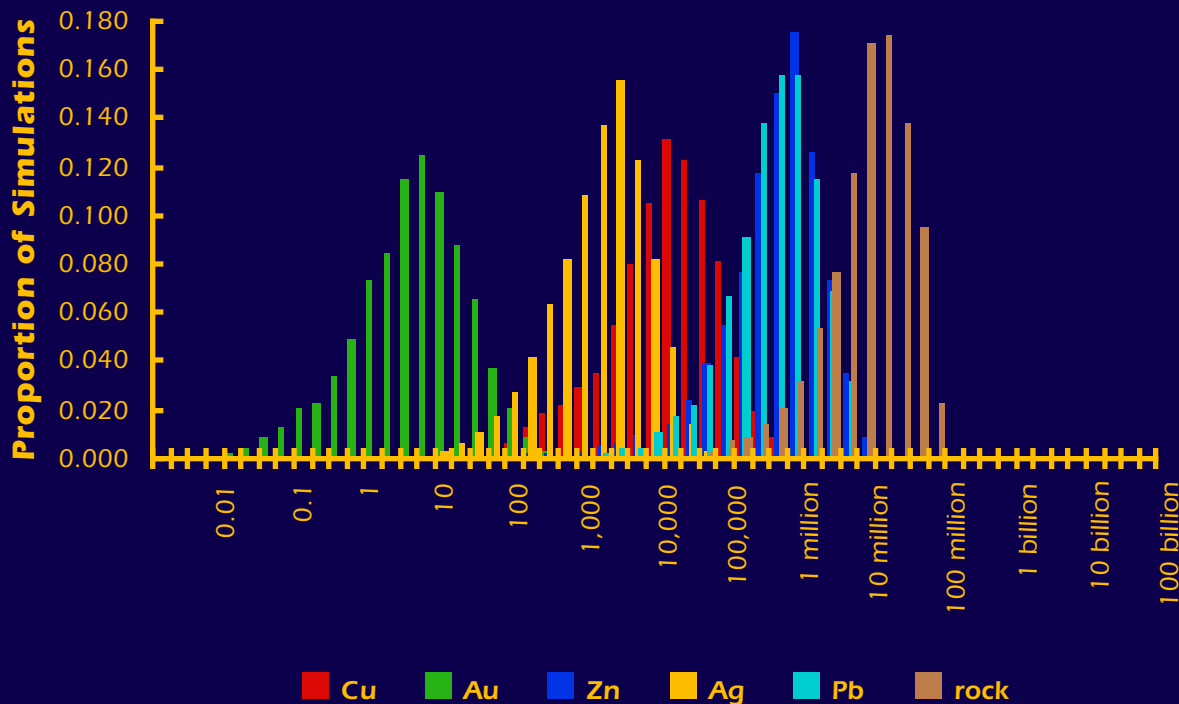


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR13

The Mark3 Index is 47:

Polymetallic replacement

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 4 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 8 or more deposits.

There is a 1% or greater chance of 12 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	9,200	43	27,000	550,000
0.50	19,000	4	740,000	2,200	660,000	15,000,000
0.10	140,000	42	3,500,000	13,000	3,400,000	62,000,000
0.05	230,000	73	5,200,000	20,000	5,100,000	82,000,000
mean	56,000	17	1,400,000	5,000	1,300,000	24,000,000
Probability of mean	0.26	0.22	0.32	0.30	0.30	0.34
Probability of zero	0.12	0.12	0.07	0.08	0.07	0.07

The tract ID is NR13The Mark3 Index is 47: **Polymetallic replacement**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 4 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 8 or more deposits.

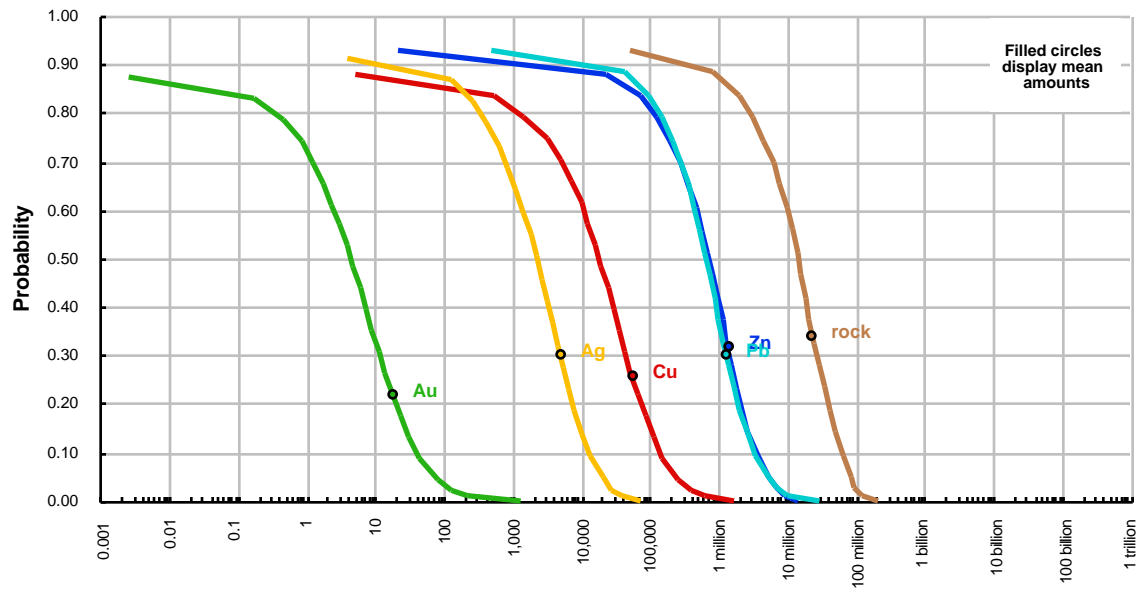
There is a 1% or greater chance of 12 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

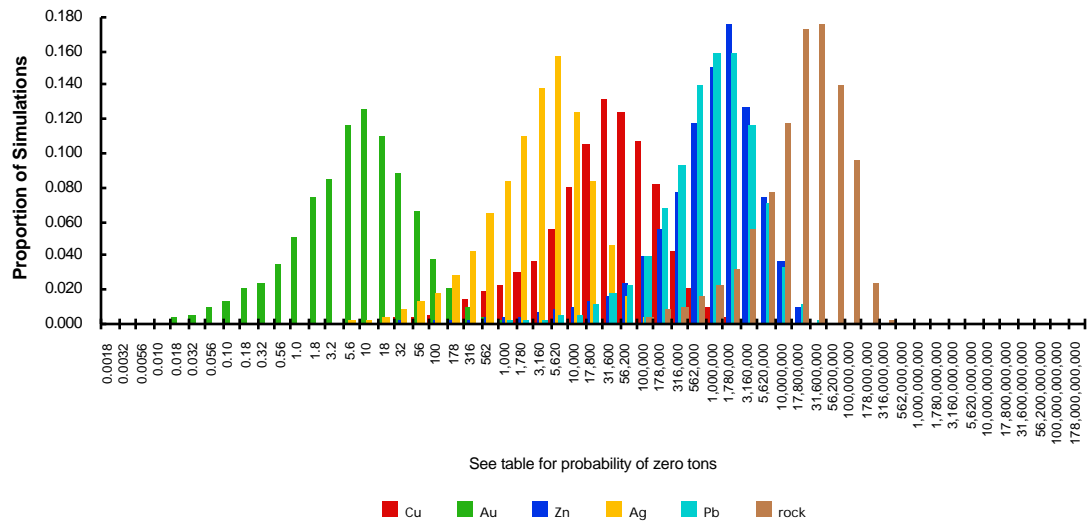
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	9,200	43	27,000	550,000
0.50	19,000	4	740,000	2,200	660,000	15,000,000
0.10	140,000	42	3,500,000	13,000	3,400,000	62,000,000
0.05	230,000	73	5,200,000	20,000	5,100,000	82,000,000
mean	56,000	17	1,400,000	5,000	1,300,000	24,000,000
Probability of mean	0.26	0.22	0.32	0.30	0.30	0.34
Probability of zero	0.12	0.12	0.07	0.08	0.07	0.07

The tract ID is NR13

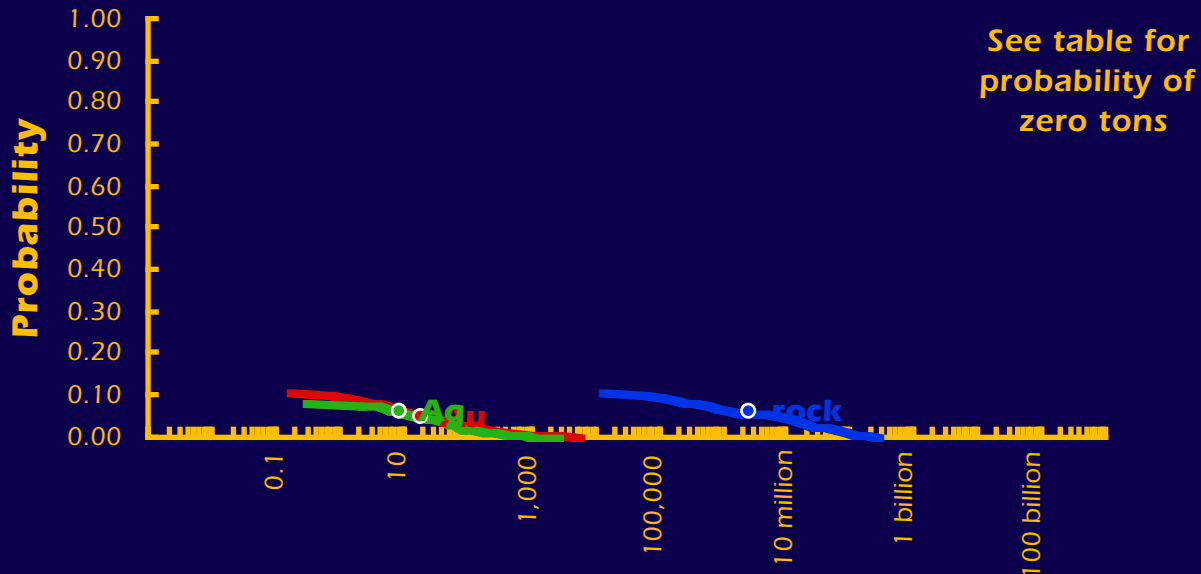
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

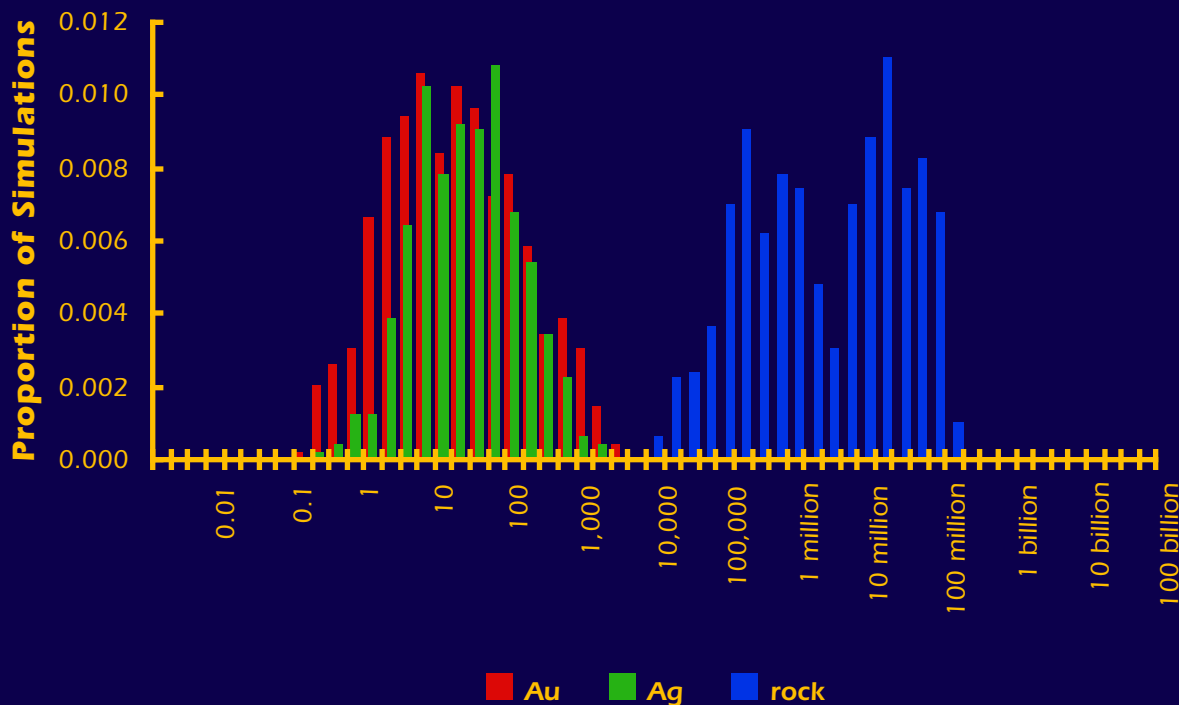


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR14

The Mark3 Index is 80:

Alkaline Au-Te

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	1	0	43,800
0.05	21	15	5,800,000
mean	18	8	2,600,000
Probability of mean	0.05	0.06	0.06
Probability of zero	0.90	0.92	0.90

The tract ID is NR14The Mark3 Index is 80: **Alkaline Au-Te**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

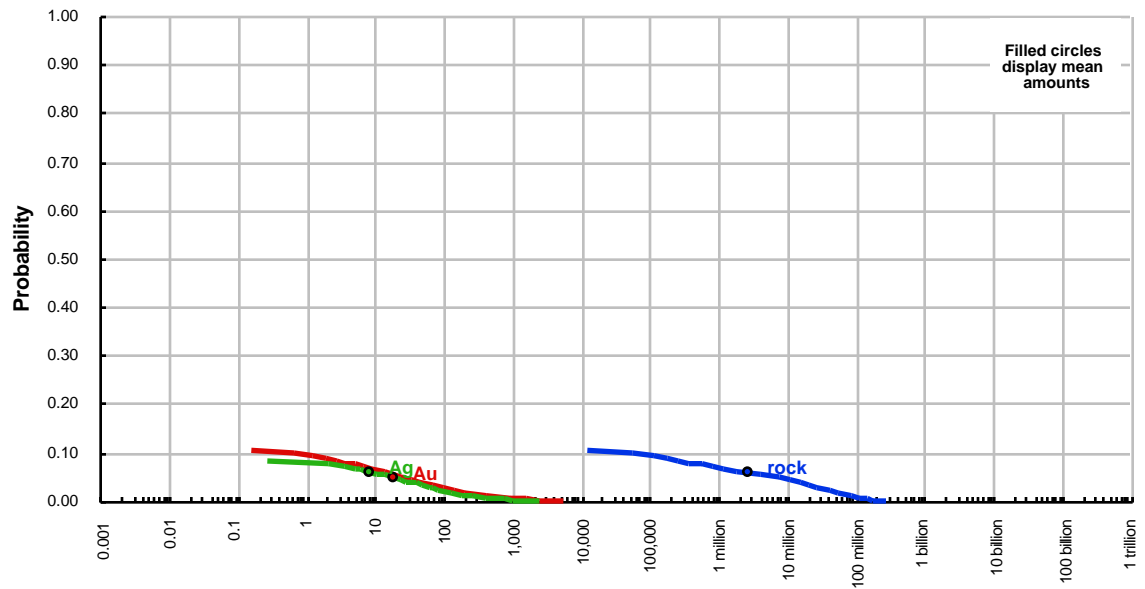
There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

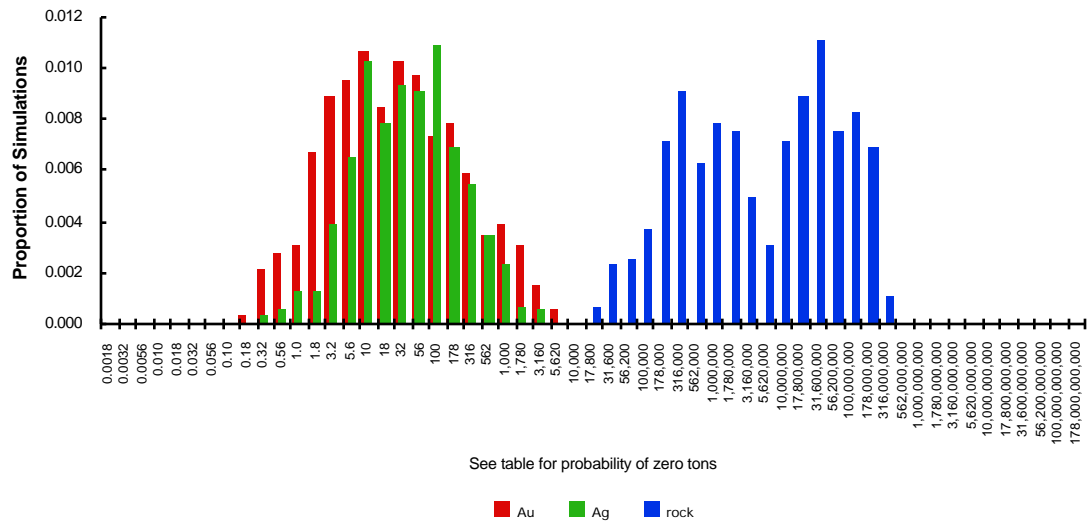
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	1	0	43,800
0.05	21	15	5,800,000
mean	18	8	2,600,000
Probability of mean	0.05	0.06	0.06
Probability of zero	0.90	0.92	0.90

The tract ID is NR14

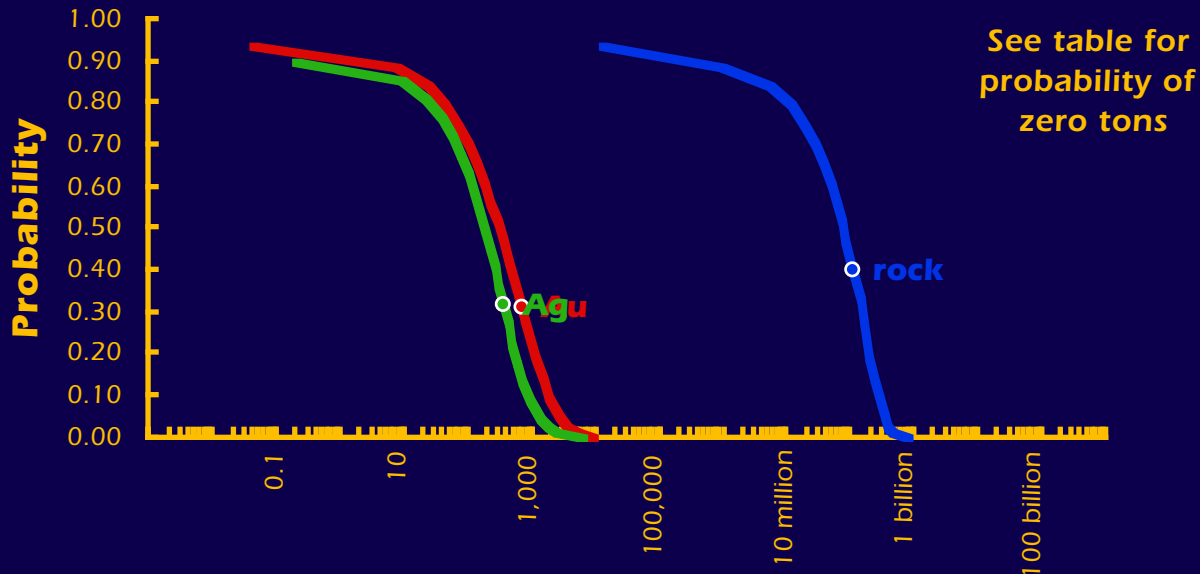
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

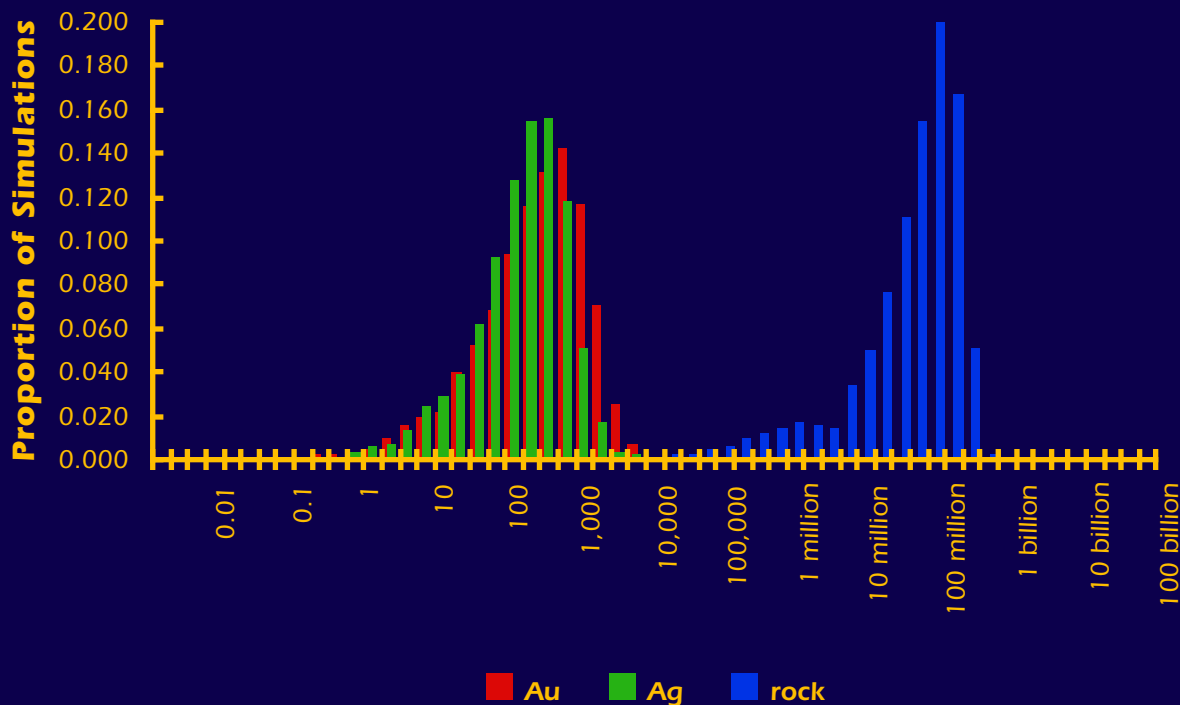


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR15

The Mark3 Index is 80:

Alkaline Au-Te

There is a 90% or greater chance of 1 or more deposits.
There is a 50% or greater chance of 6 or more deposits.
There is a 10% or greater chance of 11 or more deposits.
There is a 5% or greater chance of 12 or more deposits.
There is a 1% or greater chance of 20 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	5	0	590,000
0.50	310	180	74,000,000
0.10	1,800	830	263,000,000
0.05	2,600	1,200	320,000,000
mean	680	340	110,000,000
Probability of mean	0.31	0.32	0.40
Probability of zero	0.06	0.10	0.06

The tract ID is NR15The Mark3 Index is 80: **Alkaline Au-Te**

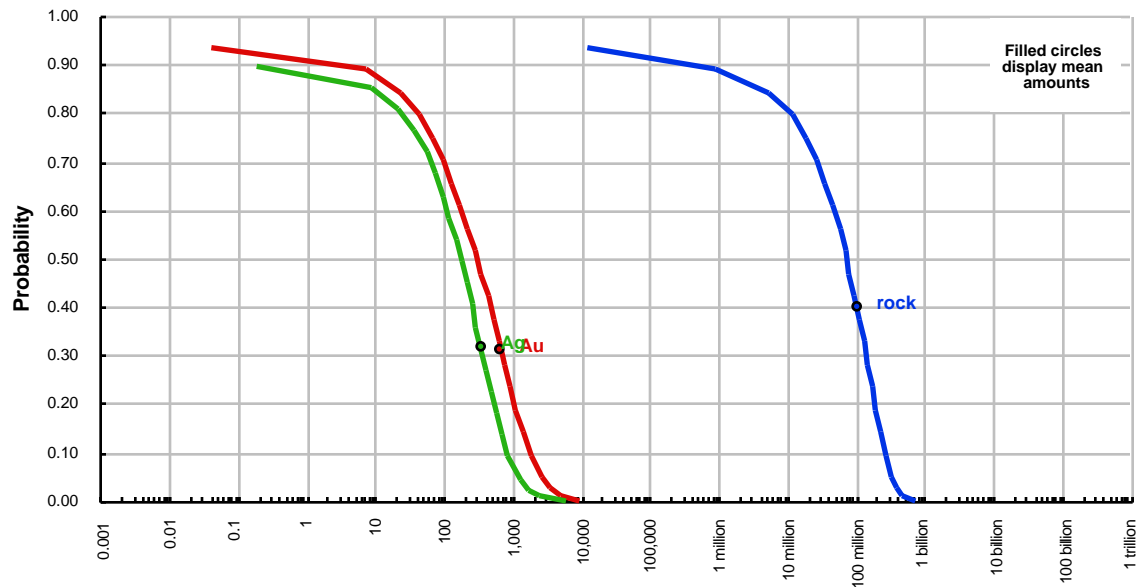
There is a 90% or greater chance of 1 or more deposits.
 There is a 50% or greater chance of 6 or more deposits.
 There is a 10% or greater chance of 11 or more deposits.
 There is a 5% or greater chance of 12 or more deposits.
 There is a 1% or greater chance of 20 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

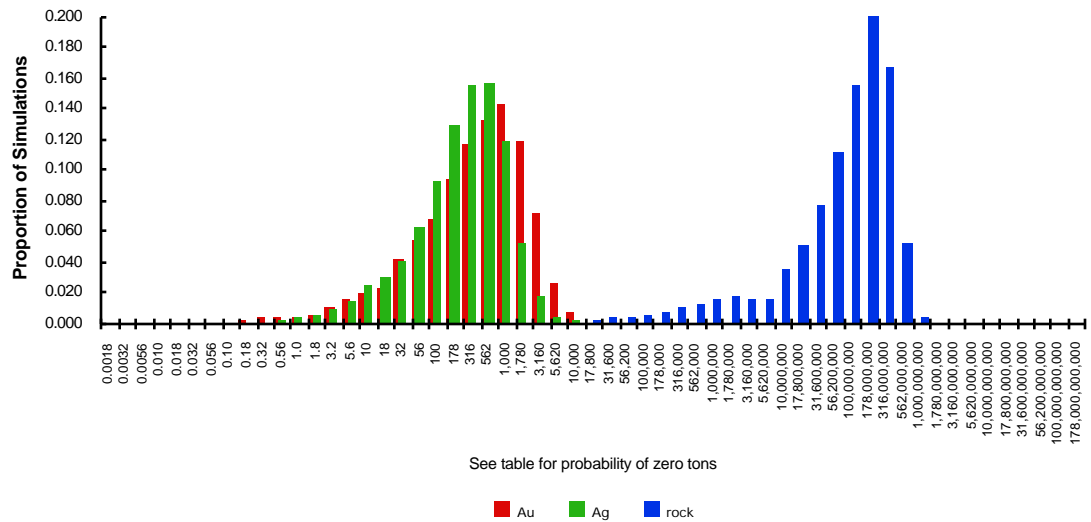
quantile	Au	Ag	rock
0.95	0	0	0
0.90	5	0	590,000
0.50	310	180	74,000,000
0.10	1,800	830	263,000,000
0.05	2,600	1,200	320,000,000
mean	680	340	110,000,000
Probability of mean	0.31	0.32	0.40
Probability of zero	0.06	0.10	0.06

The tract ID is NR15

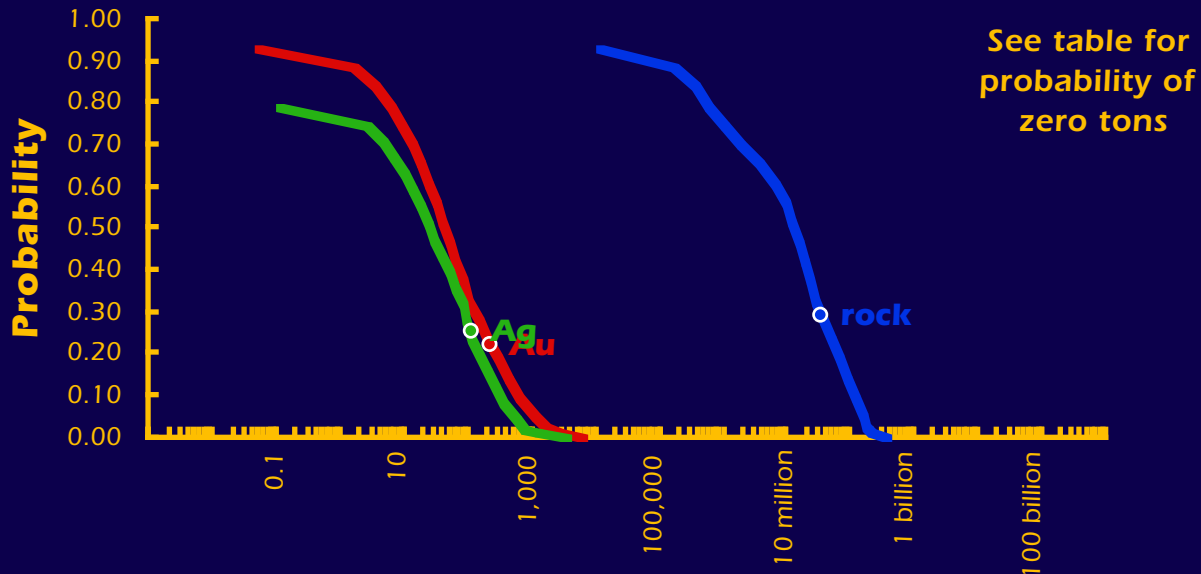
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

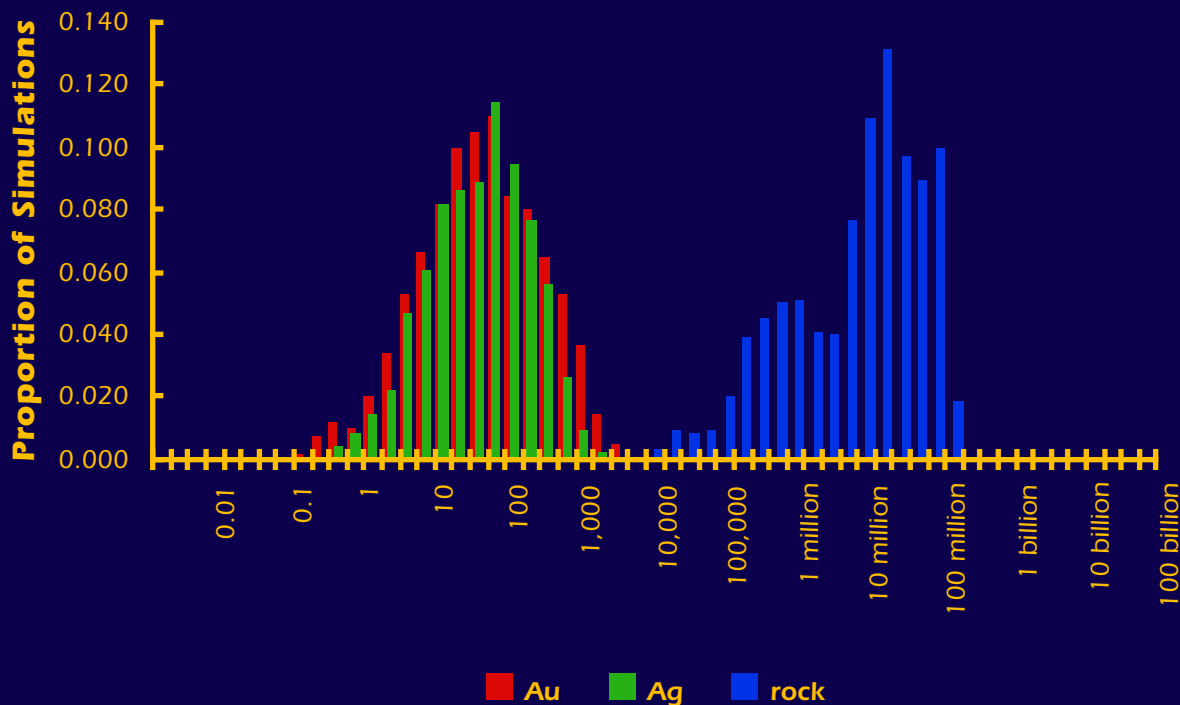


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR16

The Mark3 Index is 80:

Alkaline Au-Te

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	1	0	120,000
0.50	42	25	13,000,000
0.10	610	300	112,000,000
0.05	1,100	490	150,000,000
mean	210	110	34,000,000
Probability of mean	0.22	0.25	0.29
Probability of zero	0.07	0.21	0.07

The tract ID is NR16The Mark3 Index is 80: **Alkaline Au-Te**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

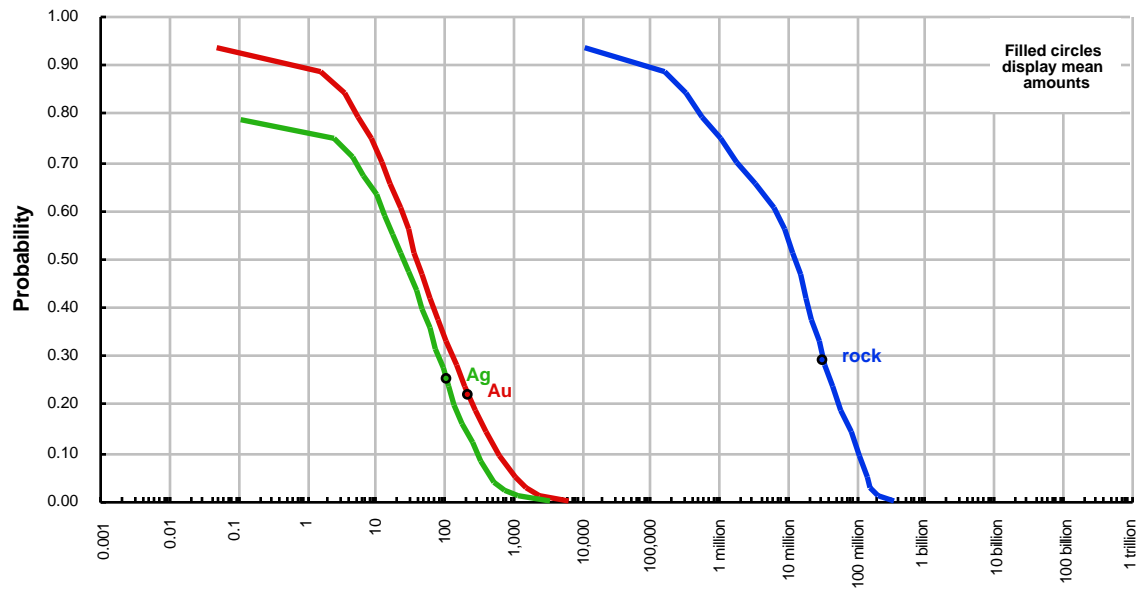
There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

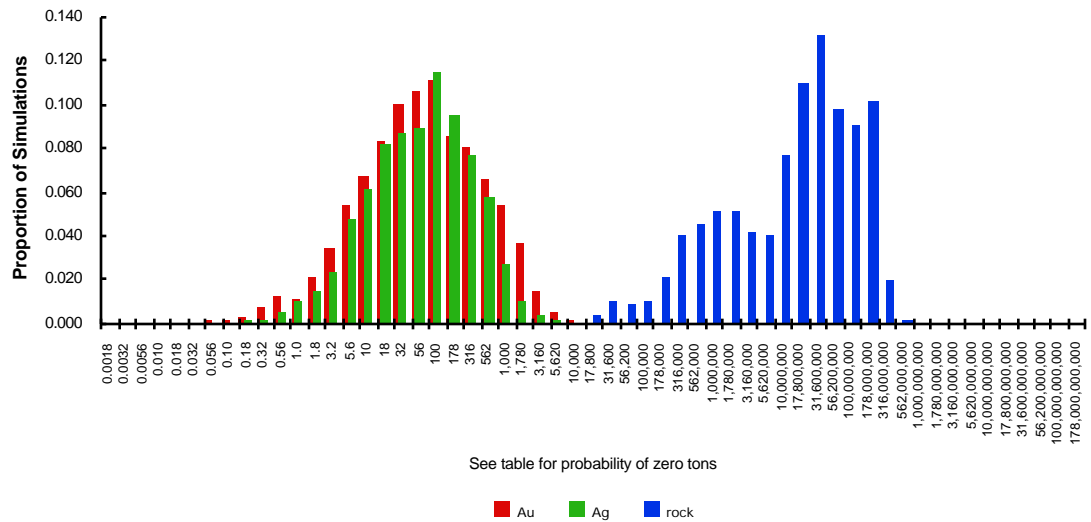
quantile	Au	Ag	rock
0.95	0	0	0
0.90	1	0	120,000
0.50	42	25	13,000,000
0.10	610	300	112,000,000
0.05	1,100	490	150,000,000
mean	210	110	34,000,000
Probability of mean	0.22	0.25	0.29
Probability of zero	0.07	0.21	0.07

The tract ID is NR16

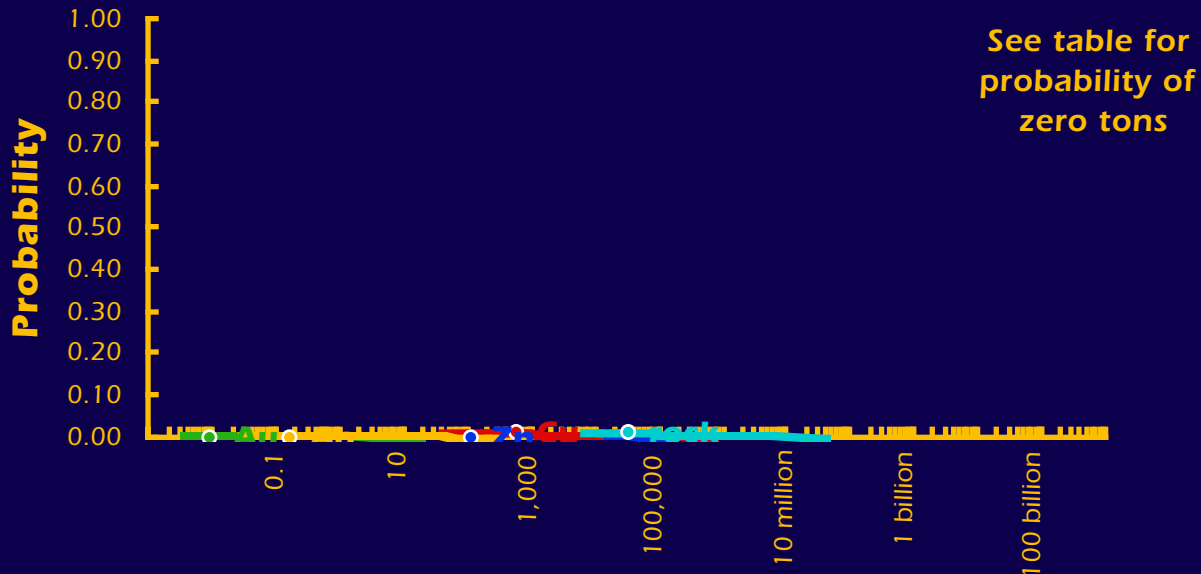
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

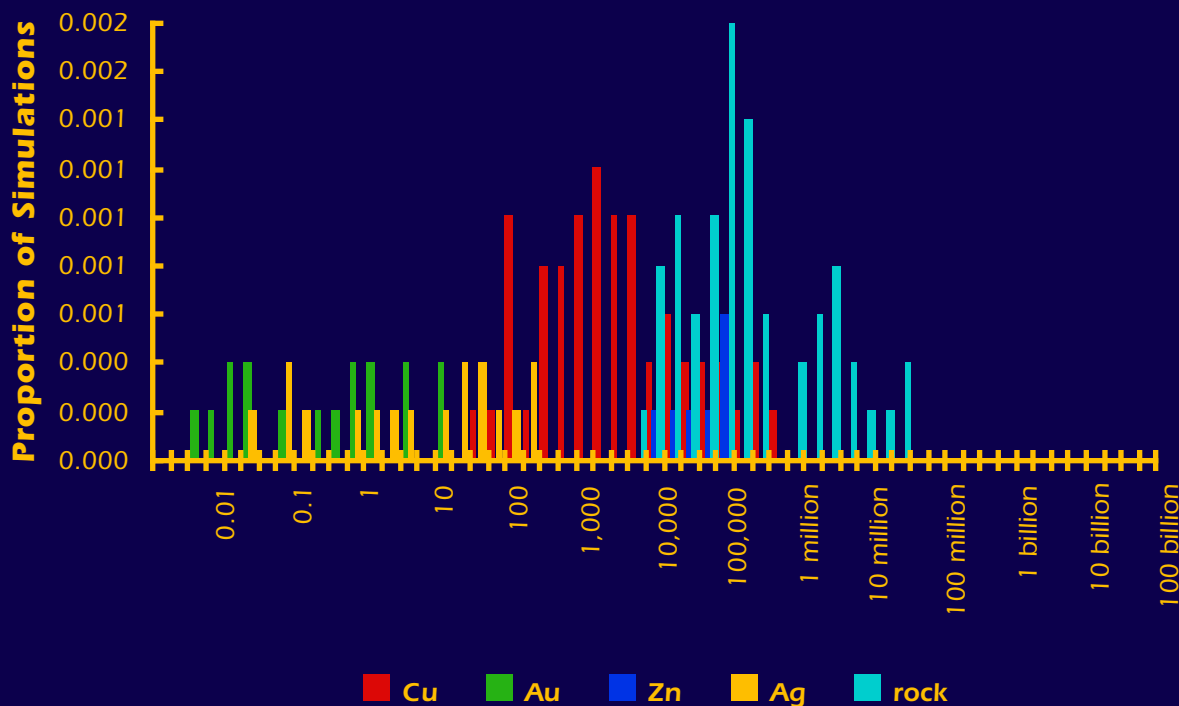


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR17

The Mark3 Index is 30:

Massive sulfide, Besshi

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	0	0	0	0	0
mean	560	0	110	0	33,000
Probability of mean	0.01	0.00	0.00	0.00	0.01
Probability of zero	0.99	1.00	1.00	1.00	0.99

The tract ID is NR17The Mark3 Index is 30: **Massive sulfide, Besshi**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

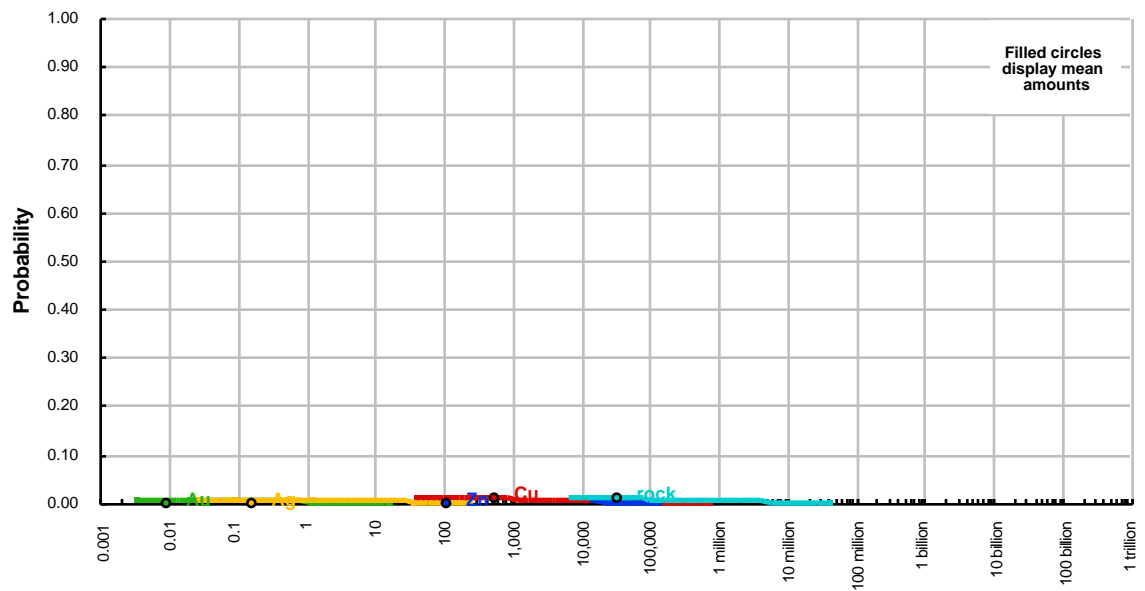
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

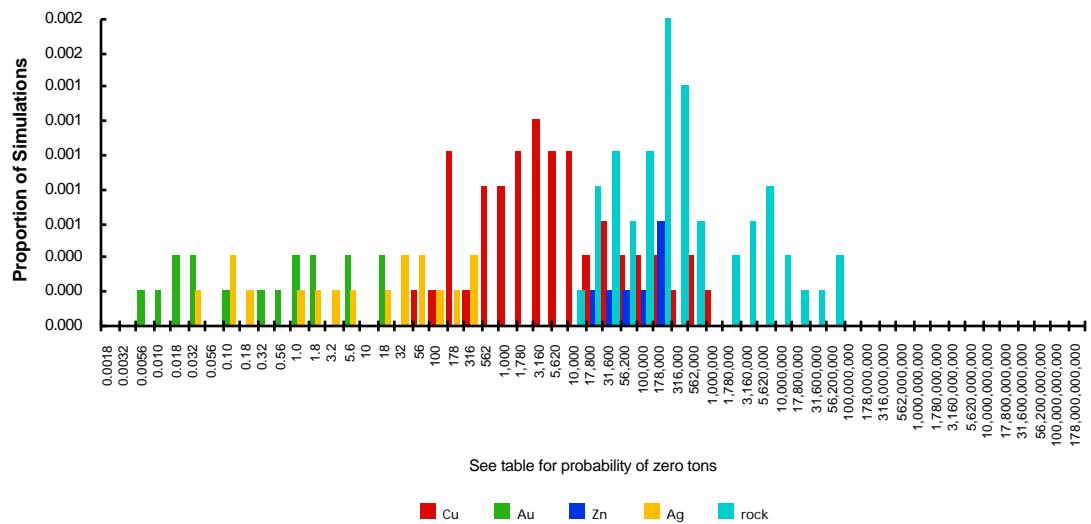
quantile	Cu	Au	Zn	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	0	0	0	0	0
mean	560	0	110	0	33,000
Probability of mean	0.01	0.00	0.00	0.00	0.01
Probability of zero	0.99	1.00	1.00	1.00	0.99

The tract ID is NR17

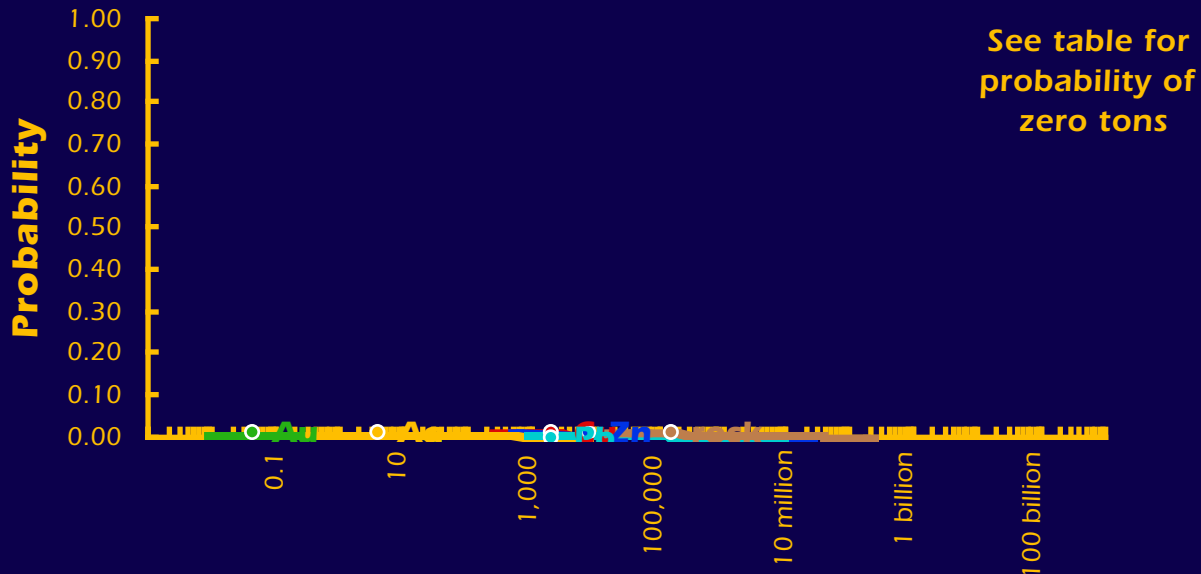
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

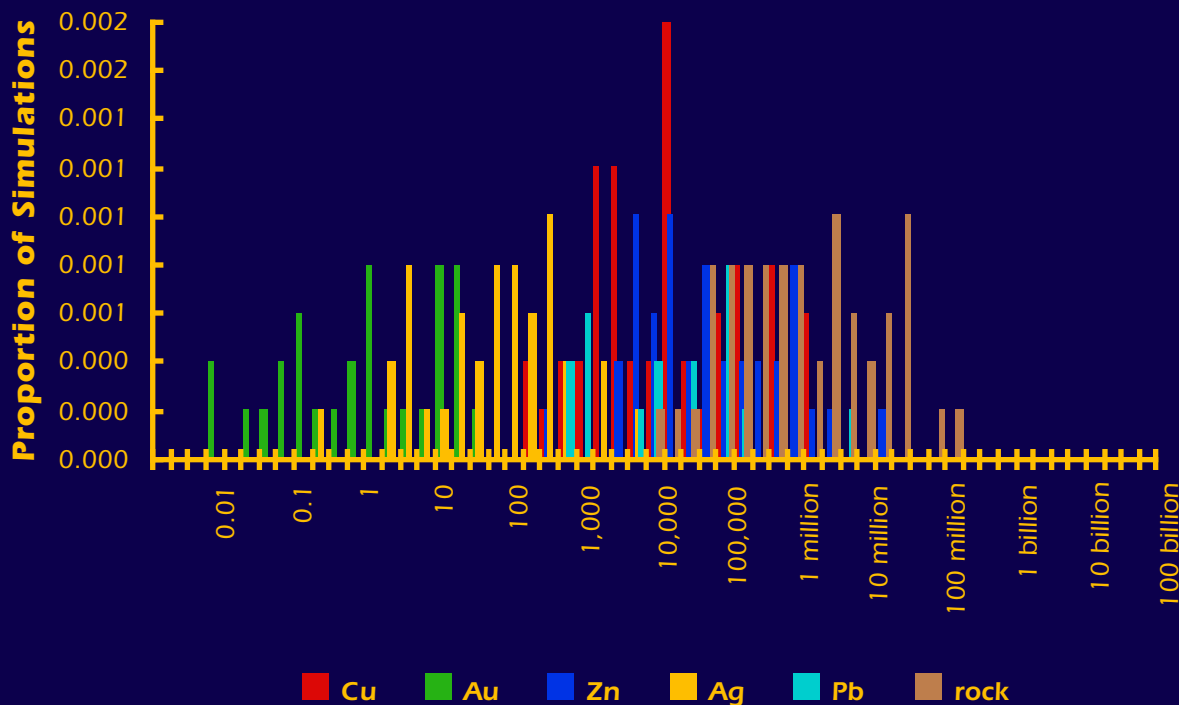


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR18

The Mark3 Index is 93:

Massive sulfide, kuroko

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	2,100	0	7,800	4	2,000	150,000
Probability of mean	0.01	0.01	0.01	0.01	0.00	0.01
Probability of zero	0.99	0.99	0.99	0.99	1.00	0.99

The tract ID is NR18The Mark3 Index is 93: **Massive sulfide, kuroko**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

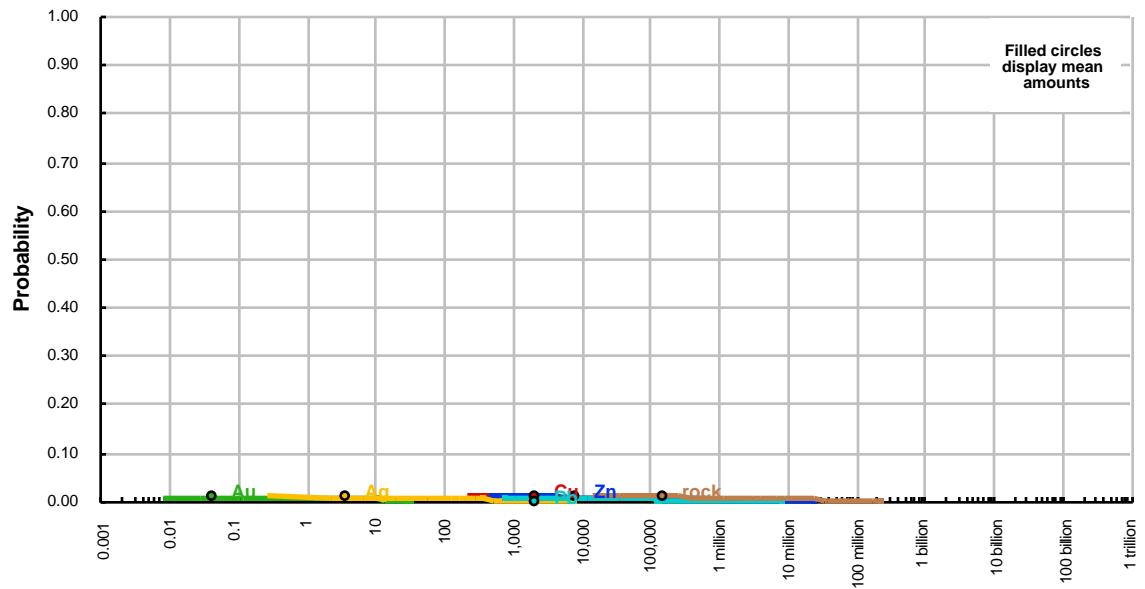
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

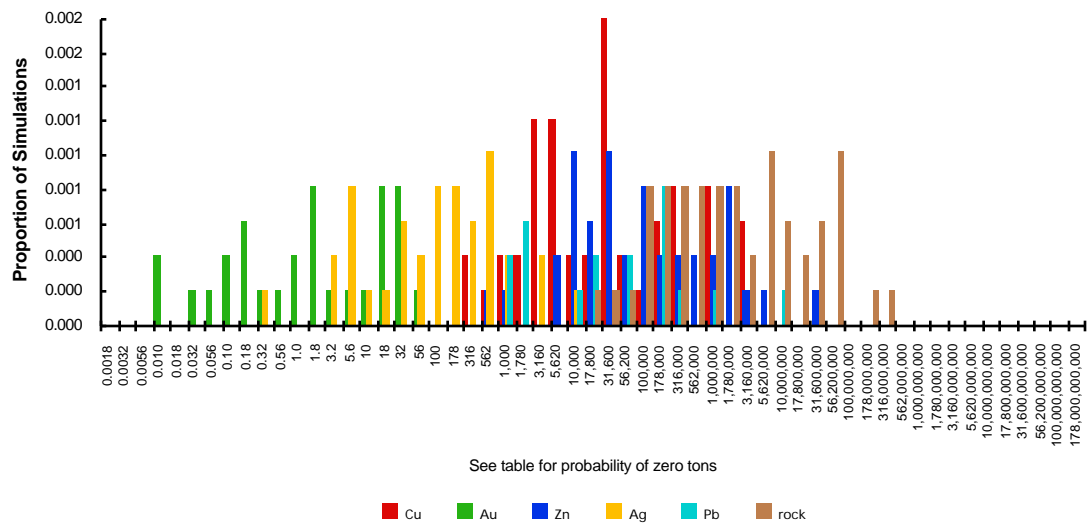
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	2,100	0	7,800	4	2,000	150,000
Probability of mean	0.01	0.01	0.01	0.01	0.00	0.01
Probability of zero	0.99	0.99	0.99	0.99	1.00	0.99

The tract ID is NR18

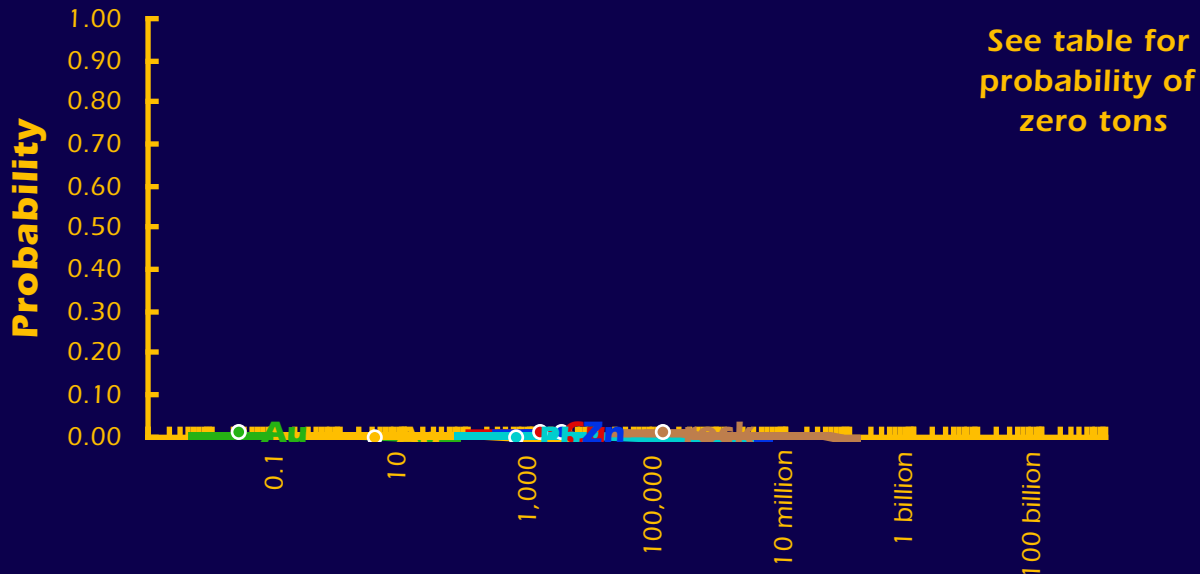
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

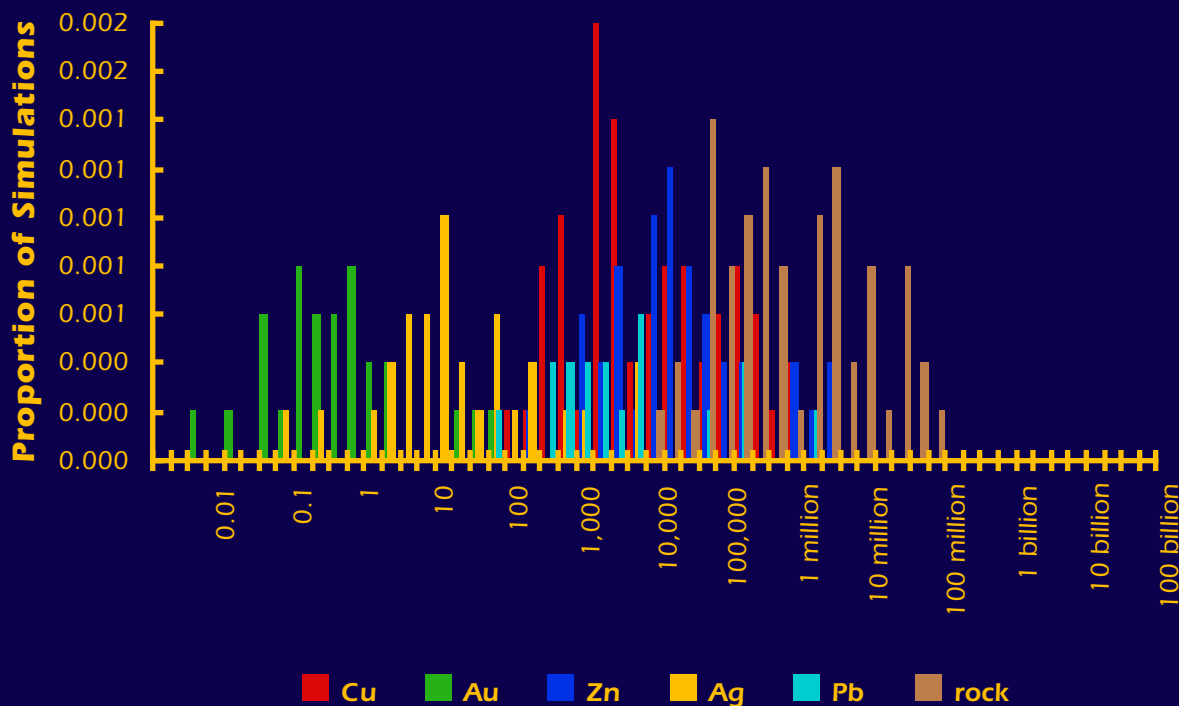


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR19

The Mark3 Index is 93:

Massive sulfide, kuroko

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	1,400	0	2,900	3	590	110,000
Probability of mean	0.01	0.01	0.01	0.00	0.00	0.01
Probability of zero	0.99	0.99	0.99	0.99	1.00	0.99

The tract ID is NR19The Mark3 Index is 93: **Massive sulfide, kuroko**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

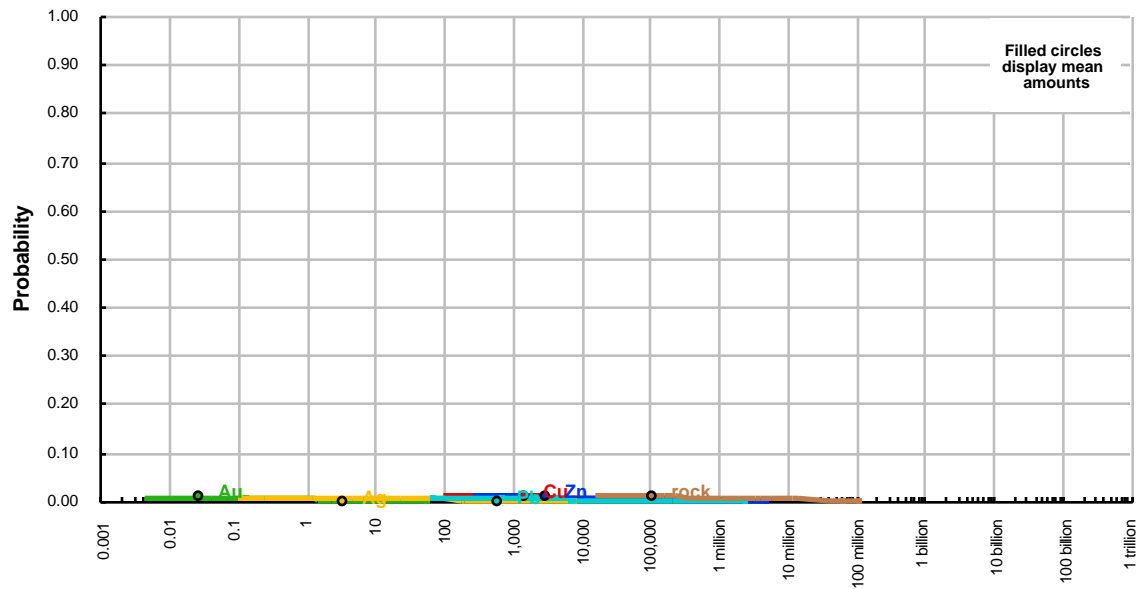
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

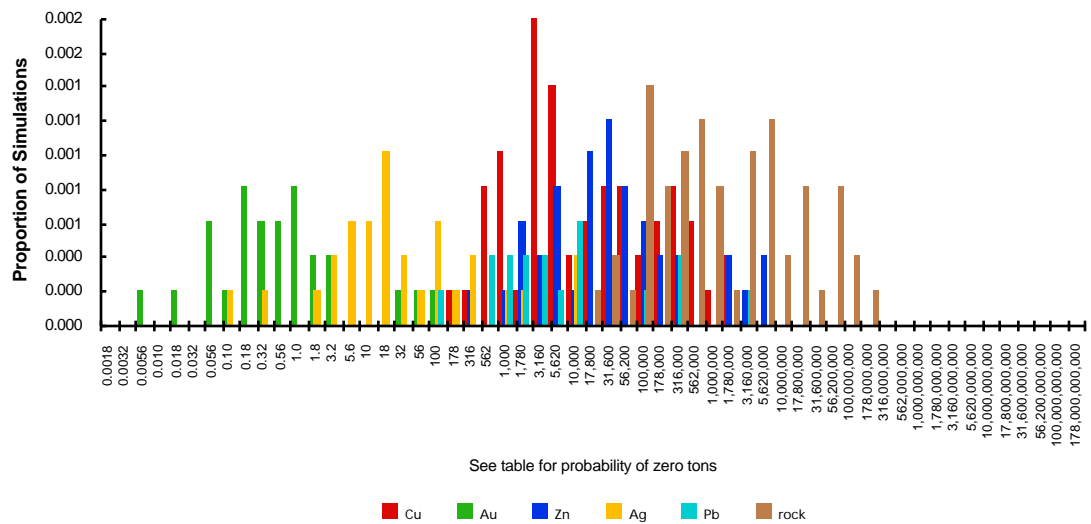
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	1,400	0	2,900	3	590	110,000
Probability of mean	0.01	0.01	0.01	0.00	0.00	0.01
Probability of zero	0.99	0.99	0.99	0.99	1.00	0.99

The tract ID is NR19

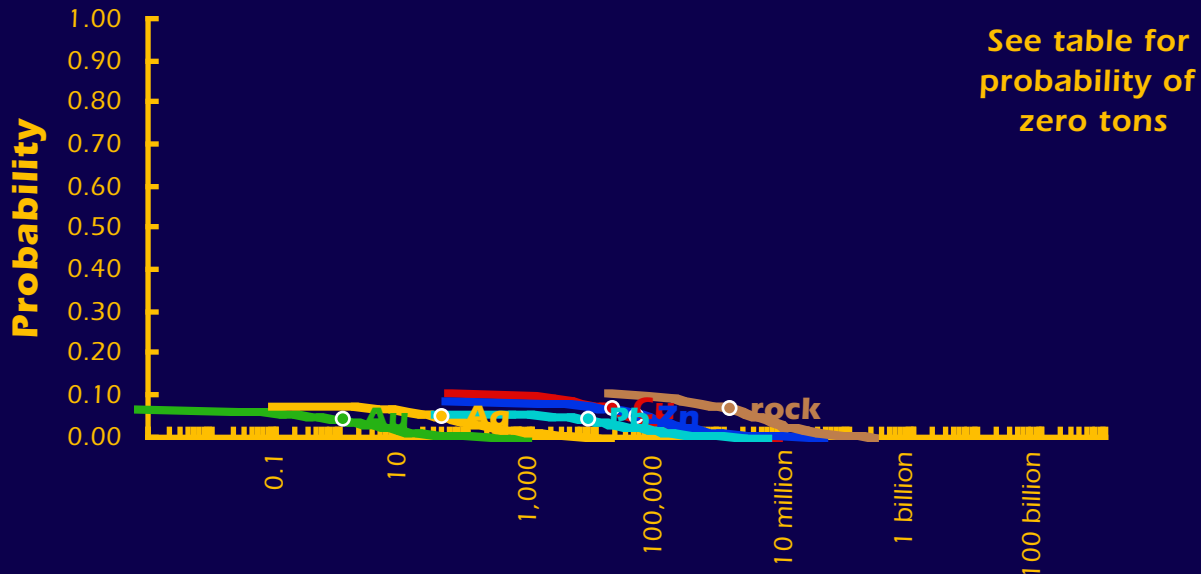
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

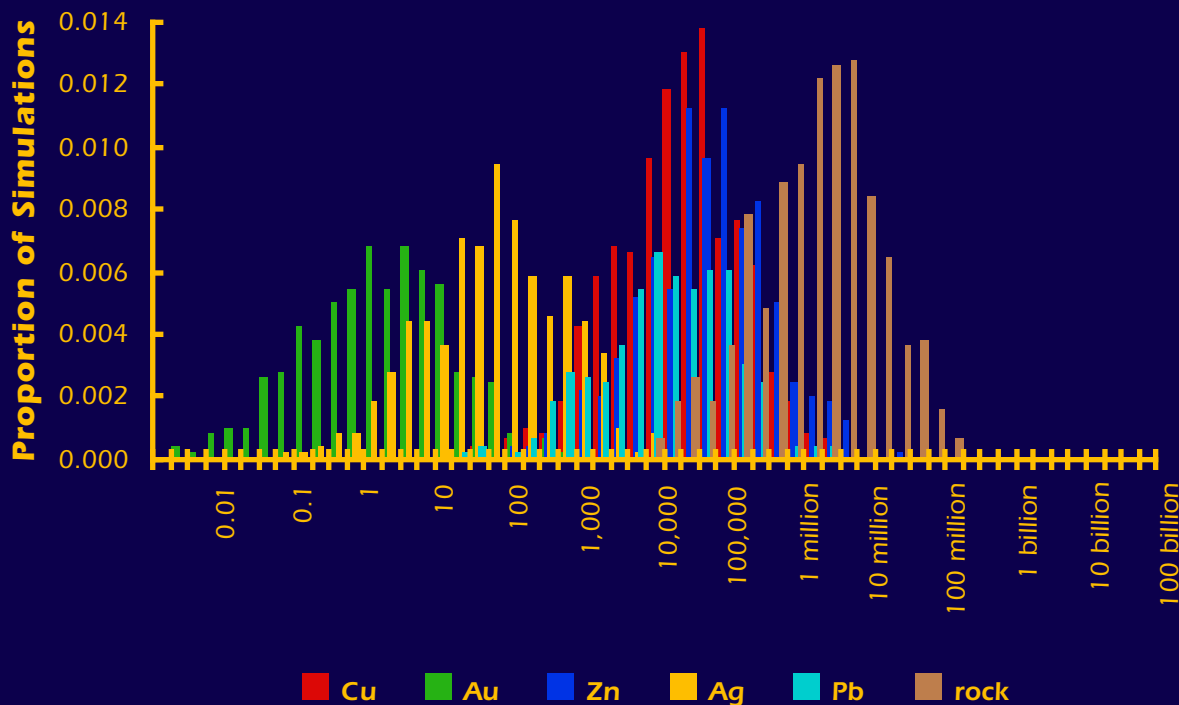


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR20

The Mark3 Index is 93:

Massive sulfide, kuroko

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	680	0	0	0	0	43,000
0.05	37,000	0	53,000	32	1,400	3,100,000
mean	18,000	1	43,000	40	7,300	1,300,000
Probability of mean	0.07	0.04	0.05	0.05	0.04	0.07
Probability of zero	0.90	0.93	0.91	0.92	0.94	0.90

The tract ID is NR20The Mark3 Index is 93: **Massive sulfide, kuroko**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

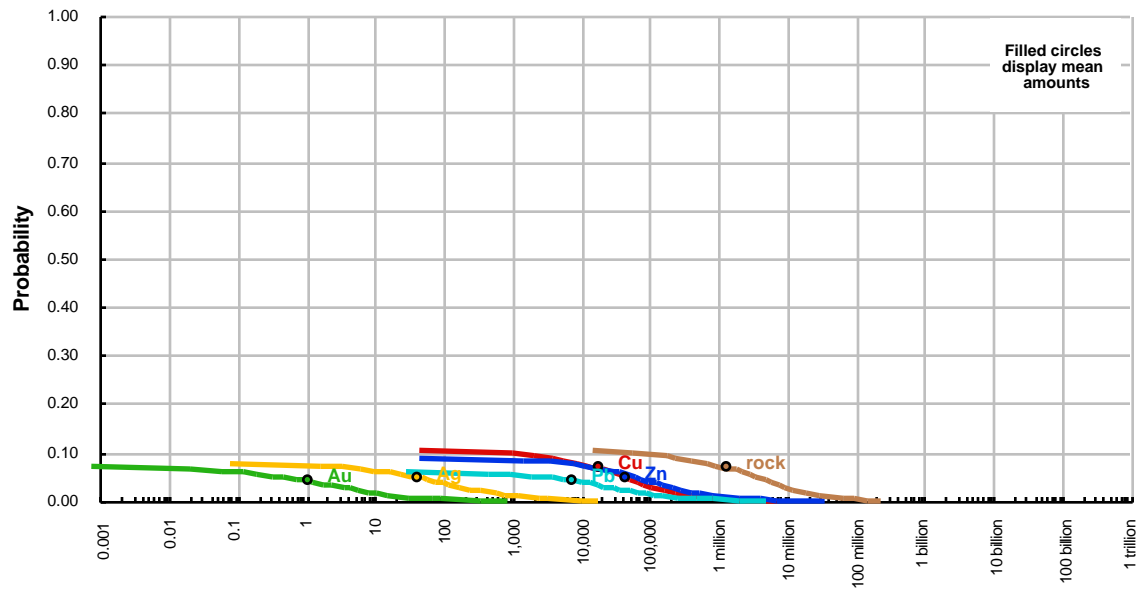
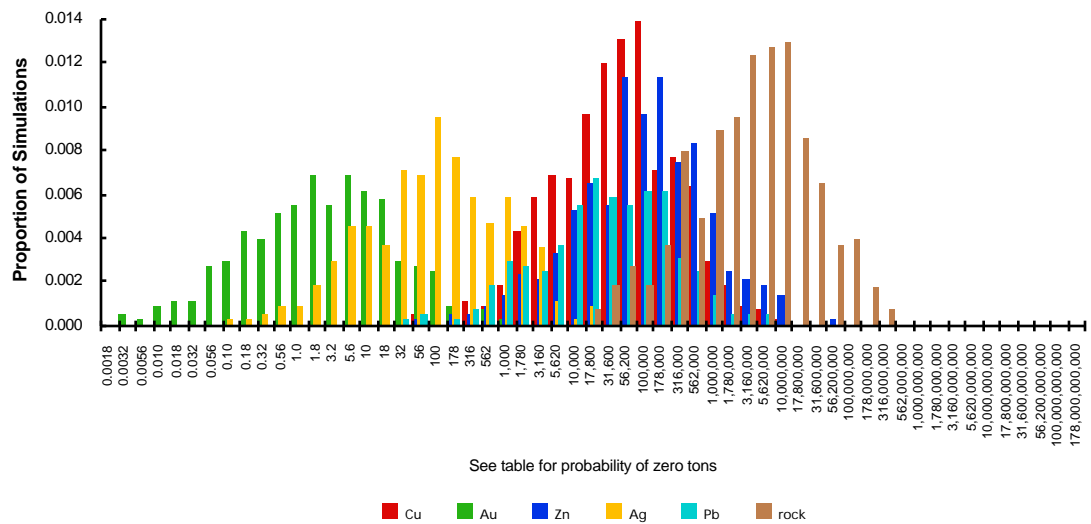
There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

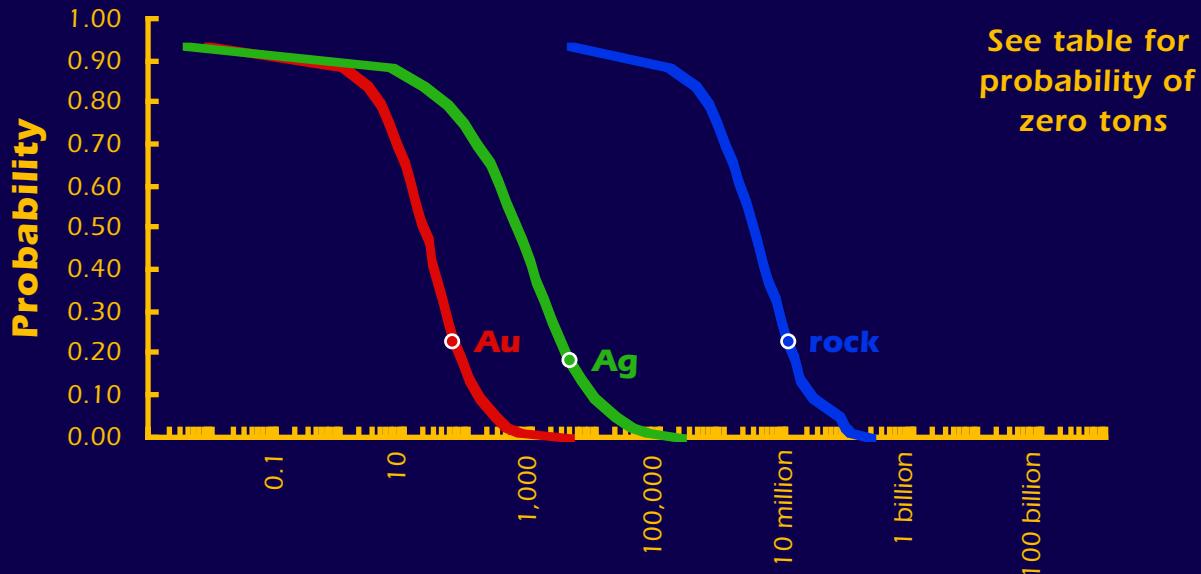
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	680	0	0	0	0	43,000
0.05	37,000	0	53,000	32	1,400	3,100,000
mean	18,000	1	43,000	40	7,300	1,300,000
Probability of mean	0.07	0.04	0.05	0.05	0.04	0.07
Probability of zero	0.90	0.93	0.91	0.92	0.94	0.90

The tract ID is NR20

Cumulative Distributions of Contained Metal and Mineralized Rock

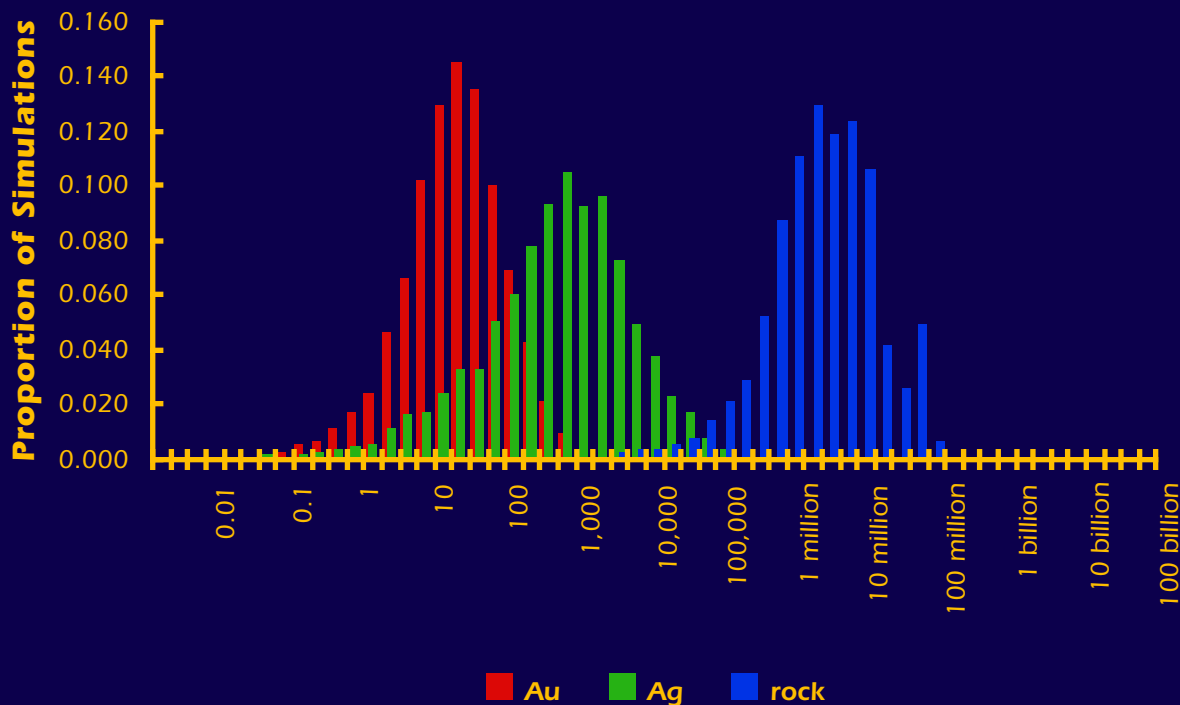
Histograms of Contained Metal and Mineralized Rock
(metric tons)

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR21

The Mark3 Index is 16:

Epithermal vein, Comstock

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	1	4	98,000
0.50	20	570	2,800,000
0.10	140	8,300	23,500,000
0.05	240	18,000	62,000,000
mean	59	4,000	10,000,000
Probability of mean	0.23	0.18	0.23
Probability of zero	0.06	0.06	0.06

The tract ID is NR21The Mark3 Index is 16: **Epithermal vein, Comstock**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

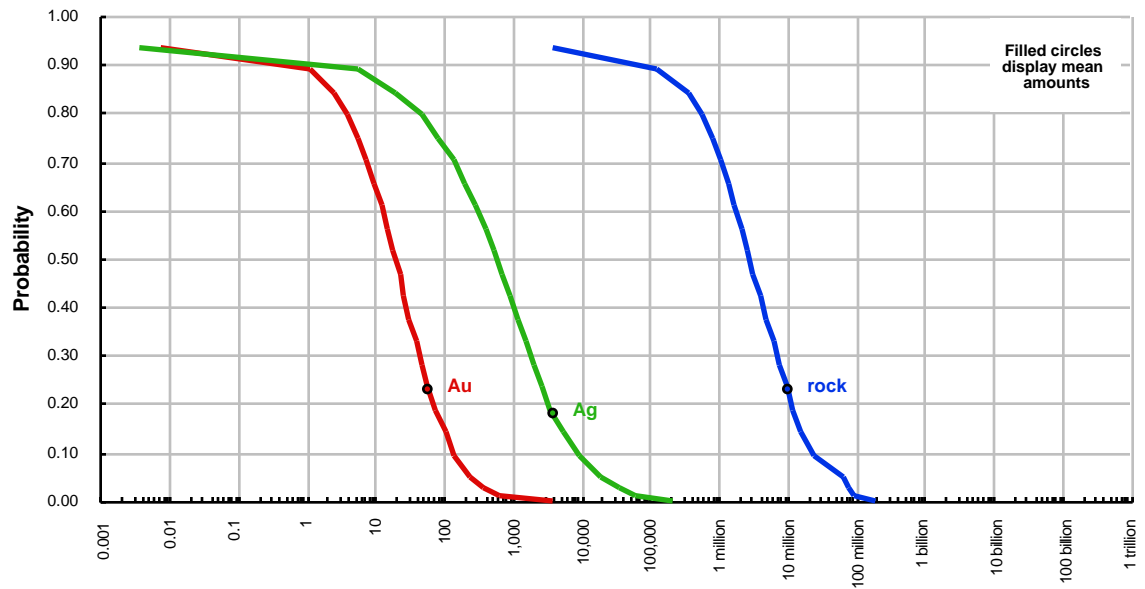
There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

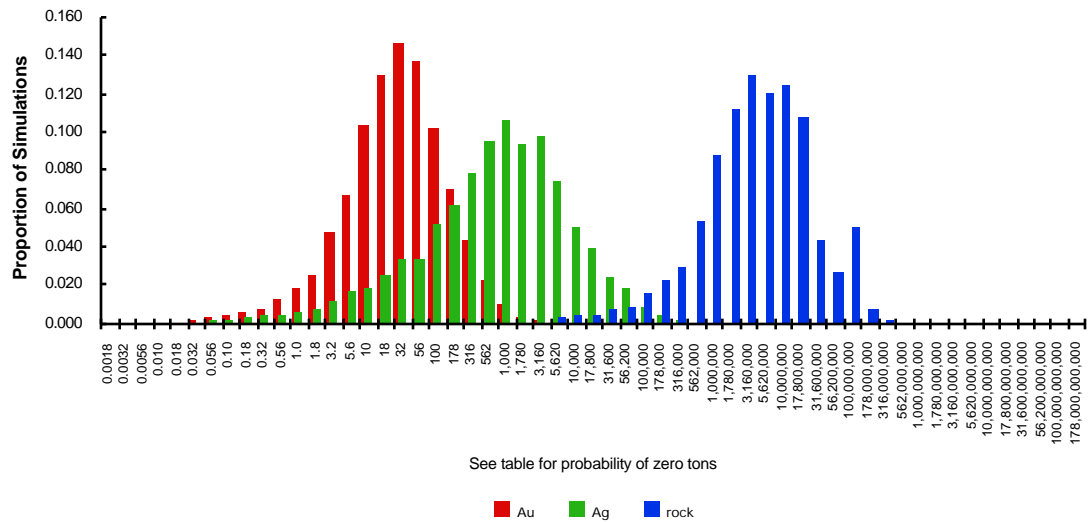
quantile	Au	Ag	rock
0.95	0	0	0
0.90	1	4	98,000
0.50	20	570	2,800,000
0.10	140	8,300	23,500,000
0.05	240	18,000	62,000,000
mean	59	4,000	10,000,000
Probability of mean	0.23	0.18	0.23
Probability of zero	0.06	0.06	0.06

The tract ID is NR21

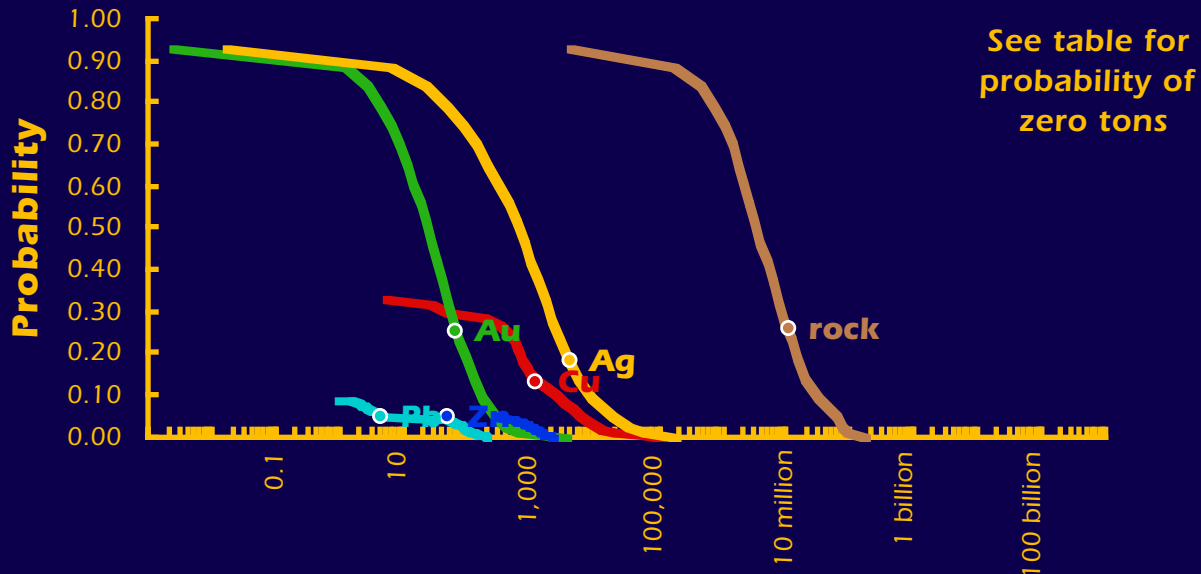
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

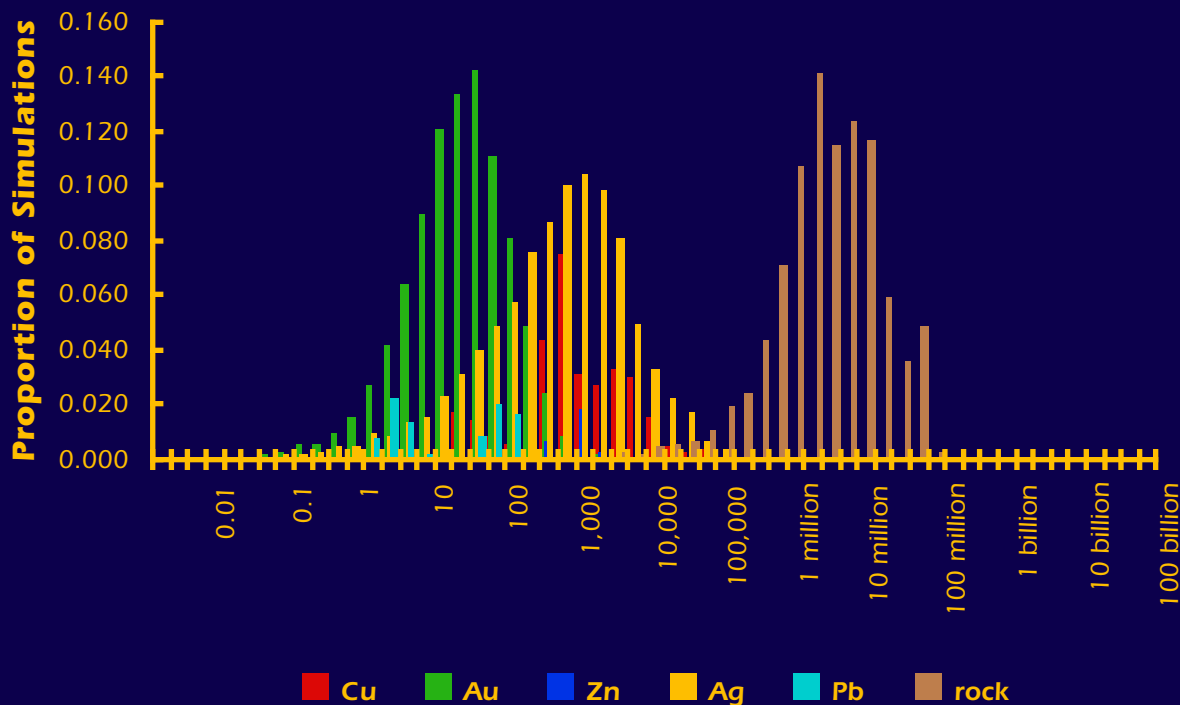


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR24

The Mark3 Index is 25:

Epithermal vein, quartz-adularia

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

There is a 1% or greater chance of 9 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	1	0	3	0	110,000
0.50	0	22	0	600	0	3,200,000
0.10	2,400	150	0	7,900	0	27,000,000
0.05	6,000	250	0	17,000	5	56,000,000
mean	1,200	63	47	3,800	4	10,000,000
Probability of mean	0.13	0.25	0.05	0.18	0.05	0.26
Probability of zero	0.67	0.07	0.95	0.07	0.91	0.07

The tract ID is NR24The Mark3 Index is 25: **Epithermal vein, quartz-adularia**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

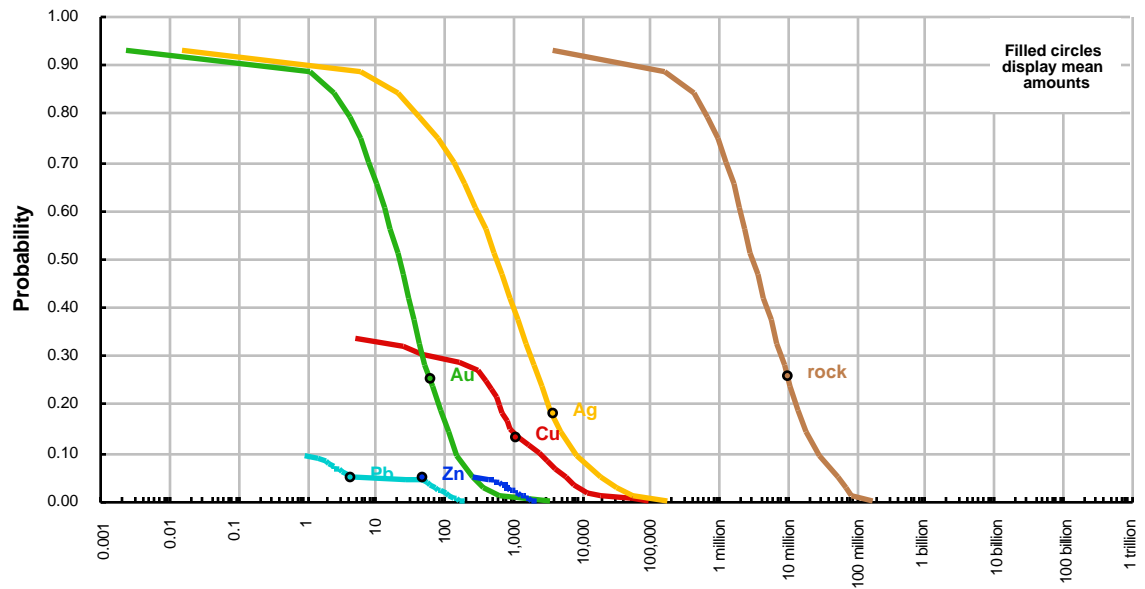
There is a 1% or greater chance of 9 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

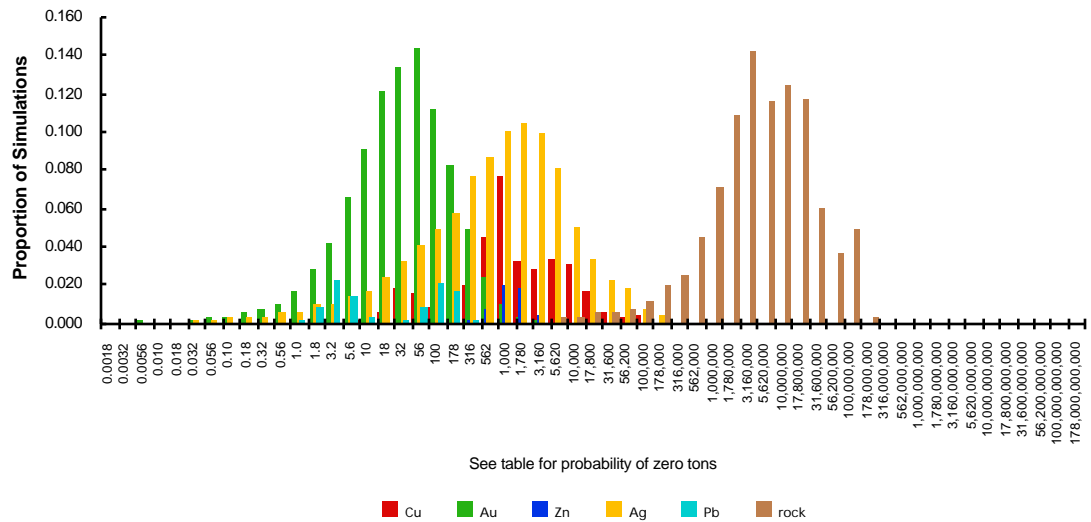
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	1	0	3	0	110,000
0.50	0	22	0	600	0	3,200,000
0.10	2,400	150	0	7,900	0	27,000,000
0.05	6,000	250	0	17,000	5	56,000,000
mean	1,200	63	47	3,800	4	10,000,000
Probability of mean	0.13	0.25	0.05	0.18	0.05	0.26
Probability of zero	0.67	0.07	0.95	0.07	0.91	0.07

The tract ID is NR24

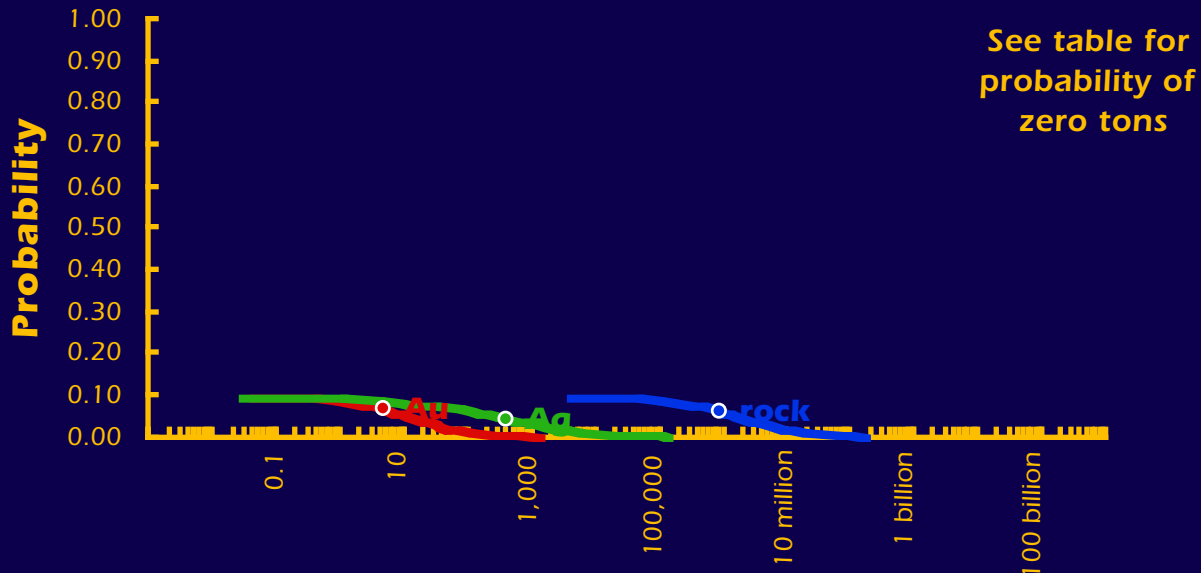
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

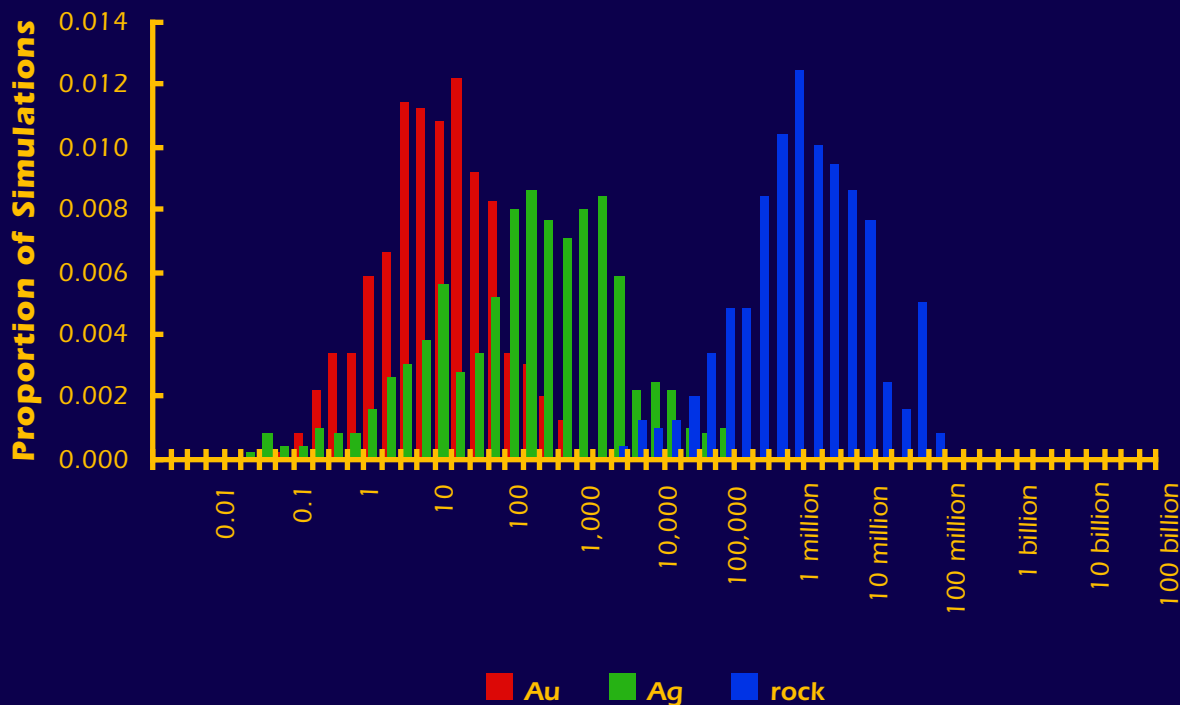


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR25

The Mark3 Index is 16:

Epithermal vein, Comstock

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	0	0
0.05	10	230	1,500,000
mean	5	380	870,000
Probability of mean	0.07	0.04	0.06
Probability of zero	0.90	0.90	0.90

The tract ID is NR25The Mark3 Index is 16: **Epithermal vein, Comstock**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

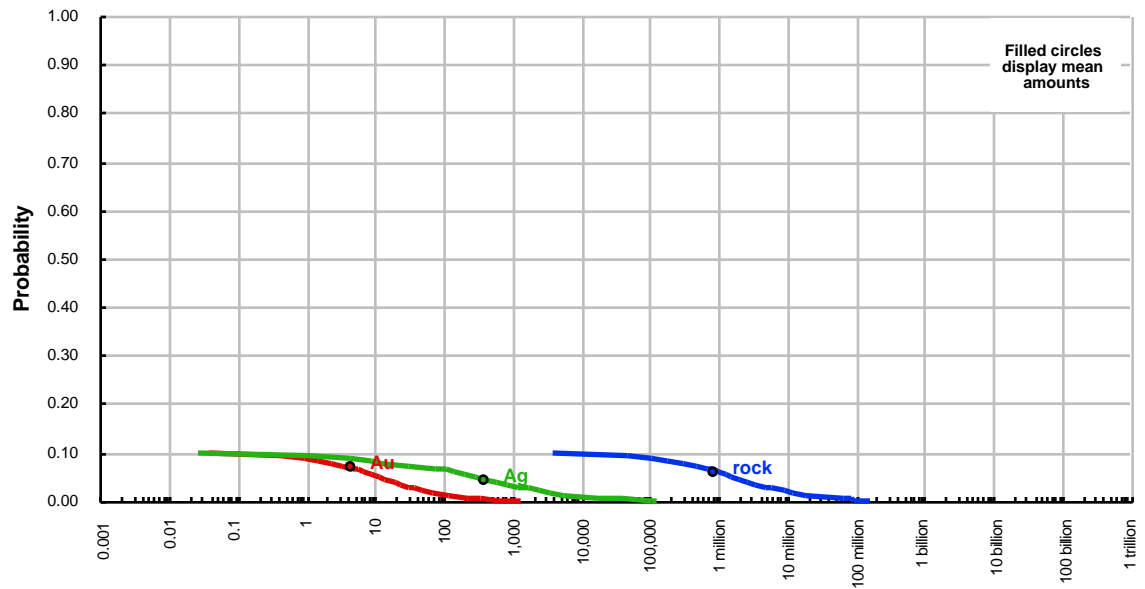
There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

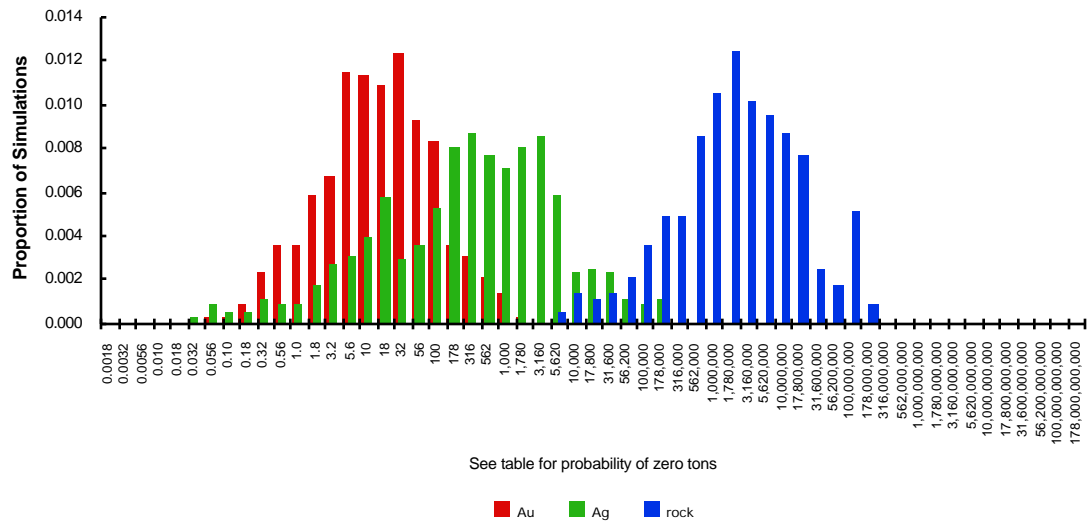
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	0	0
0.05	10	230	1,500,000
mean	5	380	870,000
Probability of mean	0.07	0.04	0.06
Probability of zero	0.90	0.90	0.90

The tract ID is NR25

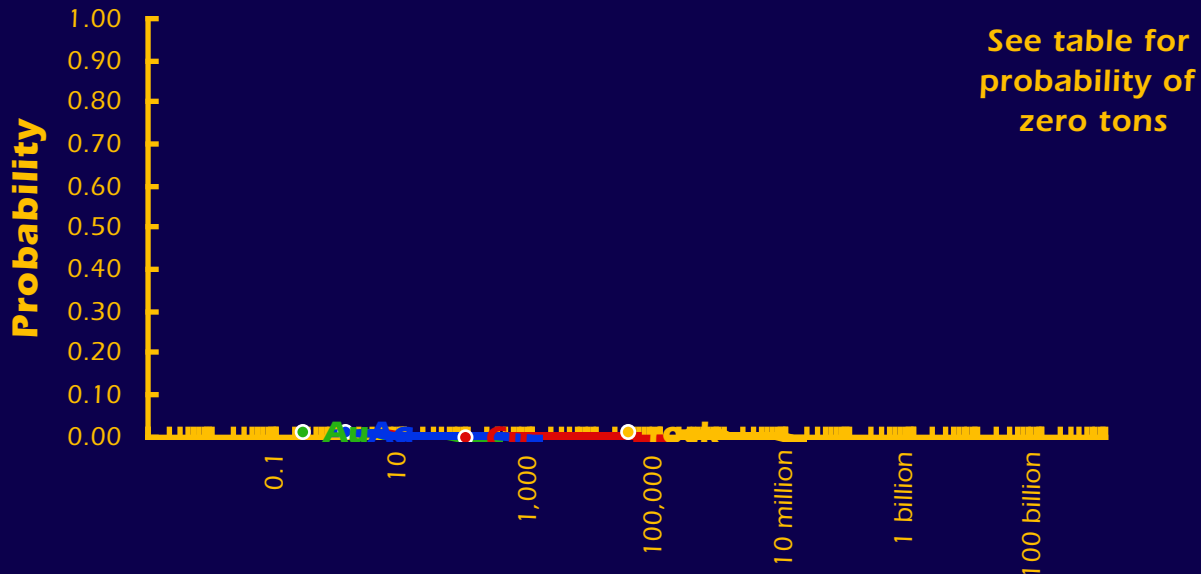
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

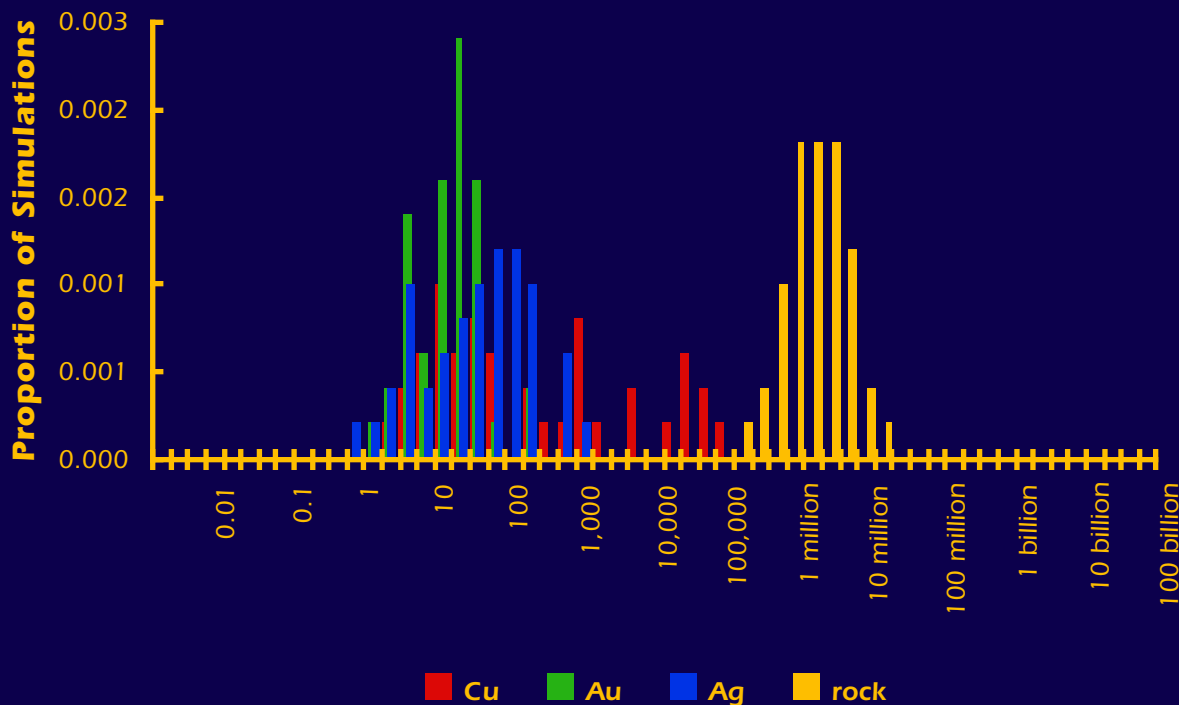


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR26

The Mark3 Index is 38:

Epithermal vein, quartz-alunite

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Ag	rock	0	0
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	91	0	1	32,000	0	0
Probability of mean	0.00	0.01	0.01	0.01	0.00	0.00
Probability of zero	0.99	0.99	0.99	0.99	0.00	0.00

The tract ID is NR26The Mark3 Index is 38: **Epithermal vein, quartz-alunite**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

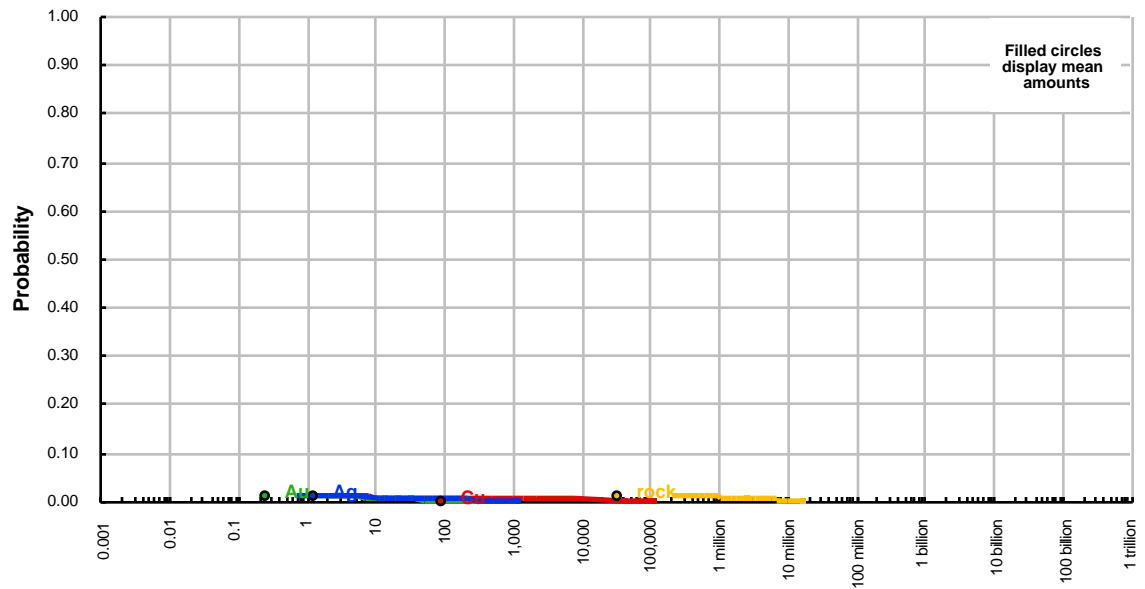
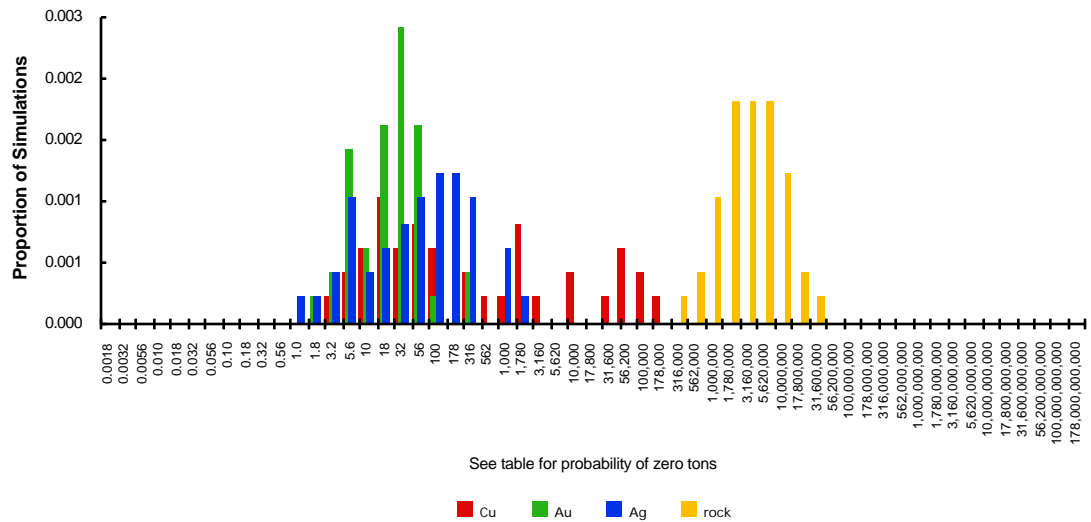
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

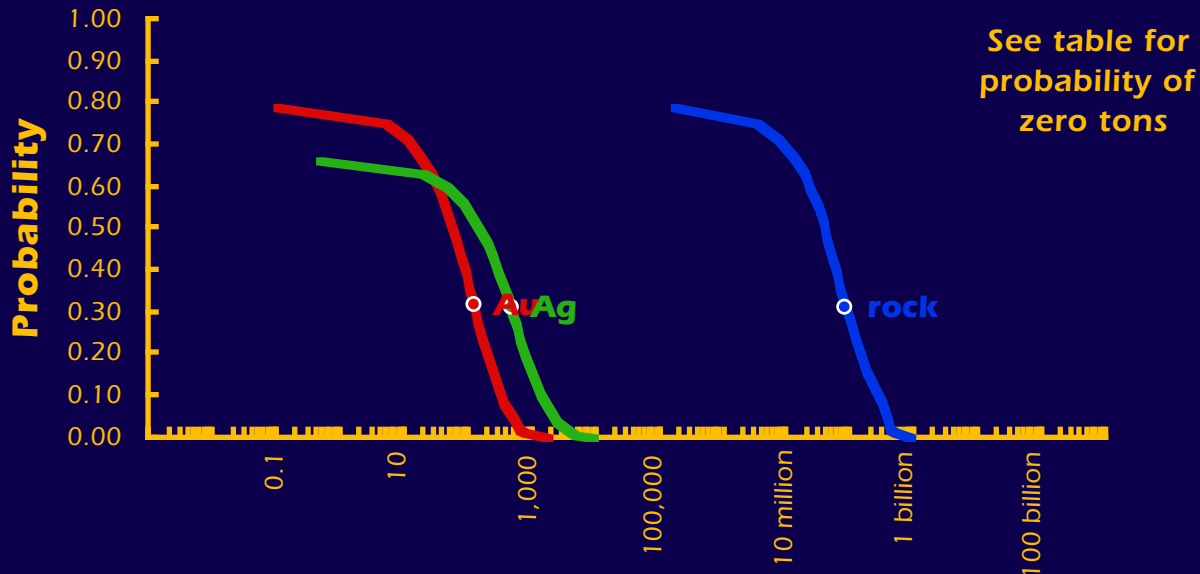
quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	0	0	0	0
mean	91	0	1	32,000
Probability of mean	0.00	0.01	0.01	0.01
Probability of zero	0.99	0.99	0.99	0.99

The tract ID is NR26

Cumulative Distributions of Contained Metal and Mineralized Rock

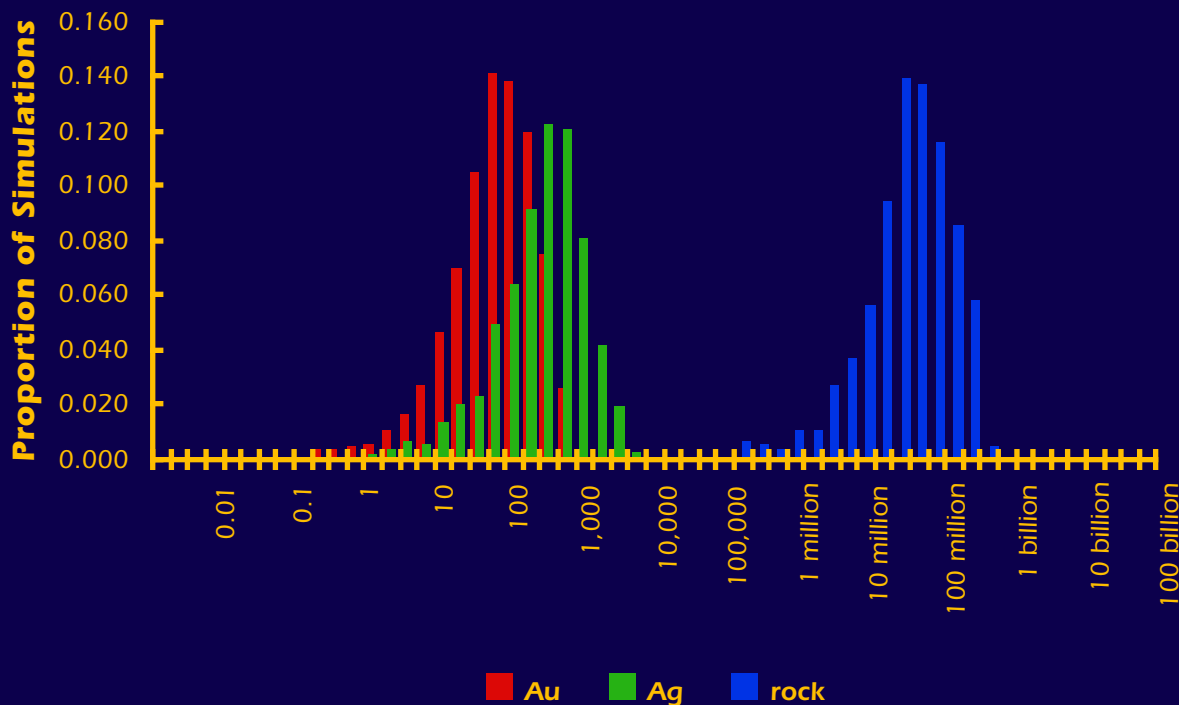
Histograms of Contained Metal and Mineralized Rock
(metric tons)

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR28

The Mark3 Index is 45:

Hot spring Au-Ag

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 7 or more deposits.

There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	56	150	38,000,000
0.10	320	1,300	250,000,000
0.05	450	2,000	340,000,000
mean	120	480	82,000,000
Probability of mean	0.32	0.31	0.31
Probability of zero	0.21	0.34	0.21

The tract ID is NR28The Mark3 Index is 45: **Hot spring Au-Ag**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 7 or more deposits.

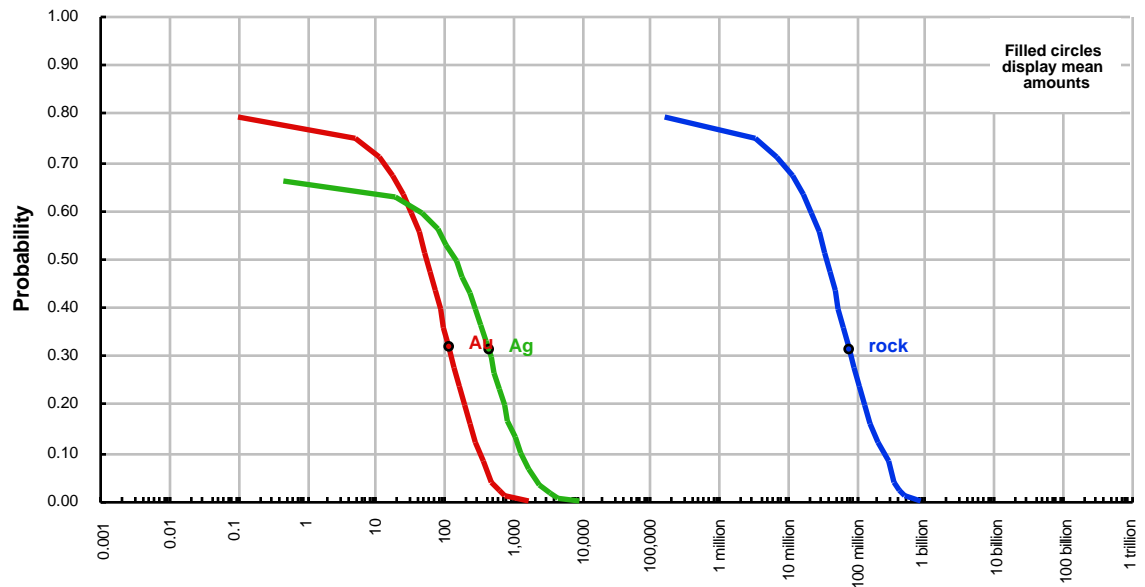
There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

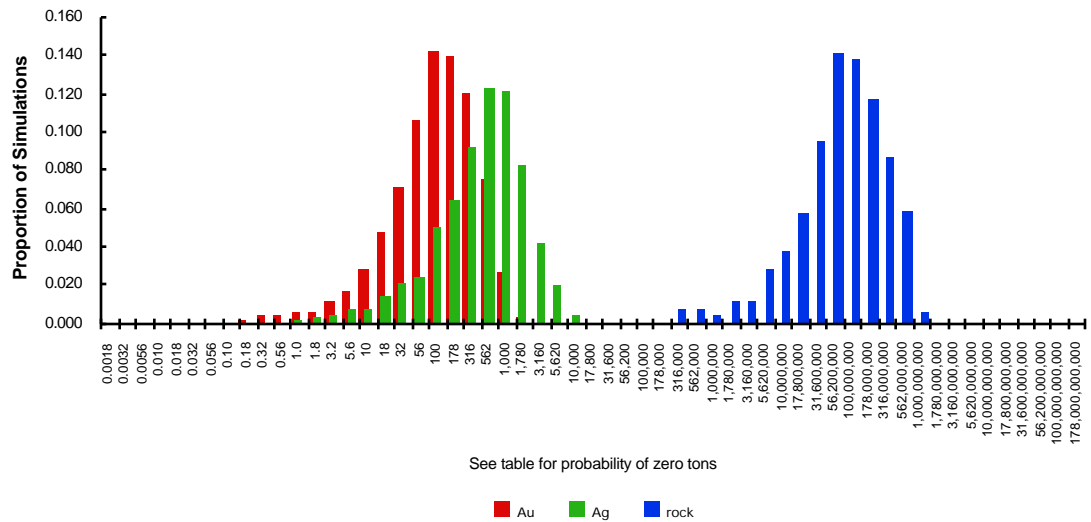
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	56	150	38,000,000
0.10	320	1,300	250,000,000
0.05	450	2,000	340,000,000
mean	120	480	82,000,000
Probability of mean	0.32	0.31	0.31
Probability of zero	0.21	0.34	0.21

The tract ID is NR28

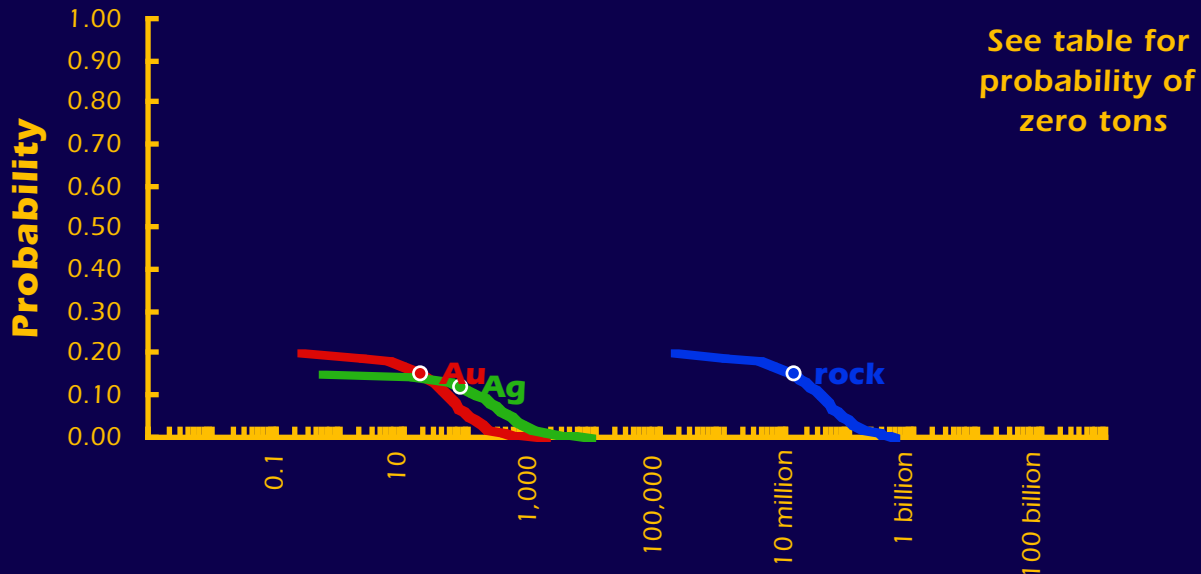
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

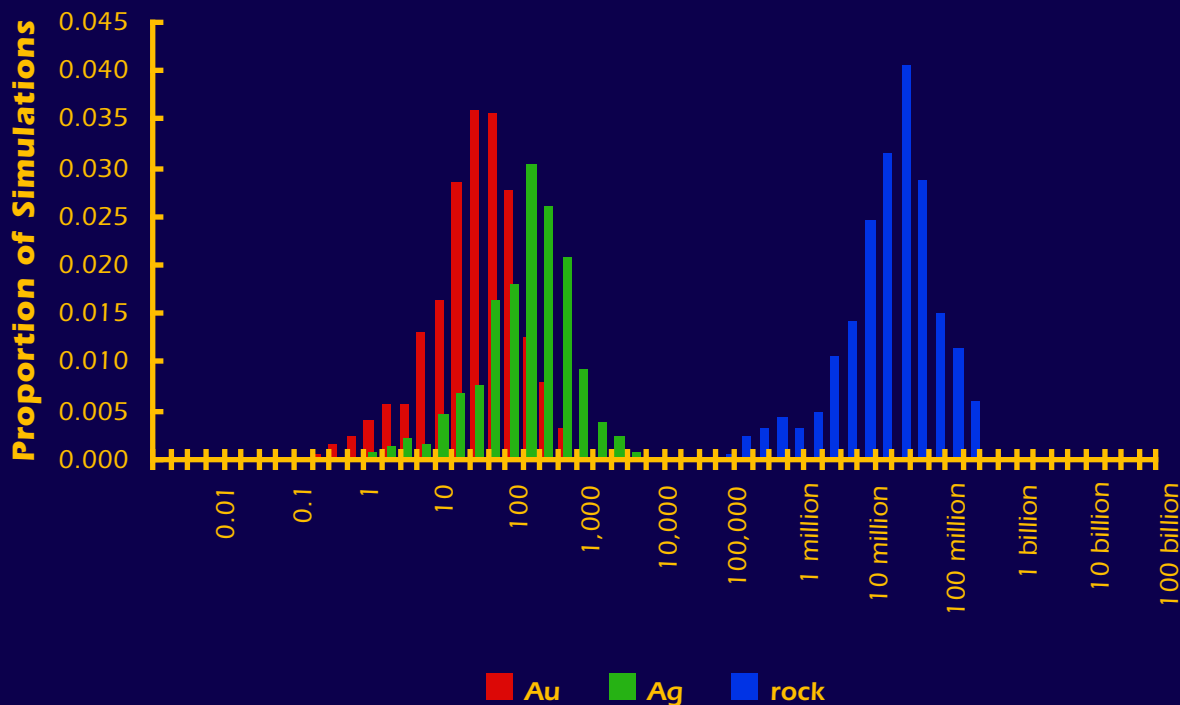


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR29

The Mark3 Index is 45:

Hot spring Au-Ag

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	47	130	32,700,000
0.05	100	410	69,000,000
mean	18	73	12,000,000
Probability of mean	0.15	0.12	0.15
Probability of zero	0.80	0.85	0.80

The tract ID is NR29The Mark3 Index is 45: **Hot spring Au-Ag**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

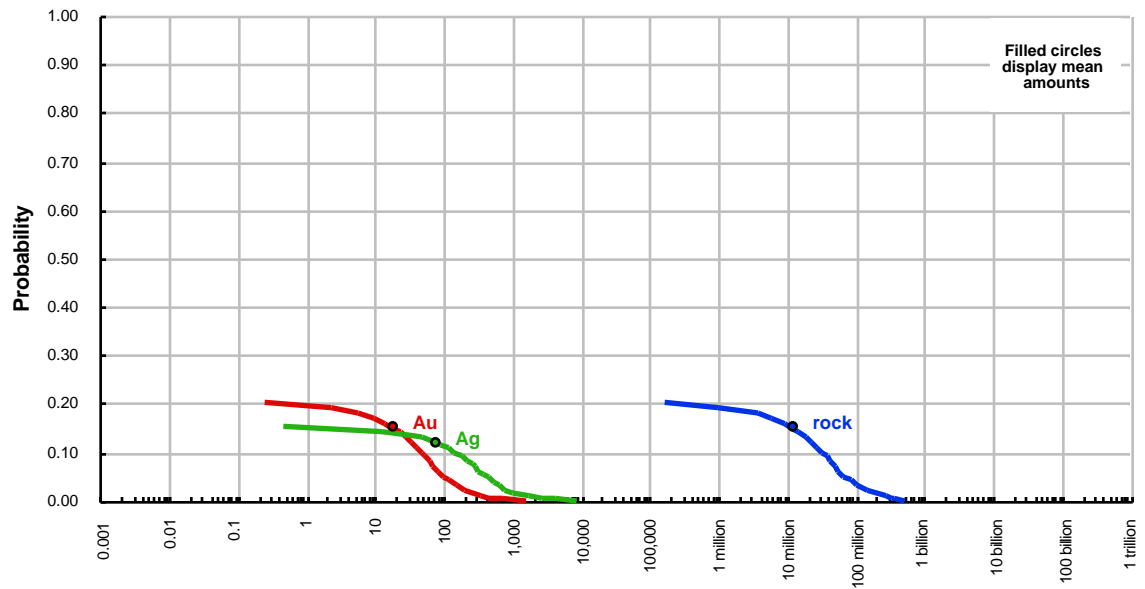
There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

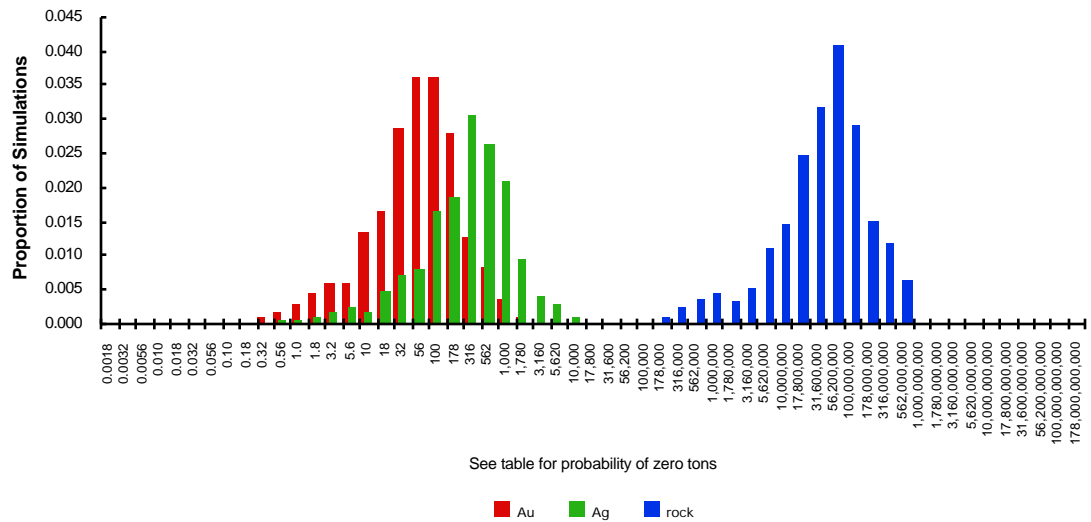
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	47	130	32,700,000
0.05	100	410	69,000,000
mean	18	73	12,000,000
Probability of mean	0.15	0.12	0.15
Probability of zero	0.80	0.85	0.80

The tract ID is NR29

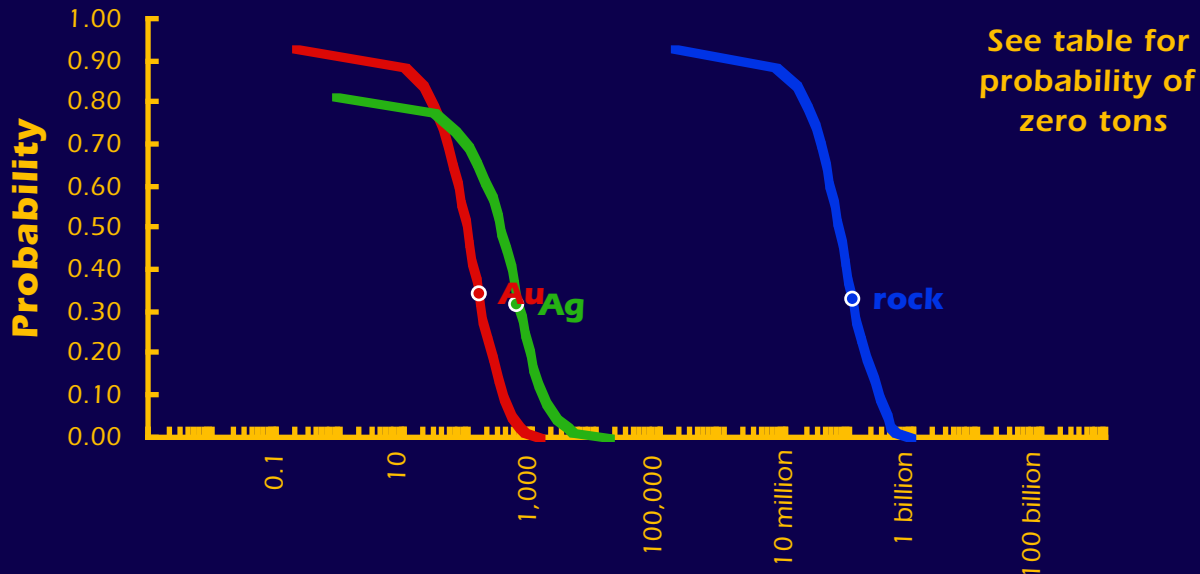
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

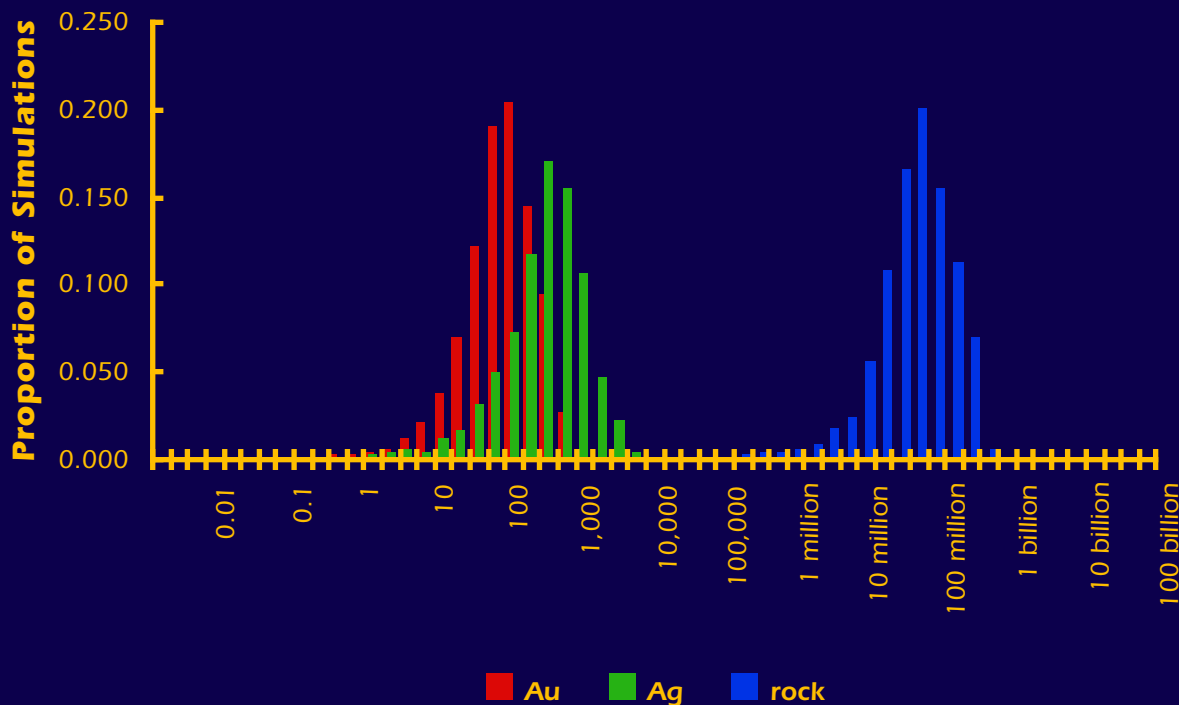


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR30

The Mark3 Index is 45:

Hot spring Au-Ag

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

There is a 1% or greater chance of 9 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	7	0	4,700,000
0.50	92	320	64,000,000
0.10	350	1,500	282,000,000
0.05	480	2,200	350,000,000
mean	140	590	100,000,000
Probability of mean	0.34	0.32	0.33
Probability of zero	0.07	0.18	0.07

The tract ID is NR30The Mark3 Index is 45: **Hot spring Au-Ag**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

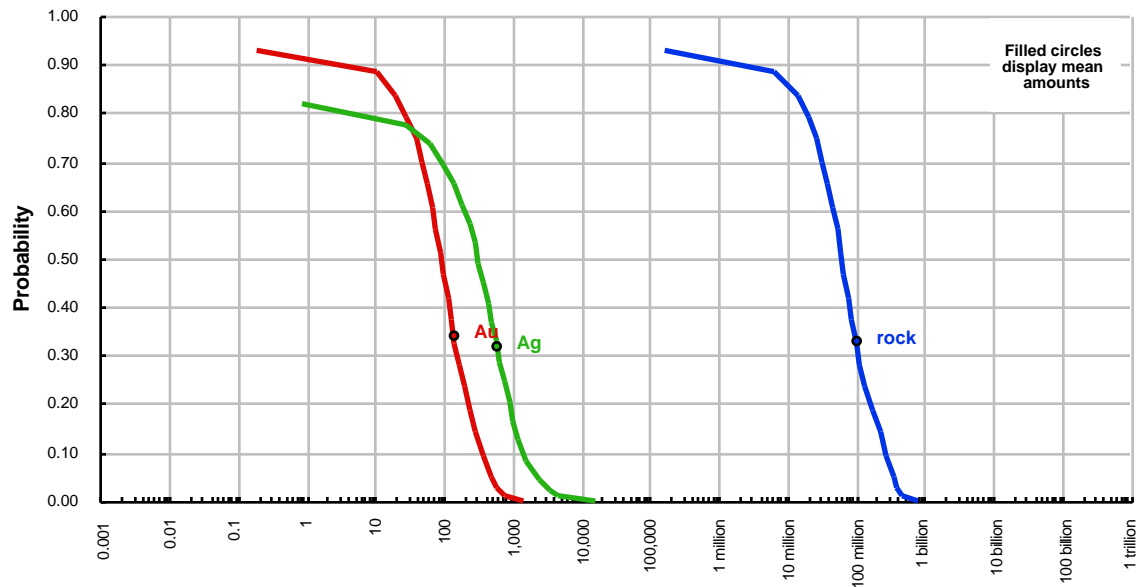
There is a 1% or greater chance of 9 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

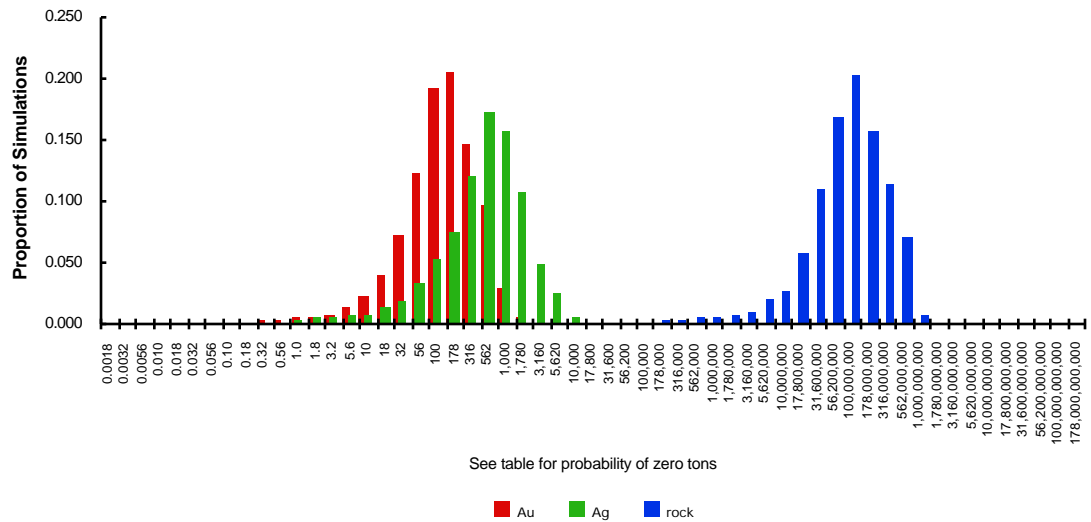
quantile	Au	Ag	rock
0.95	0	0	0
0.90	7	0	4,700,000
0.50	92	320	64,000,000
0.10	350	1,500	282,000,000
0.05	480	2,200	350,000,000
mean	140	590	100,000,000
Probability of mean	0.34	0.32	0.33
Probability of zero	0.07	0.18	0.07

The tract ID is NR30

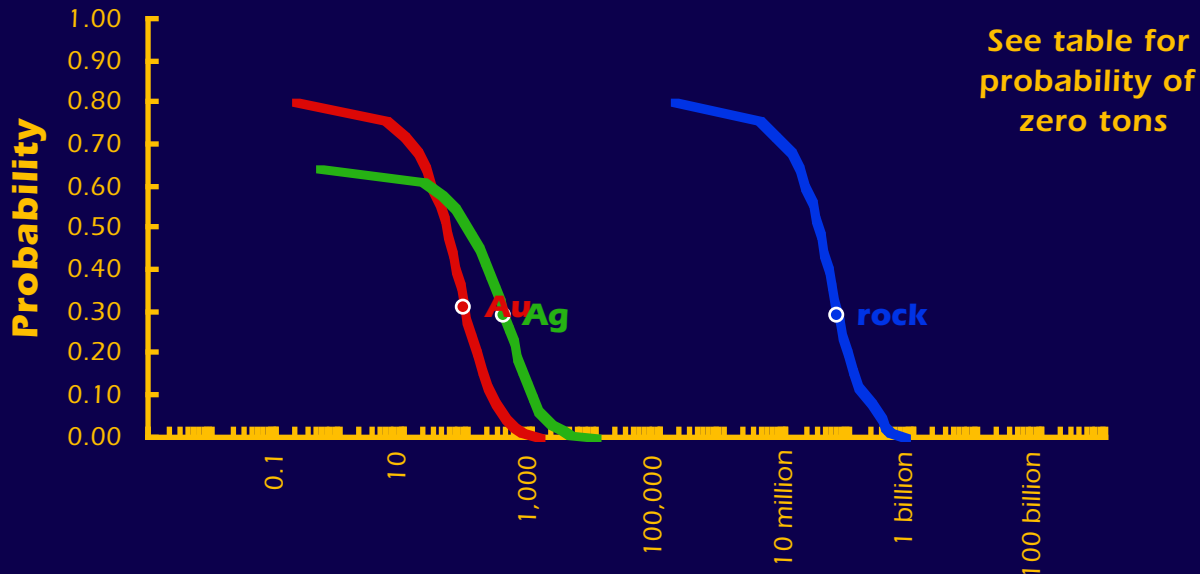
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

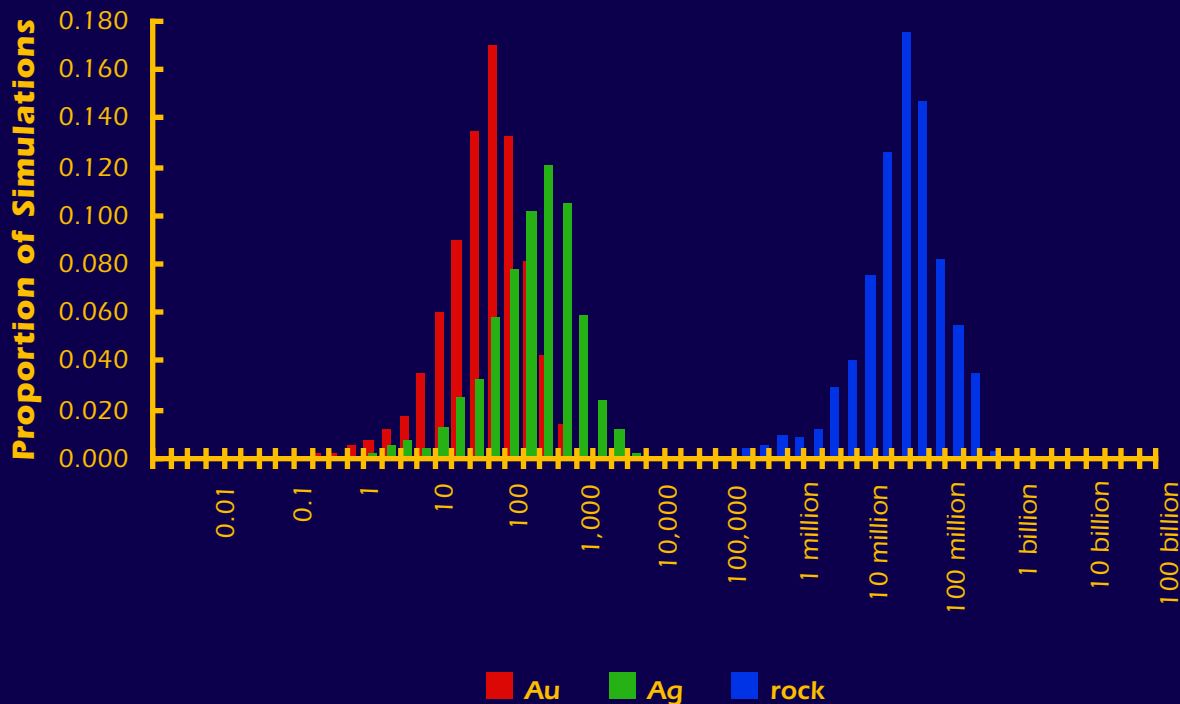


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR31

The Mark3 Index is 45:

Hot spring Au-Ag

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	45	98	31,000,000
0.10	230	960	160,000,000
0.05	340	1,500	290,000,000
mean	87	360	61,000,000
Probability of mean	0.31	0.29	0.29
Probability of zero	0.20	0.36	0.20

The tract ID is NR31The Mark3 Index is 45: **Hot spring Au-Ag**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

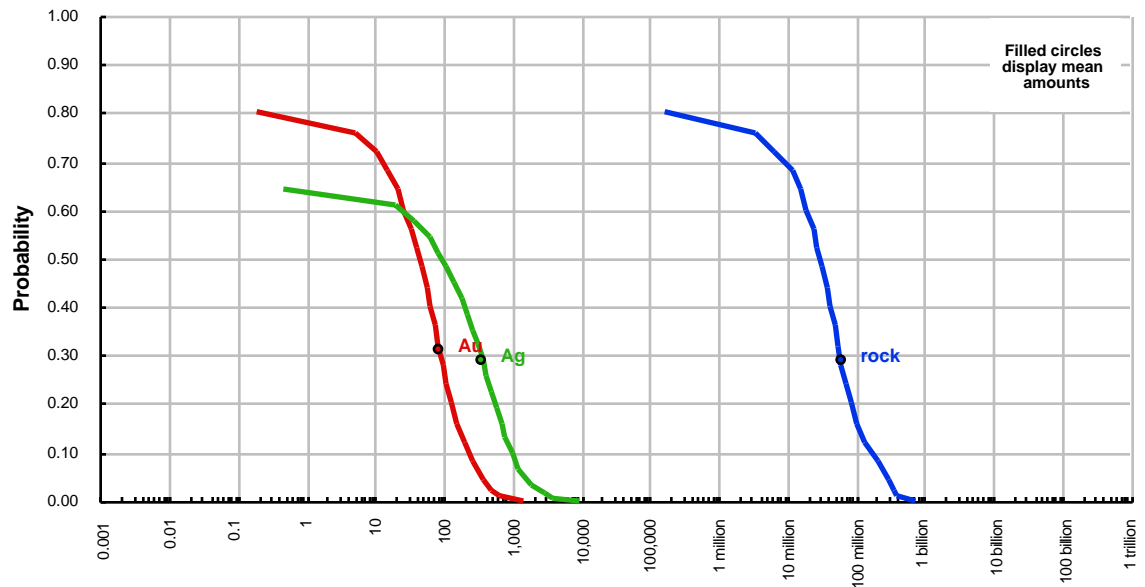
There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

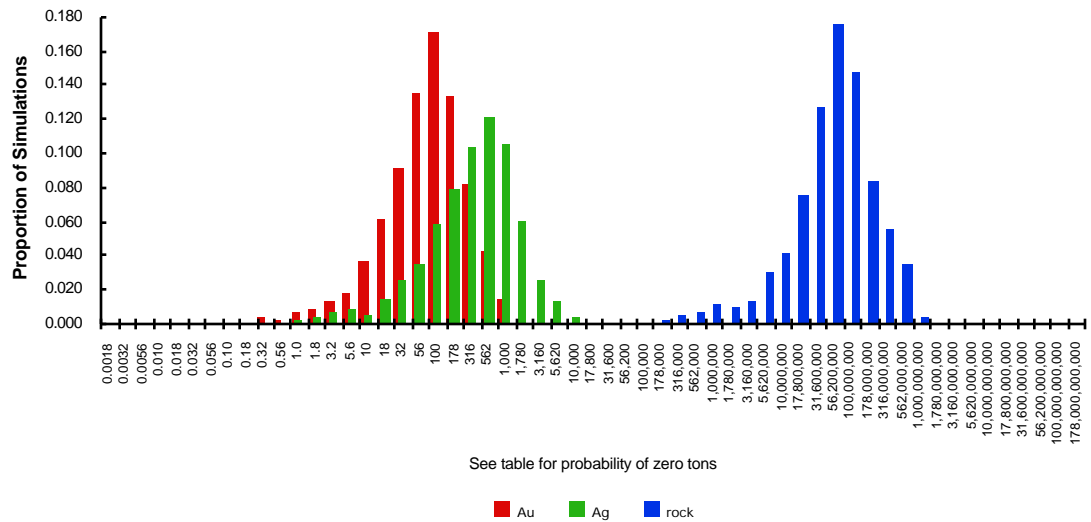
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	45	98	31,000,000
0.10	230	960	160,000,000
0.05	340	1,500	290,000,000
mean	87	360	61,000,000
Probability of mean	0.31	0.29	0.29
Probability of zero	0.20	0.36	0.20

The tract ID is NR31

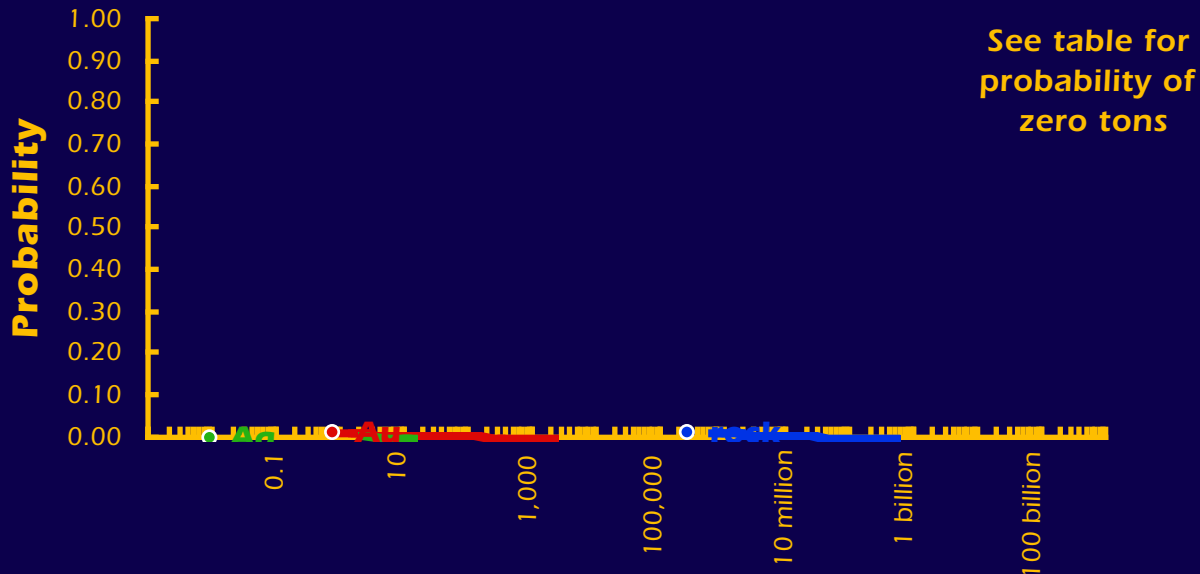
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

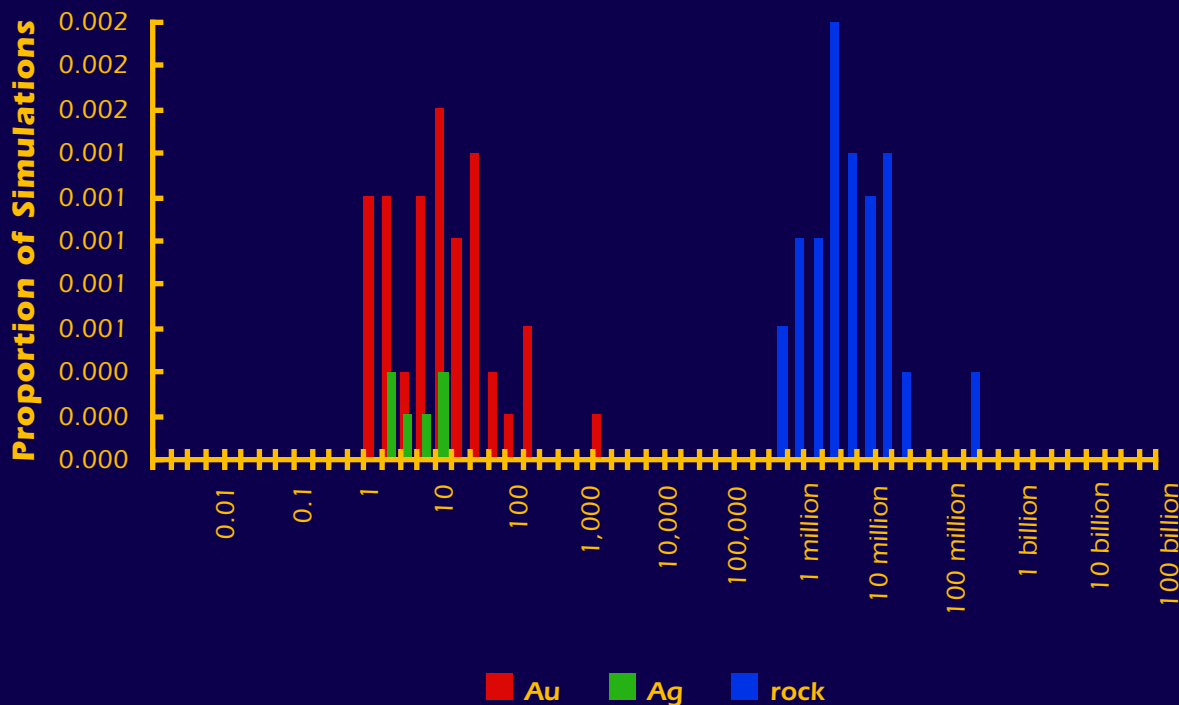


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR32

The Mark3 Index is 17:
Sediment-hosted Au

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	0	0
0.05	0	0	0
mean	1	0	280,000
Probability of mean	0.01	0.00	0.01
Probability of zero	0.99	1.00	0.99

The tract ID is NR32The Mark3 Index is 17: **Sediment-hosted Au**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

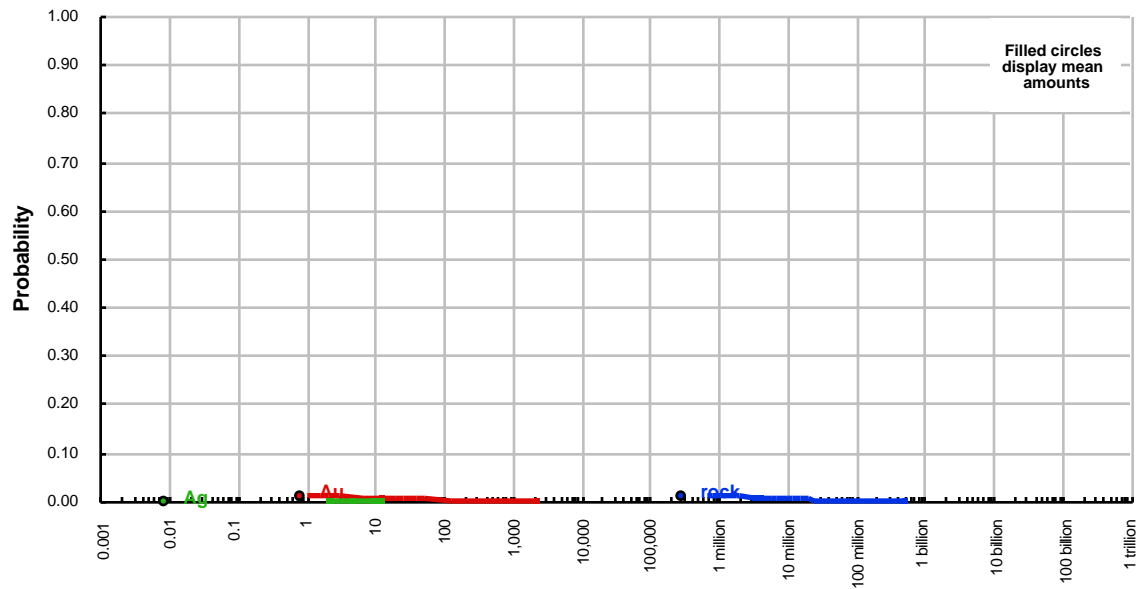
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

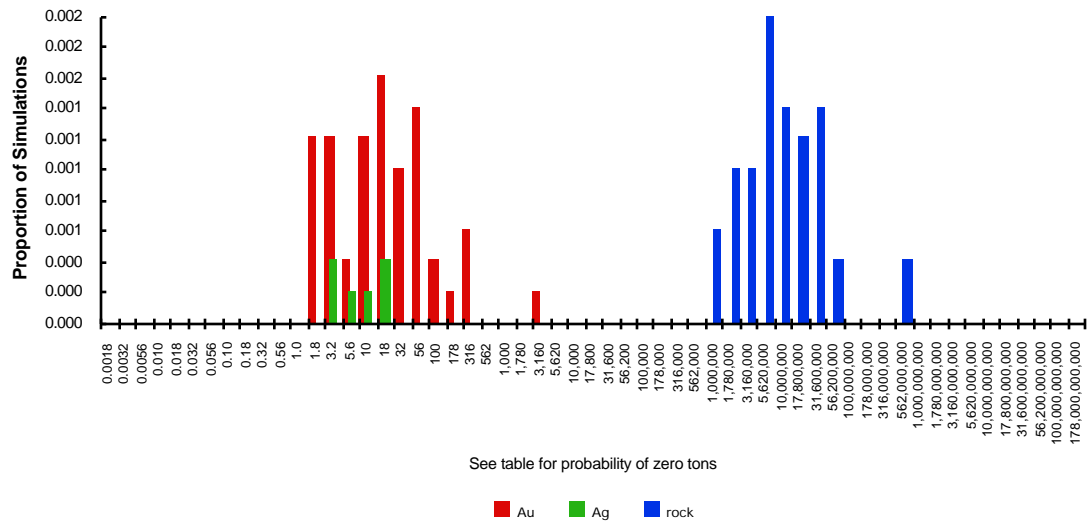
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	0	0
0.05	0	0	0
mean	1	0	280,000
Probability of mean	0.01	0.00	0.01
Probability of zero	0.99	1.00	0.99

The tract ID is NR32

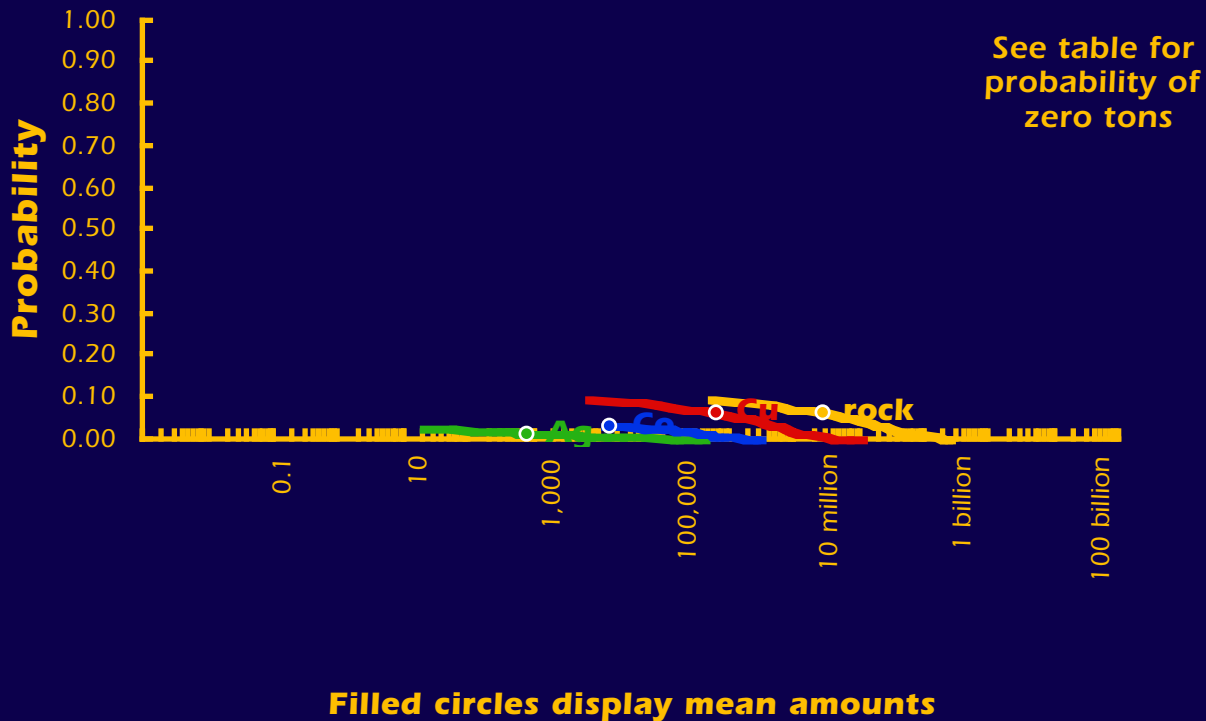
Cumulative Distributions of Contained Metal and Mineralized Rock



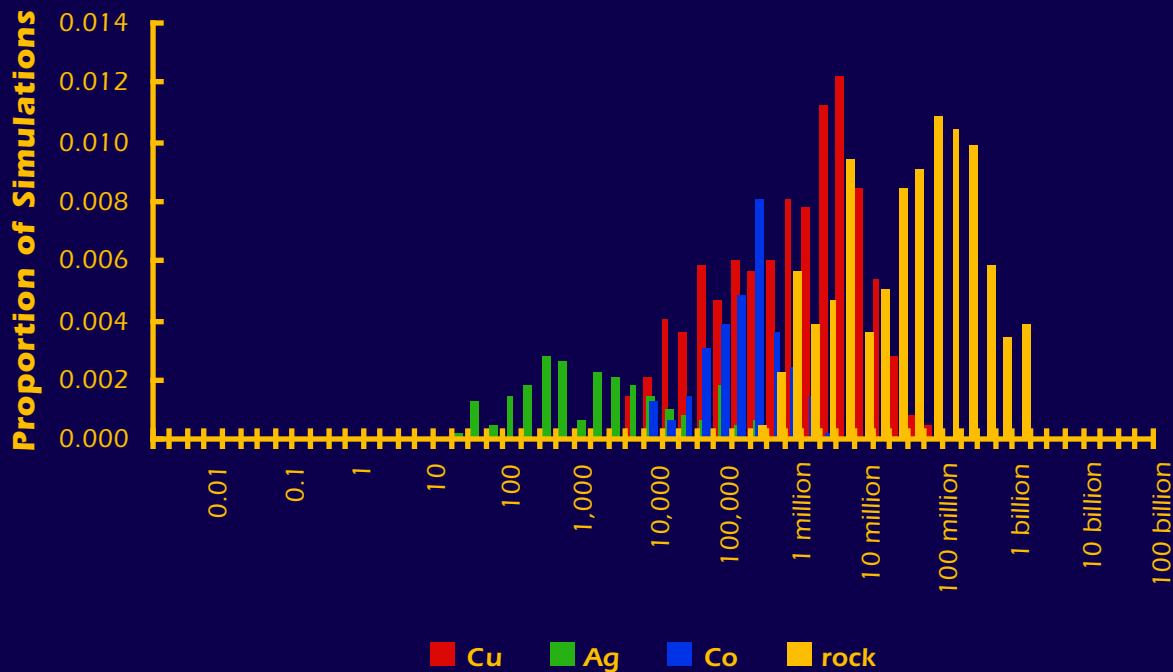
Histograms of Contained Metal and Mineralized Rock (metric tons)



Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR36

The Mark3 Index is 96:

Sediment-hosted Cu, reduced facies

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Ag	Co	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	1,700,000	0	0	71,000,000
mean	630,000	770	15,000	27,000,000
Probability of mean	0.06	0.01	0.03	0.06
Probability of zero	0.90	0.98	0.97	0.90

The tract ID is NR36The Mark3 Index is 96: **Sediment-hosted Cu, reduced facies**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

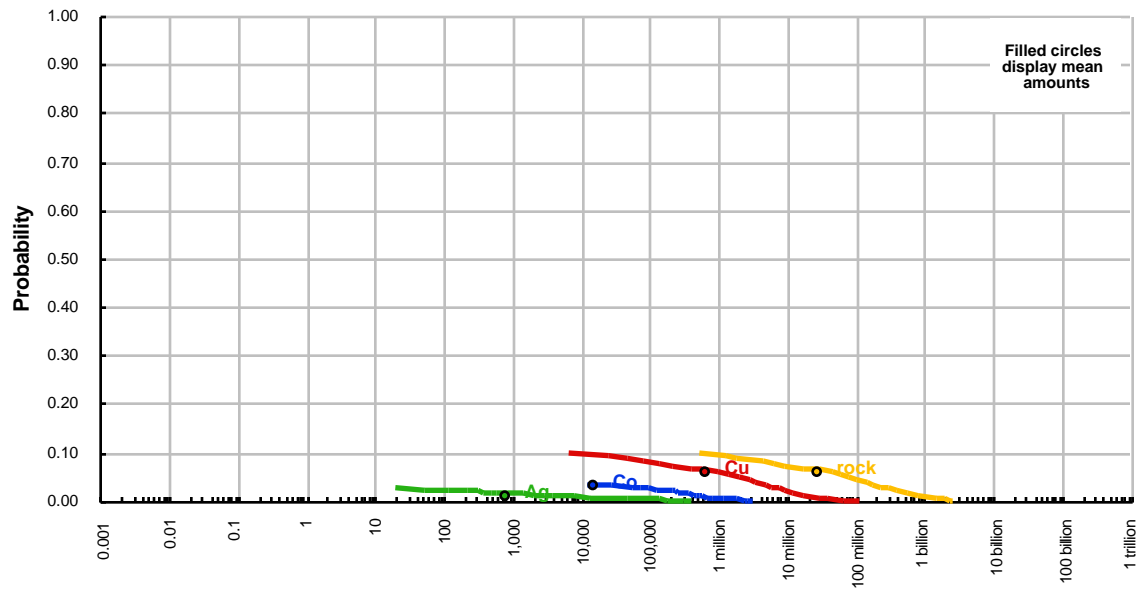
There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

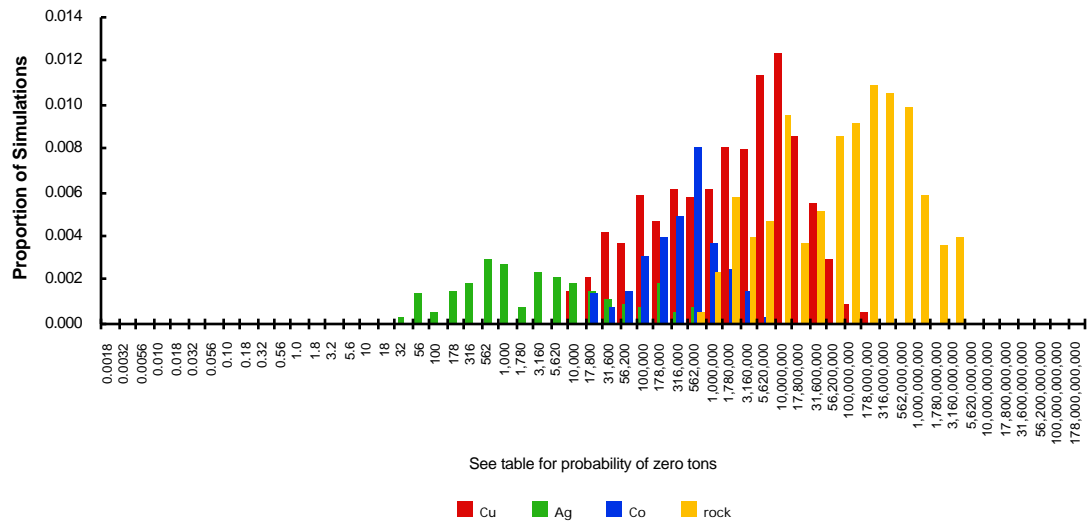
quantile	Cu	Ag	Co	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	1,700,000	0	0	71,000,000
mean	630,000	770	15,000	27,000,000
Probability of mean	0.06	0.01	0.03	0.06
Probability of zero	0.90	0.98	0.97	0.90

The tract ID is NR36

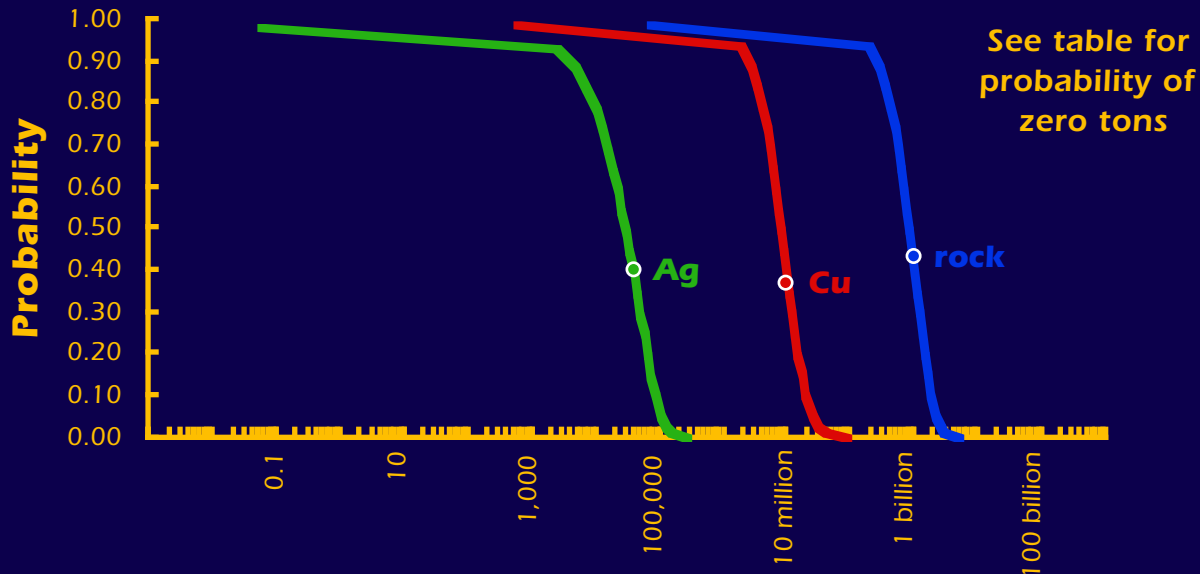
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

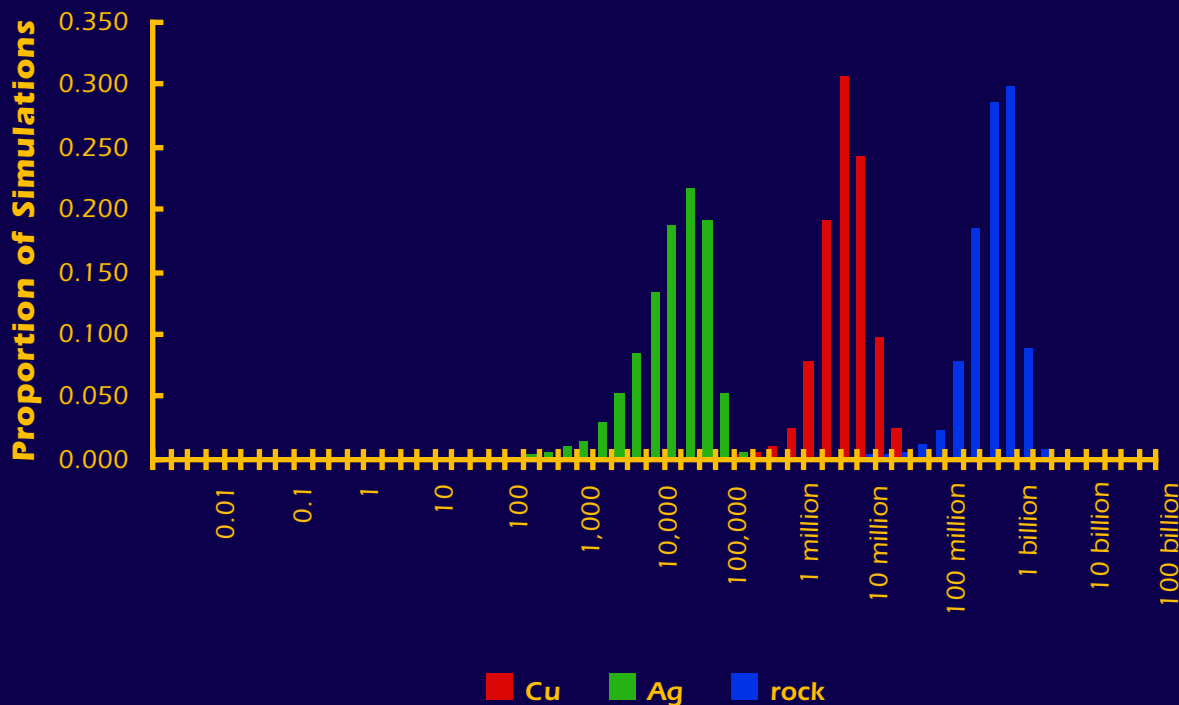


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR37

The Mark3 Index is 64:

Sediment-hosted Cu, Revett

There is a 90% or greater chance of 9 or more deposits.
There is a 50% or greater chance of 10 or more deposits.
There is a 10% or greater chance of 15 or more deposits.
There is a 5% or greater chance of 20 or more deposits.
There is a 1% or greater chance of 30 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Ag	rock
0.95	1,500,000	1,600	150,000,000
0.90	2,600,000	4,100	260,000,000
0.50	7,900,000	29,000	830,000,000
0.10	19,000,000	84,000	1,760,000,000
0.05	26,000,000	110,000	2,100,000,000
mean	9,900,000	38,000	940,000,000
Probability of mean	0.37	0.40	0.43
Probability of zero	0.01	0.02	0.01

The tract ID is NR37The Mark3 Index is 64: **Sediment-hosted Cu, Revett**

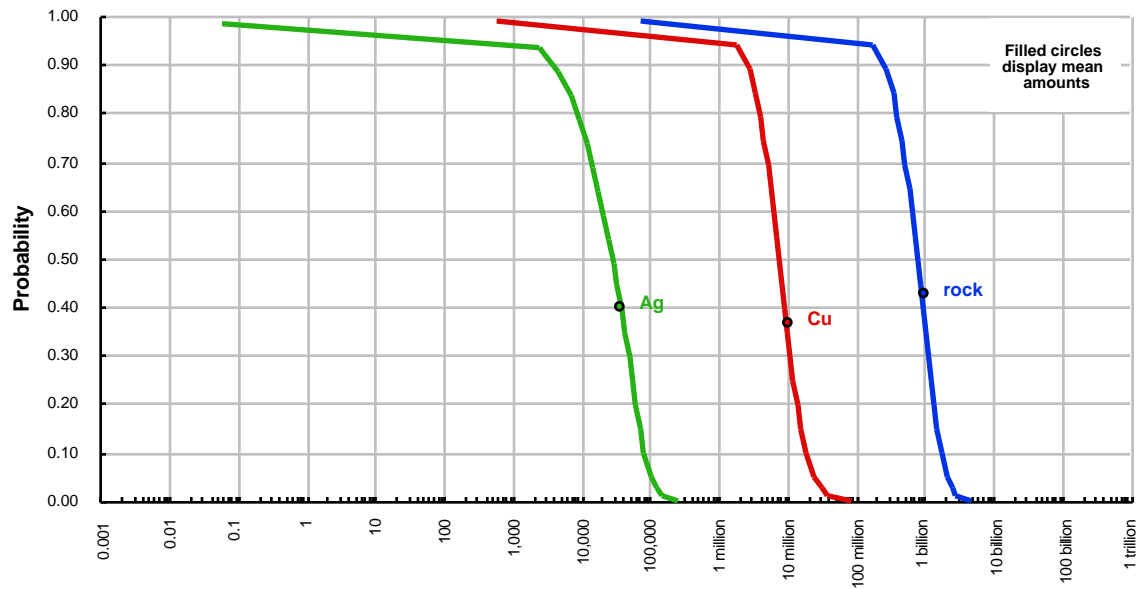
There is a 90% or greater chance of 9 or more deposits.
 There is a 50% or greater chance of 10 or more deposits.
 There is a 10% or greater chance of 15 or more deposits.
 There is a 5% or greater chance of 20 or more deposits.
 There is a 1% or greater chance of 30 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

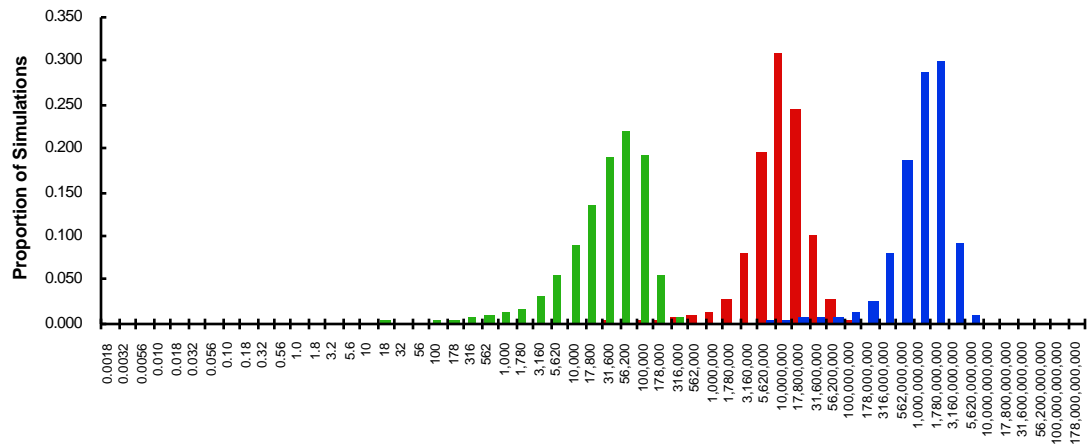
quantile	Cu	Ag	rock
0.95	1,500,000	1,600	150,000,000
0.90	2,600,000	4,100	260,000,000
0.50	7,900,000	29,000	830,000,000
0.10	19,000,000	84,000	1,760,000,000
0.05	26,000,000	110,000	2,100,000,000
mean	9,900,000	38,000	940,000,000
Probability of mean	0.37	0.40	0.43
Probability of zero	0.01	0.02	0.01

The tract ID is NR37

Cumulative Distributions of Contained Metal and Mineralized Rock



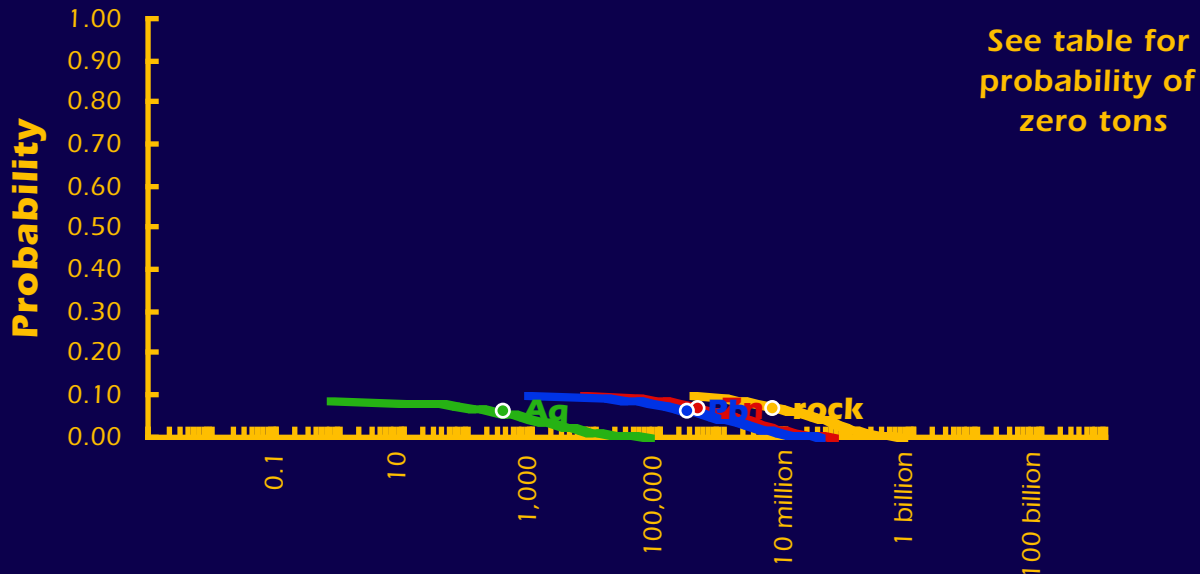
Histograms of Contained Metal and Mineralized Rock (metric tons)



See table for probability of zero tons

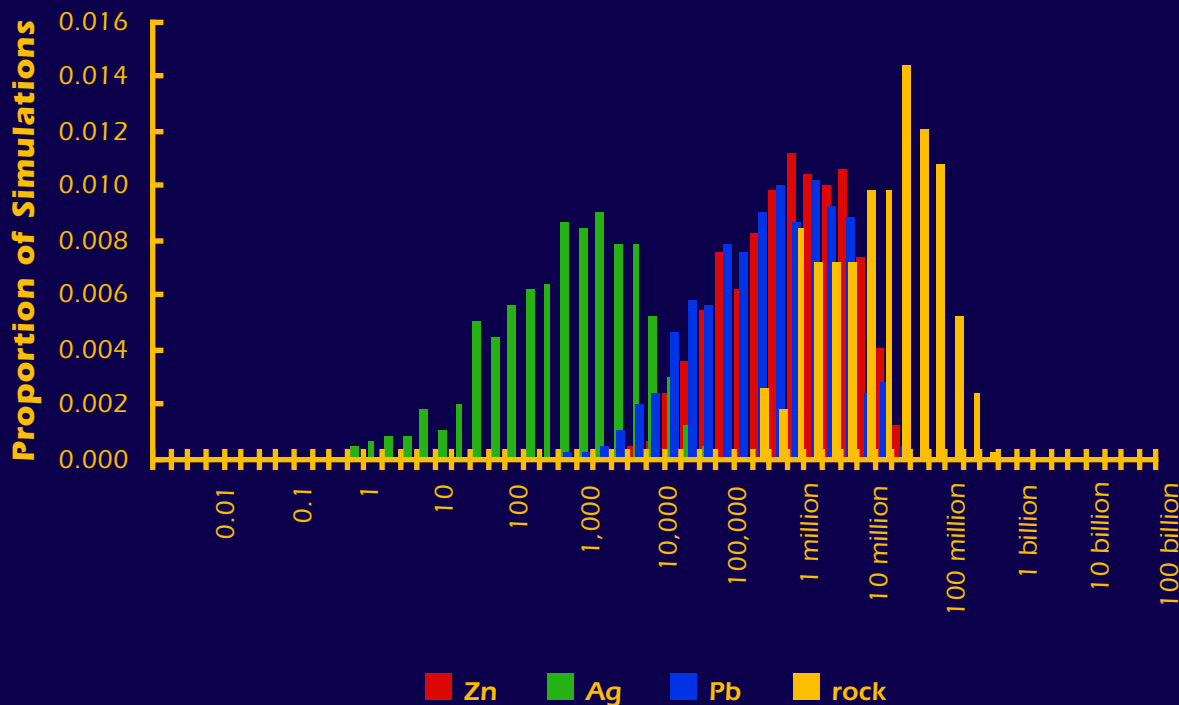
Cu Ag rock

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR38

The Mark3 Index is 13:

Sedimentary exhalative Zn-Pb

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Zn	Ag	Pb	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	1,400,000	610	620,000	24,000,000
mean	410,000	350	260,000	5,800,000
Probability of mean	0.07	0.06	0.06	0.07
Probability of zero	0.90	0.91	0.90	0.90

The tract ID is NR38The Mark3 Index is 13: **Sedimentary exhalative Zn-Pb**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

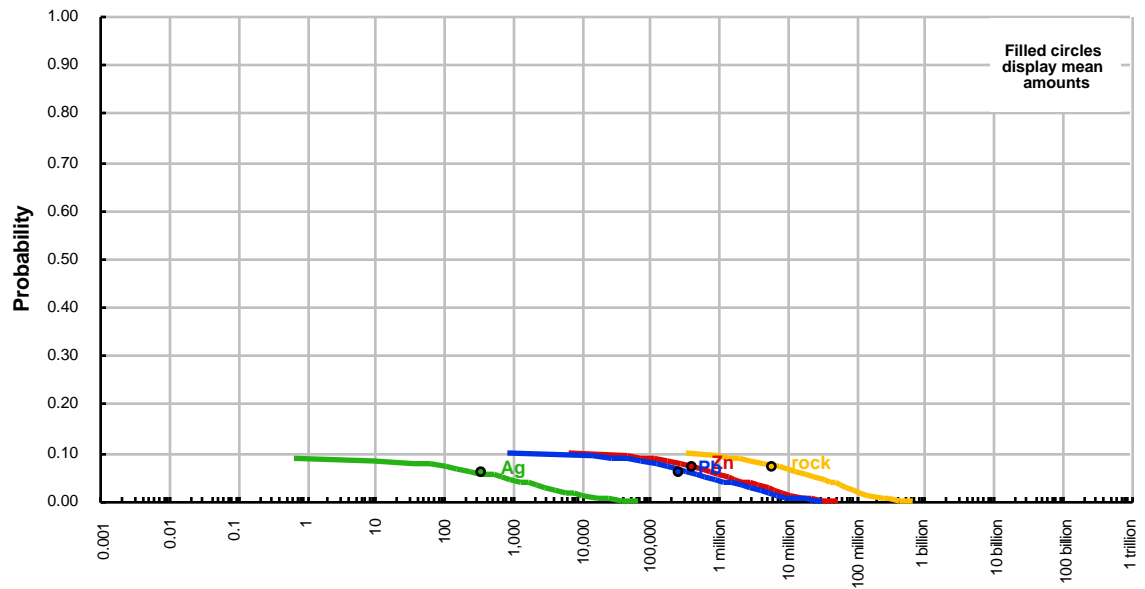
There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

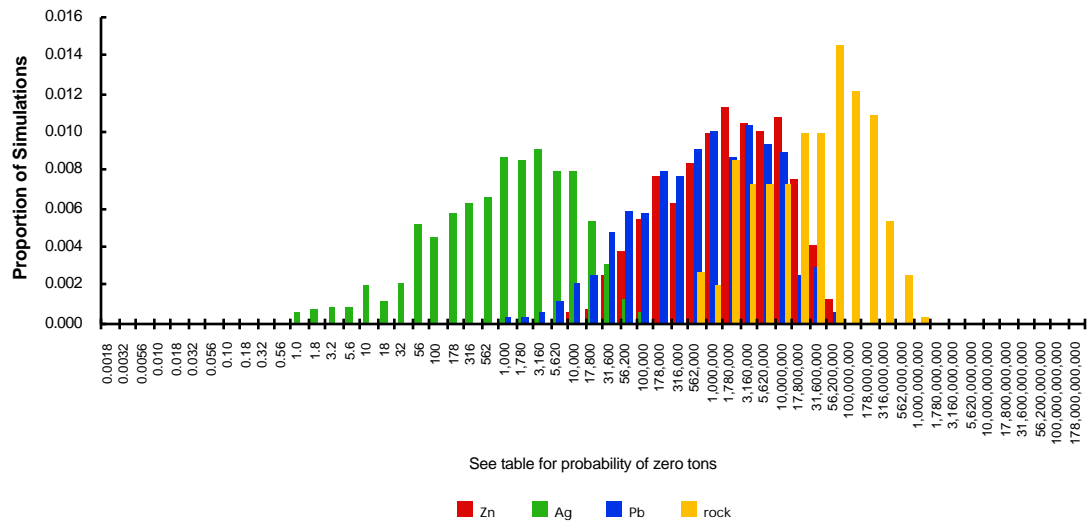
quantile	Zn	Ag	Pb	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	1,400,000	610	620,000	24,000,000
mean	410,000	350	260,000	5,800,000
Probability of mean	0.07	0.06	0.06	0.07
Probability of zero	0.90	0.91	0.90	0.90

The tract ID is NR38

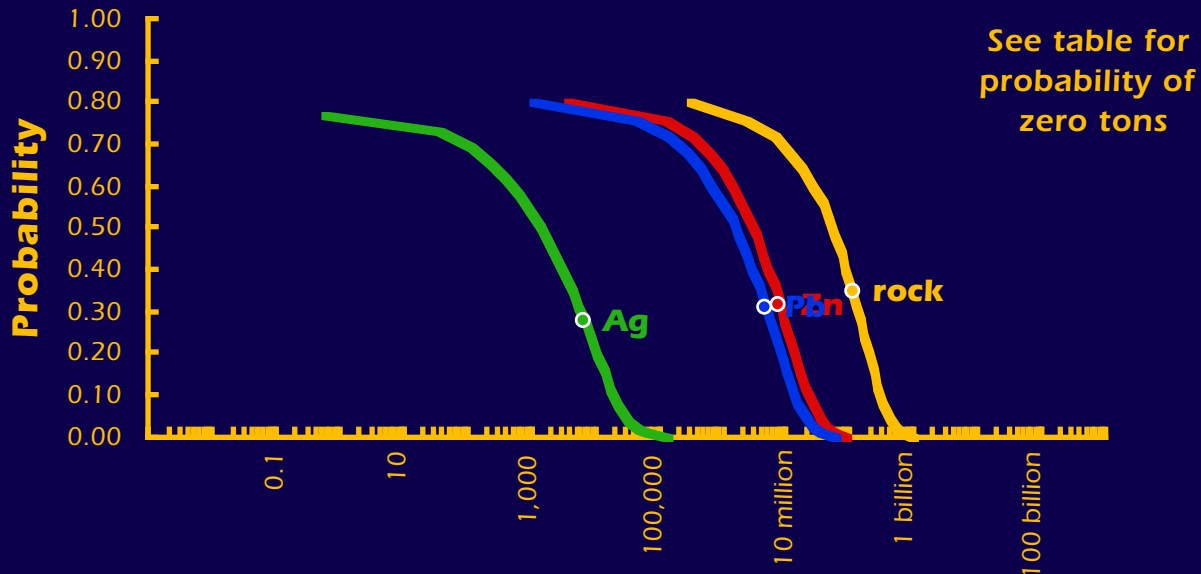
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

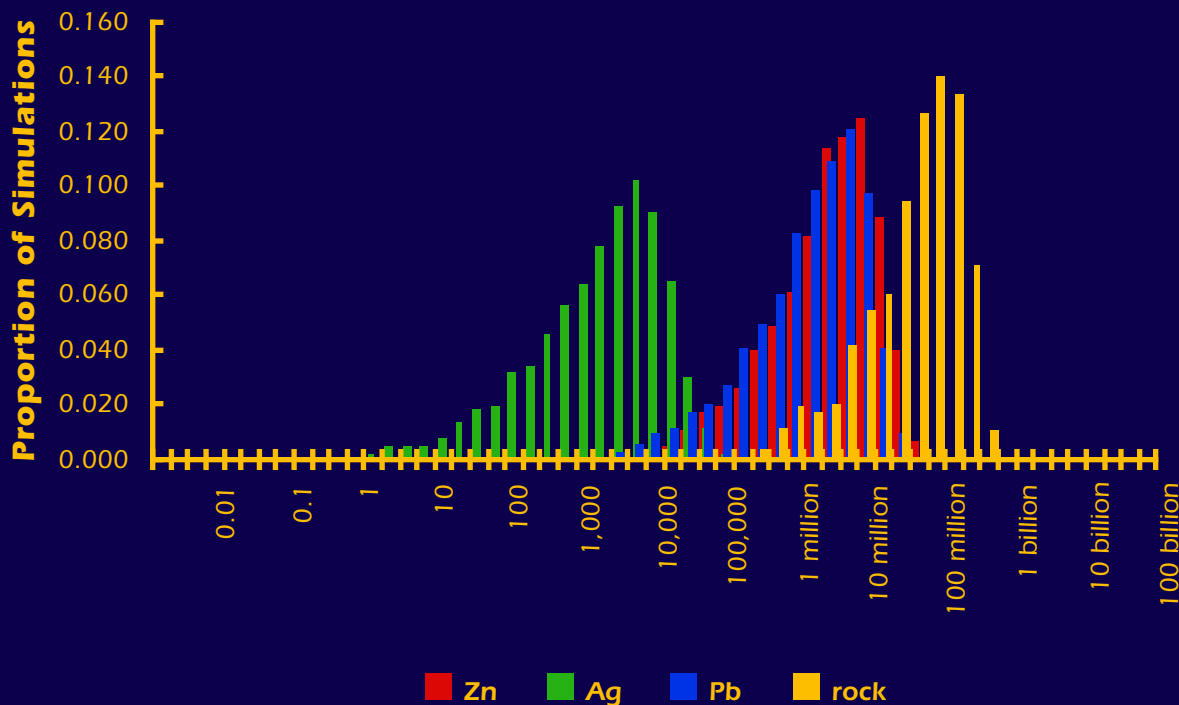


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR39

The Mark3 Index is 13:

Sedimentary exhalative Zn-Pb

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Zn	Ag	Pb	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	3,000,000	1,300	1,500,000	50,000,000
0.10	21,000,000	19,000	12,900,000	290,000,000
0.05	30,000,000	29,000	18,000,000	380,000,000
mean	7,500,000	6,400	4,400,000	100,000,000
Probability of mean	0.32	0.28	0.31	0.35
Probability of zero	0.20	0.23	0.20	0.20

The tract ID is NR39The Mark3 Index is 13: **Sedimentary exhalative Zn-Pb**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

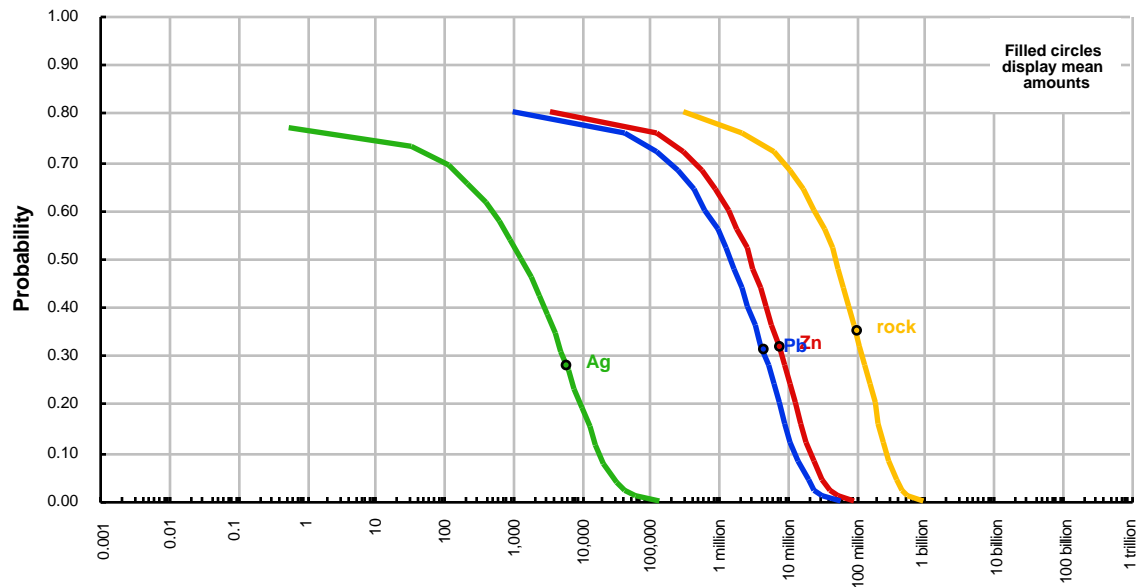
There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

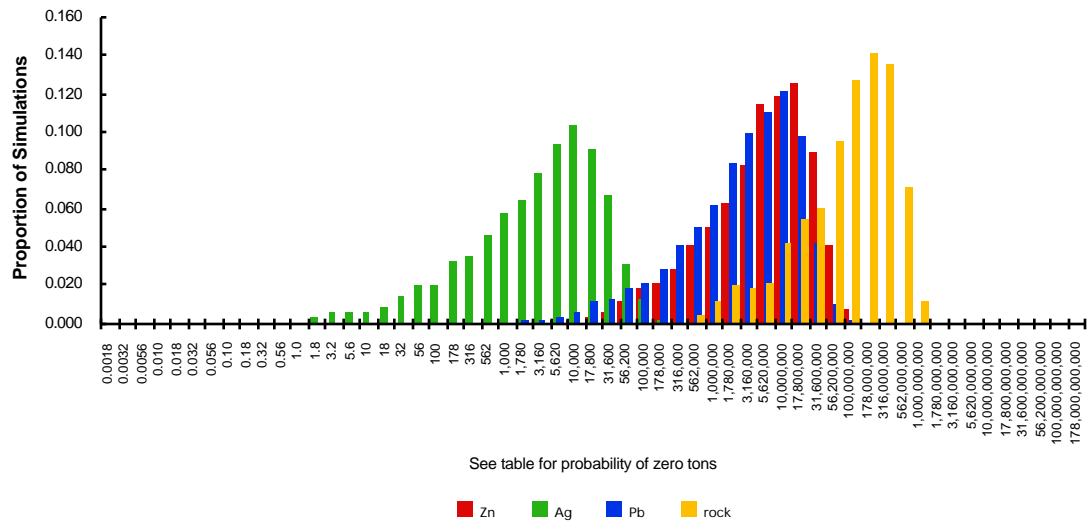
quantile	Zn	Ag	Pb	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	3,000,000	1,300	1,500,000	50,000,000
0.10	21,000,000	19,000	12,900,000	290,000,000
0.05	30,000,000	29,000	18,000,000	380,000,000
mean	7,500,000	6,400	4,400,000	100,000,000
Probability of mean	0.32	0.28	0.31	0.35
Probability of zero	0.20	0.23	0.20	0.20

The tract ID is NR39

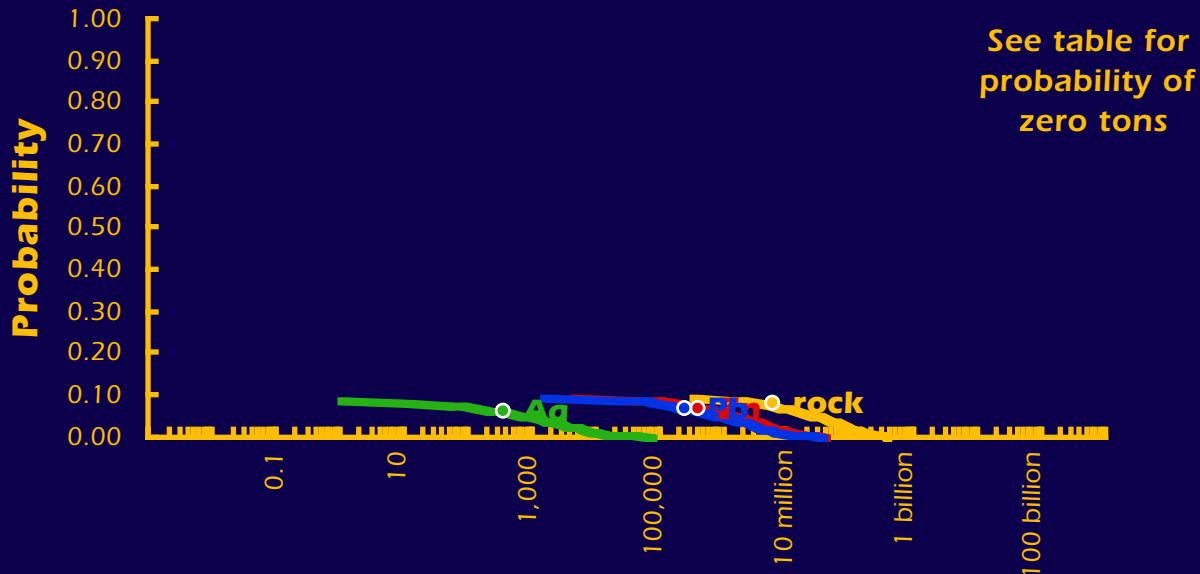
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

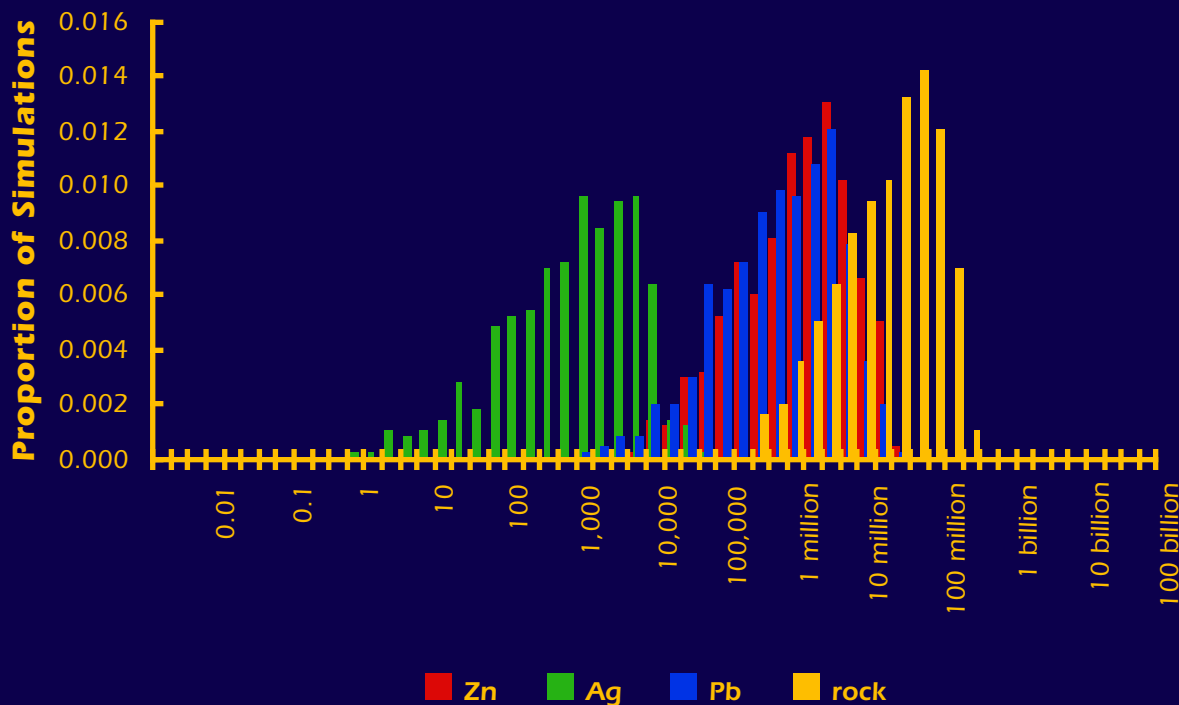


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR40

The Mark3 Index is 13:

Sedimentary exhalative Zn-Pb

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Zn	Ag	Pb	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	1,600,000	770	800,000	28,000,000
mean	400,000	340	260,000	5,700,000
Probability of mean	0.07	0.06	0.07	0.08
Probability of zero	0.91	0.92	0.91	0.91

The tract ID is NR40The Mark3 Index is 13: **Sedimentary exhalative Zn-Pb**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

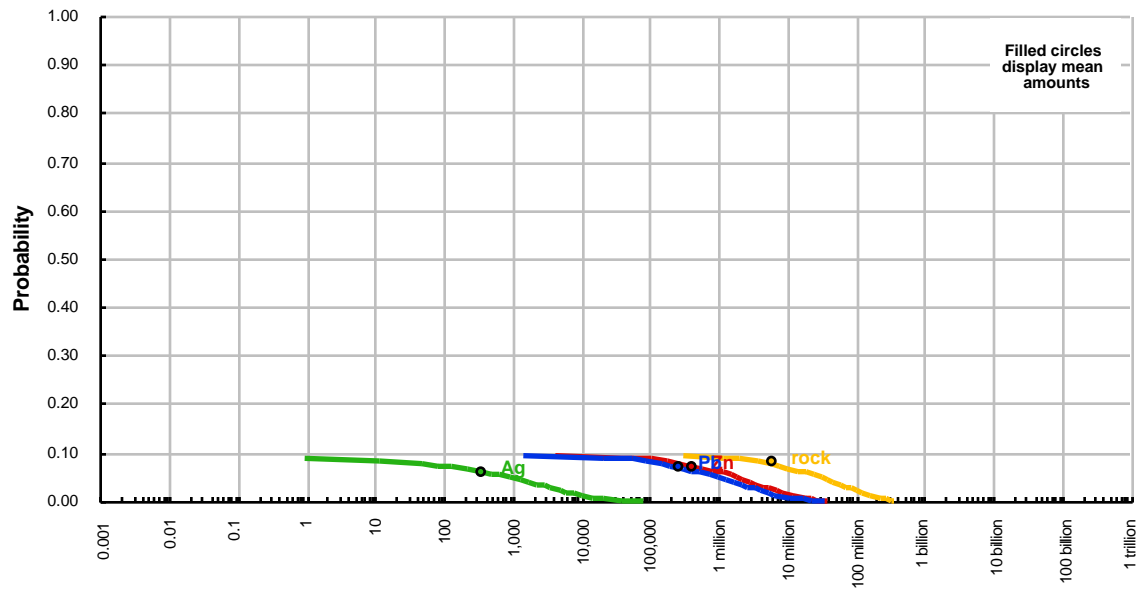
There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

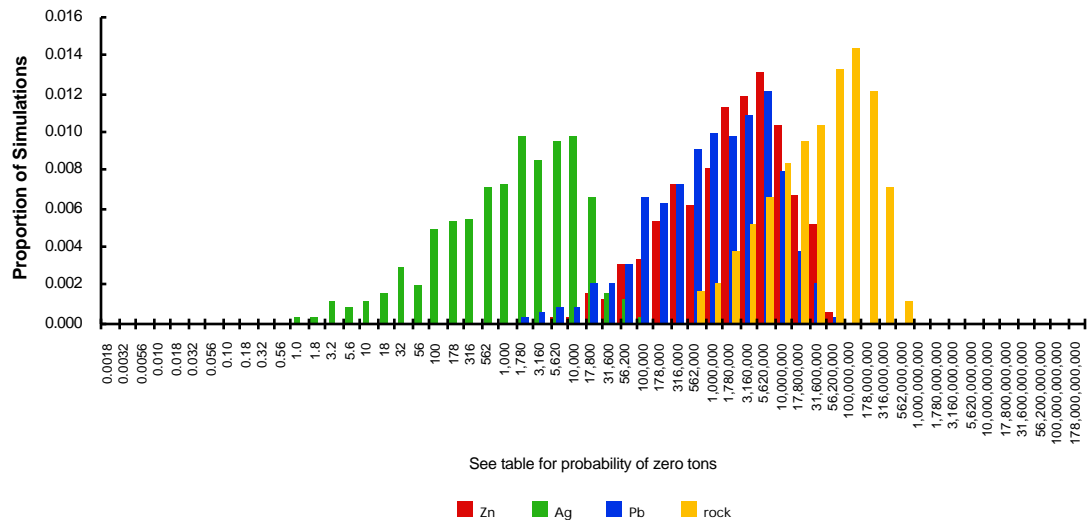
quantile	Zn	Ag	Pb	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	1,600,000	770	800,000	28,000,000
mean	400,000	340	260,000	5,700,000
Probability of mean	0.07	0.06	0.07	0.08
Probability of zero	0.91	0.92	0.91	0.91

The tract ID is NR40

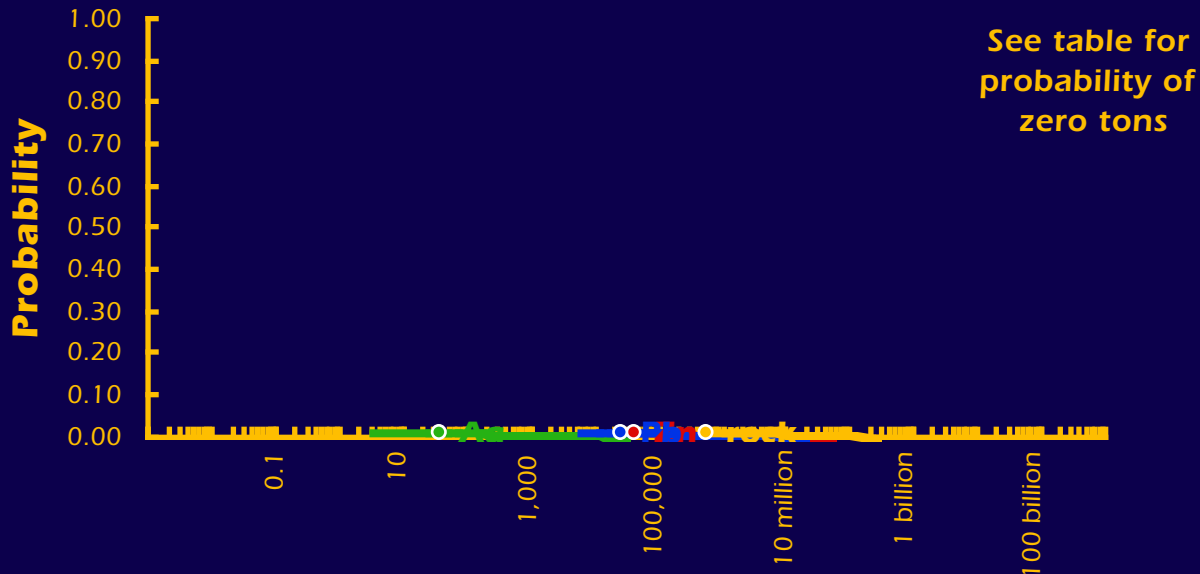
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

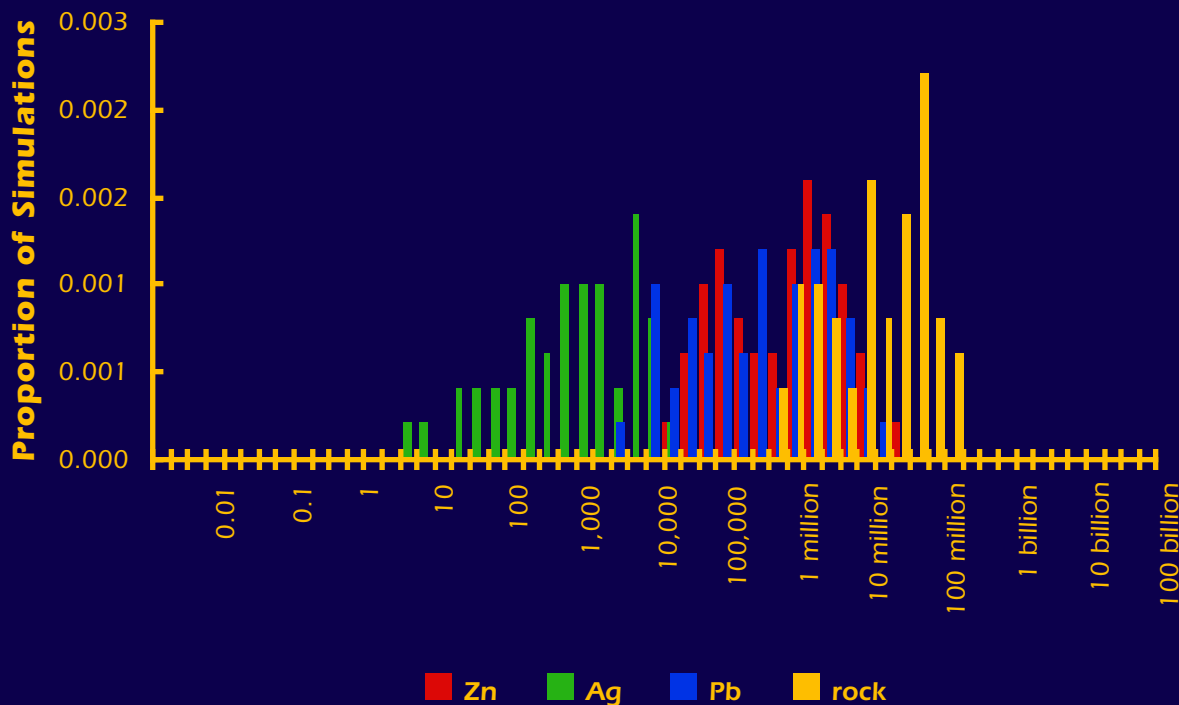


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR42

The Mark3 Index is 13:

Sedimentary exhalative Zn-Pb

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Zn	Ag	Pb	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	0	0	0	0
mean	39,000	35	25,000	530,000
Probability of mean	0.01	0.01	0.01	0.01
Probability of zero	0.99	0.99	0.99	0.99

The tract ID is NR42The Mark3 Index is 13: **Sedimentary exhalative Zn-Pb**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

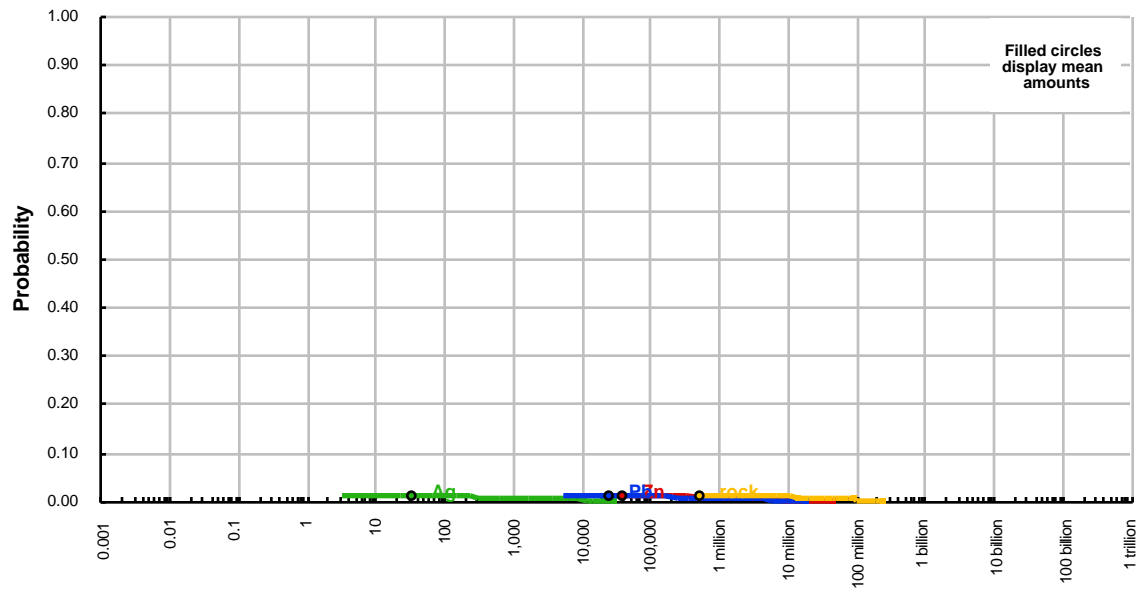
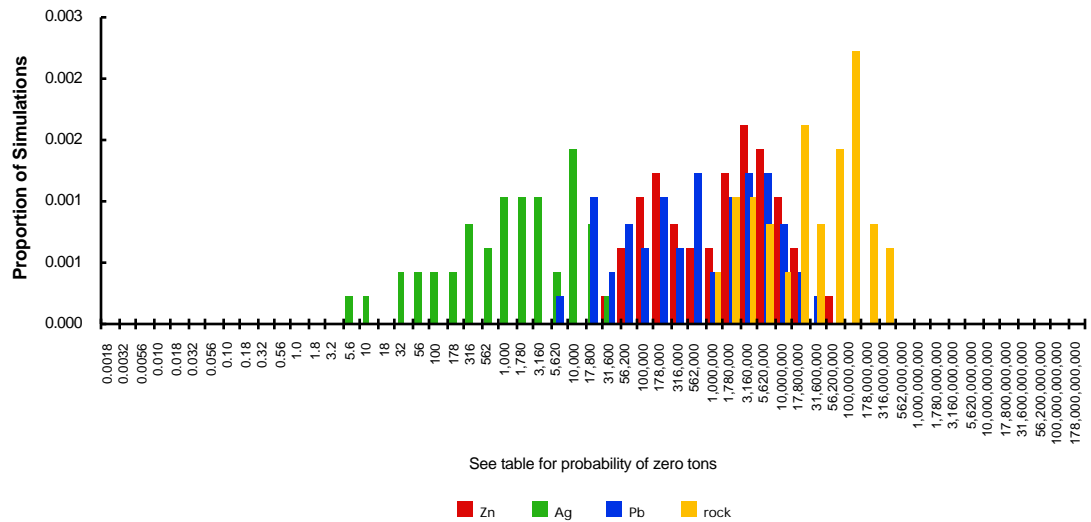
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

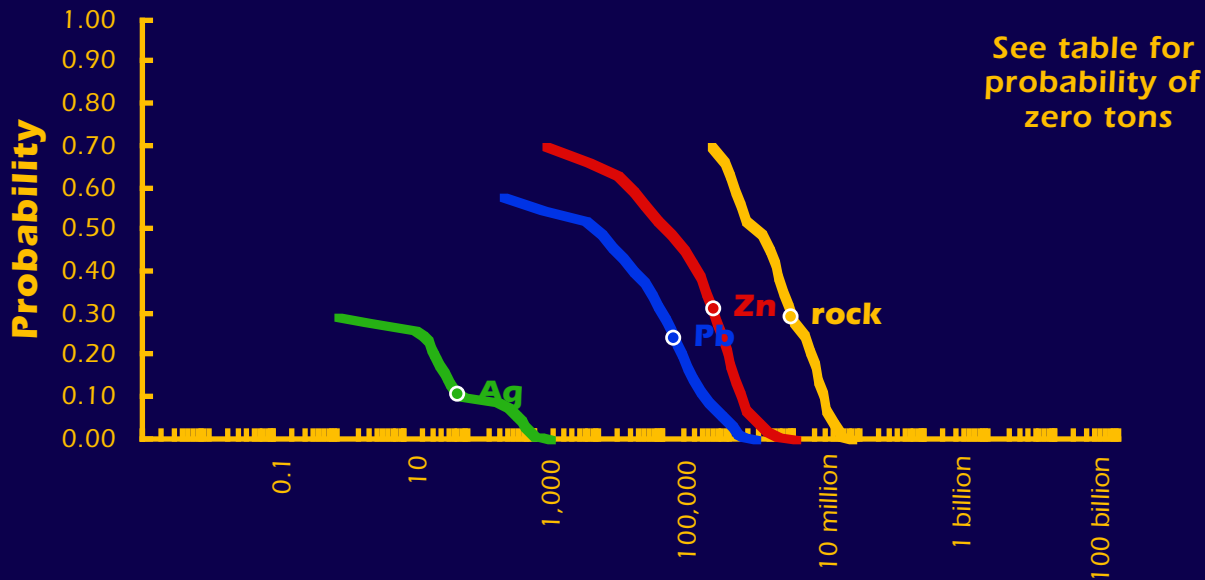
quantile	Zn	Ag	Pb	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	0	0	0	0
mean	39,000	35	25,000	530,000
Probability of mean	0.01	0.01	0.01	0.01
Probability of zero	0.99	0.99	0.99	0.99

The tract ID is NR42

Cumulative Distributions of Contained Metal and Mineralized Rock

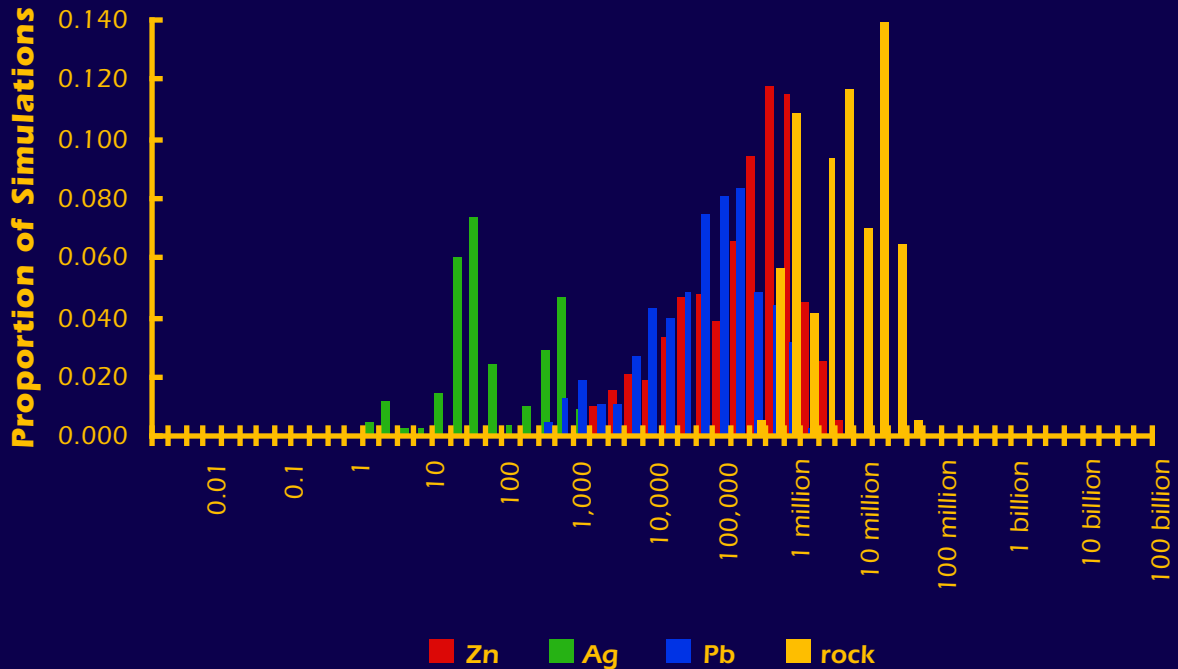
Histograms of Contained Metal and Mineralized Rock
(metric tons)

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR43

The Mark3 Index is 94:

Mississippi Valley, minor

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Zn	Ag	Pb	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	100,000	0	8,700	2,600,000
0.10	1,500,000	89	421,000	28,000,000
0.05	2,400,000	600	840,000	34,000,000
mean	550,000	67	140,000	8,800,000
Probability of mean	0.31	0.11	0.24	0.29
Probability of zero	0.30	0.71	0.42	0.30

The tract ID is NR43The Mark3 Index is 94: **Mississippi Valley, minor**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

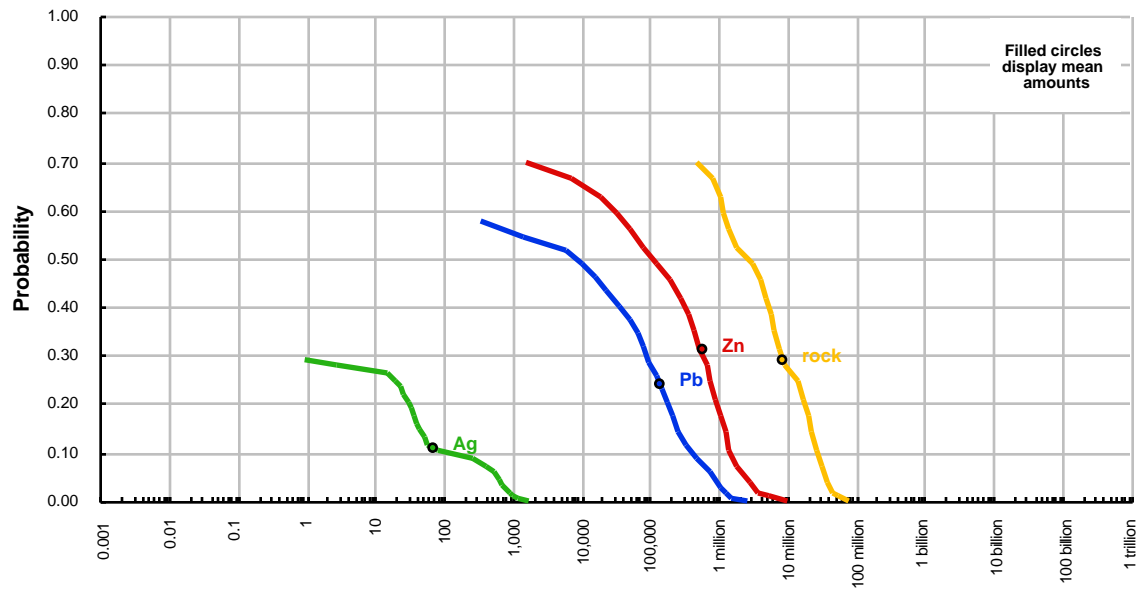
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

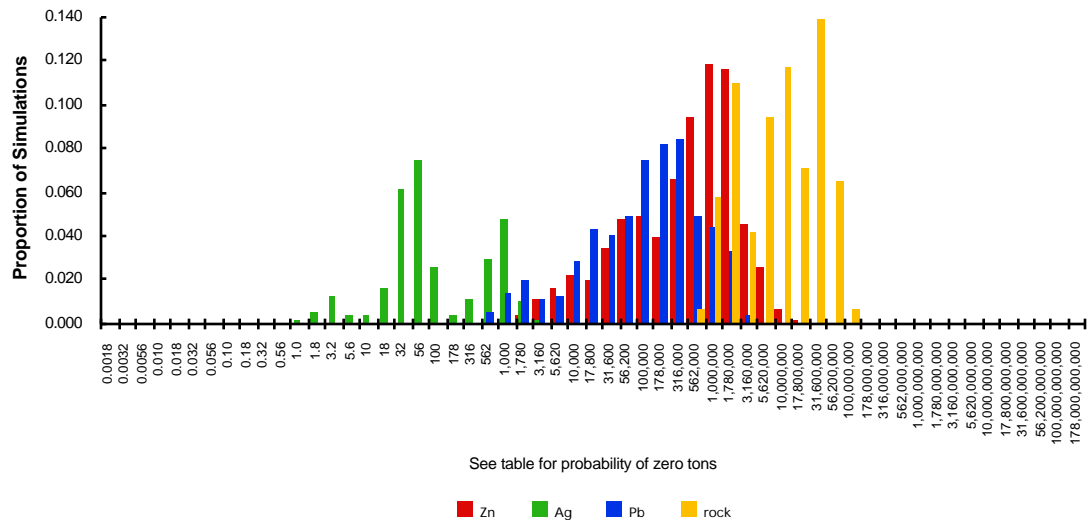
quantile	Zn	Ag	Pb	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	100,000	0	8,700	2,600,000
0.10	1,500,000	89	421,000	28,000,000
0.05	2,400,000	600	840,000	34,000,000
mean	550,000	67	140,000	8,800,000
Probability of mean	0.31	0.11	0.24	0.29
Probability of zero	0.30	0.71	0.42	0.30

The tract ID is NR43

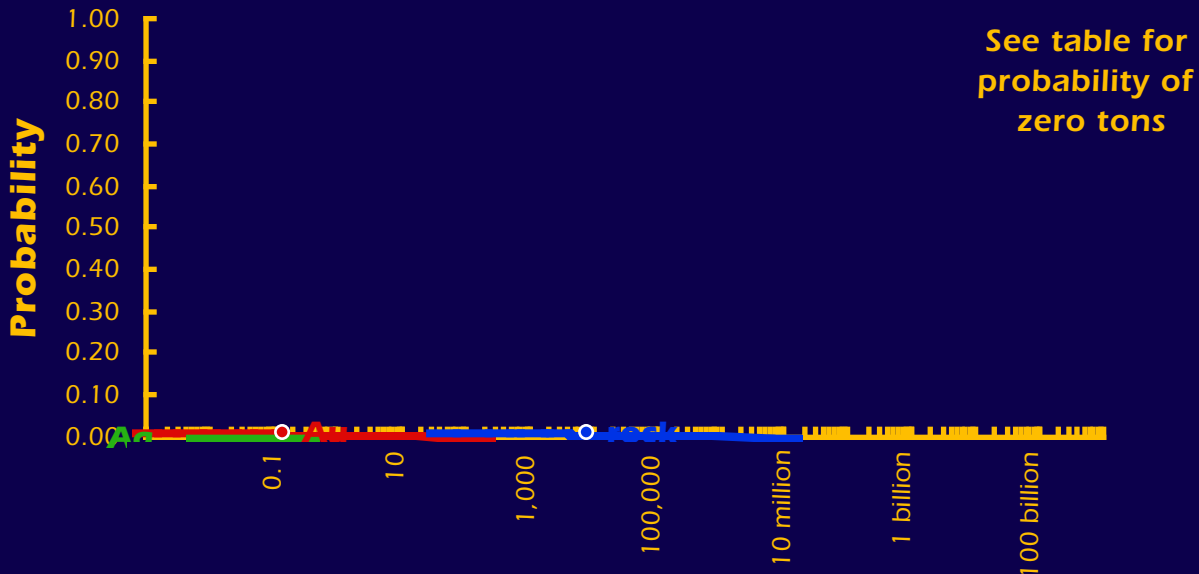
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

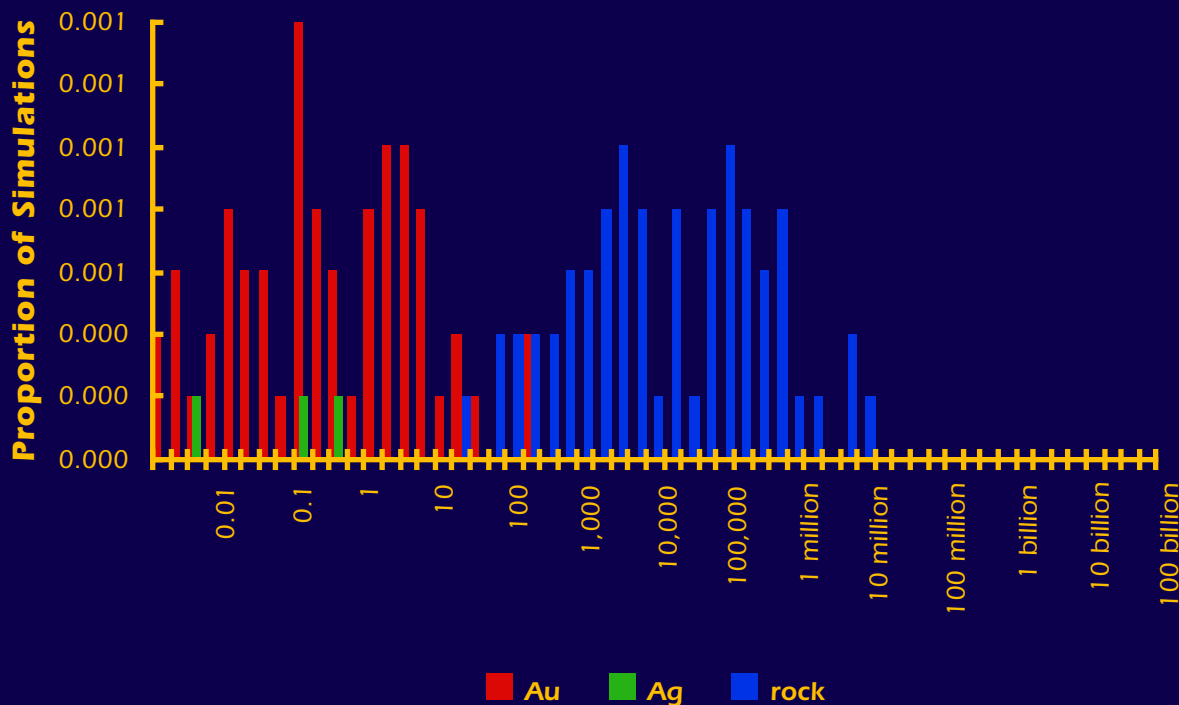


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR44

The Mark3 Index is 27:

Low sulfide Au-quartz vein

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	0	0
0.05	0	0	0
mean	0	0	7,600
Probability of mean	0.01	0.00	0.01
Probability of zero	0.99	1.00	0.99

The tract ID is NR44

The Mark3 Index is 27: **Low sulfide Au-quartz vein**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

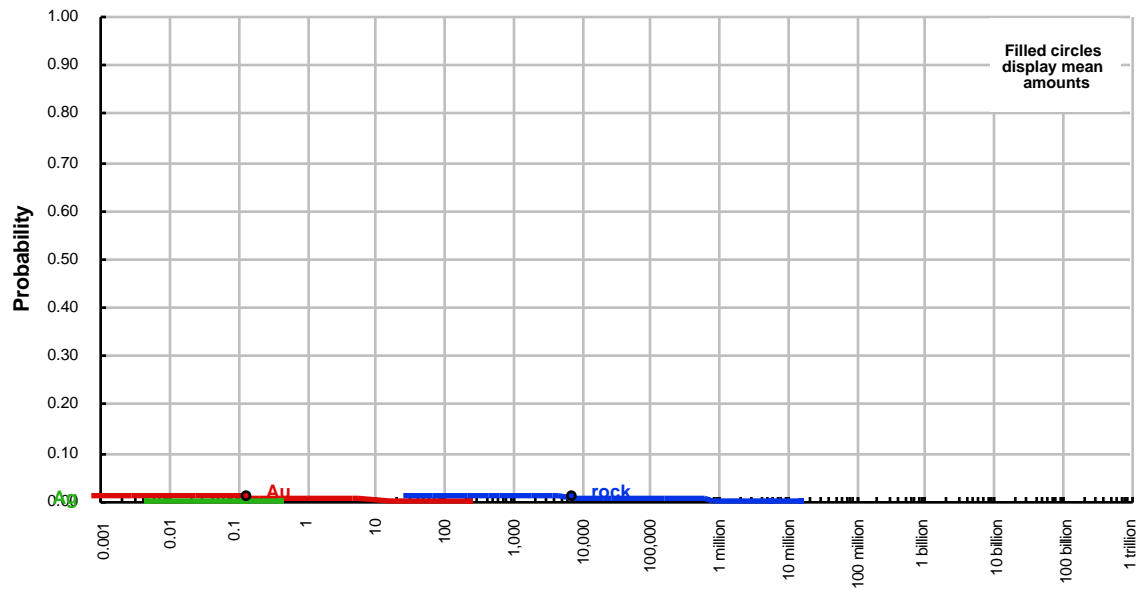
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

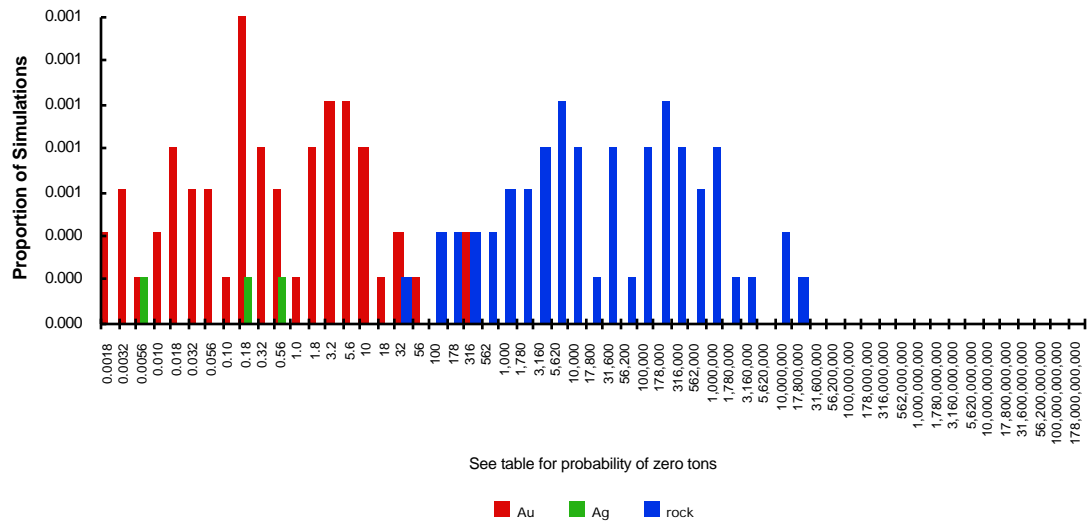
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	0	0
0.05	0	0	0
mean	0	0	7,600
Probability of mean	0.01	0.00	0.01
Probability of zero	0.99	1.00	0.99

The tract ID is NR44

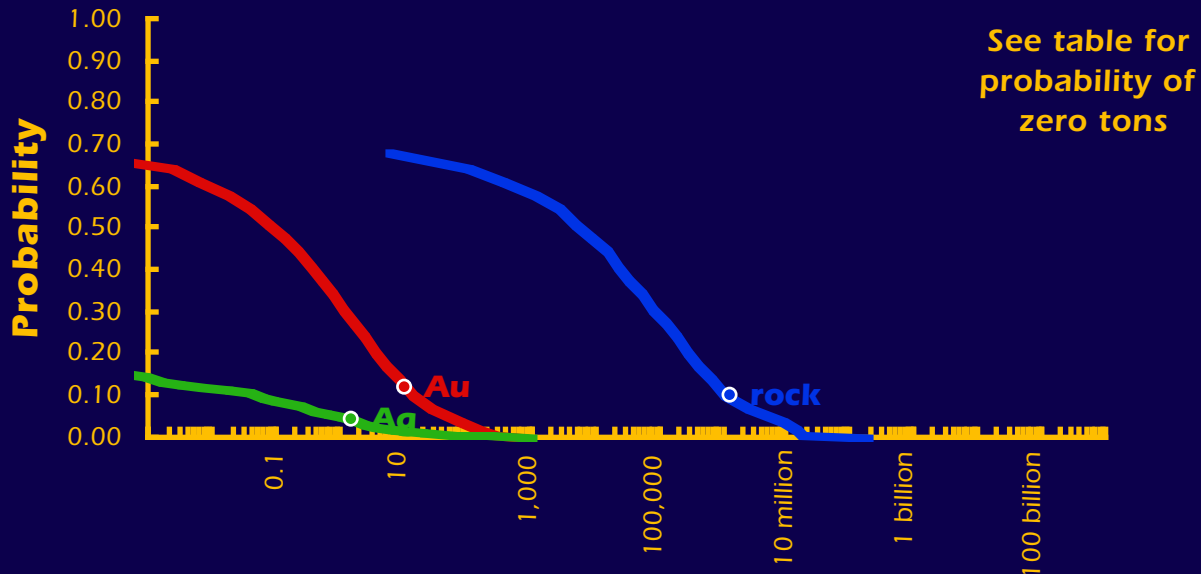
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

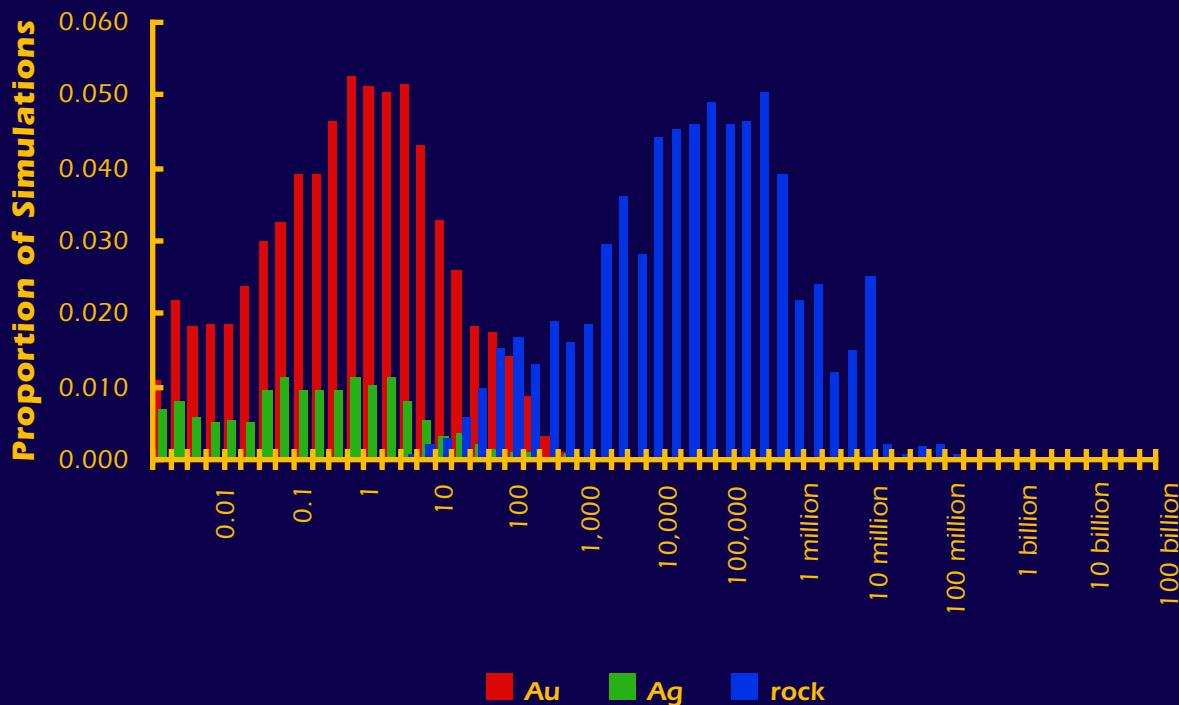


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR45

The Mark3 Index is 27:

Low sulfide Au-quartz vein

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	5,400
0.10	14	0	1,120,000
0.05	46	1	4,800,000
mean	10	1	1,200,000
Probability of mean	0.12	0.04	0.10
Probability of zero	0.32	0.84	0.32

The tract ID is NR45The Mark3 Index is 27: **Low sulfide Au-quartz vein**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

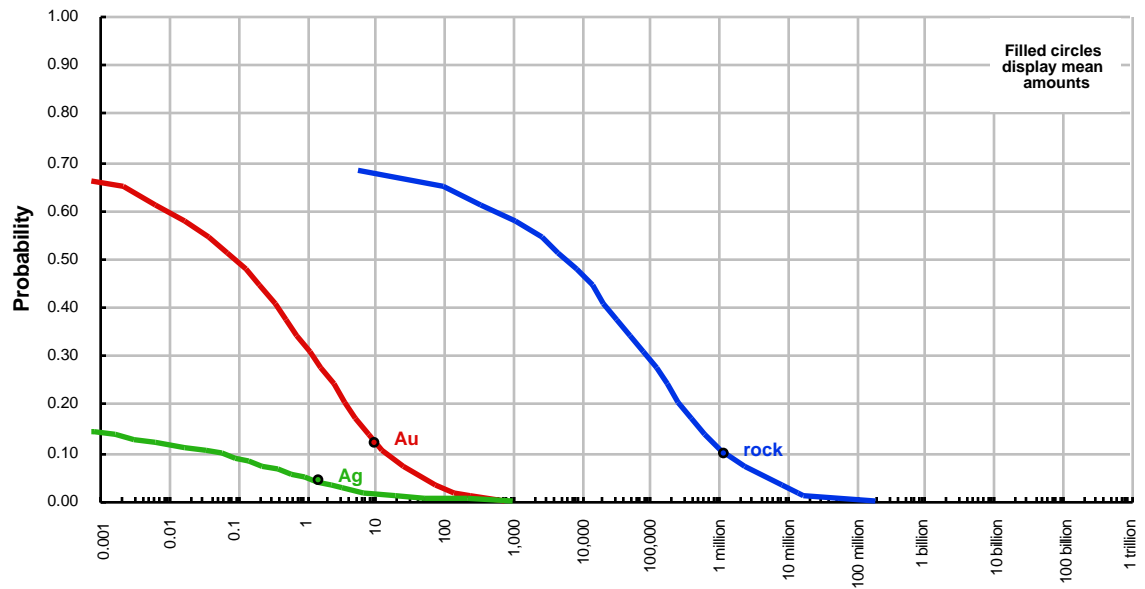
There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

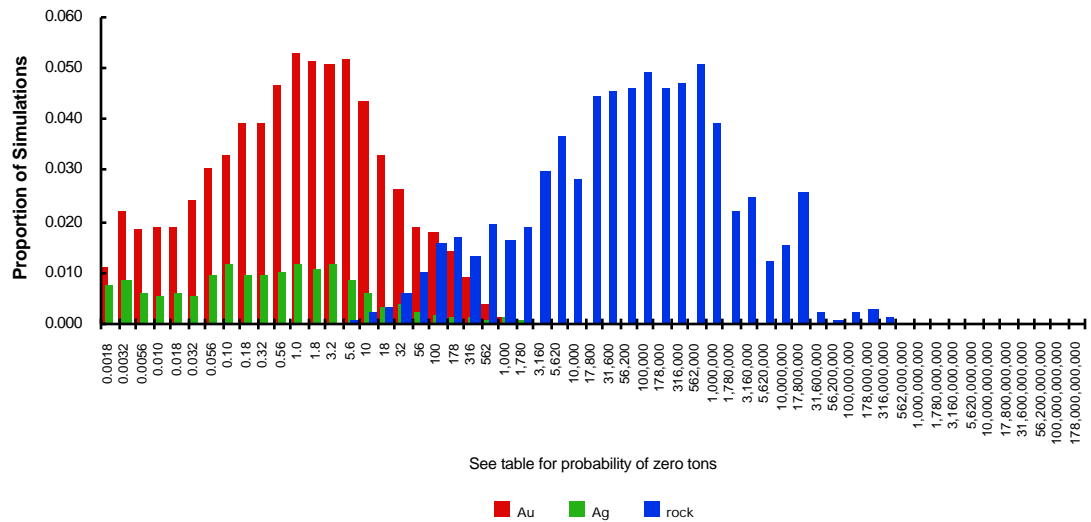
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	5,400
0.10	14	0	1,120,000
0.05	46	1	4,800,000
mean	10	1	1,200,000
Probability of mean	0.12	0.04	0.10
Probability of zero	0.32	0.84	0.32

The tract ID is NR45

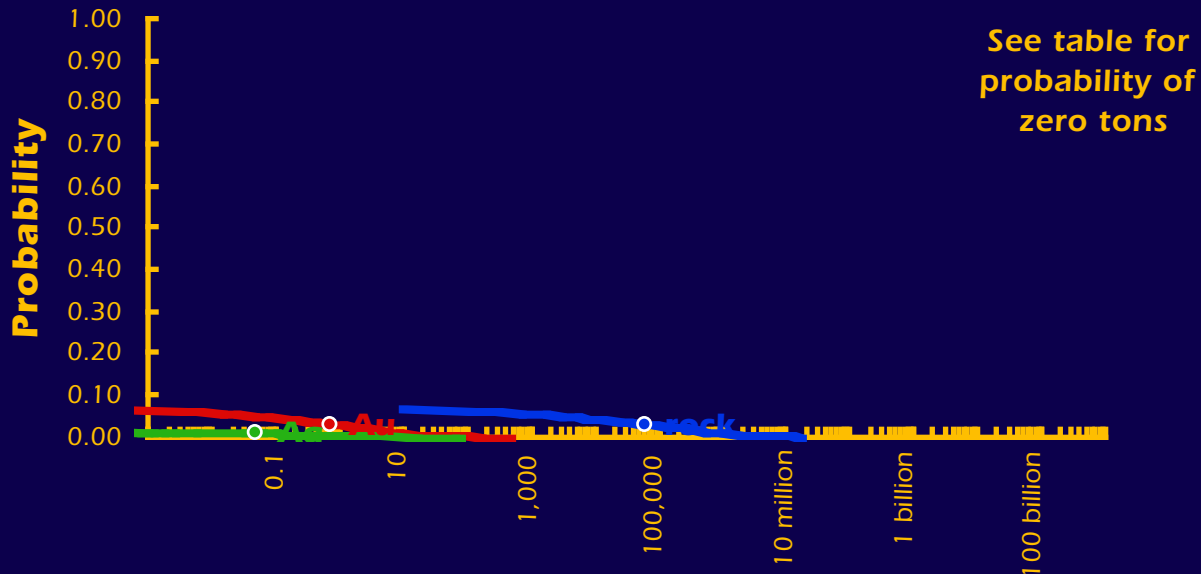
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

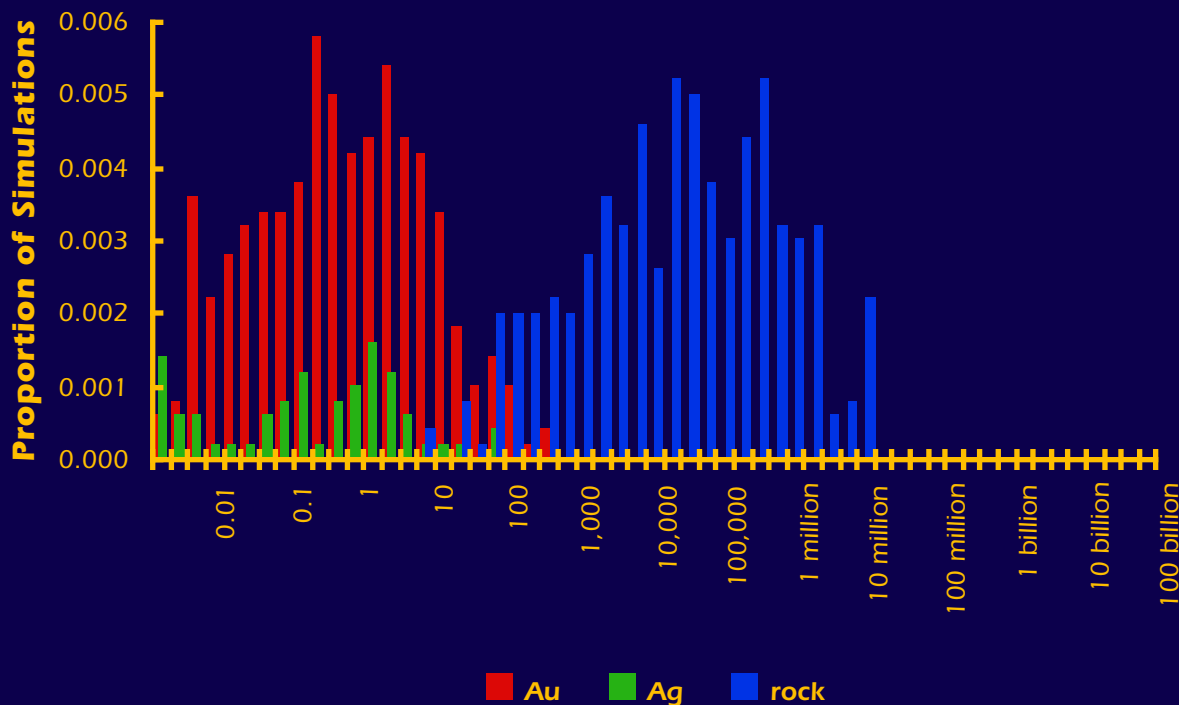


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR46

The Mark3 Index is 27:

Low sulfide Au-quartz vein

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	0	0
0.05	0	0	3,400
mean	1	0	58,000
Probability of mean	0.03	0.01	0.03
Probability of zero	0.93	0.99	0.93

The tract ID is NR46The Mark3 Index is 27: **Low sulfide Au-quartz vein**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

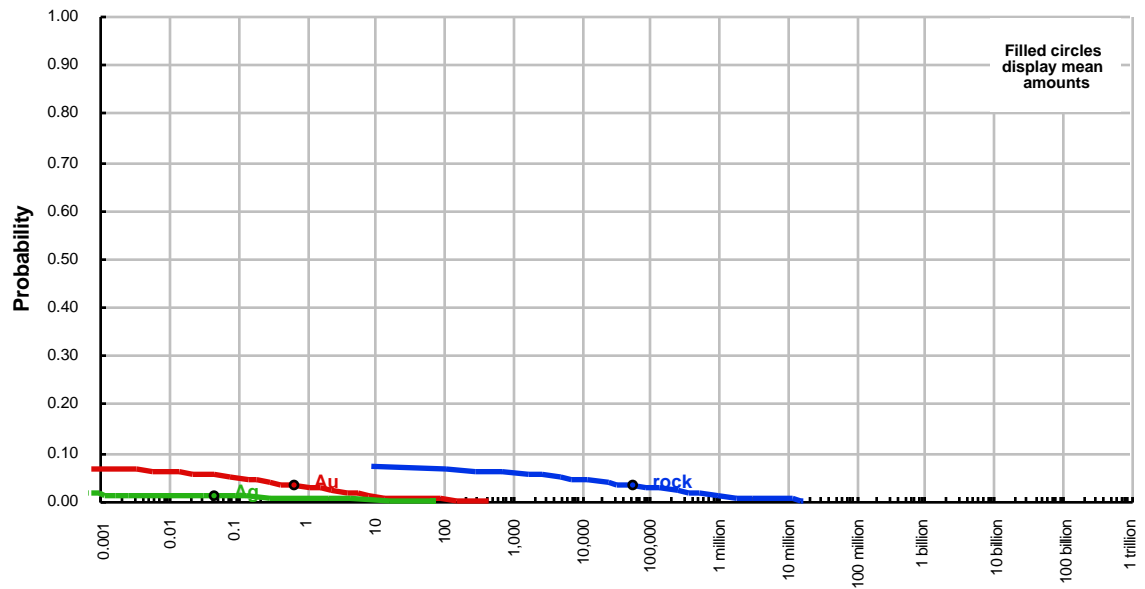
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

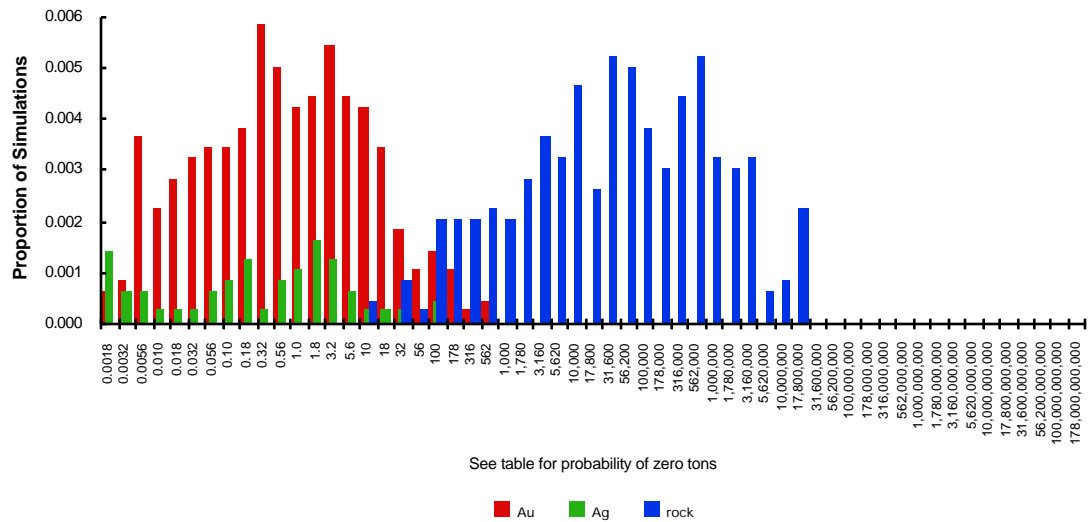
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	0	0
0.05	0	0	3,400
mean	1	0	58,000
Probability of mean	0.03	0.01	0.03
Probability of zero	0.93	0.99	0.93

The tract ID is NR46

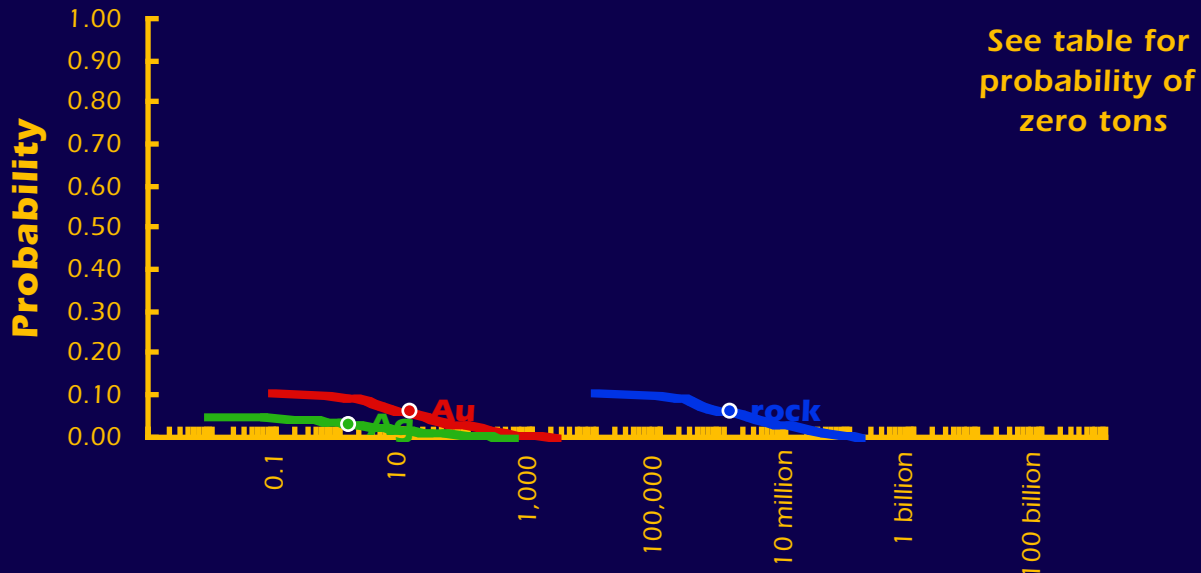
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

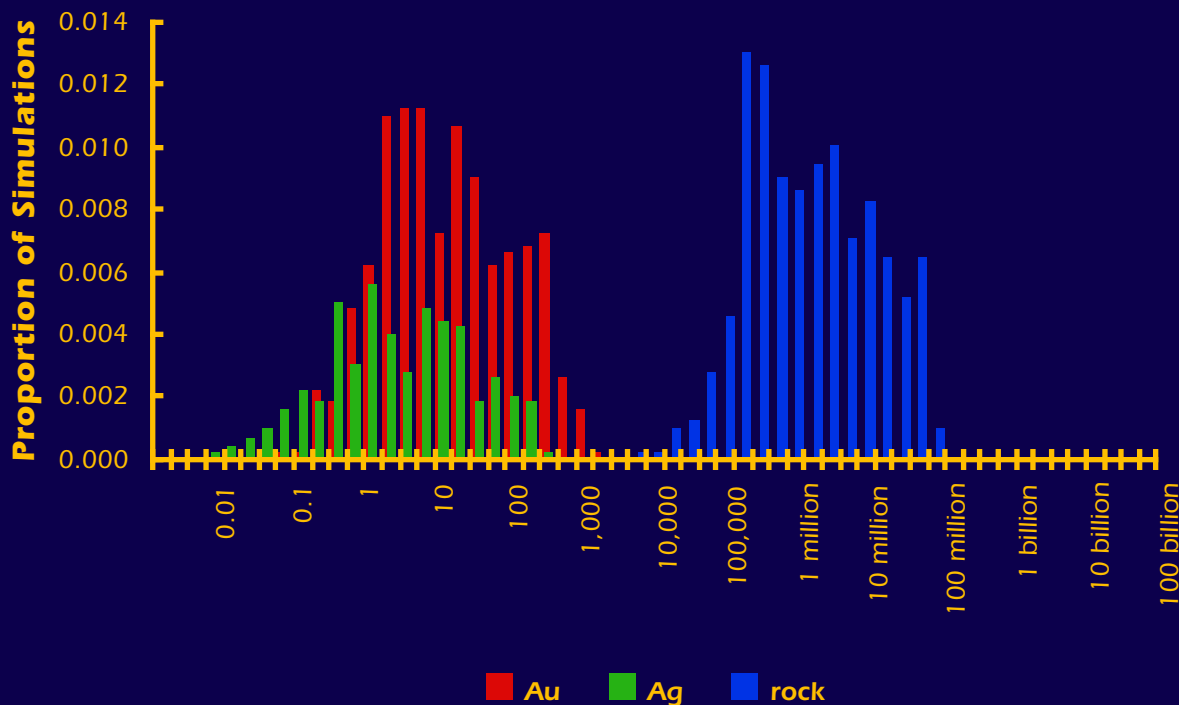


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR47

The Mark3 Index is 101:

Low-sulfide Au-quartz, Archean

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	1	0	135,000
0.05	18	0	2,200,000
mean	12	1	1,200,000
Probability of mean	0.06	0.03	0.06
Probability of zero	0.89	0.95	0.89

The tract ID is NR47

The Mark3 Index is 101: **Low-sulfide Au-quartz, Archean**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

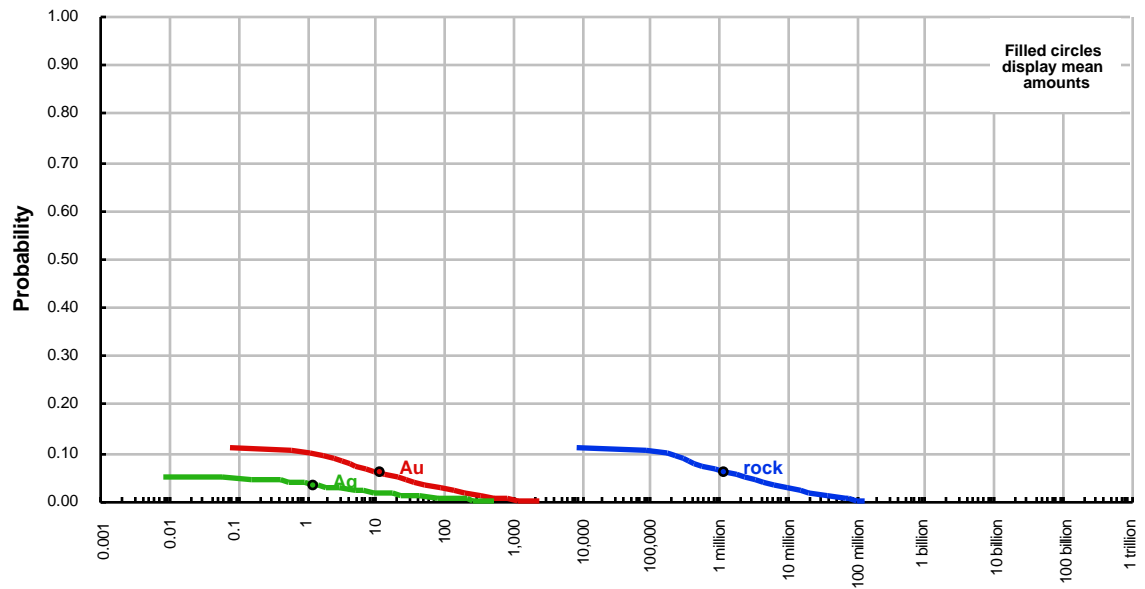
There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

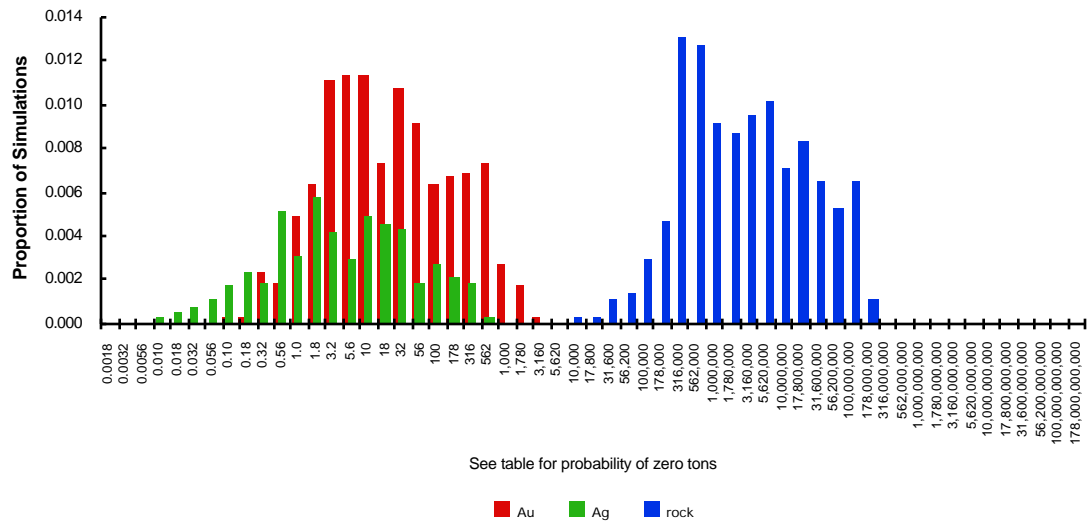
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	1	0	135,000
0.05	18	0	2,200,000
mean	12	1	1,200,000
Probability of mean	0.06	0.03	0.06
Probability of zero	0.89	0.95	0.89

The tract ID is NR47

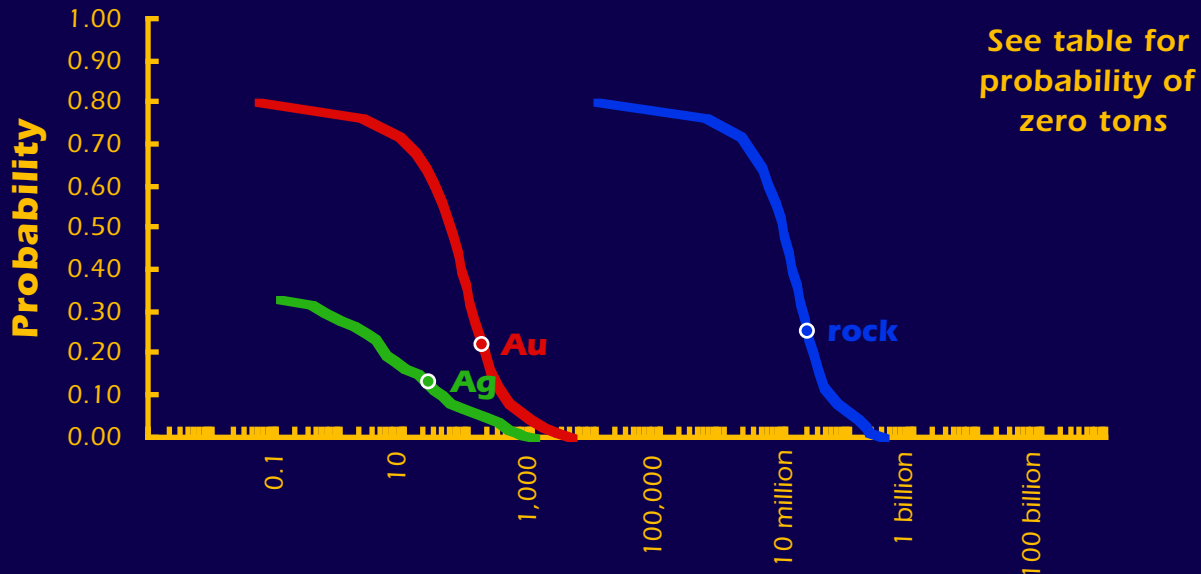
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)



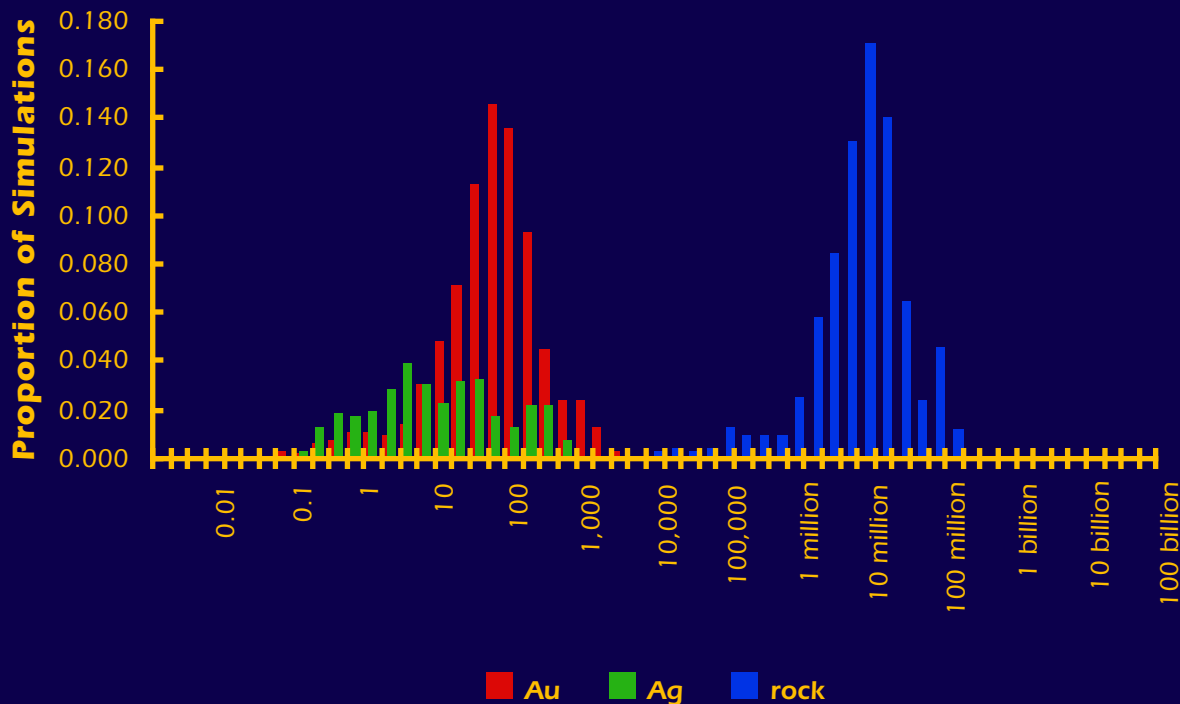
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



See table for
probability of
zero tons

Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR48

The Mark3 Index is 100:

Homestake stratiform gold

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

There is a 1% or greater chance of 6 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	52	0	8,400,000
0.10	330	39	42,000,000
0.05	720	170	120,000,000
mean	160	25	21,000,000
Probability of mean	0.22	0.13	0.25
Probability of zero	0.20	0.67	0.20

The tract ID is NR48The Mark3 Index is 100: **Homestake stratiform gold**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

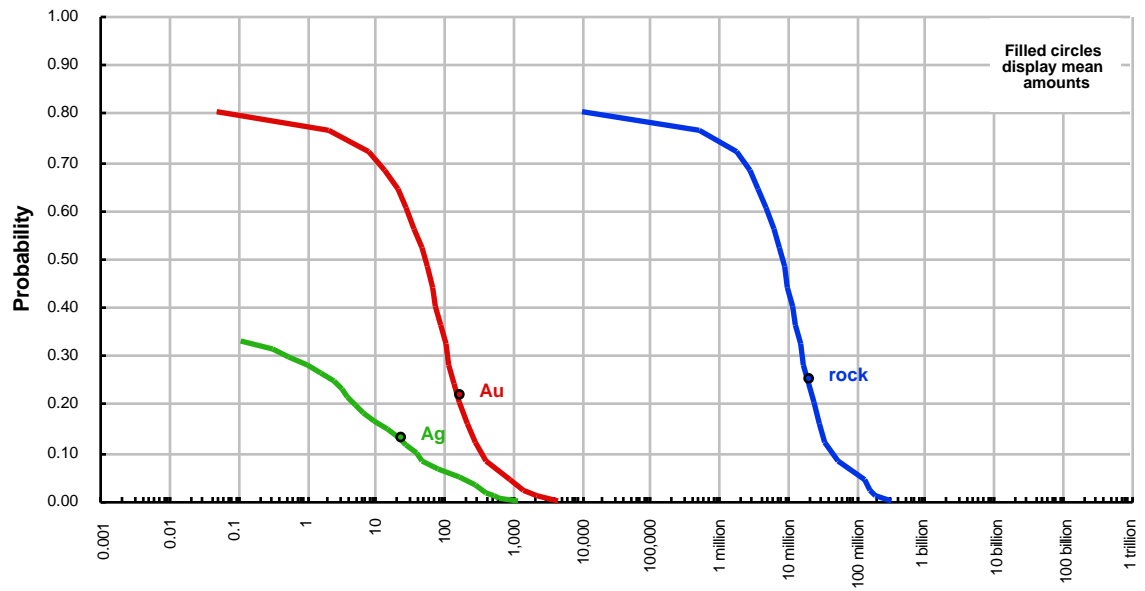
There is a 1% or greater chance of 6 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

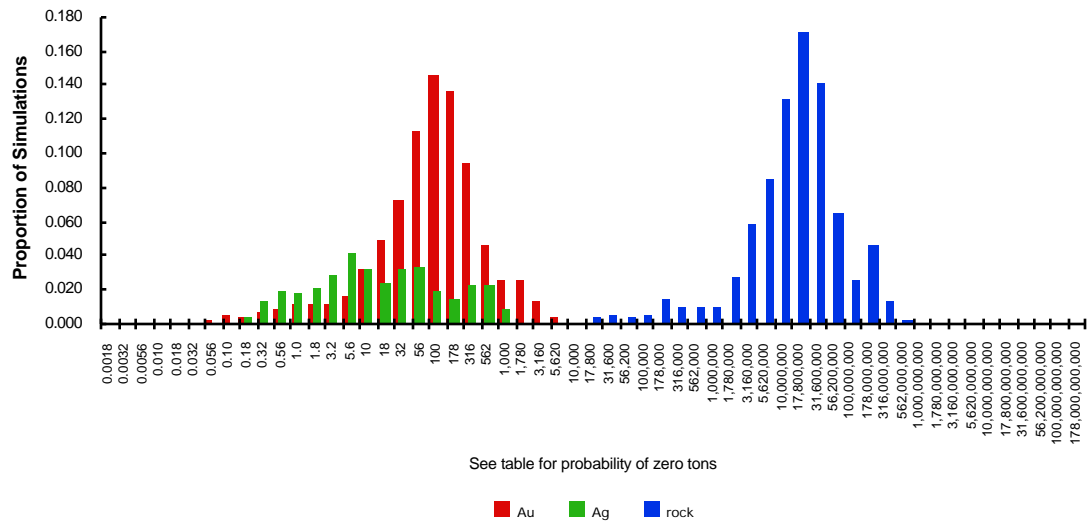
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	52	0	8,400,000
0.10	330	39	42,000,000
0.05	720	170	120,000,000
mean	160	25	21,000,000
Probability of mean	0.22	0.13	0.25
Probability of zero	0.20	0.67	0.20

The tract ID is NR48

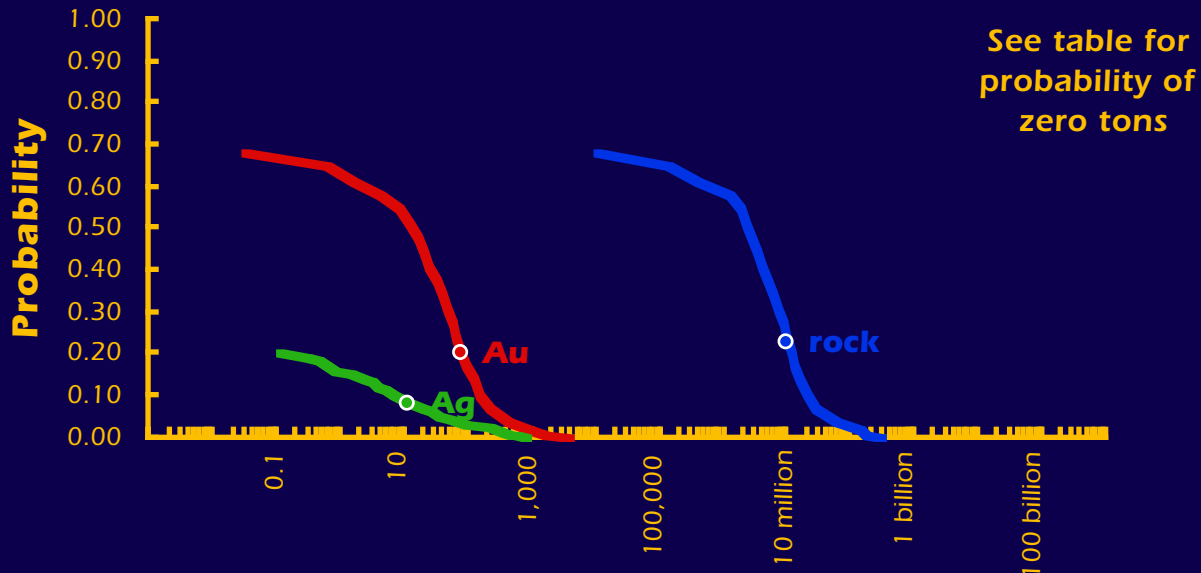
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

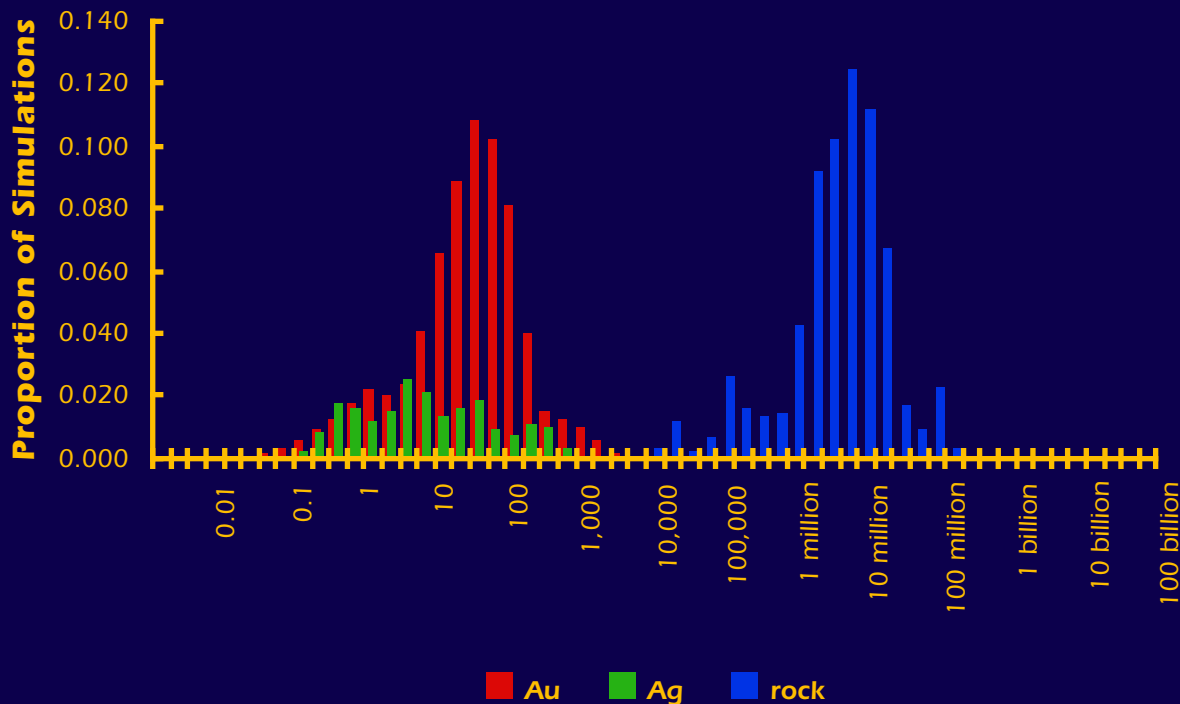


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR49

The Mark3 Index is 100:

Homestake stratiform gold

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	13	0	2,500,000
0.10	150	7	20,200,000
0.05	280	36	32,000,000
mean	79	11	10,000,000
Probability of mean	0.20	0.08	0.23
Probability of zero	0.32	0.80	0.32

The tract ID is NR49The Mark3 Index is 100: **Homestake stratiform gold**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

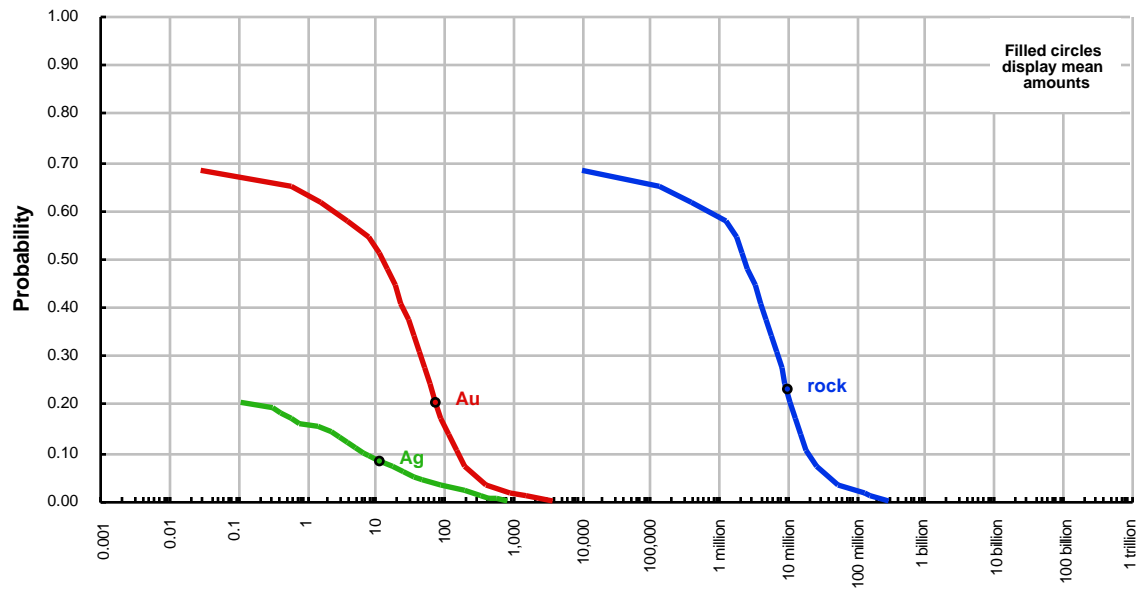
There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

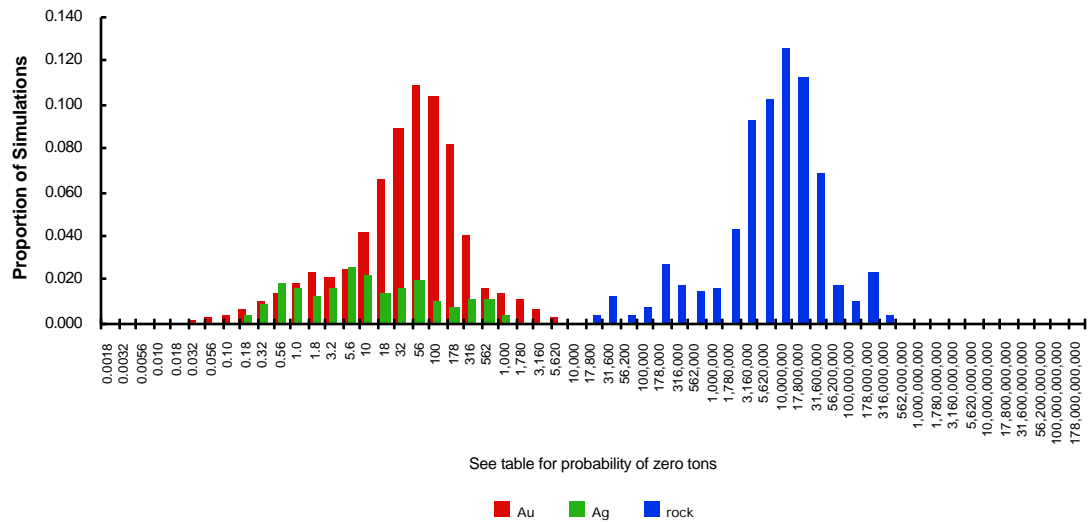
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	13	0	2,500,000
0.10	150	7	20,200,000
0.05	280	36	32,000,000
mean	79	11	10,000,000
Probability of mean	0.20	0.08	0.23
Probability of zero	0.32	0.80	0.32

The tract ID is NR49

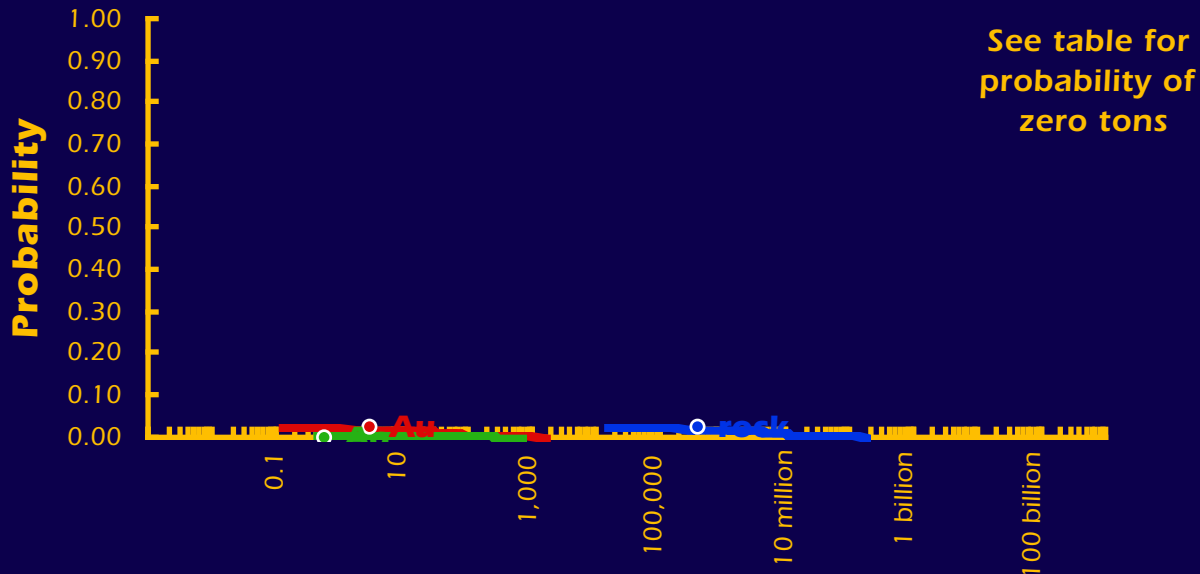
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

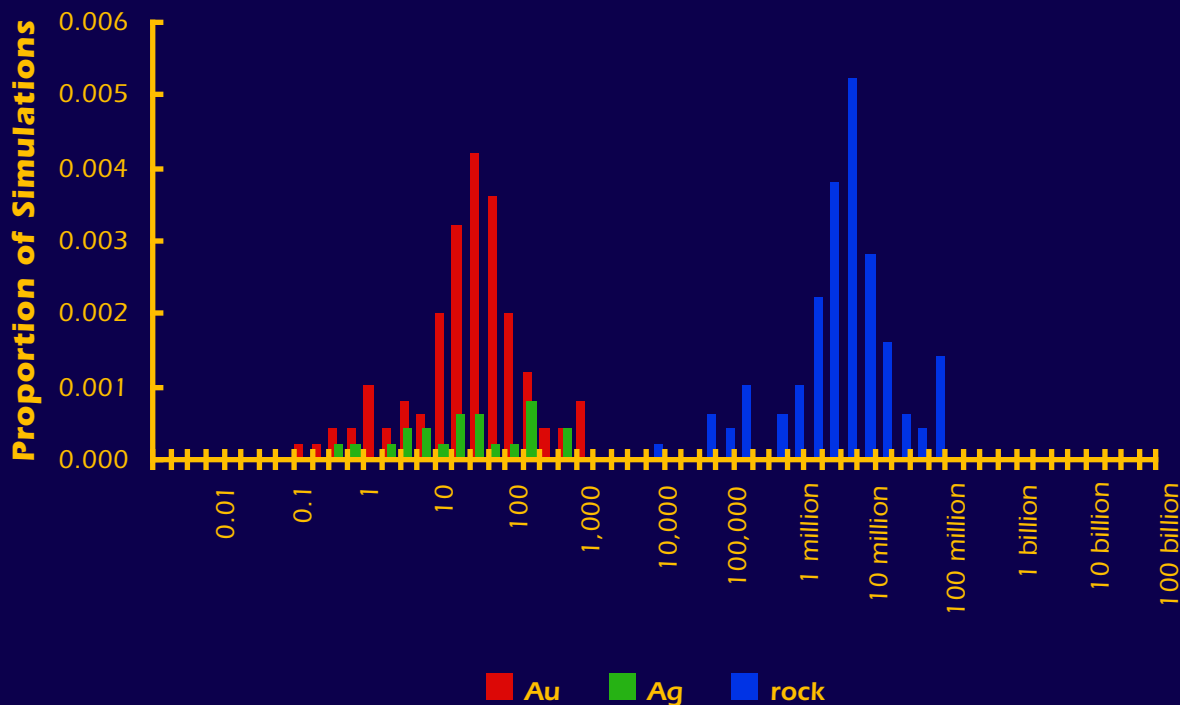


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is NR50

The Mark3 Index is 100:

Homestake stratiform gold

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	0	0
0.05	0	0	0
mean	3	1	390,000
Probability of mean	0.02	0.00	0.02
Probability of zero	0.98	1.00	0.98

The tract ID is NR50The Mark3 Index is 100: **Homestake stratiform gold**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

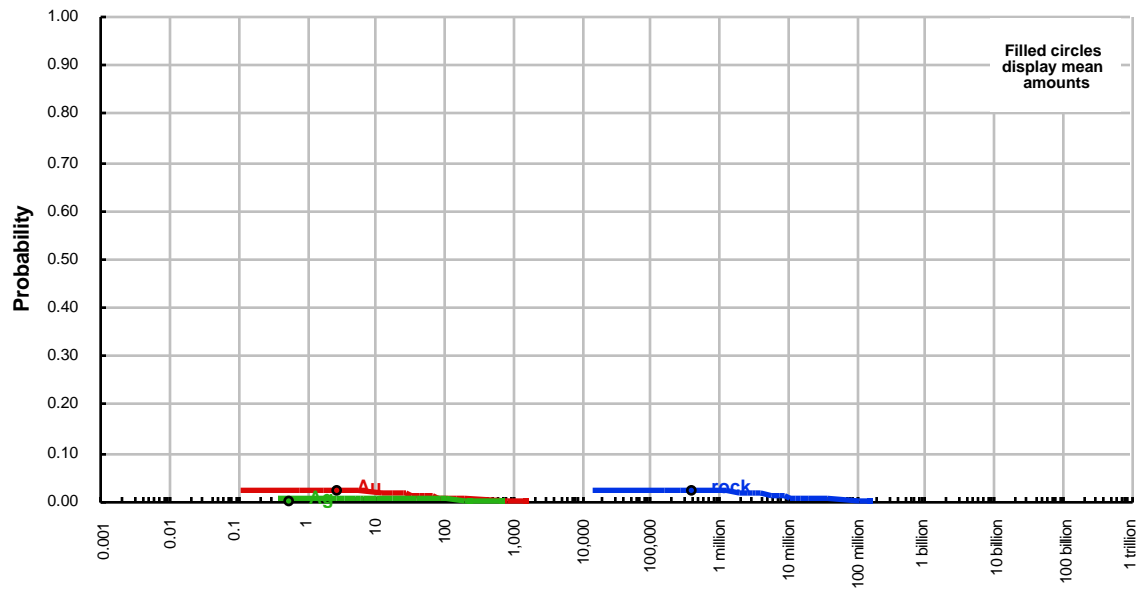
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

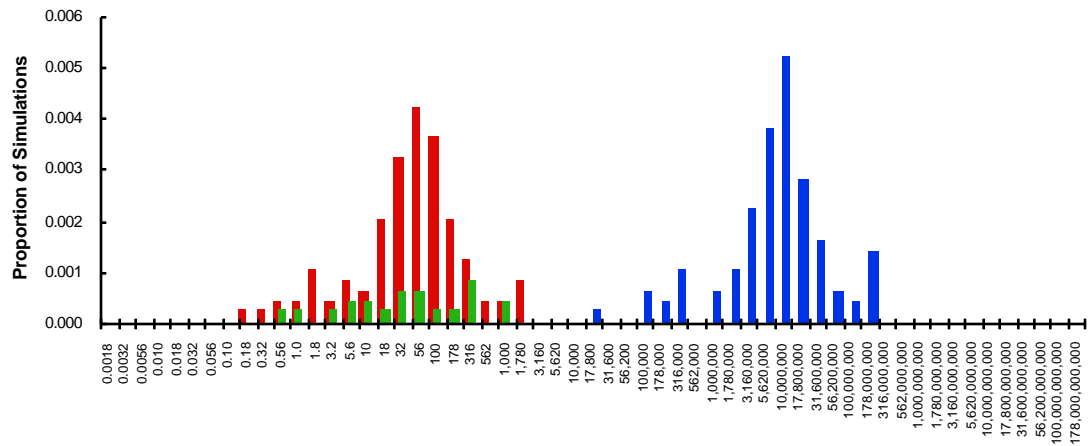
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	0	0
0.05	0	0	0
mean	3	1	390,000
Probability of mean	0.02	0.00	0.02
Probability of zero	0.98	1.00	0.98

The tract ID is NR50

Cumulative Distributions of Contained Metal and Mineralized Rock



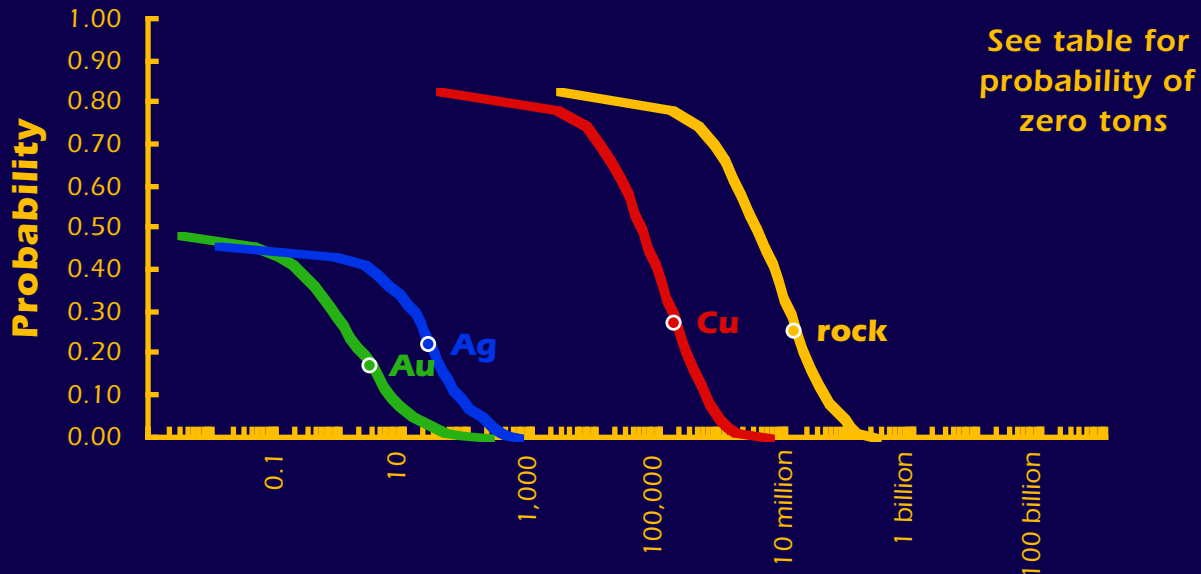
Histograms of Contained Metal and Mineralized Rock (metric tons)



See table for probability of zero tons

Au Ag rock

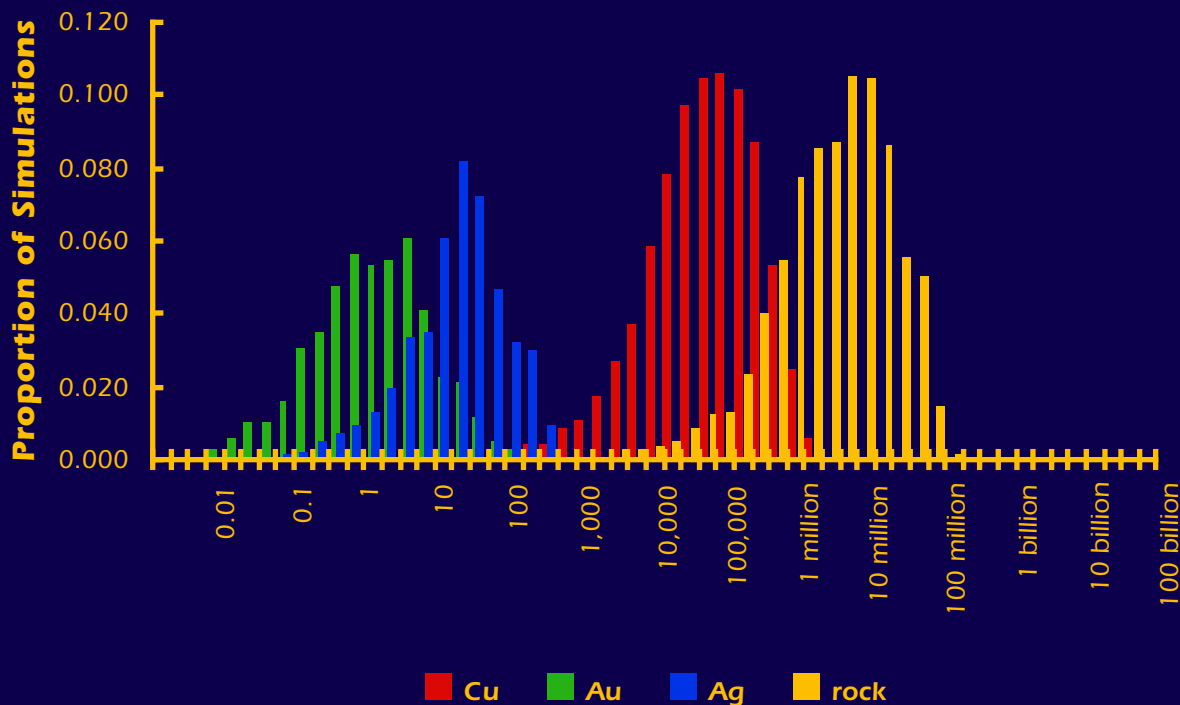
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



See table for
probability of
zero tons

Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC01

The Mark3 Index is 8:

Skarn Cu

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 9 or more deposits.

There is a 1% or greater chance of 12 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	51,000	0	0	3,200,000
0.10	500,000	6	66	38,000,000
0.05	780,000	13	140	71,000,000
mean	170,000	3	25	13,000,000
Probability of mean	0.27	0.17	0.22	0.25
Probability of zero	0.17	0.52	0.54	0.17

The tract ID is PC01The Mark3 Index is 8: **Skarn Cu**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 9 or more deposits.

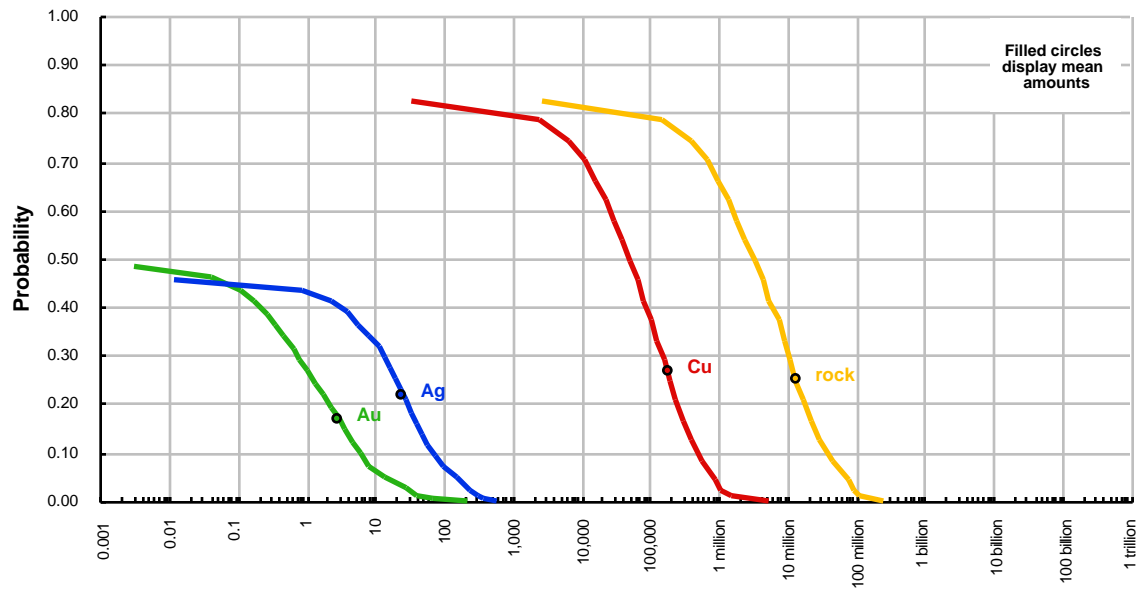
There is a 1% or greater chance of 12 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

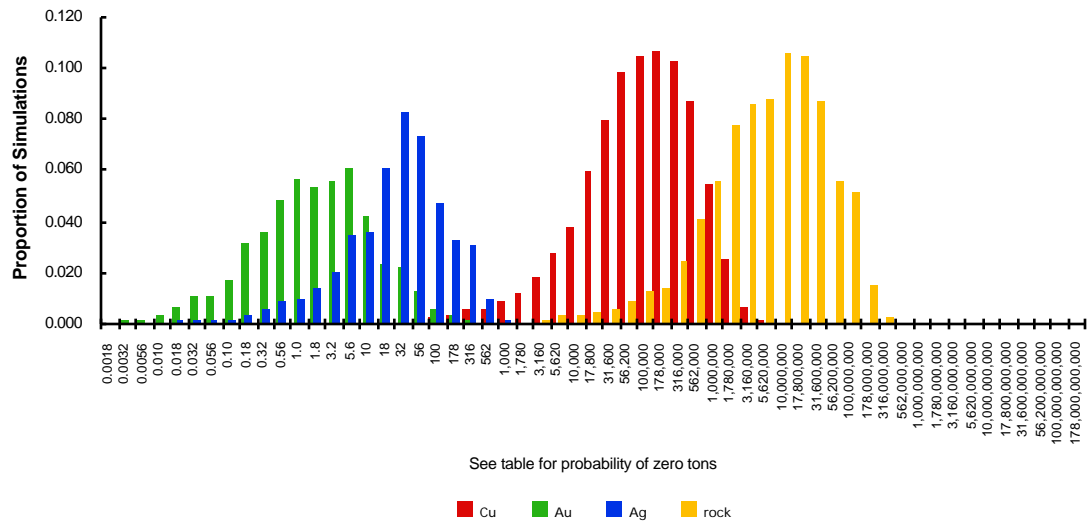
quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	51,000	0	0	3,200,000
0.10	500,000	6	66	38,000,000
0.05	780,000	13	140	71,000,000
mean	170,000	3	25	13,000,000
Probability of mean	0.27	0.17	0.22	0.25
Probability of zero	0.17	0.52	0.54	0.17

The tract ID is PC01

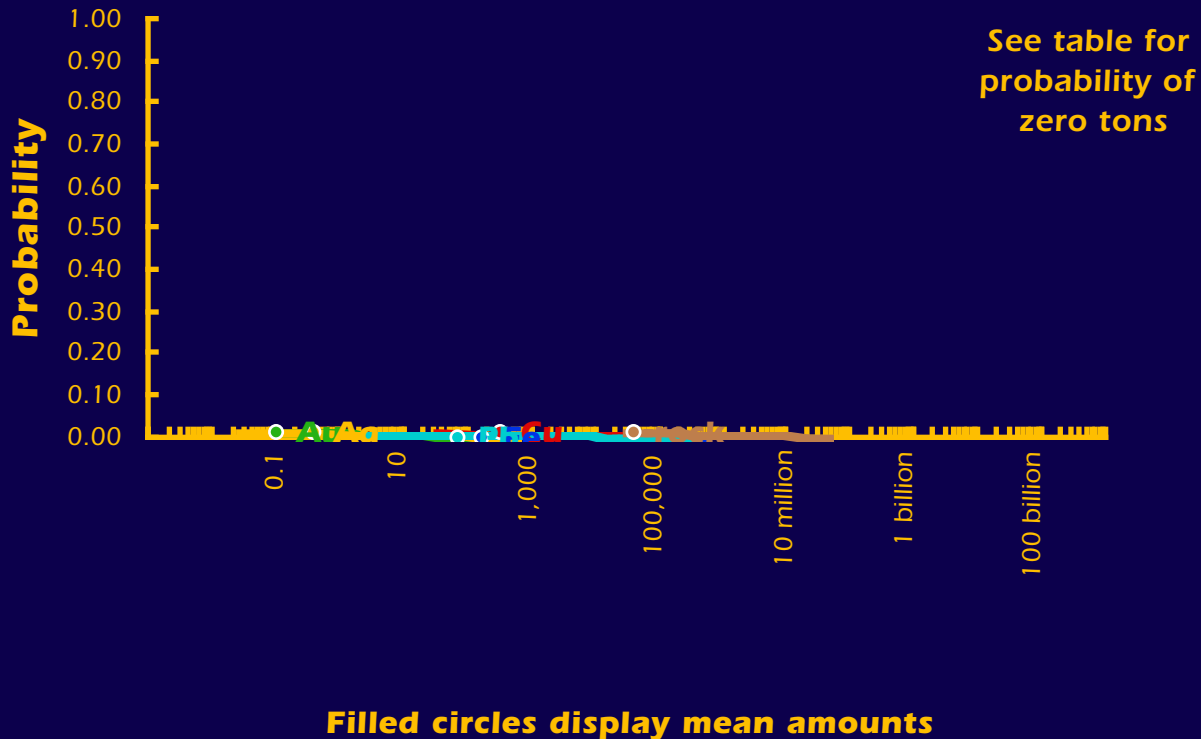
Cumulative Distributions of Contained Metal and Mineralized Rock



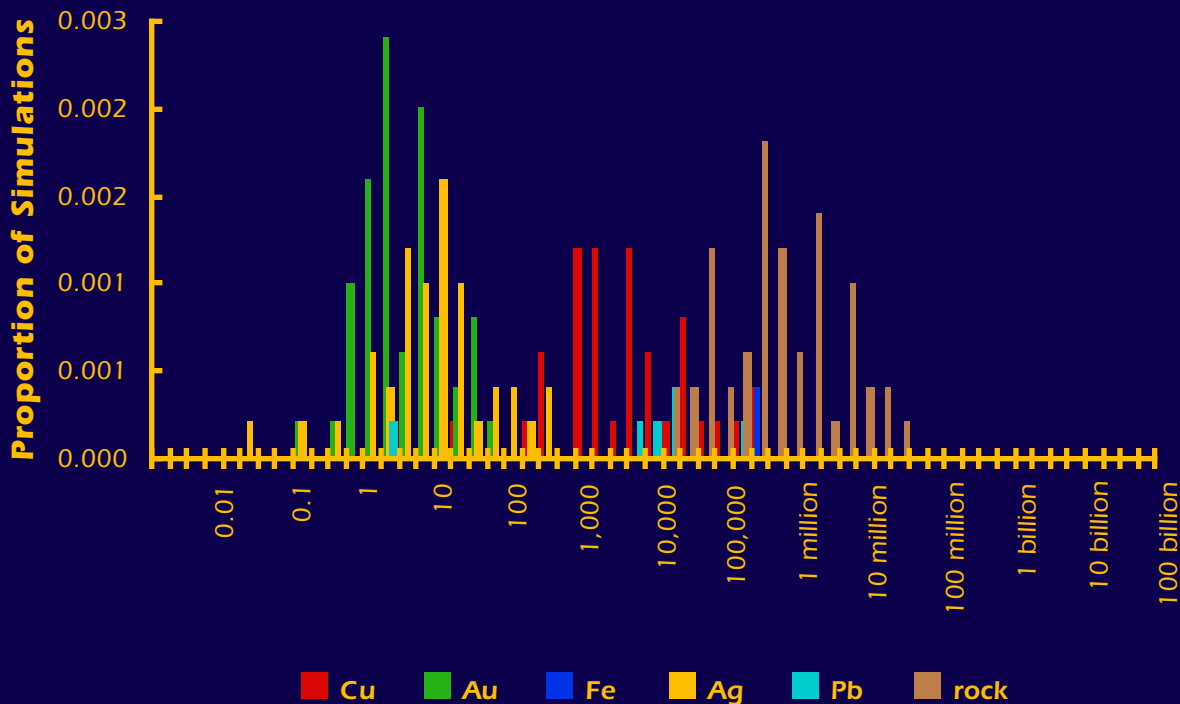
Histograms of Contained Metal and Mineralized Rock (metric tons)



Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC02

The Mark3 Index is 105:

Skarn Au, truncated

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Fe	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	310	0	170	0	66	38,000
Probability of mean	0.01	0.01	0.00	0.01	0.00	0.01
Probability of zero	0.99	0.99	1.00	0.99	1.00	0.99

The tract ID is PC02The Mark3 Index is 105: **Skarn Au, truncated**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

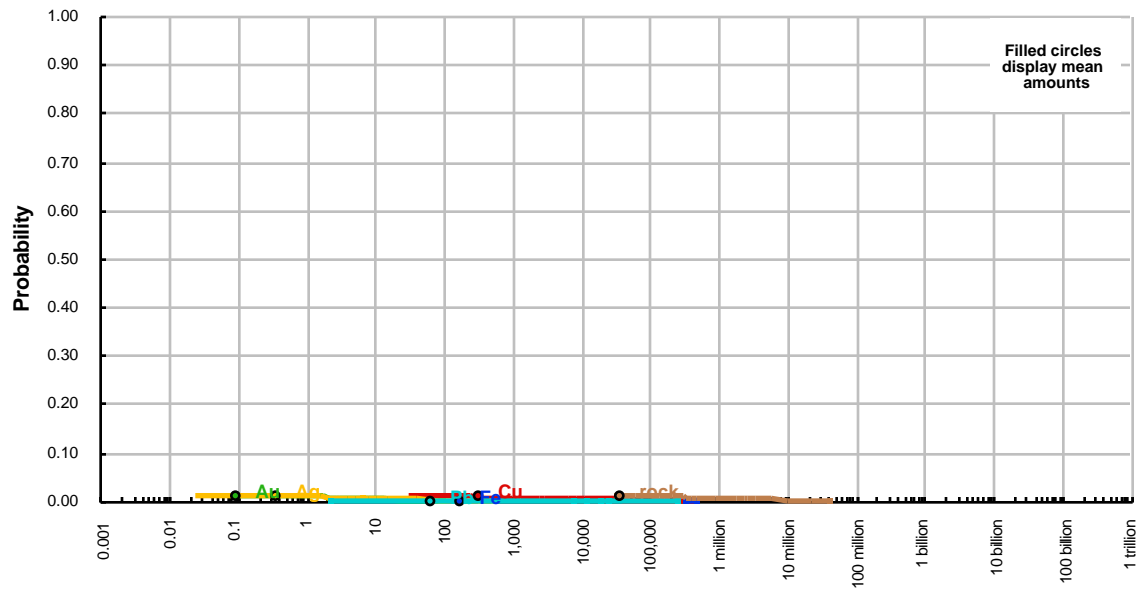
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

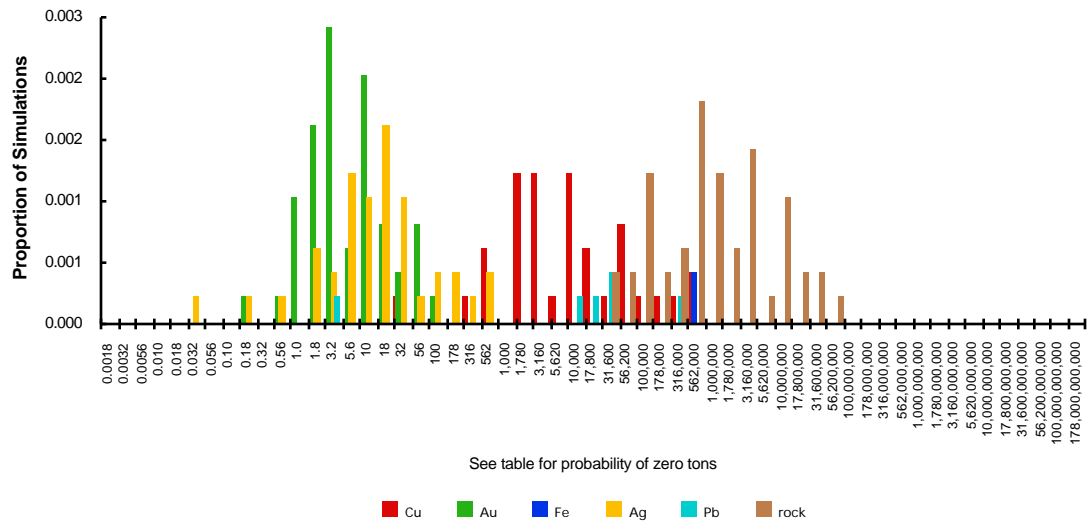
quantile	Cu	Au	Fe	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	310	0	170	0	66	38,000
Probability of mean	0.01	0.01	0.00	0.01	0.00	0.01
Probability of zero	0.99	0.99	1.00	0.99	1.00	0.99

The tract ID is PC02

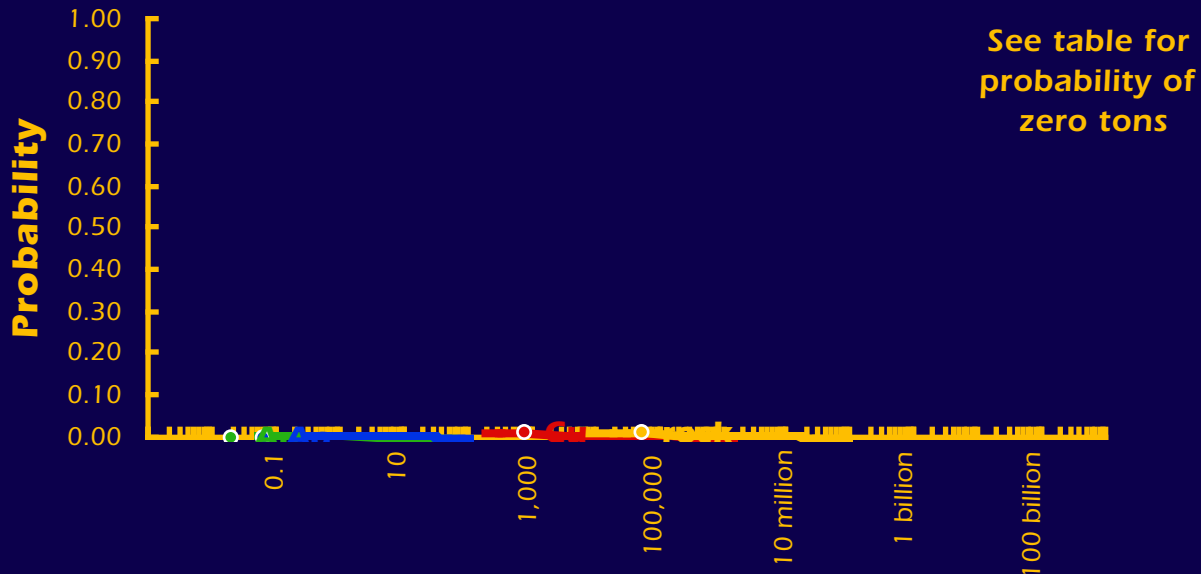
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

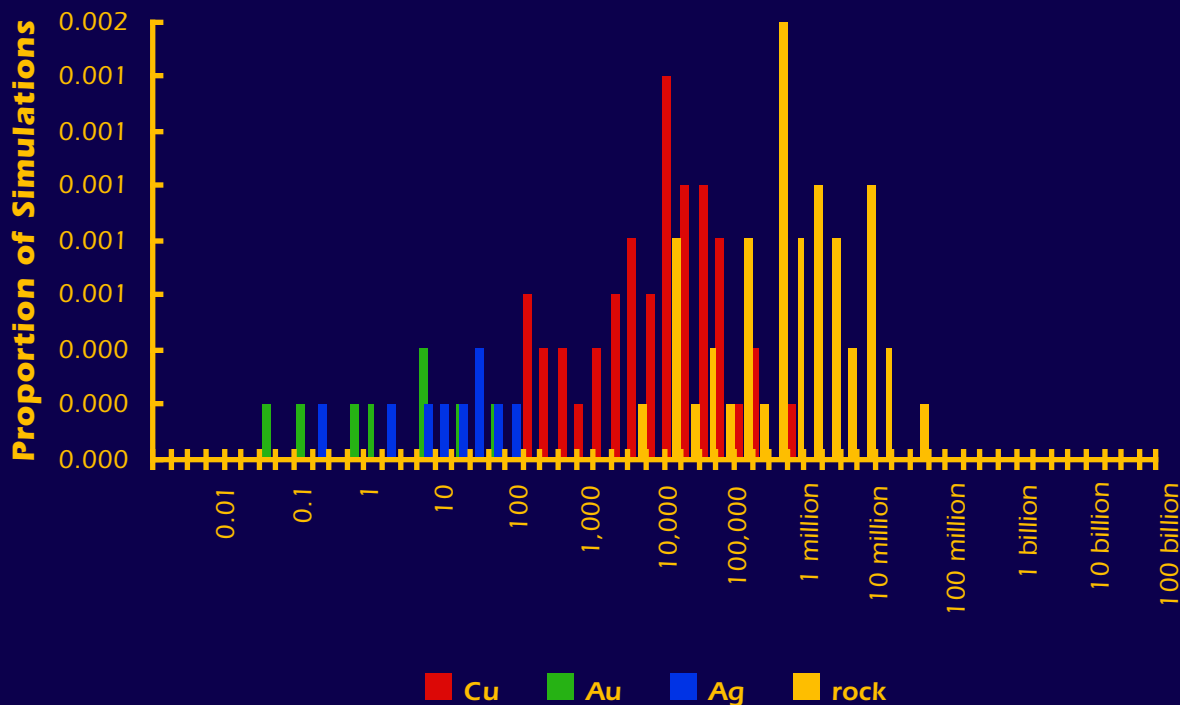


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC03

The Mark3 Index is 8:

Skarn Cu

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Ag	rock	0	0
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	760	0	0	53,000	0	0
Probability of mean	0.01	0.00	0.00	0.01	0.00	0.00
Probability of zero	0.99	1.00	1.00	0.99	0.00	0.00

The tract ID is PC03The Mark3 Index is 8: **Skarn Cu**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

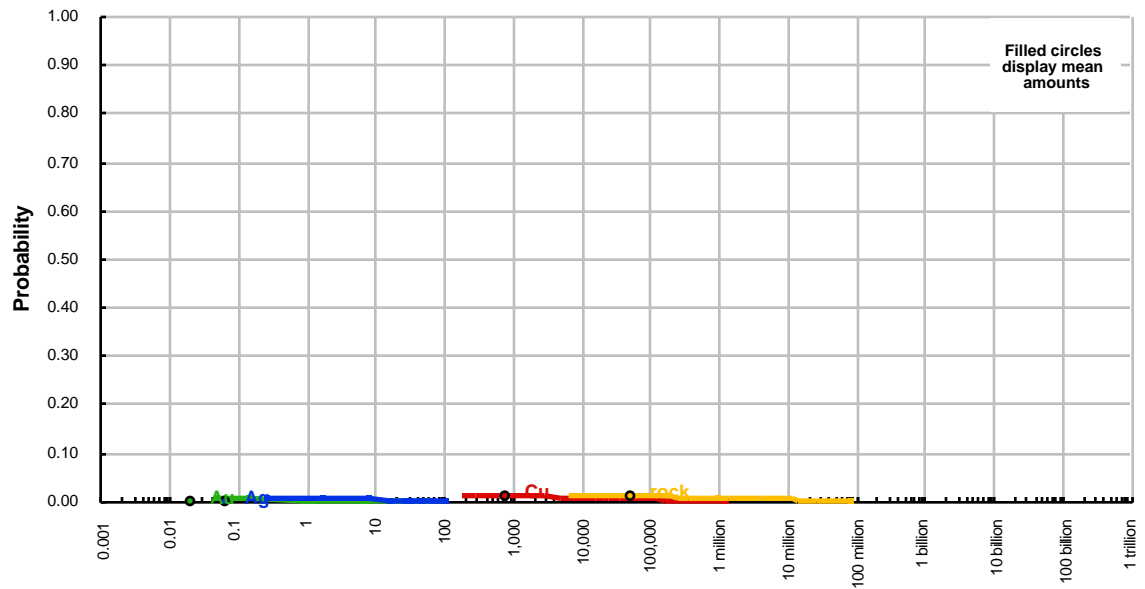
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

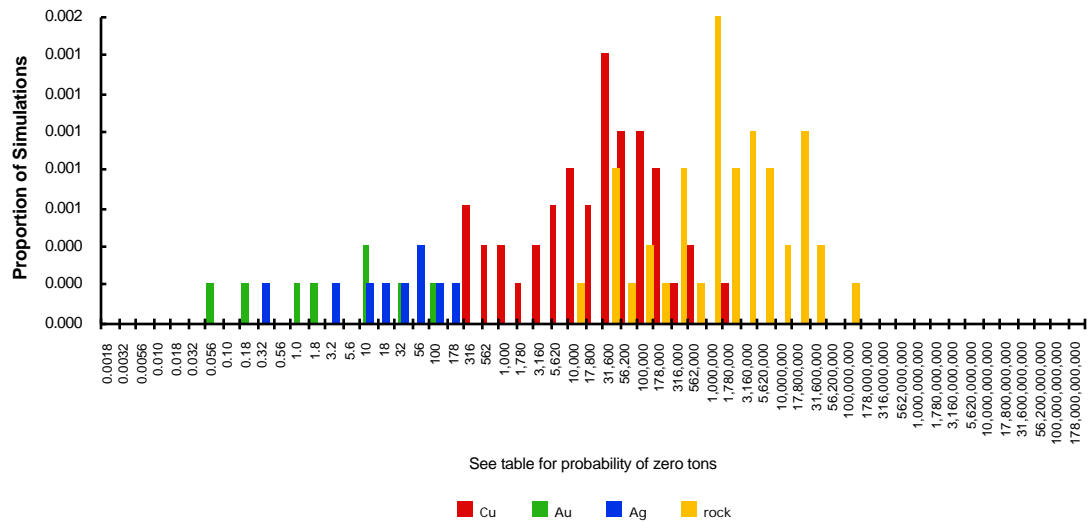
quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	0	0	0	0
mean	760	0	0	53,000
Probability of mean	0.01	0.00	0.00	0.01
Probability of zero	0.99	1.00	1.00	0.99

The tract ID is PC03

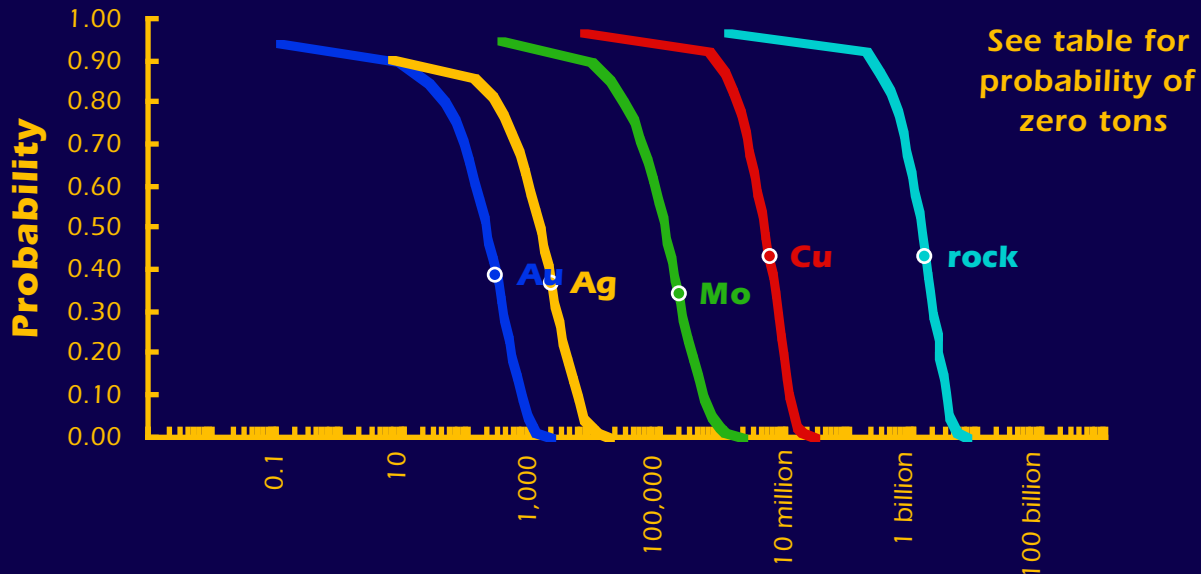
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

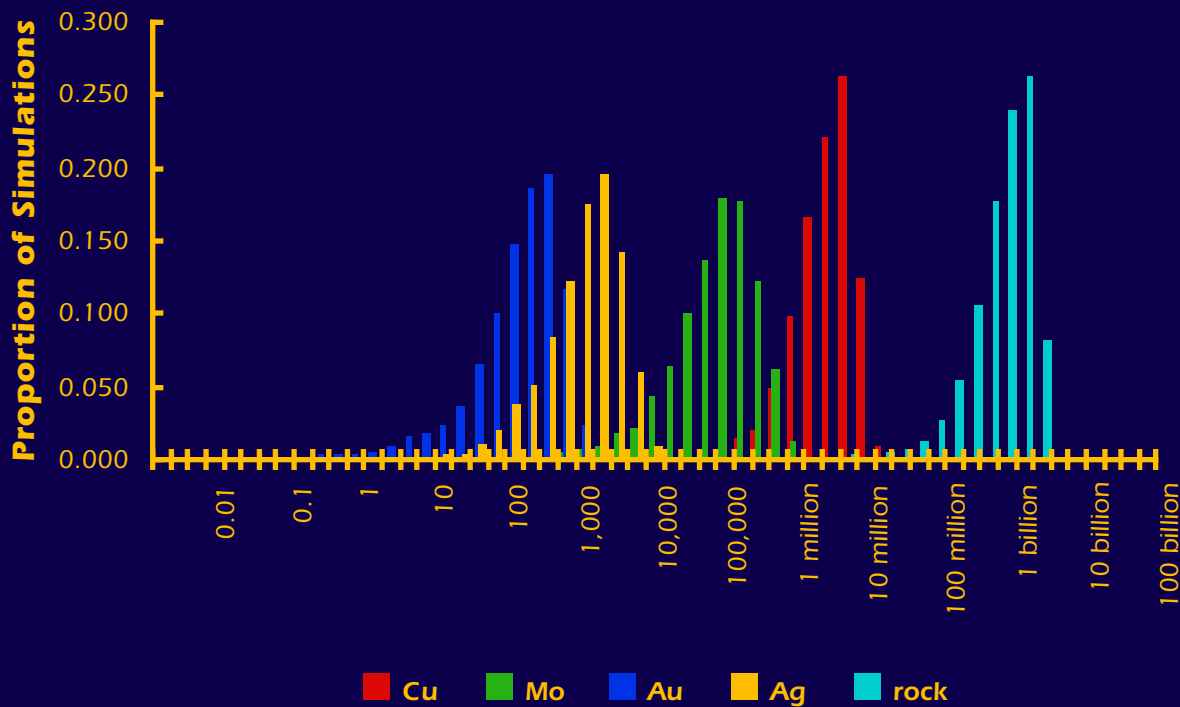


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC04

The Mark3 Index is 89:

Porphyry Cu (BC-AK)

There is a 90% or greater chance of 3 or more deposits.
There is a 50% or greater chance of 6 or more deposits.
There is a 10% or greater chance of 15 or more deposits.
There is a 5% or greater chance of 15 or more deposits.
There is a 1% or greater chance of 15 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	270,000	0	0	0	77,000,000
0.90	810,000	8,300	8	32	230,000,000
0.50	4,300,000	120,000	190	1,300	1,300,000,000
0.10	11,000,000	480,000	649	4,800	3,000,000,000
0.05	13,000,000	660,000	820	6,400	3,600,000,000
mean	5,200,000	190,000	270	2,000	1,500,000,000
Probability of mean	0.43	0.34	0.39	0.37	0.43
Probability of zero	0.03	0.05	0.06	0.09	0.03

The tract ID is PC04The Mark3 Index is 89: **Porphyry Cu (BC-AK)**

There is a 90% or greater chance of 3 or more deposits.

There is a 50% or greater chance of 6 or more deposits.

There is a 10% or greater chance of 15 or more deposits.

There is a 5% or greater chance of 15 or more deposits.

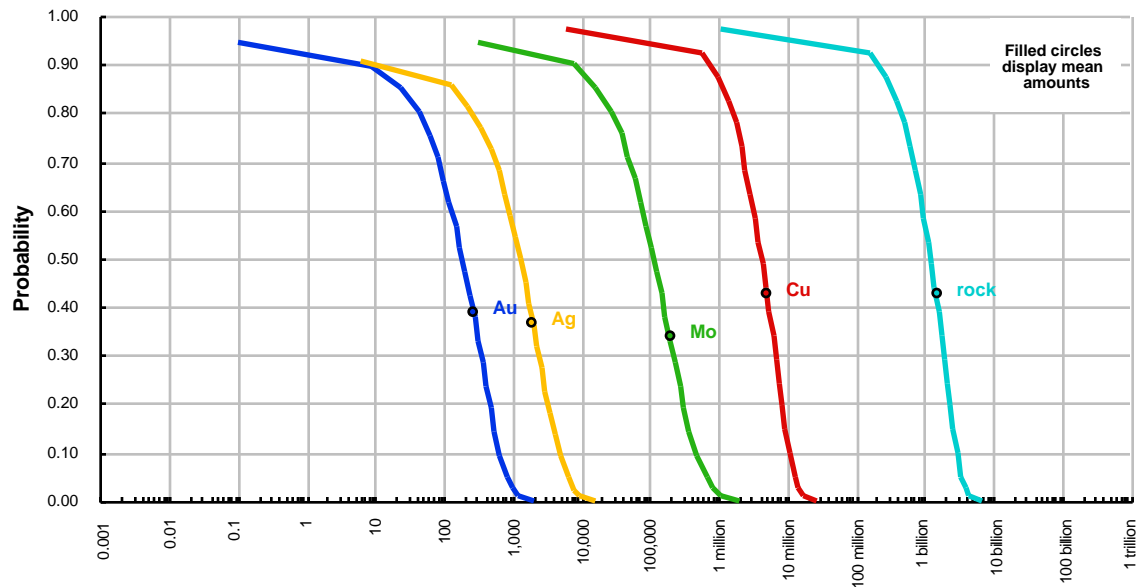
There is a 1% or greater chance of 15 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

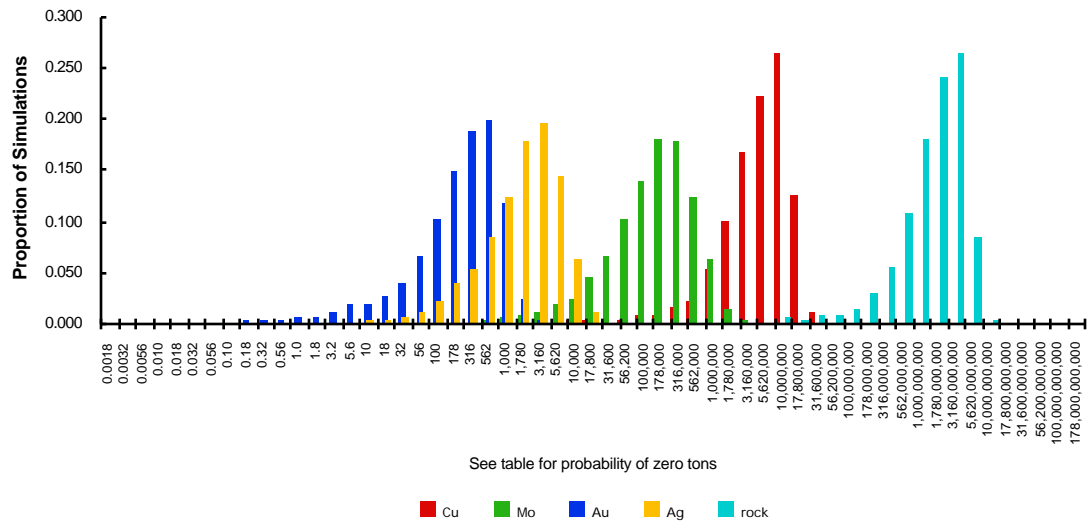
quantile	Cu	Mo	Au	Ag	rock
0.95	270,000	0	0	0	77,000,000
0.90	810,000	8,300	8	32	230,000,000
0.50	4,300,000	120,000	190	1,300	1,300,000,000
0.10	11,000,000	480,000	649	4,800	3,000,000,000
0.05	13,000,000	660,000	820	6,400	3,600,000,000
mean	5,200,000	190,000	270	2,000	1,500,000,000
Probability of mean	0.43	0.34	0.39	0.37	0.43
Probability of zero	0.03	0.05	0.06	0.09	0.03

The tract ID is PC04

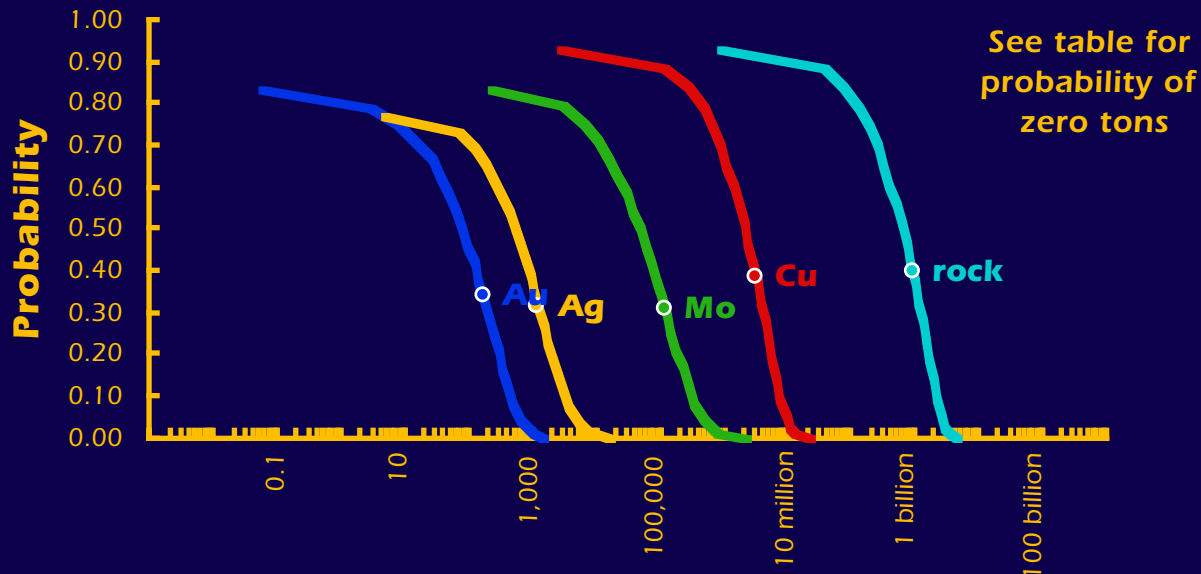
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

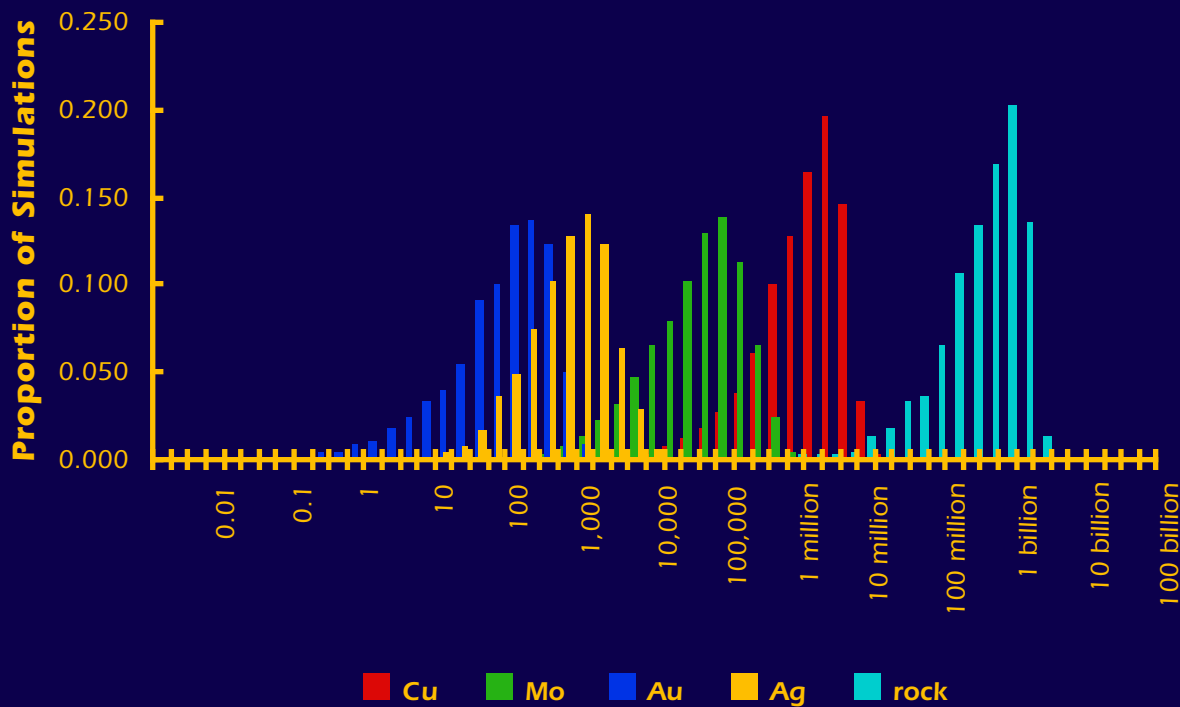


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC05

The Mark3 Index is 89:

Porphyry Cu (BC-AK)

There is a 90% or greater chance of 1 or more deposits.
There is a 50% or greater chance of 3 or more deposits.
There is a 10% or greater chance of 10 or more deposits.
There is a 5% or greater chance of 10 or more deposits.
There is a 1% or greater chance of 10 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	75,000	0	0	0	23,000,000
0.50	2,100,000	48,000	77	520	610,000,000
0.10	7,200,000	300,000	445	3,100	2,100,000,000
0.05	9,000,000	440,000	600	4,600	2,500,000,000
mean	3,000,000	110,000	160	1,200	860,000,000
Probability of mean	0.39	0.31	0.34	0.32	0.40
Probability of zero	0.07	0.16	0.17	0.23	0.07

The tract ID is PC05The Mark3 Index is 89: **Porphyry Cu (BC-AK)**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 10 or more deposits.

There is a 5% or greater chance of 10 or more deposits.

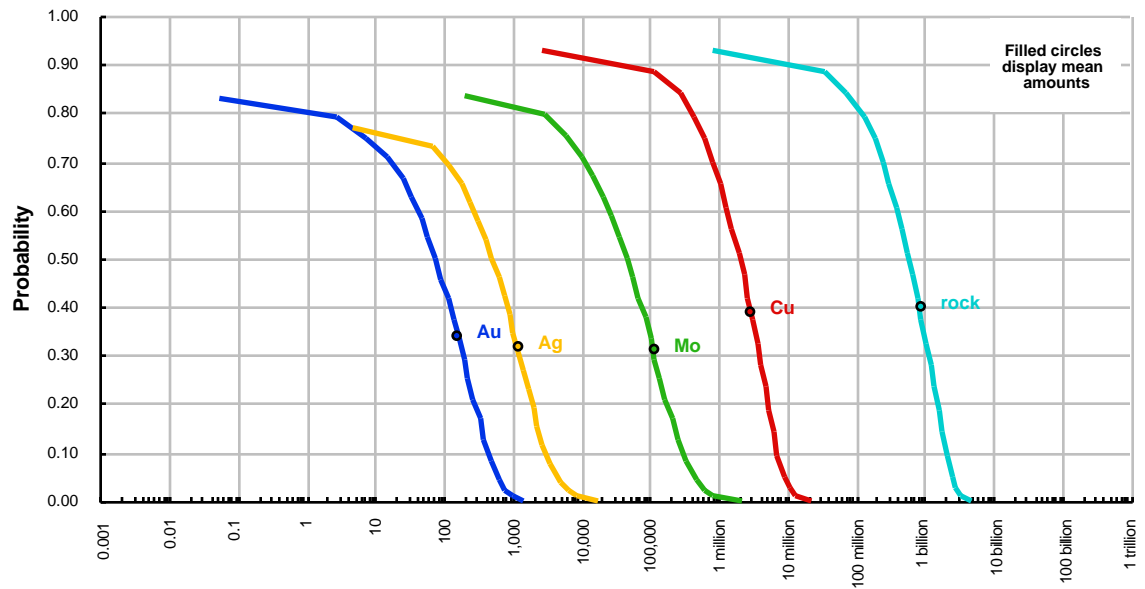
There is a 1% or greater chance of 10 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

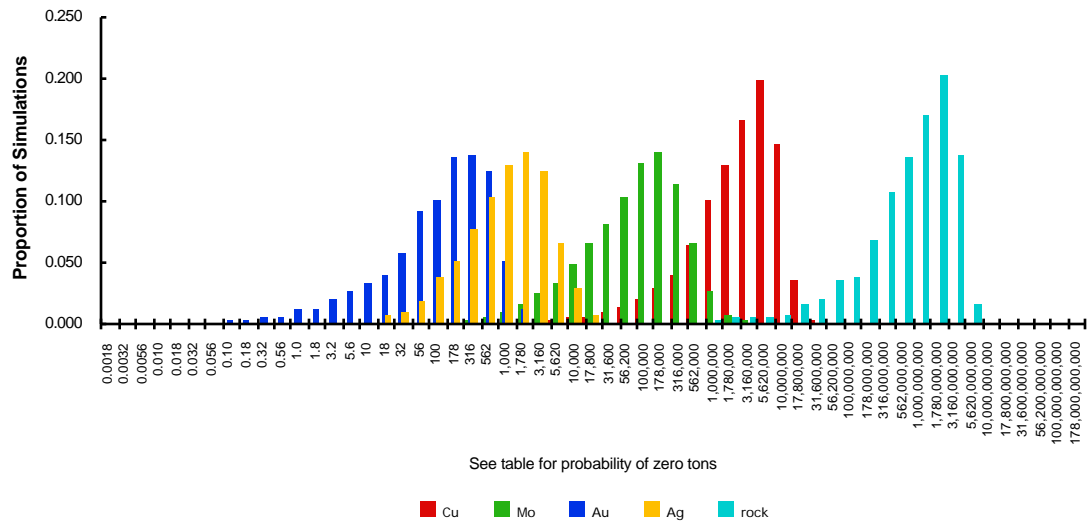
quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	75,000	0	0	0	23,000,000
0.50	2,100,000	48,000	77	520	610,000,000
0.10	7,200,000	300,000	445	3,100	2,100,000,000
0.05	9,000,000	440,000	600	4,600	2,500,000,000
mean	3,000,000	110,000	160	1,200	860,000,000
Probability of mean	0.39	0.31	0.34	0.32	0.40
Probability of zero	0.07	0.16	0.17	0.23	0.07

The tract ID is PC05

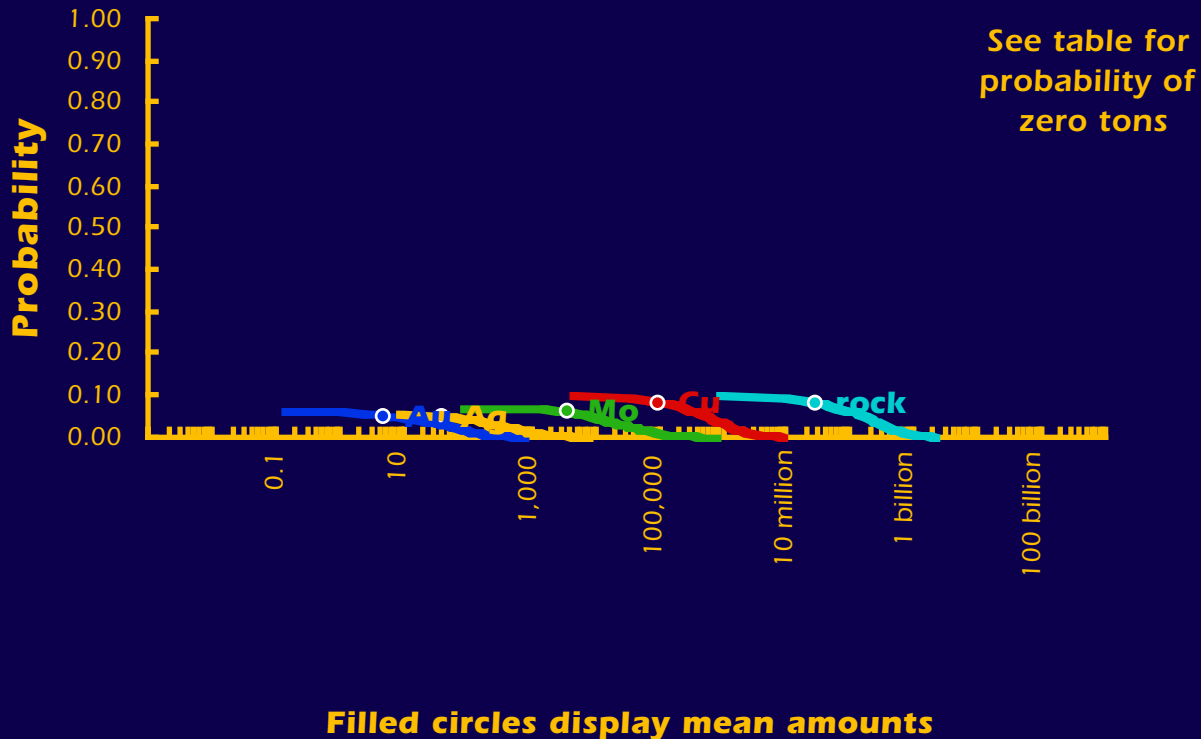
Cumulative Distributions of Contained Metal and Mineralized Rock



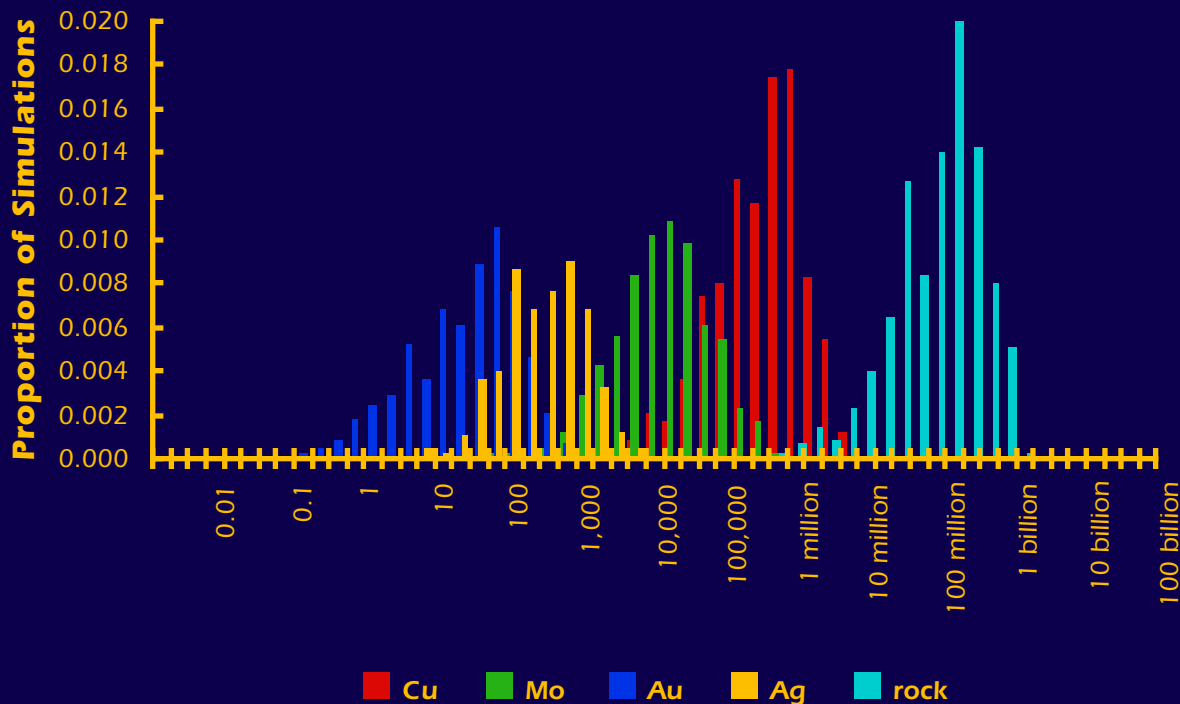
Histograms of Contained Metal and Mineralized Rock (metric tons)



Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC06

The Mark3 Index is 89:

Porphry Cu (BC-AK)

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	560,000	7,700	6	40	160,000,000
mean	96,000	3,500	5	37	27,000,000
Probability of mean	0.08	0.06	0.05	0.05	0.08
Probability of zero	0.90	0.93	0.94	0.95	0.90

The tract ID is PC06The Mark3 Index is 89: **Porphyry Cu (BC-AK)**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

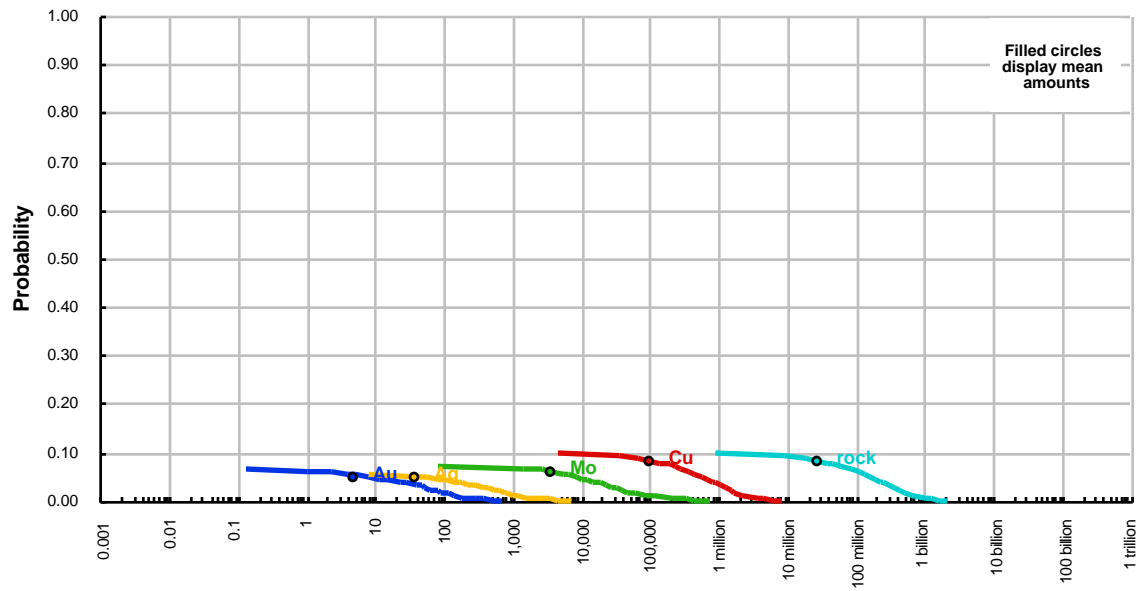
There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

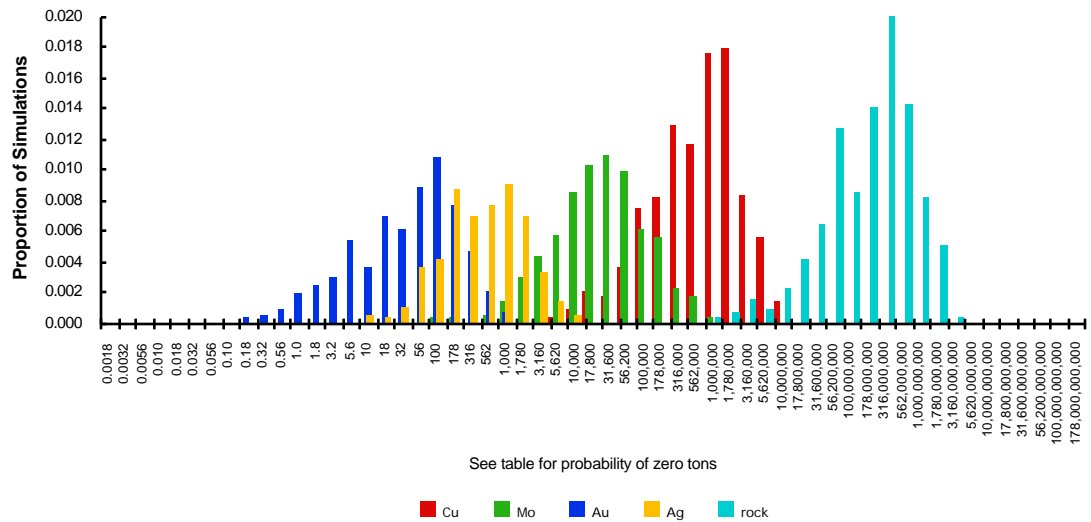
quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	560,000	7,700	6	40	160,000,000
mean	96,000	3,500	5	37	27,000,000
Probability of mean	0.08	0.06	0.05	0.05	0.08
Probability of zero	0.90	0.93	0.94	0.95	0.90

The tract ID is PC06

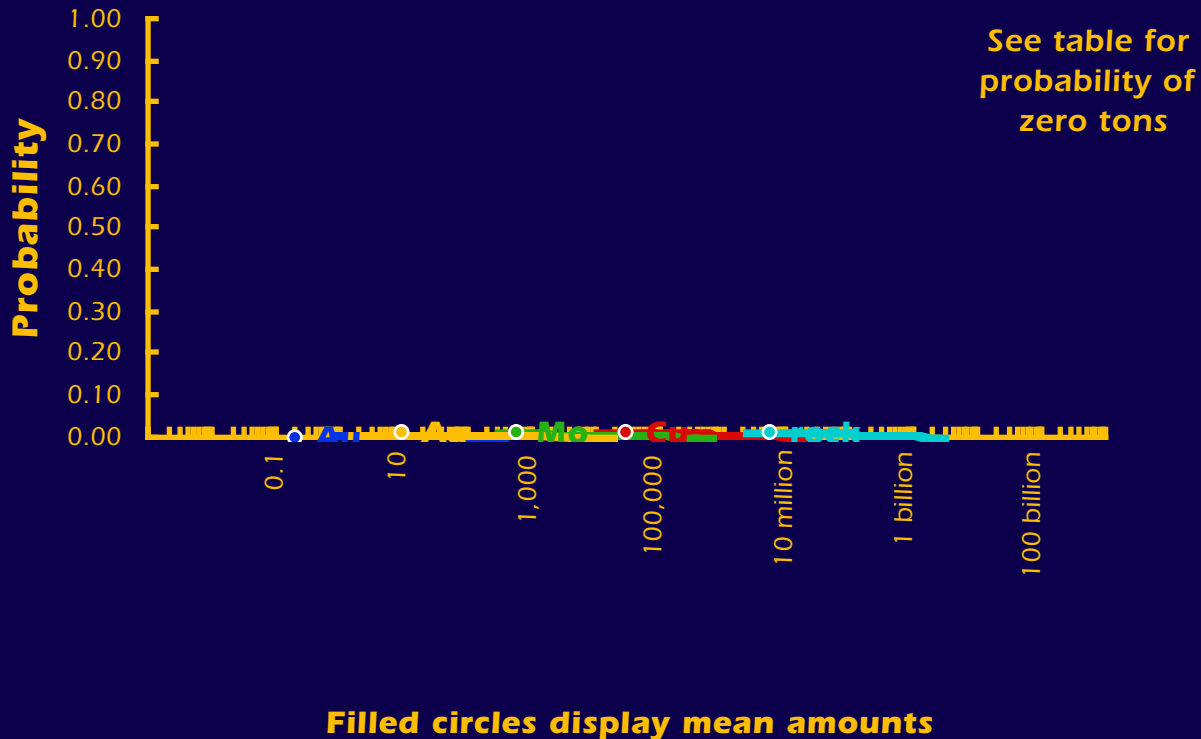
Cumulative Distributions of Contained Metal and Mineralized Rock



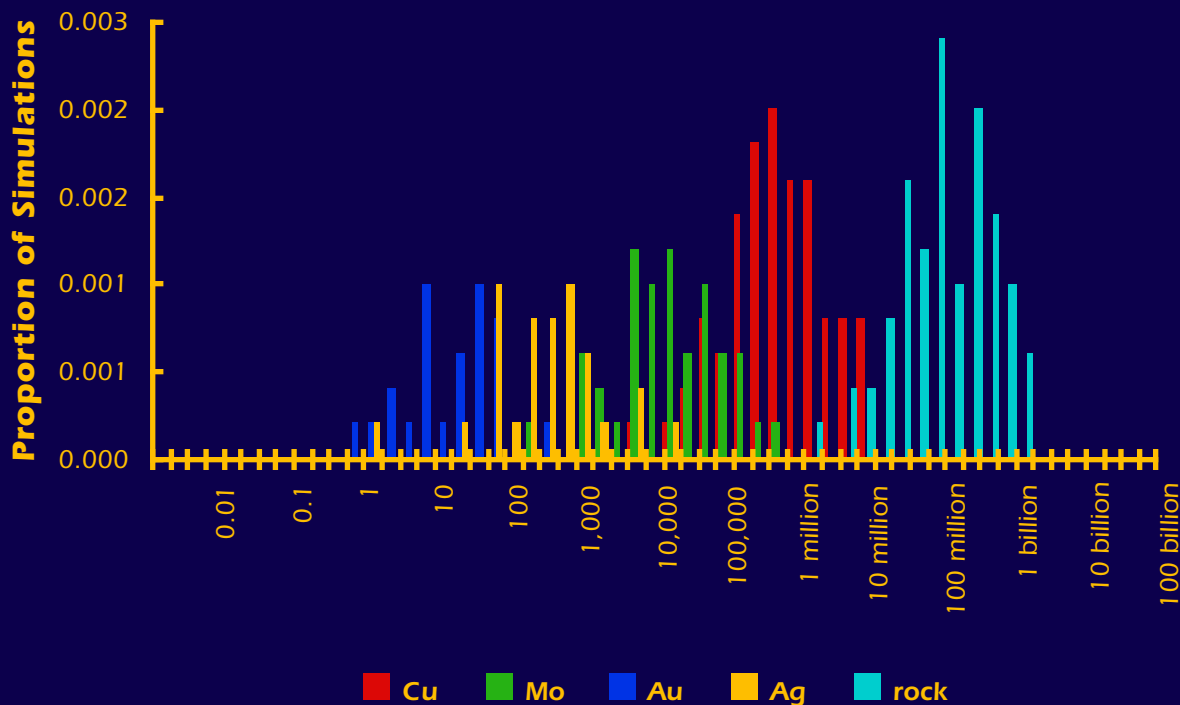
Histograms of Contained Metal and Mineralized Rock (metric tons)



Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC07

The Mark3 Index is 81:

Porphyry Cu (North America)

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	0	0	0	0	0
mean	30,000	570	0	9	5,100,000
Probability of mean	0.01	0.01	0.00	0.01	0.01
Probability of zero	0.99	0.99	1.00	0.99	0.99

The tract ID is PC07The Mark3 Index is 81: **Porphyry Cu (North America)**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

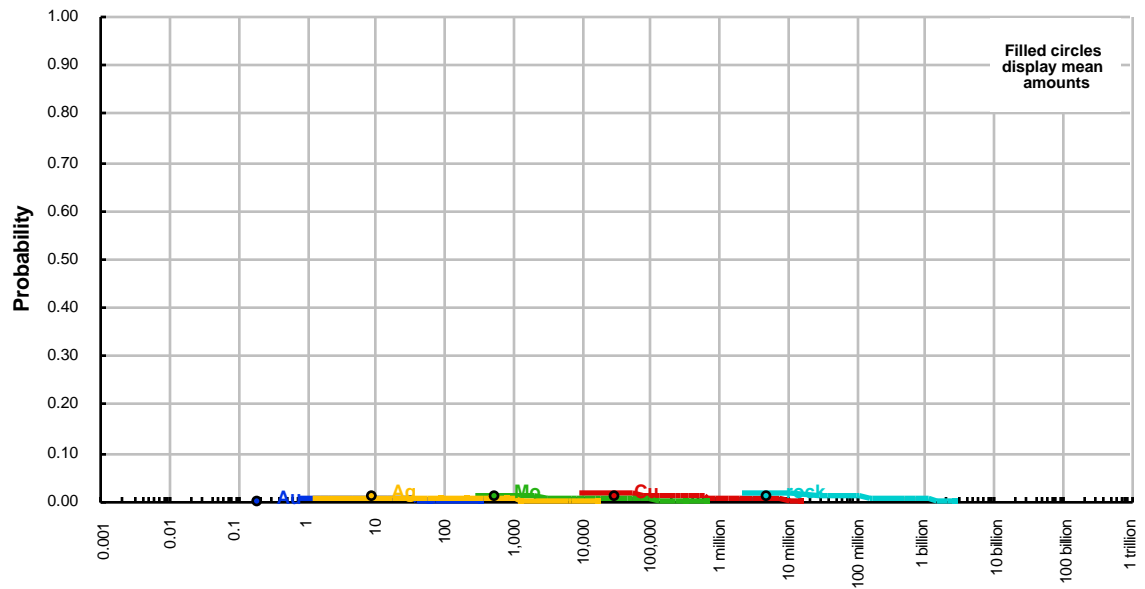
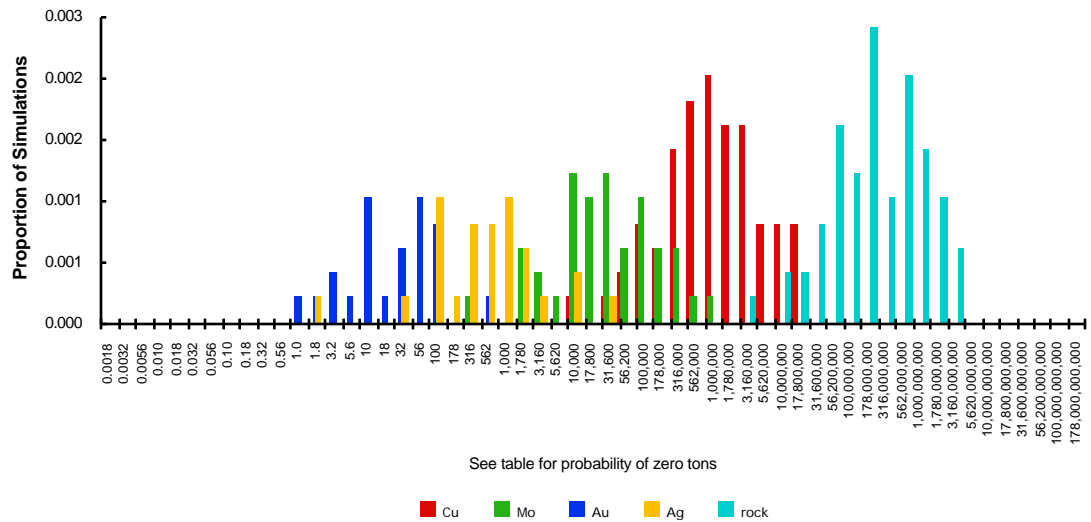
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

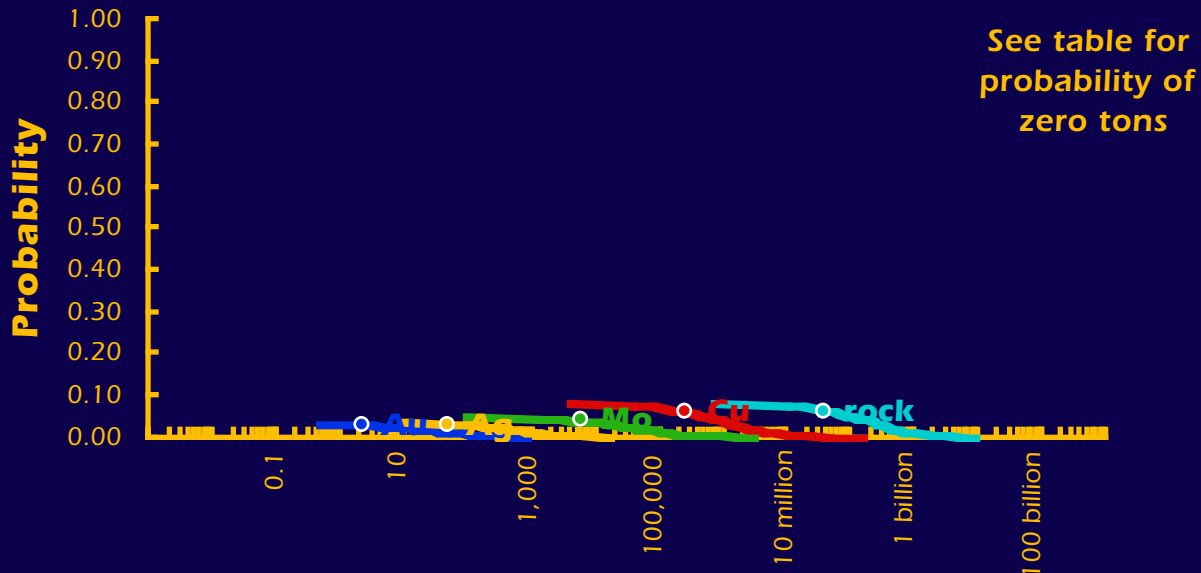
quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	0	0	0	0	0
mean	30,000	570	0	9	5,100,000
Probability of mean	0.01	0.01	0.00	0.01	0.01
Probability of zero	0.99	0.99	1.00	0.99	0.99

The tract ID is PC07

Cumulative Distributions of Contained Metal and Mineralized Rock

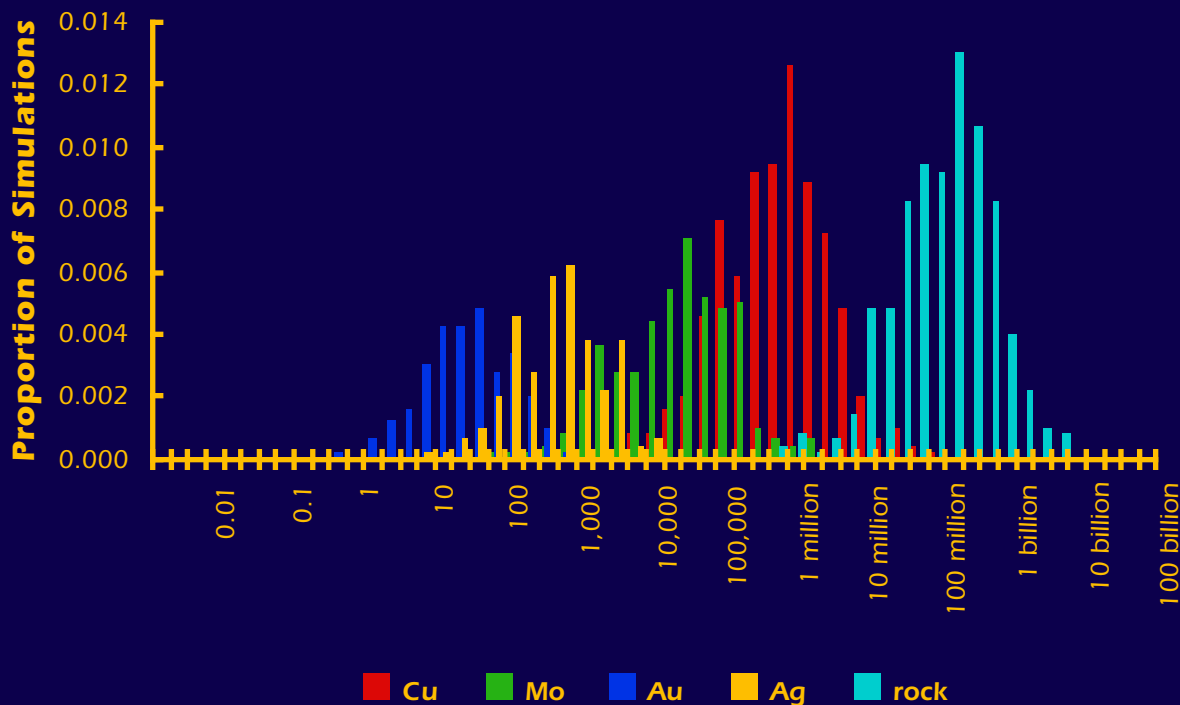
Histograms of Contained Metal and Mineralized Rock
(metric tons)

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC08

The Mark3 Index is 4:

Porphry Cu

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	500,000	0	0	0	95,000,000
mean	260,000	5,600	2	46	37,000,000
Probability of mean	0.06	0.04	0.03	0.03	0.06
Probability of zero	0.92	0.95	0.97	0.97	0.92

The tract ID is PC08The Mark3 Index is 4: **Porphyry Cu**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

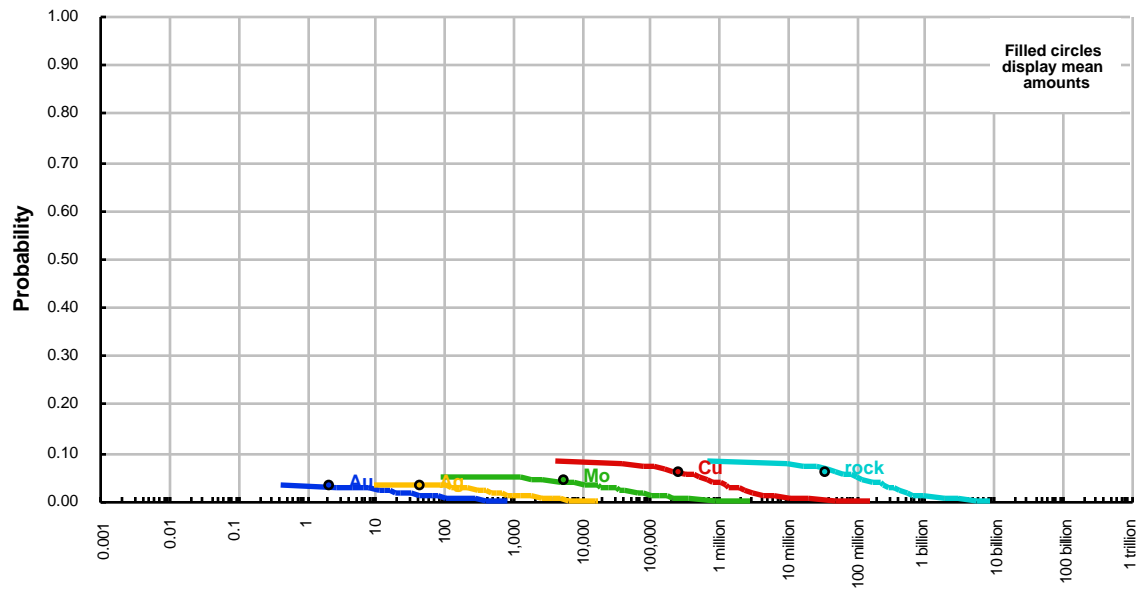
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

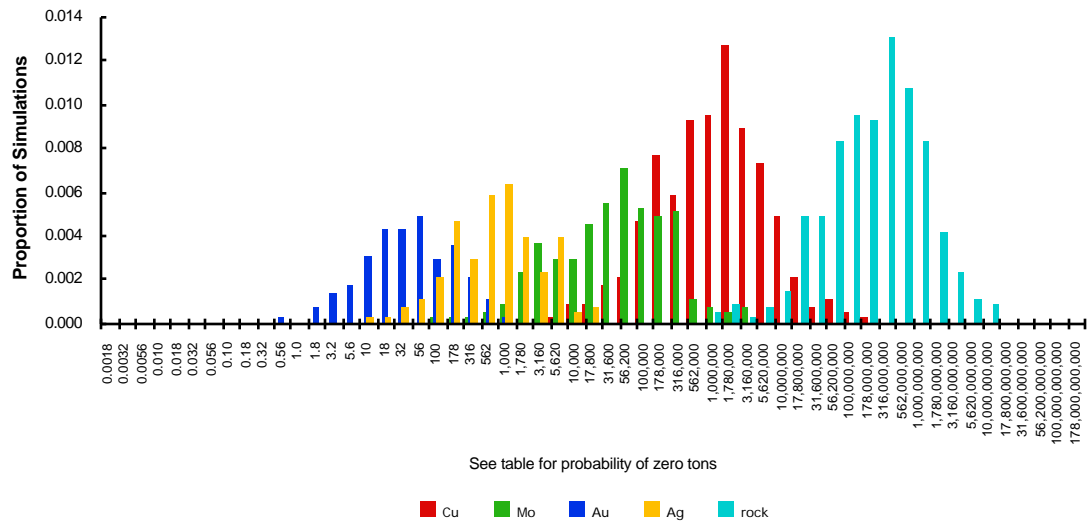
quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	500,000	0	0	0	95,000,000
mean	260,000	5,600	2	46	37,000,000
Probability of mean	0.06	0.04	0.03	0.03	0.06
Probability of zero	0.92	0.95	0.97	0.97	0.92

The tract ID is PC08

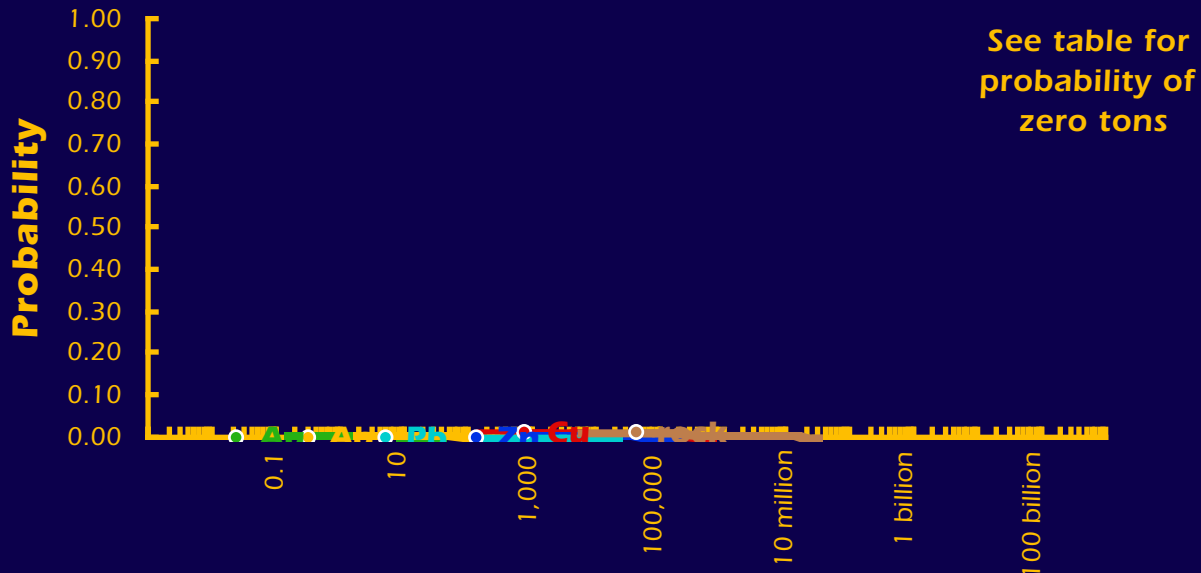
Cumulative Distributions of Contained Metal and Mineralized Rock



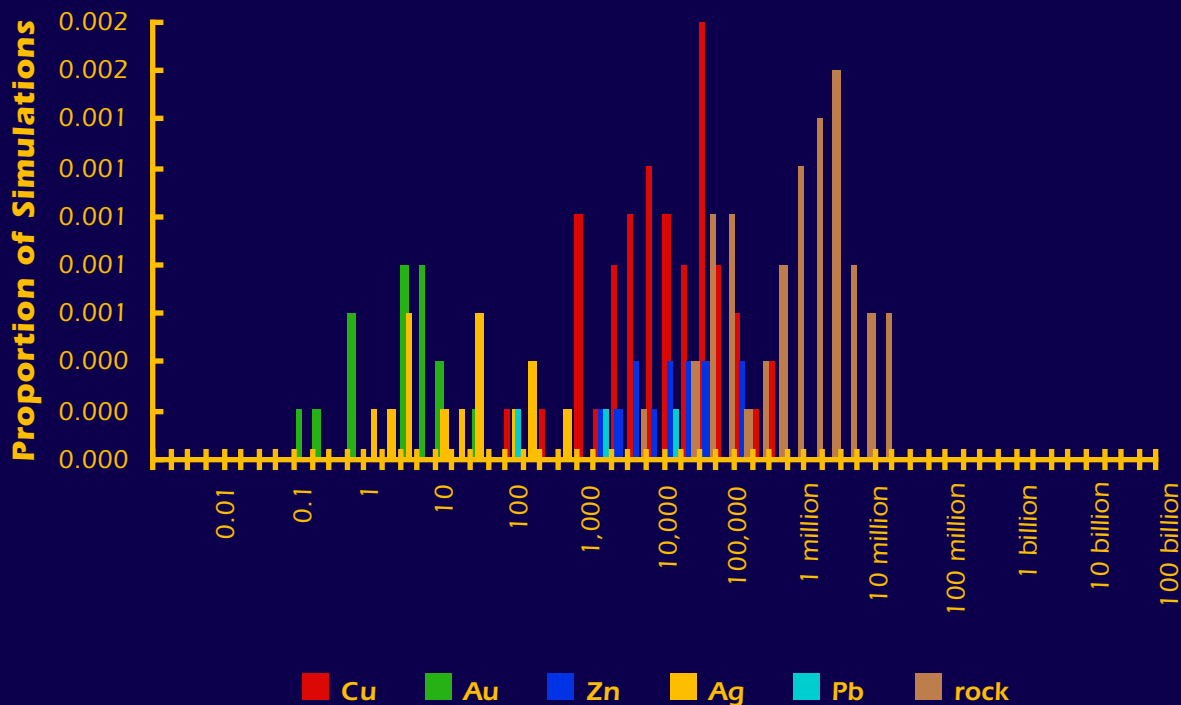
Histograms of Contained Metal and Mineralized Rock (metric tons)



Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC09

The Mark3 Index is 11:

Massive sulfide, Cyprus

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	800	0	140	0	5	45,000
Probability of mean	0.01	0.00	0.00	0.00	0.00	0.01
Probability of zero	0.99	1.00	1.00	1.00	1.00	0.99

The tract ID is PC09The Mark3 Index is 11: **Massive sulfide, Cyprus**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

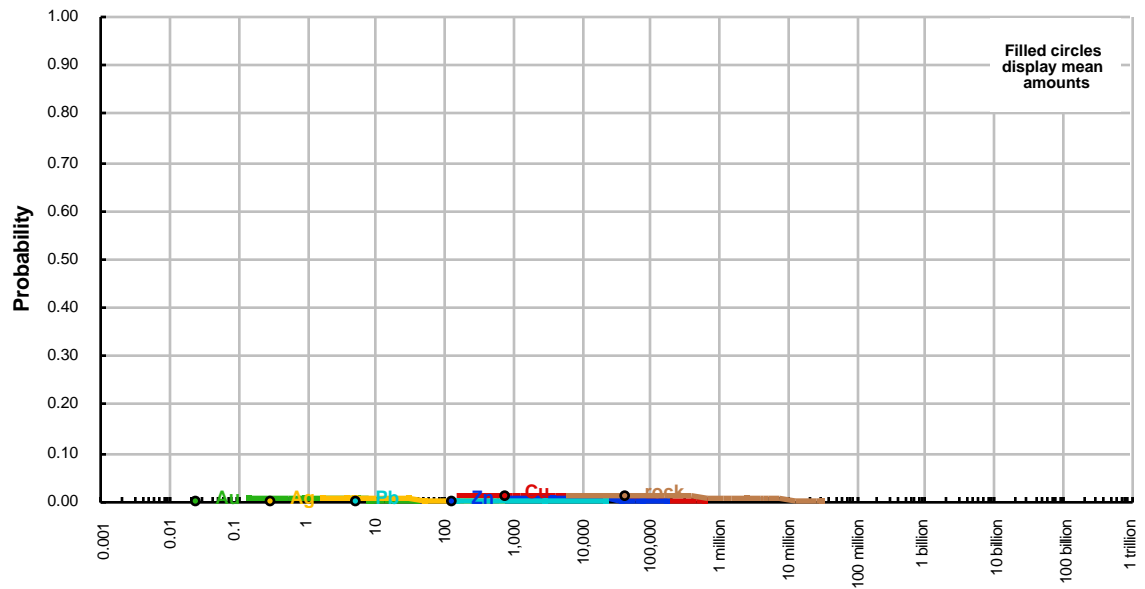
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

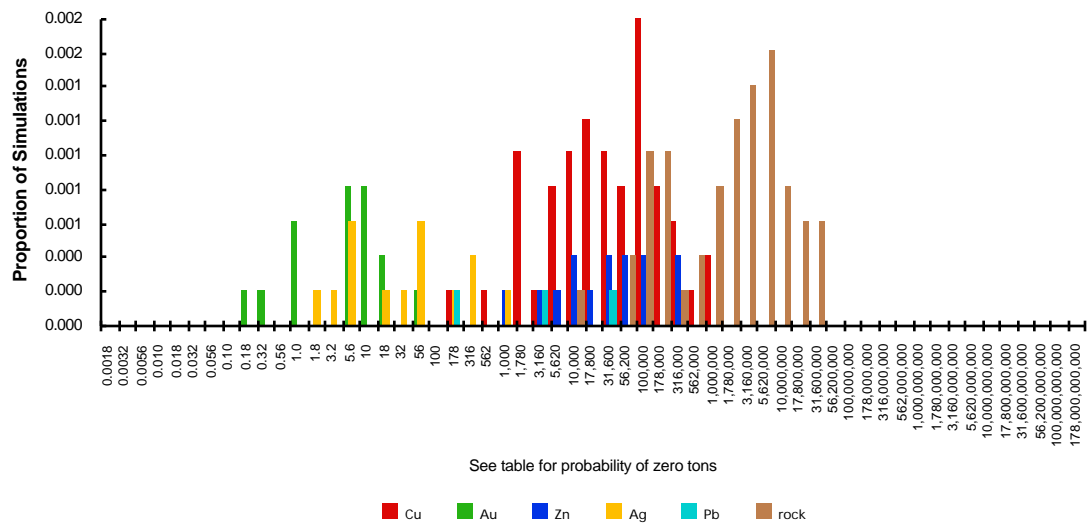
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	800	0	140	0	5	45,000
Probability of mean	0.01	0.00	0.00	0.00	0.00	0.01
Probability of zero	0.99	1.00	1.00	1.00	1.00	0.99

The tract ID is PC09

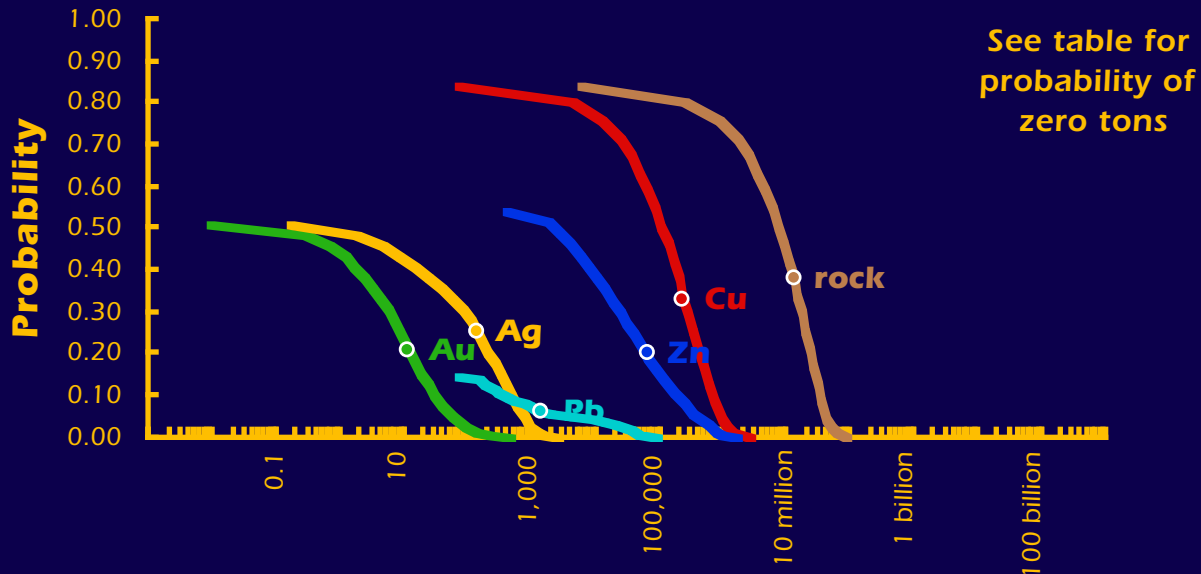
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

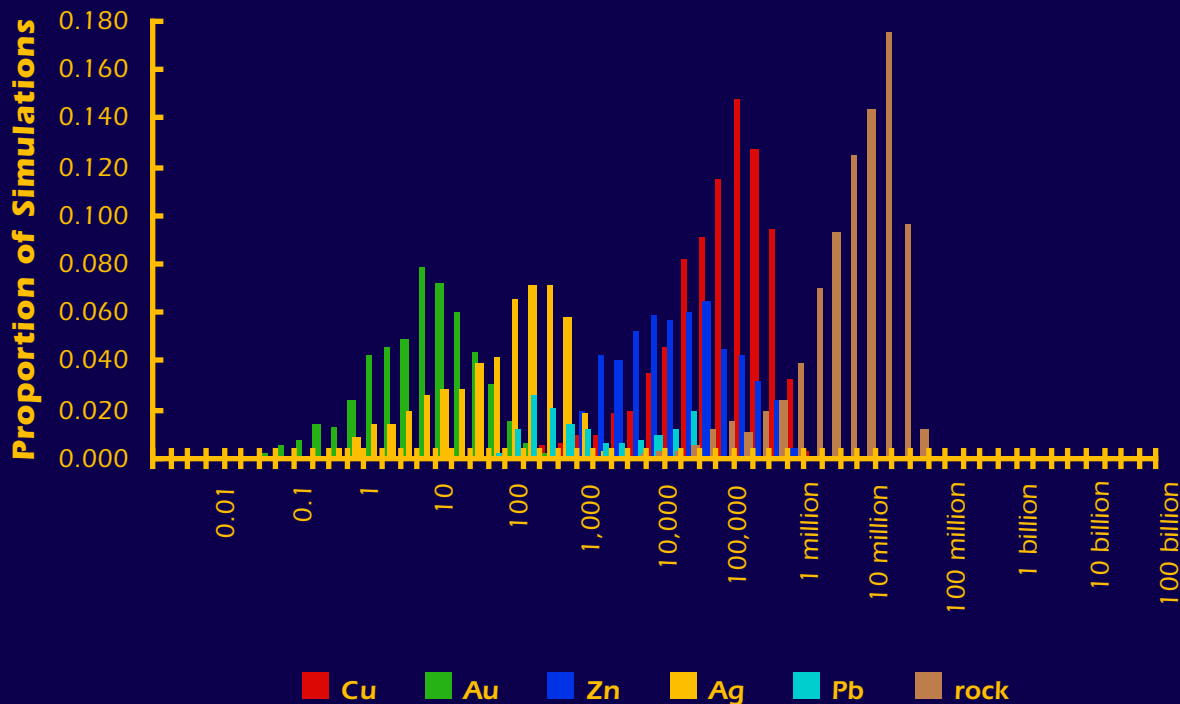


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC10

The Mark3 Index is 11:

Massive sulfide, Cyprus

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

There is a 1% or greater chance of 6 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	110,000	0	2,300	1	0	7,200,000
0.10	650,000	30	180,000	470	350	33,000,000
0.05	880,000	58	360,000	740	4,200	40,000,000
mean	230,000	11	61,000	130	1,400	12,000,000
Probability of mean	0.33	0.21	0.20	0.25	0.06	0.38
Probability of zero	0.16	0.49	0.46	0.49	0.86	0.16

The tract ID is PC10The Mark3 Index is 11: **Massive sulfide, Cyprus**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

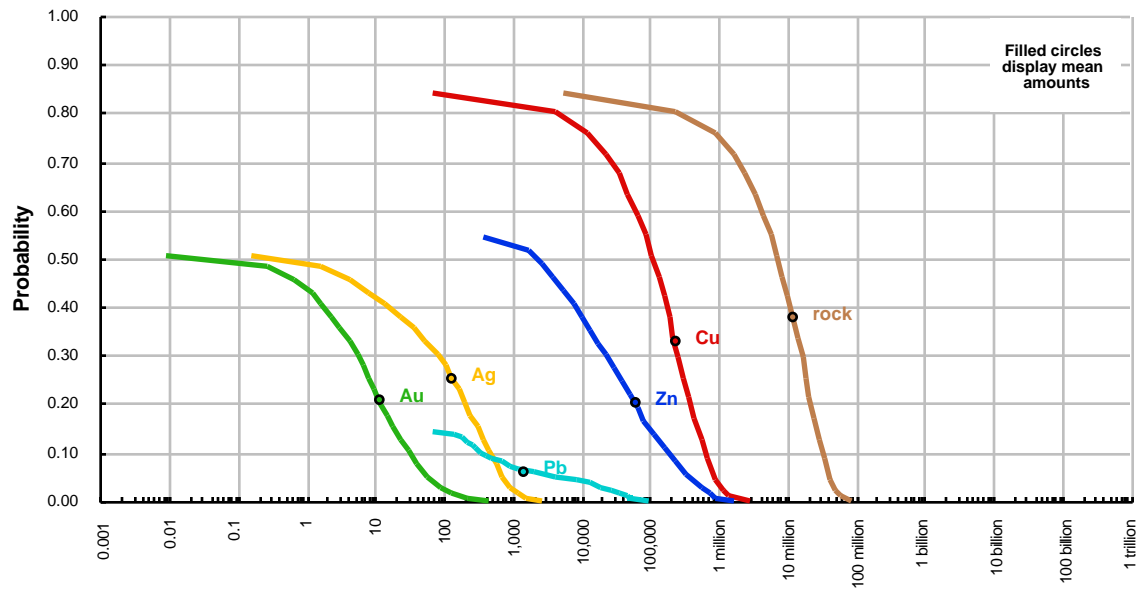
There is a 1% or greater chance of 6 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

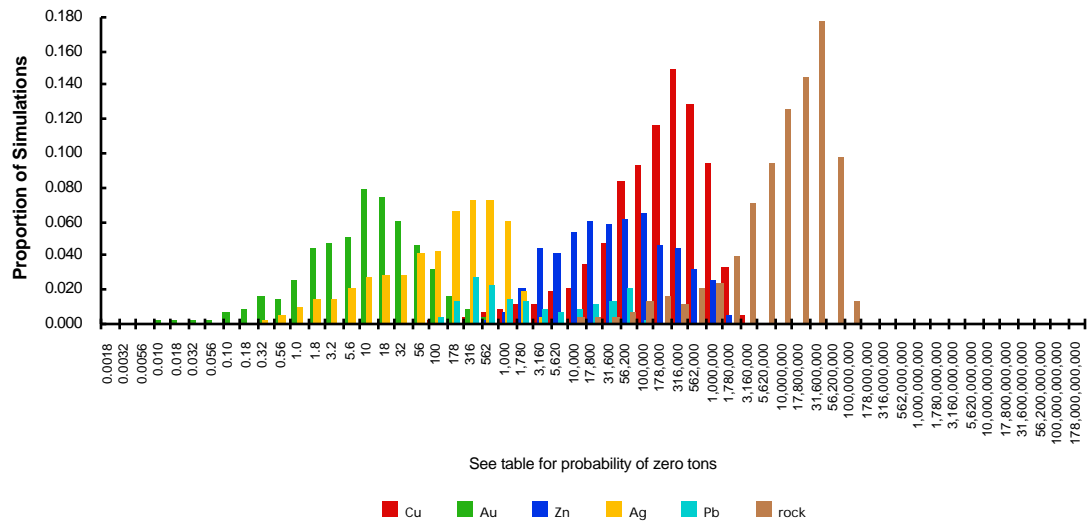
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	110,000	0	2,300	1	0	7,200,000
0.10	650,000	30	180,000	470	350	33,000,000
0.05	880,000	58	360,000	740	4,200	40,000,000
mean	230,000	11	61,000	130	1,400	12,000,000
Probability of mean	0.33	0.21	0.20	0.25	0.06	0.38
Probability of zero	0.16	0.49	0.46	0.49	0.86	0.16

The tract ID is PC10

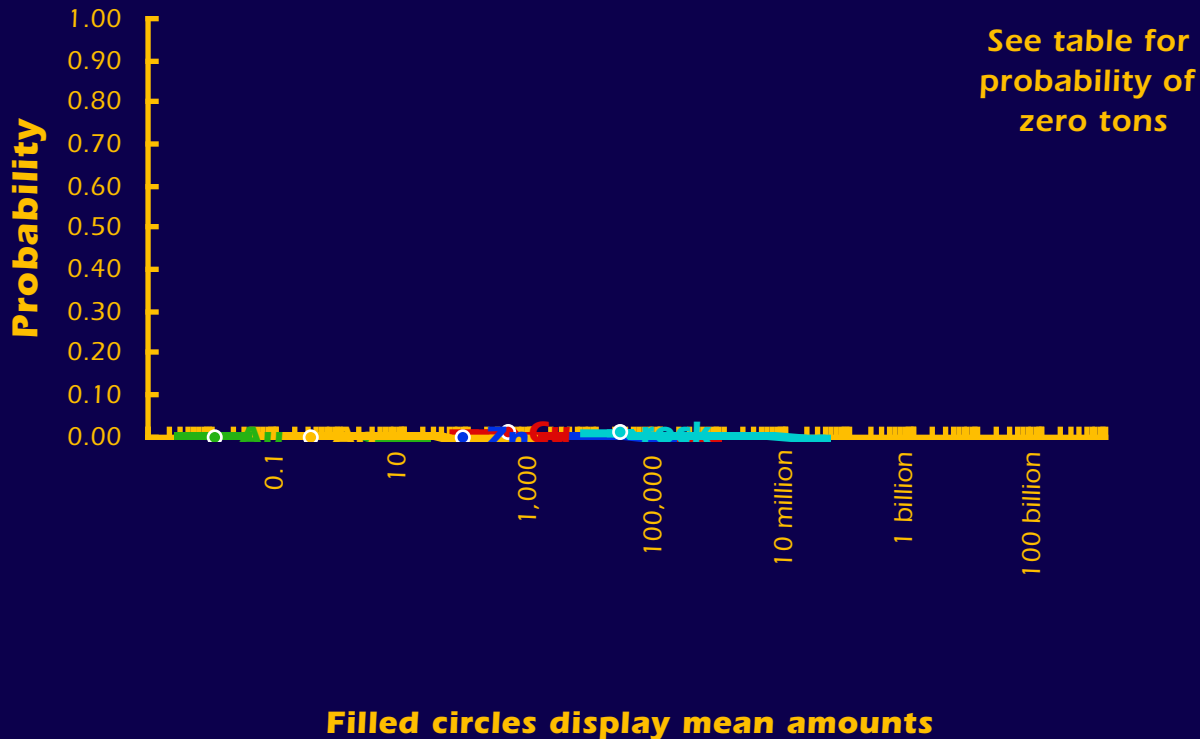
Cumulative Distributions of Contained Metal and Mineralized Rock



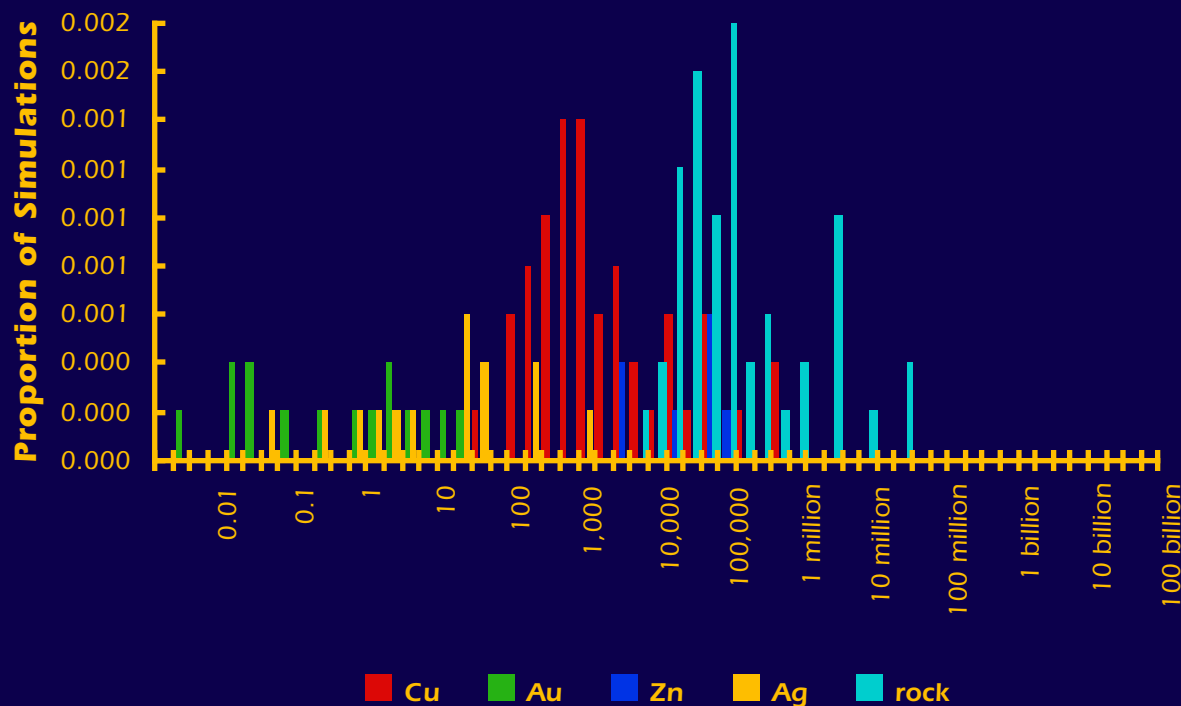
Histograms of Contained Metal and Mineralized Rock (metric tons)



Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC11

The Mark3 Index is 30:

Massive sulfide, Besshi

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	0	0	0	0	0
mean	410	0	86	0	24,000
Probability of mean	0.01	0.00	0.00	0.00	0.01
Probability of zero	0.99	1.00	1.00	1.00	0.99

The tract ID is PC11The Mark3 Index is 30: **Massive sulfide, Besshi**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

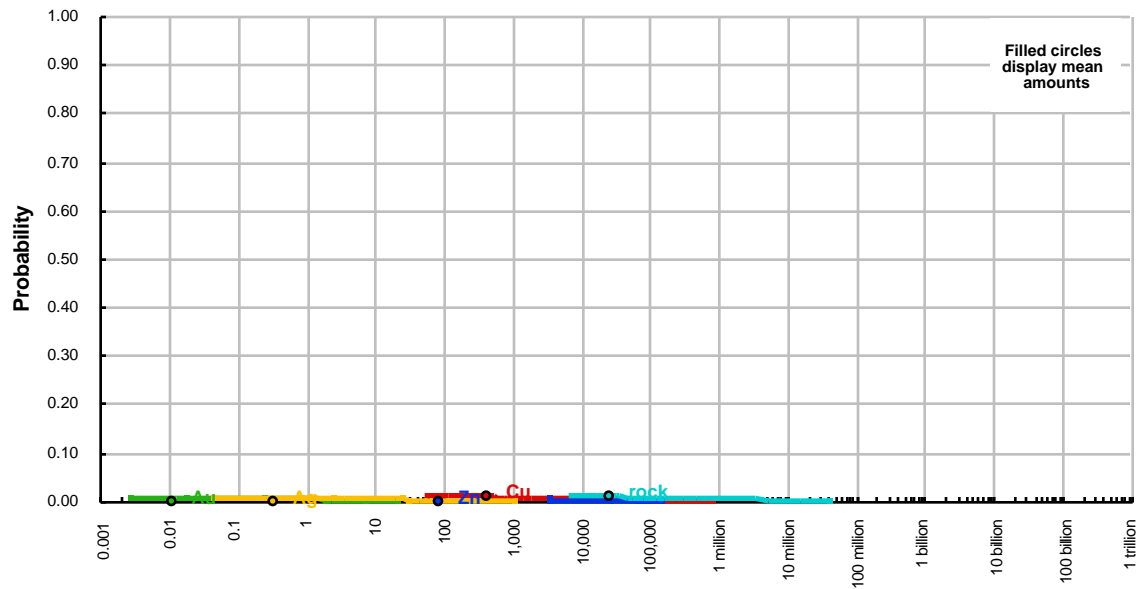
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

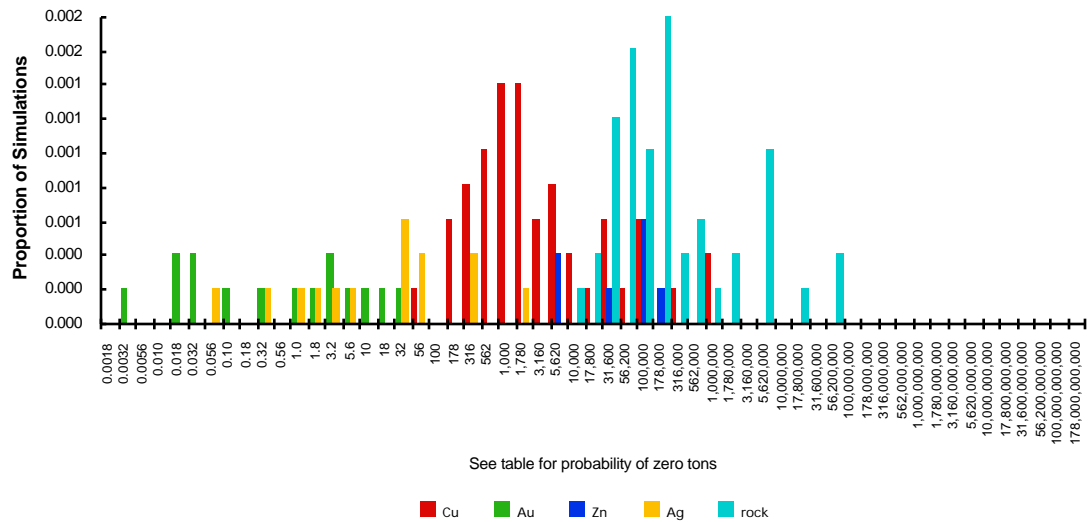
quantile	Cu	Au	Zn	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	0	0	0	0	0
mean	410	0	86	0	24,000
Probability of mean	0.01	0.00	0.00	0.00	0.01
Probability of zero	0.99	1.00	1.00	1.00	0.99

The tract ID is PC11

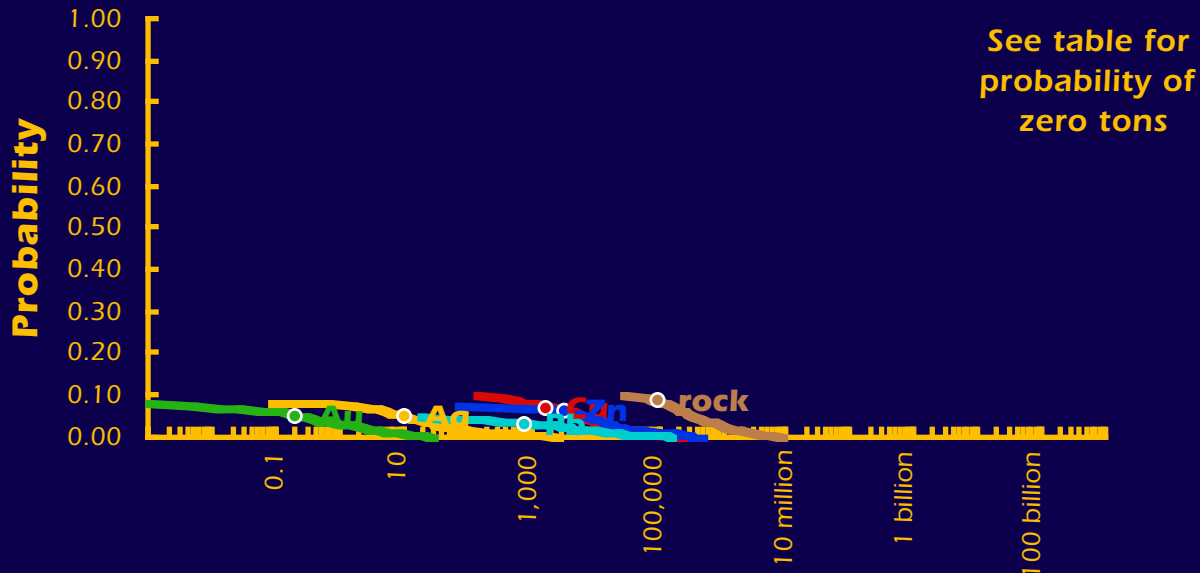
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

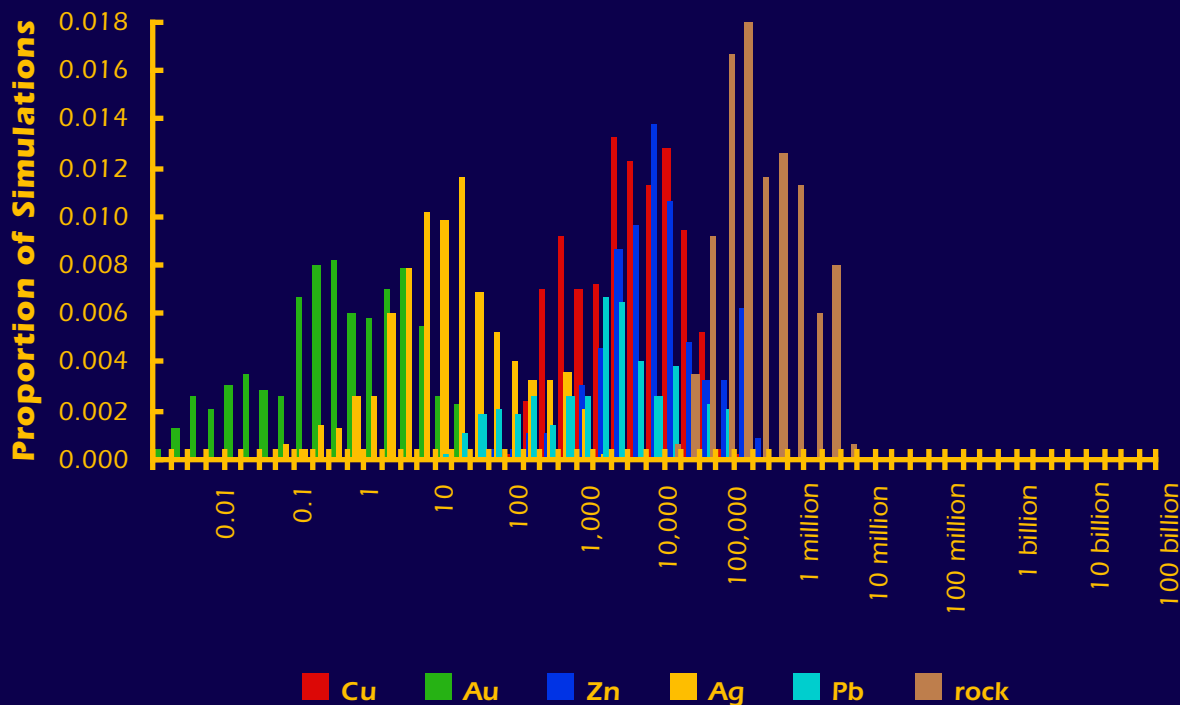


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC12

The Mark3 Index is 44:

Massive sulfide, Sierran kuroko

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	6,200	0	6,300	10	0	320,000
mean	1,600	0	3,300	10	750	90,000
Probability of mean	0.07	0.05	0.06	0.05	0.03	0.09
Probability of zero	0.90	0.92	0.93	0.92	0.95	0.90

The tract ID is PC12The Mark3 Index is 44: **Massive sulfide, Sierran kuroko**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

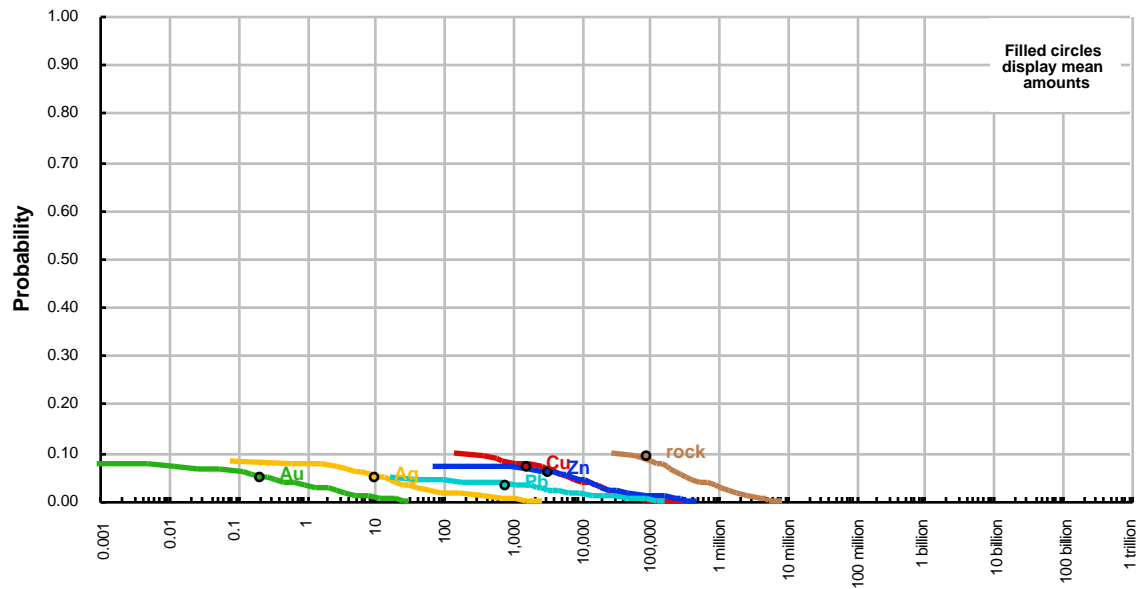
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

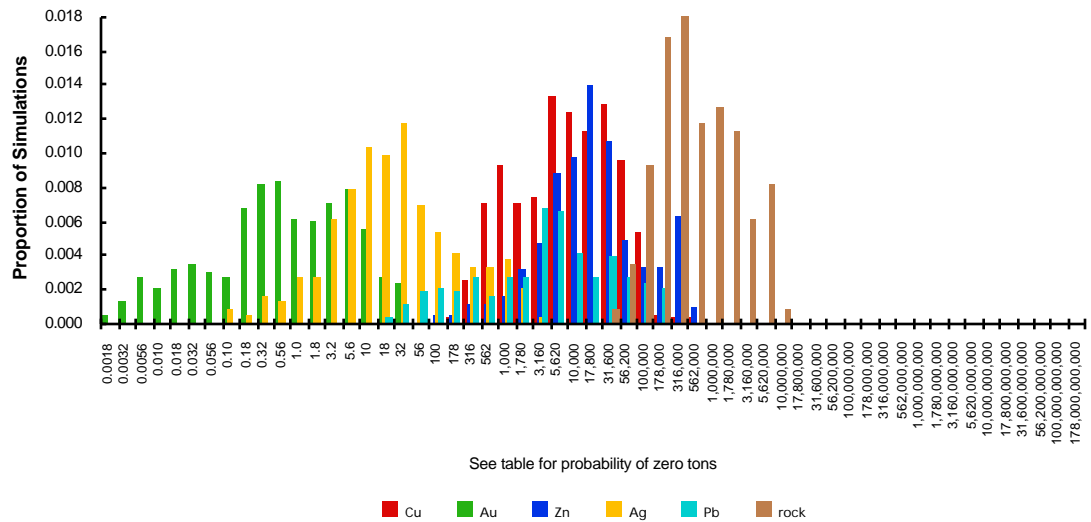
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	6,200	0	6,300	10	0	320,000
mean	1,600	0	3,300	10	750	90,000
Probability of mean	0.07	0.05	0.06	0.05	0.03	0.09
Probability of zero	0.90	0.92	0.93	0.92	0.95	0.90

The tract ID is PC12

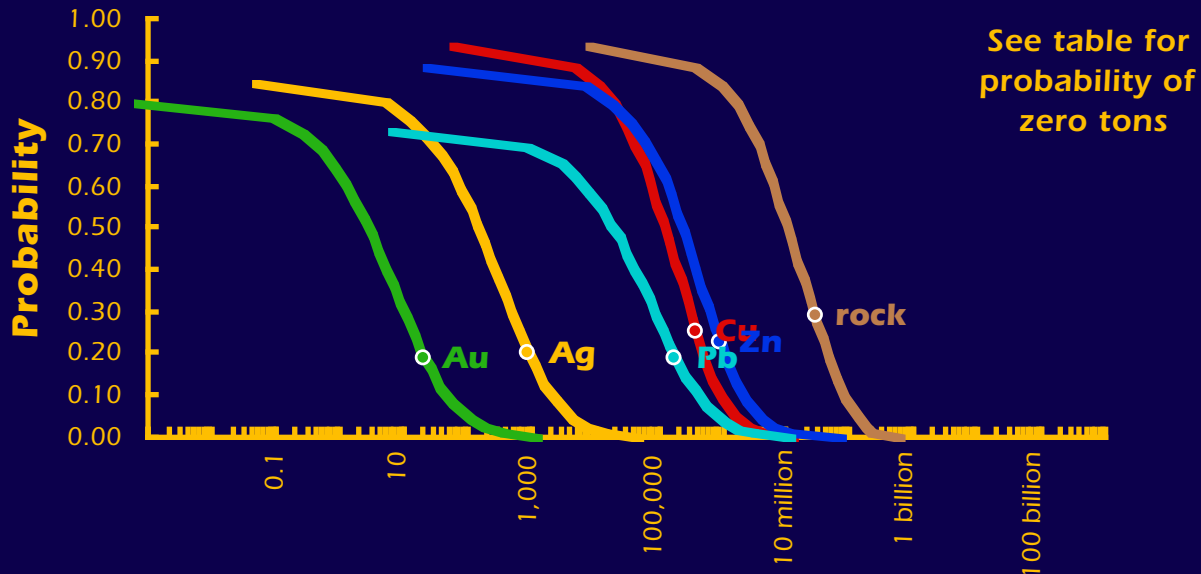
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)



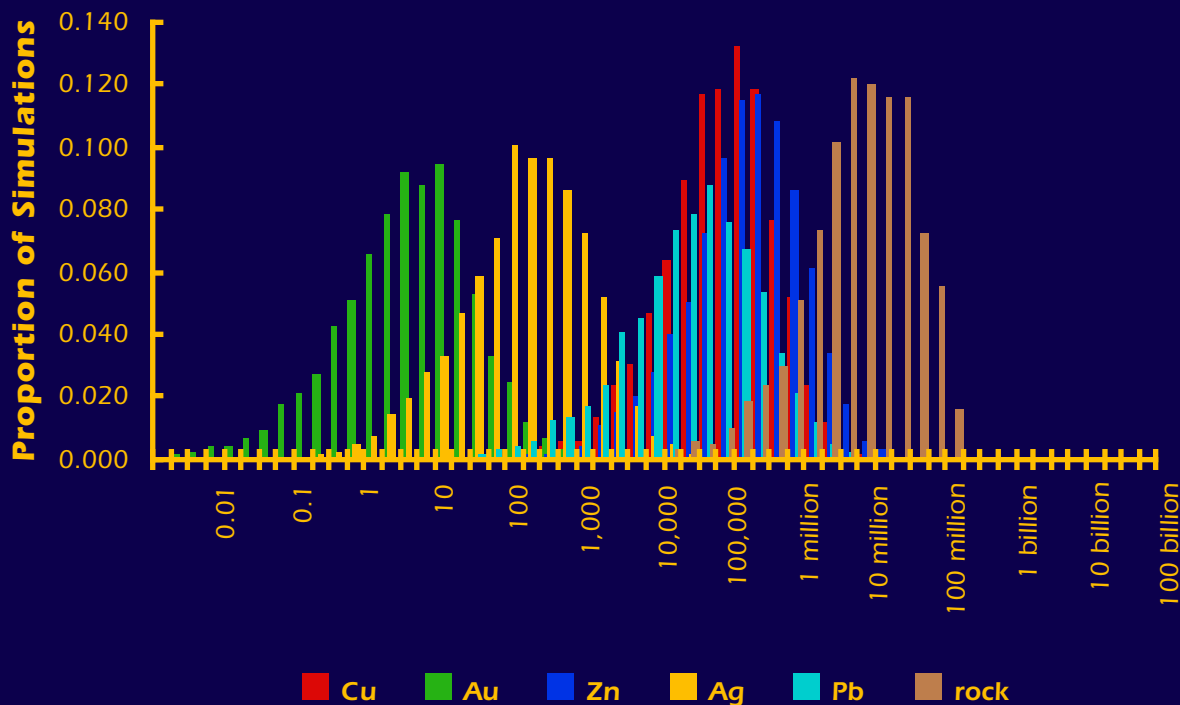
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



See table for
probability of
zero tons

Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC13

The Mark3 Index is 93:

Massive sulfide, kuroko

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

There is a 1% or greater chance of 6 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	3,700	0	0	0	0	270,000
0.50	120,000	3	220,000	140	19,000	9,900,000
0.10	910,000	43	2,080,000	2,000	400,000	75,000,000
0.05	1,500,000	91	3,600,000	3,800	810,000	130,000,000
mean	370,000	20	880,000	870	170,000	28,000,000
Probability of mean	0.25	0.19	0.23	0.20	0.19	0.29
Probability of zero	0.06	0.19	0.11	0.15	0.27	0.06

The tract ID is PC13The Mark3 Index is 93: **Massive sulfide, kuroko**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

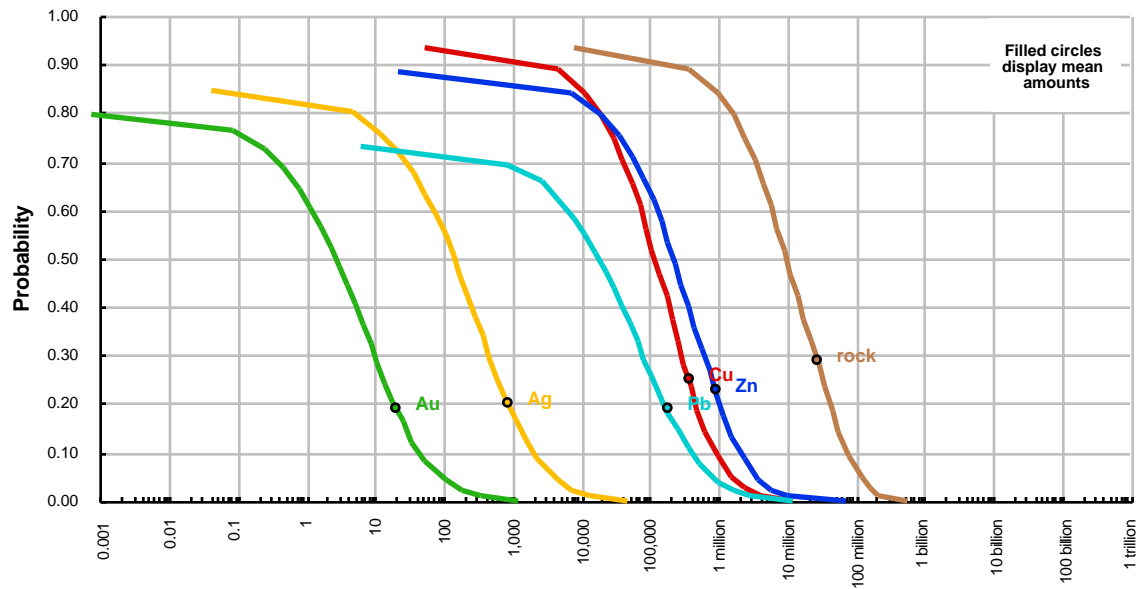
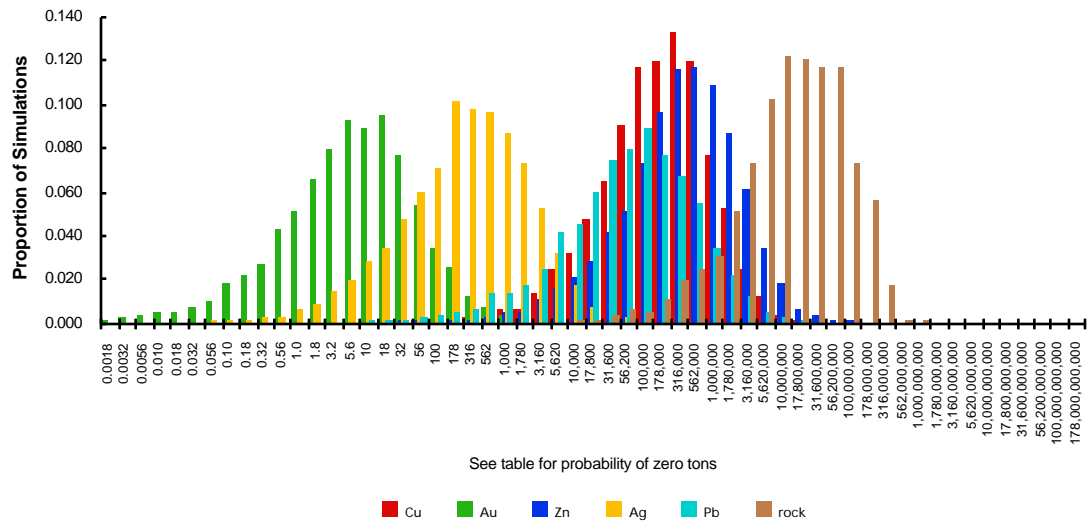
There is a 1% or greater chance of 6 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

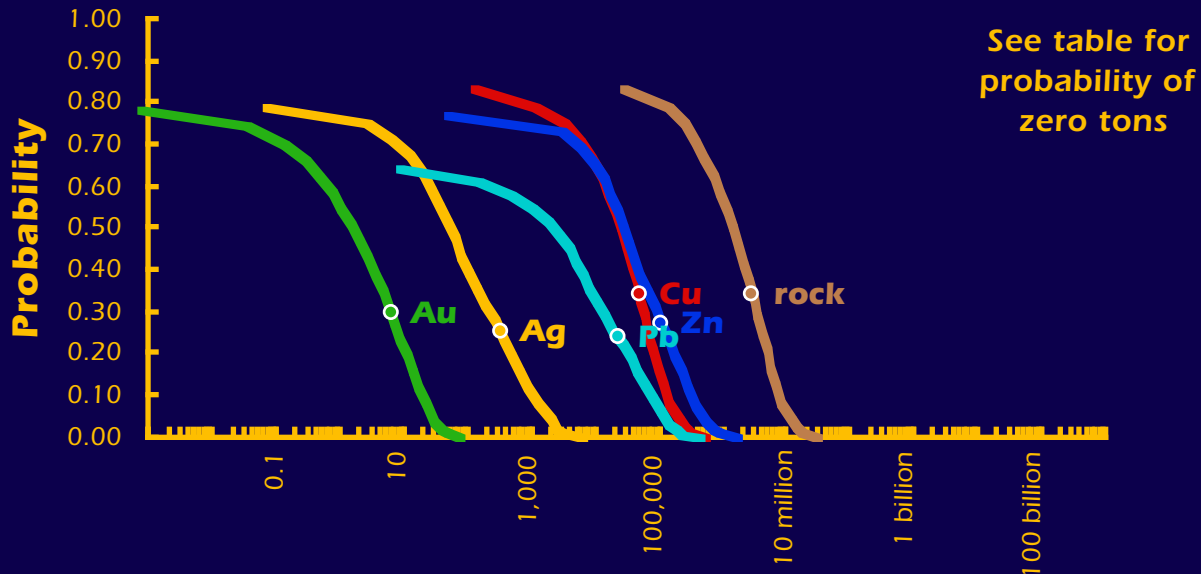
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	3,700	0	0	0	0	270,000
0.50	120,000	3	220,000	140	19,000	9,900,000
0.10	910,000	43	2,080,000	2,000	400,000	75,000,000
0.05	1,500,000	91	3,600,000	3,800	810,000	130,000,000
mean	370,000	20	880,000	870	170,000	28,000,000
Probability of mean	0.25	0.19	0.23	0.20	0.19	0.29
Probability of zero	0.06	0.19	0.11	0.15	0.27	0.06

The tract ID is PC13

Cumulative Distributions of Contained Metal and Mineralized Rock

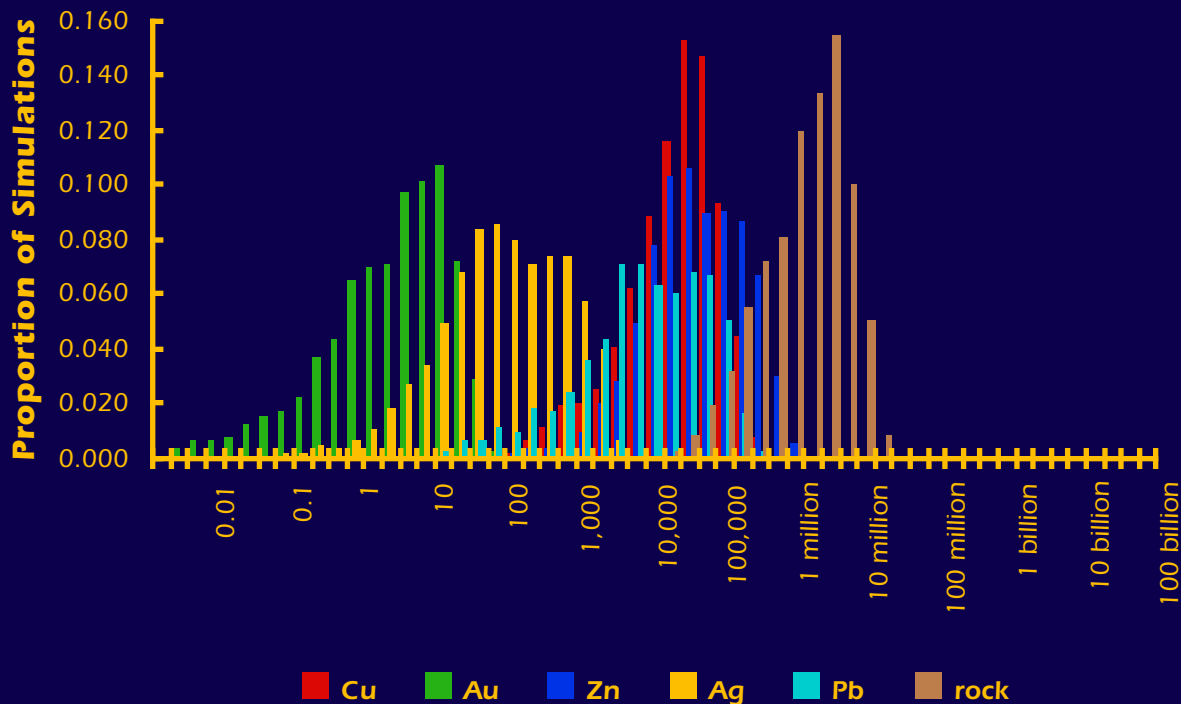
Histograms of Contained Metal and Mineralized Rock
(metric tons)

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC14

The Mark3 Index is 44:

Massive sulfide, Sierran kuroko

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 7 or more deposits.

There is a 5% or greater chance of 15 or more deposits.

There is a 1% or greater chance of 20 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	24,000	2	27,000	52	2,100	1,400,000
0.10	130,000	18	317,000	1,000	75,000	7,200,000
0.05	180,000	26	470,000	1,700	120,000	11,000,000
mean	48,000	6	100,000	320	22,000	2,800,000
Probability of mean	0.34	0.30	0.27	0.25	0.24	0.34
Probability of zero	0.17	0.22	0.23	0.21	0.36	0.17

The tract ID is PC14The Mark3 Index is 44: **Massive sulfide, Sierran kuroko**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 7 or more deposits.

There is a 5% or greater chance of 15 or more deposits.

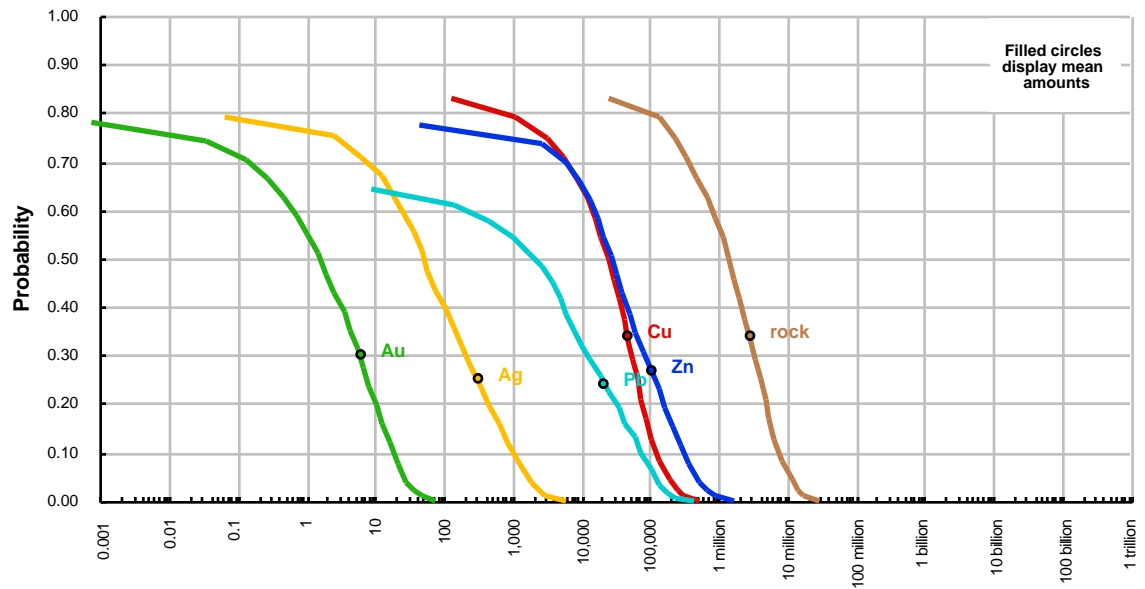
There is a 1% or greater chance of 20 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

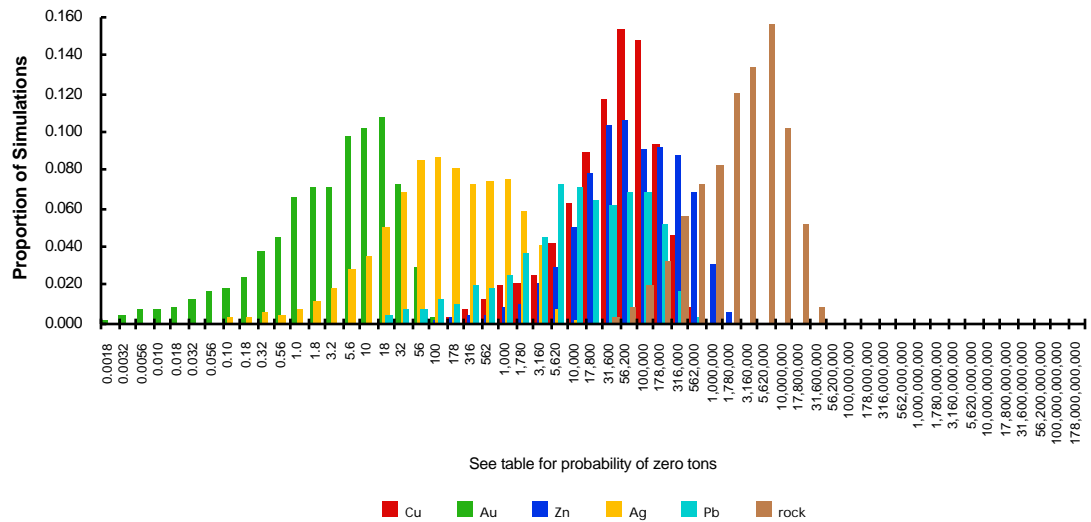
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	24,000	2	27,000	52	2,100	1,400,000
0.10	130,000	18	317,000	1,000	75,000	7,200,000
0.05	180,000	26	470,000	1,700	120,000	11,000,000
mean	48,000	6	100,000	320	22,000	2,800,000
Probability of mean	0.34	0.30	0.27	0.25	0.24	0.34
Probability of zero	0.17	0.22	0.23	0.21	0.36	0.17

The tract ID is PC14

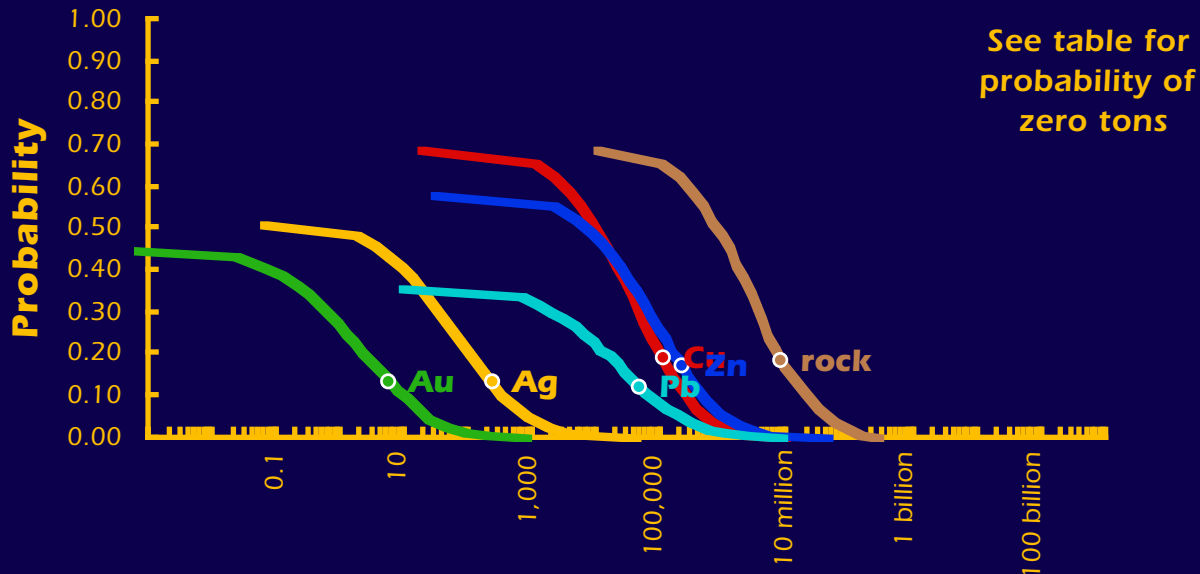
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

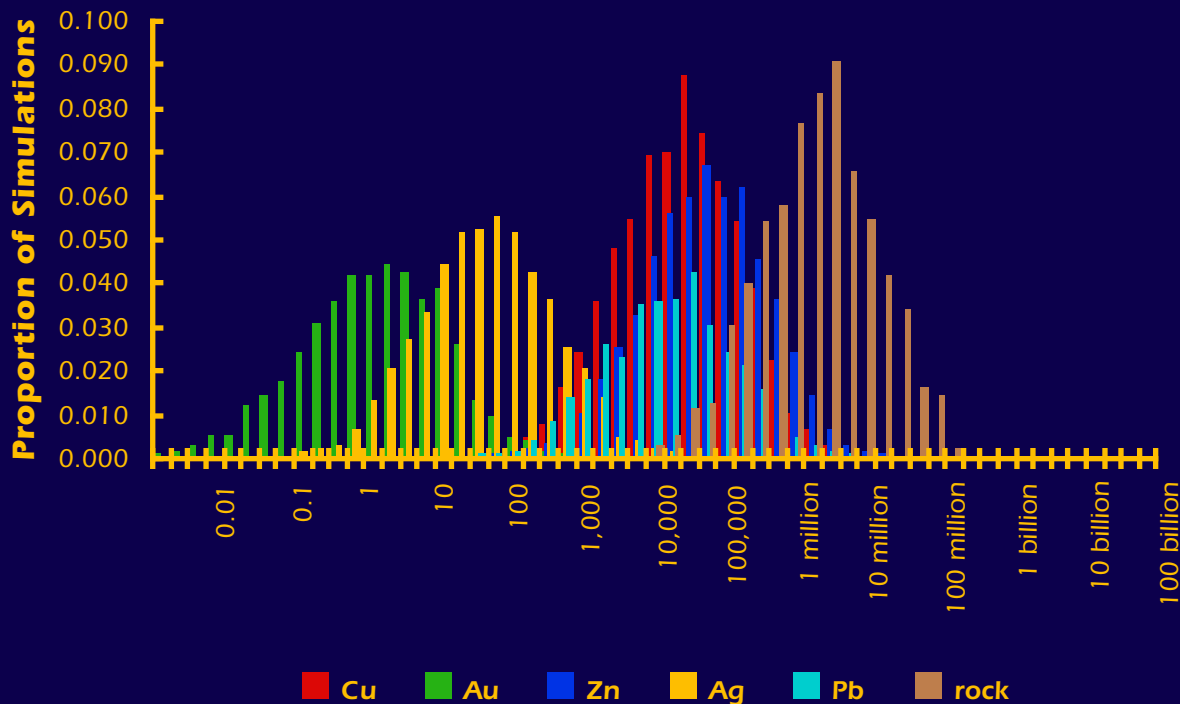


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC15

The Mark3 Index is 93:

Massive sulfide, kuroko

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	9,800	0	7,600	1	0	810,000
0.10	240,000	10	477,000	350	67,000	20,000,000
0.05	480,000	22	990,000	890	200,000	42,000,000
mean	110,000	6	230,000	240	49,000	7,900,000
Probability of mean	0.19	0.13	0.17	0.13	0.12	0.18
Probability of zero	0.31	0.55	0.42	0.49	0.65	0.31

The tract ID is PC15The Mark3 Index is 93: **Massive sulfide, kuroko**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

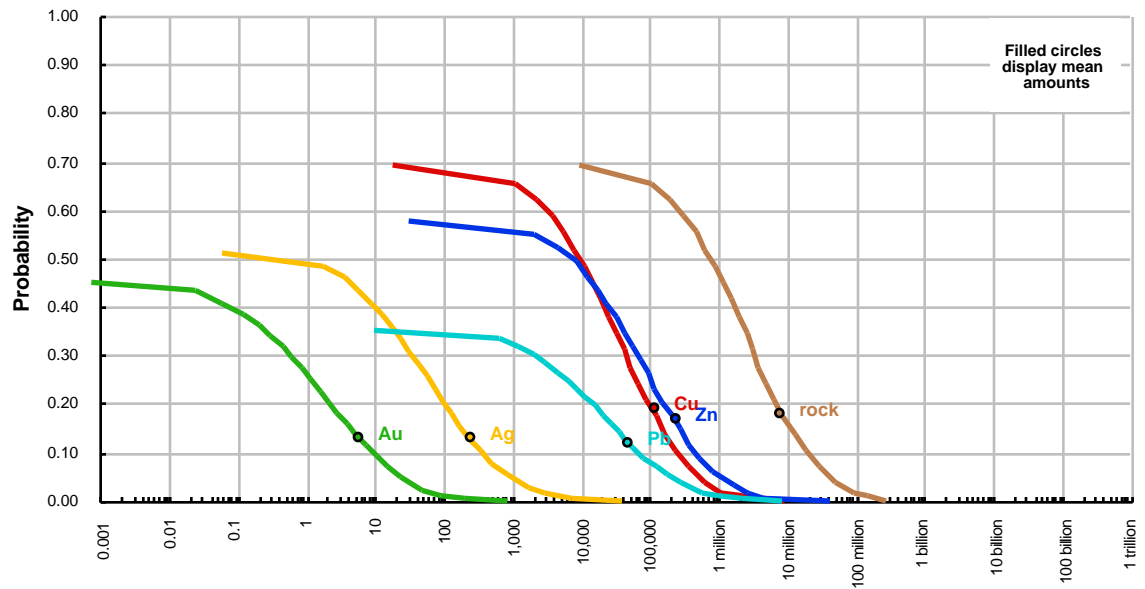
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

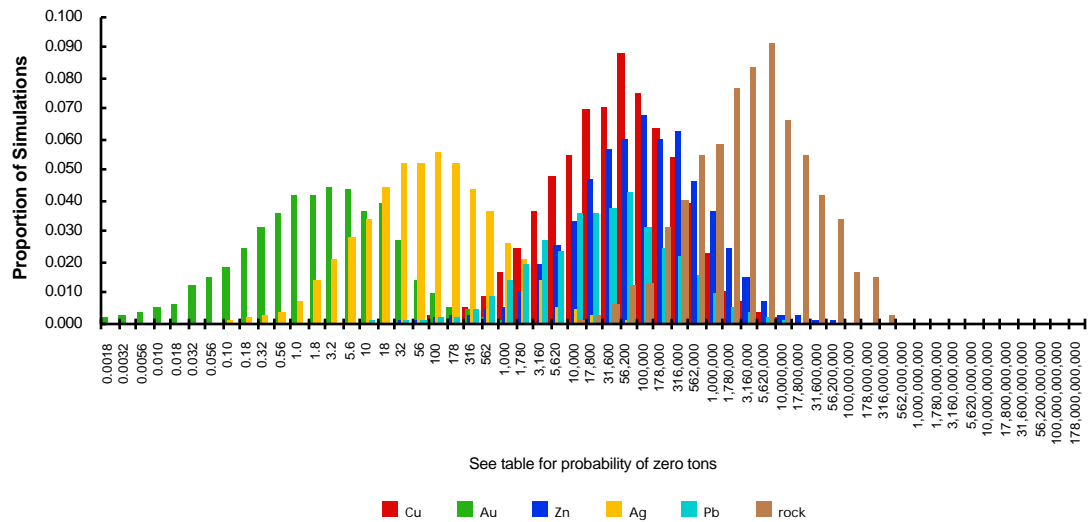
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	9,800	0	7,600	1	0	810,000
0.10	240,000	10	477,000	350	67,000	20,000,000
0.05	480,000	22	990,000	890	200,000	42,000,000
mean	110,000	6	230,000	240	49,000	7,900,000
Probability of mean	0.19	0.13	0.17	0.13	0.12	0.18
Probability of zero	0.31	0.55	0.42	0.49	0.65	0.31

The tract ID is PC15

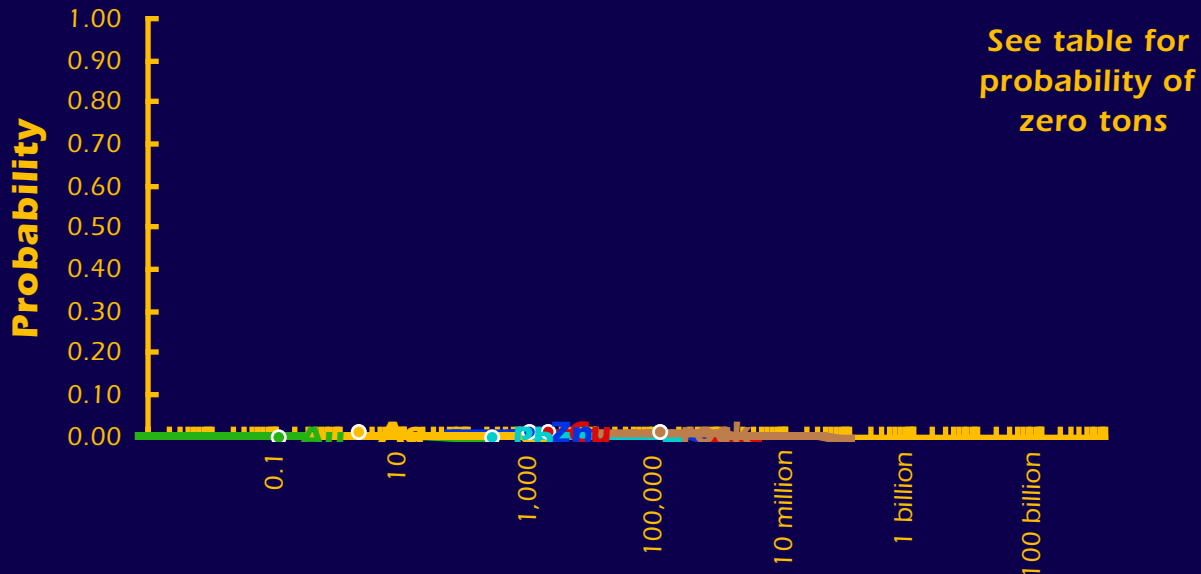
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

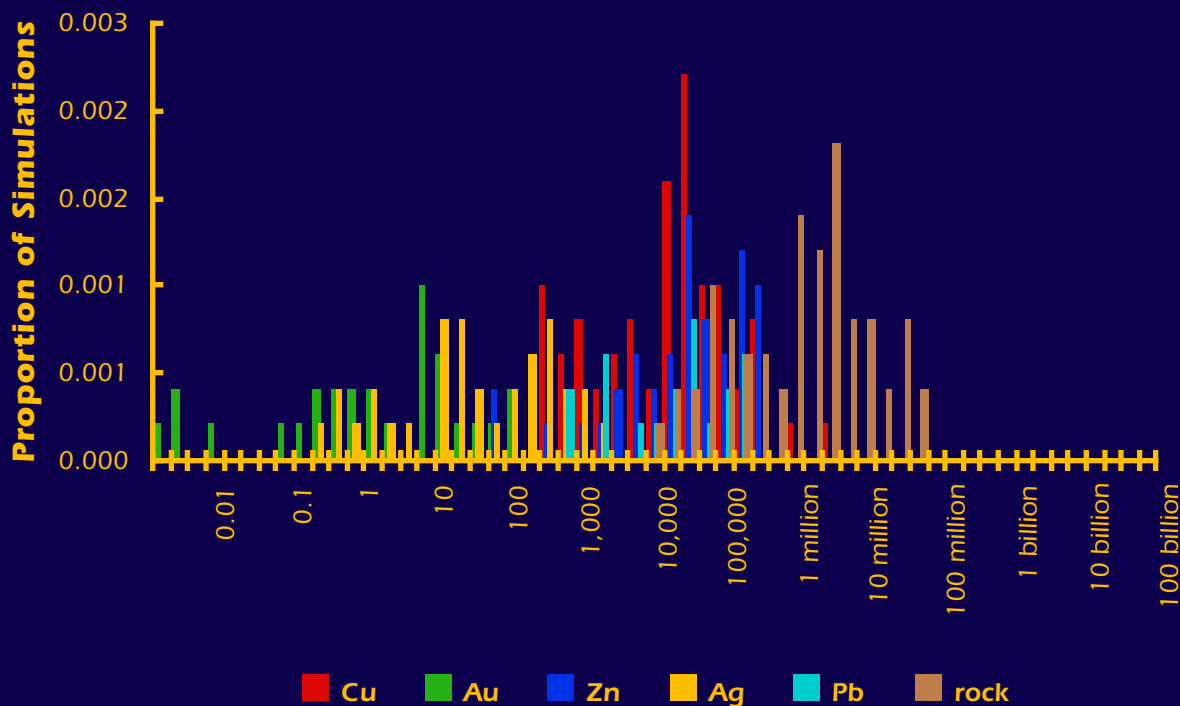


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC16

The Mark3 Index is 93:

Massive sulfide, kuroko

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	1,700	0	920	2	240	110,000
Probability of mean	0.01	0.00	0.01	0.01	0.00	0.01
Probability of zero	0.99	0.99	0.99	0.99	1.00	0.99

The tract ID is PC16The Mark3 Index is 93: **Massive sulfide, kuroko**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

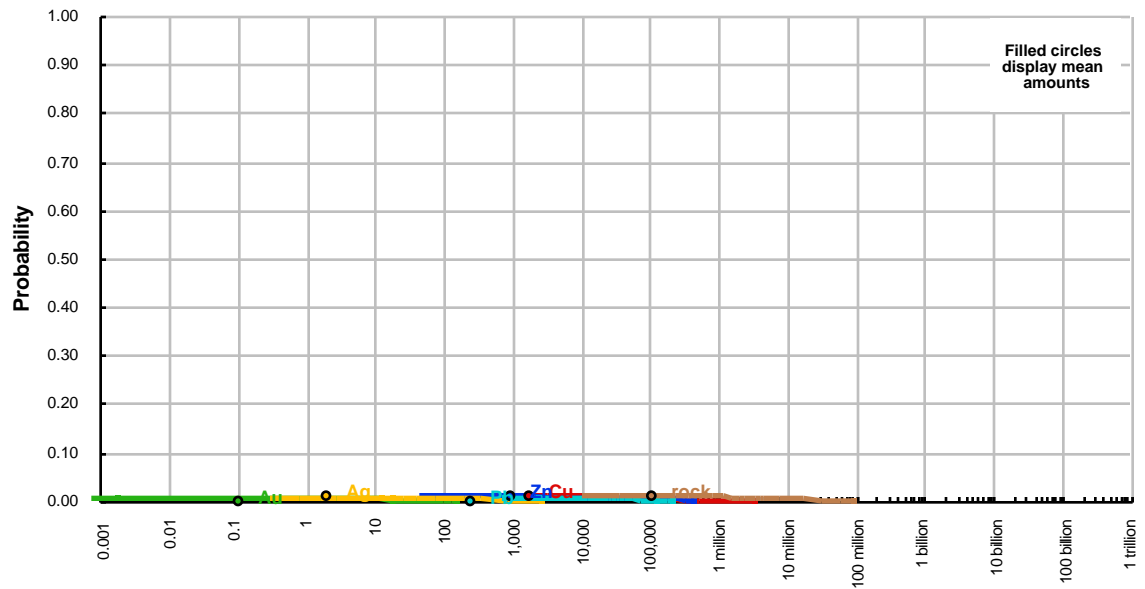
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

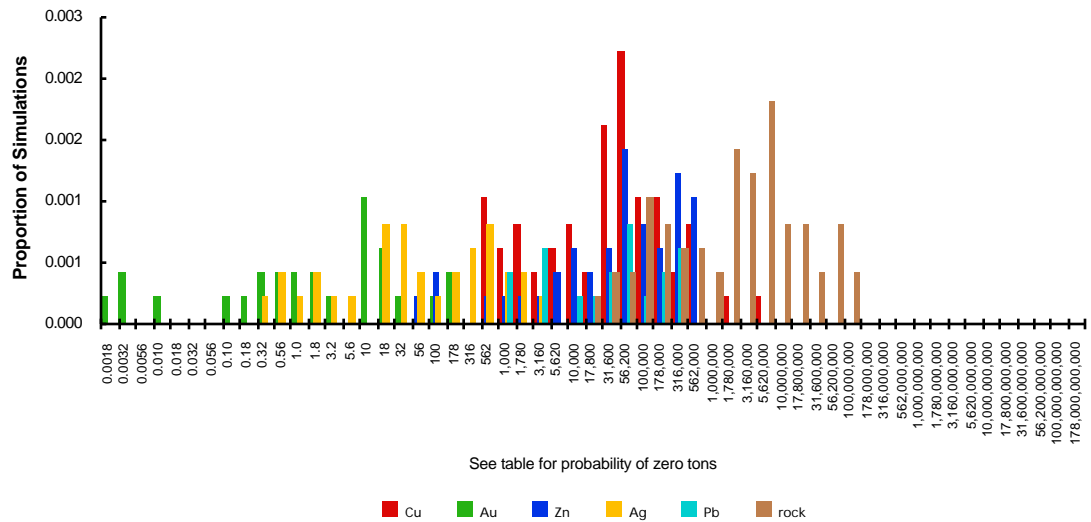
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	1,700	0	920	2	240	110,000
Probability of mean	0.01	0.00	0.01	0.01	0.00	0.01
Probability of zero	0.99	0.99	0.99	0.99	1.00	0.99

The tract ID is PC16

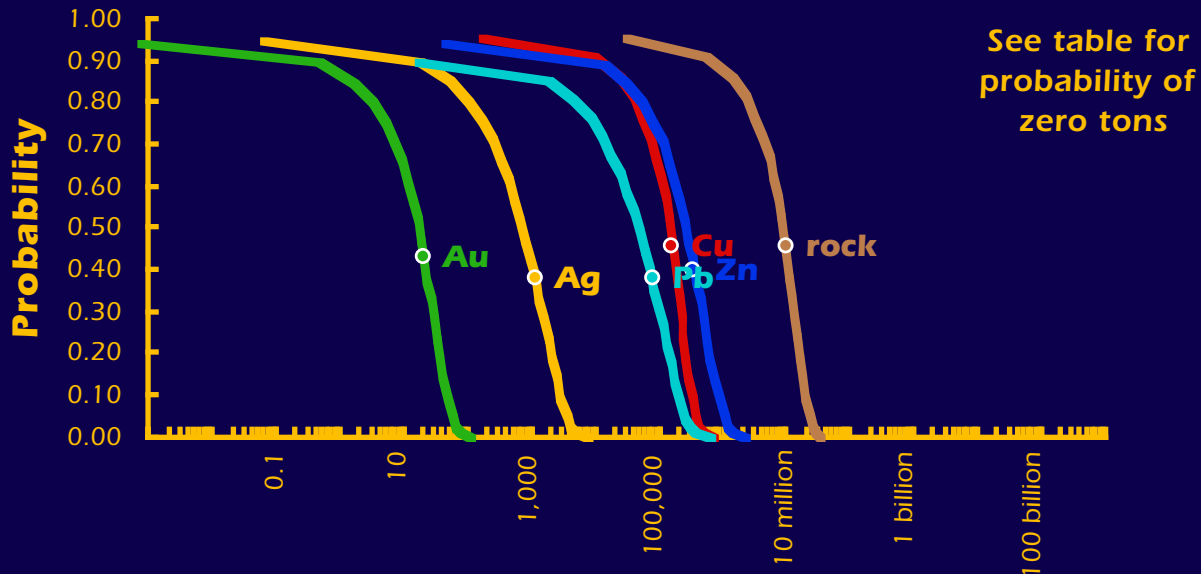
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

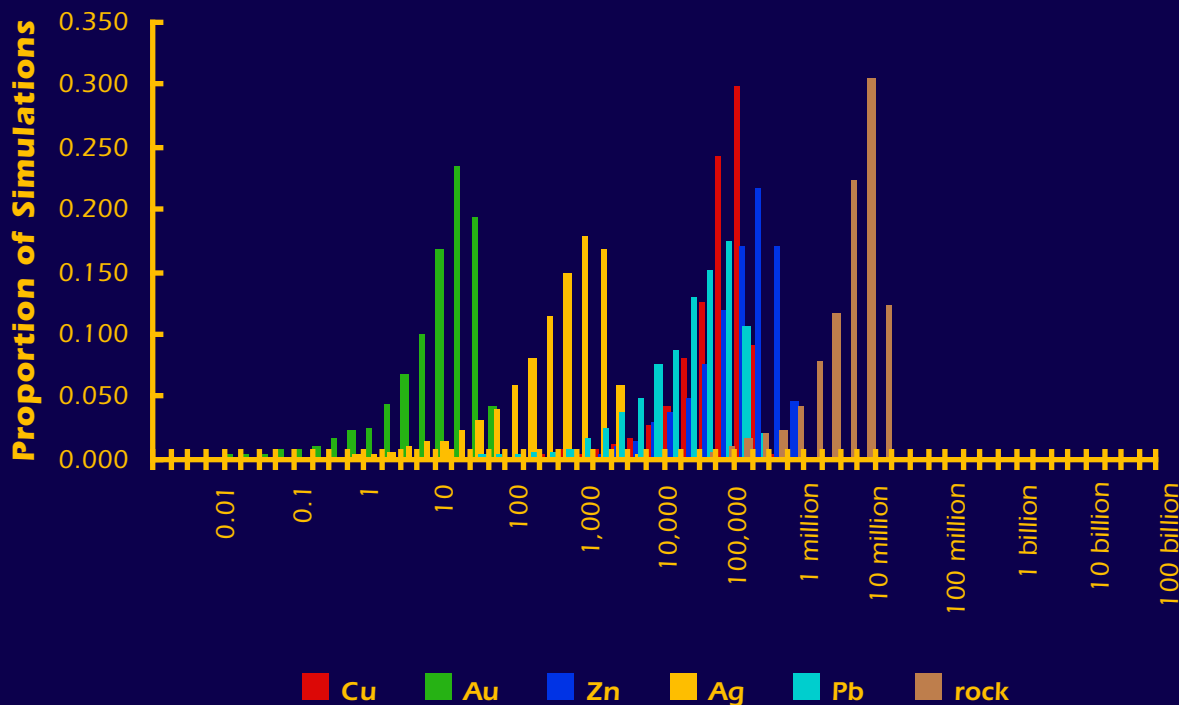


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC17

The Mark3 Index is 44:

Massive sulfide, Sierran kuroko

There is a 90% or greater chance of 2 or more deposits.
There is a 50% or greater chance of 13 or more deposits.
There is a 10% or greater chance of 25 or more deposits.
There is a 5% or greater chance of 25 or more deposits.
There is a 1% or greater chance of 25 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	700	0	0	0	0	97,000
0.90	12,000	0	12,000	18	0	690,000
0.50	140,000	16	260,000	710	46,000	8,500,000
0.10	310,000	45	815,000	2,700	200,000	19,000,000
0.05	360,000	55	990,000	3,400	250,000	22,000,000
mean	160,000	20	340,000	1,100	76,000	9,200,000
Probability of mean	0.46	0.43	0.40	0.38	0.38	0.46
Probability of zero	0.04	0.06	0.06	0.05	0.10	0.04

The tract ID is PC17The Mark3 Index is 44: **Massive sulfide, Sierran kuroko**

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 13 or more deposits.

There is a 10% or greater chance of 25 or more deposits.

There is a 5% or greater chance of 25 or more deposits.

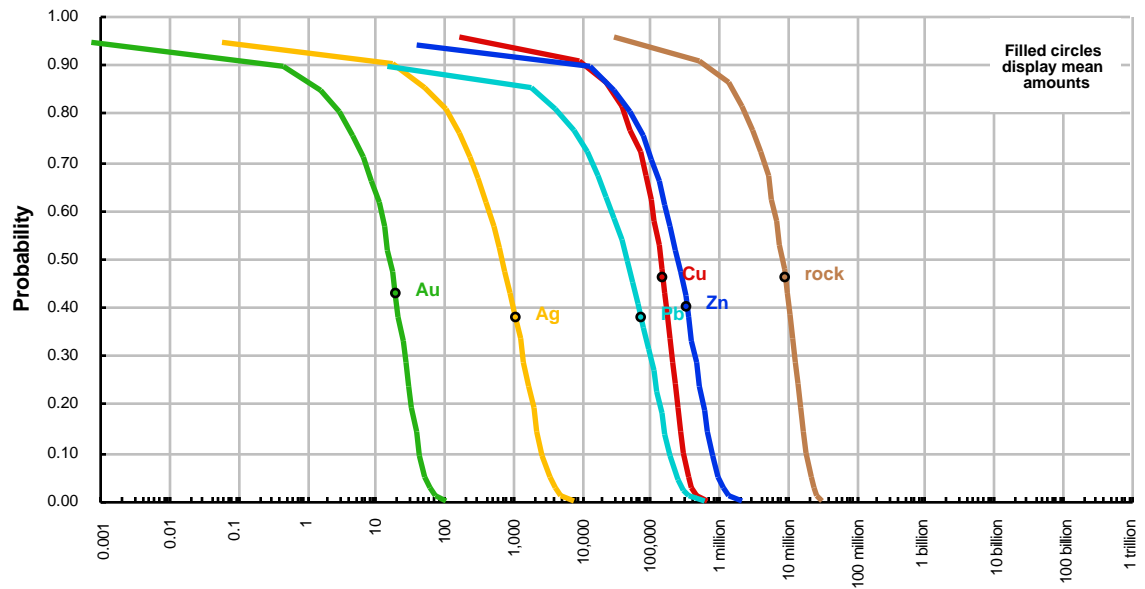
There is a 1% or greater chance of 25 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

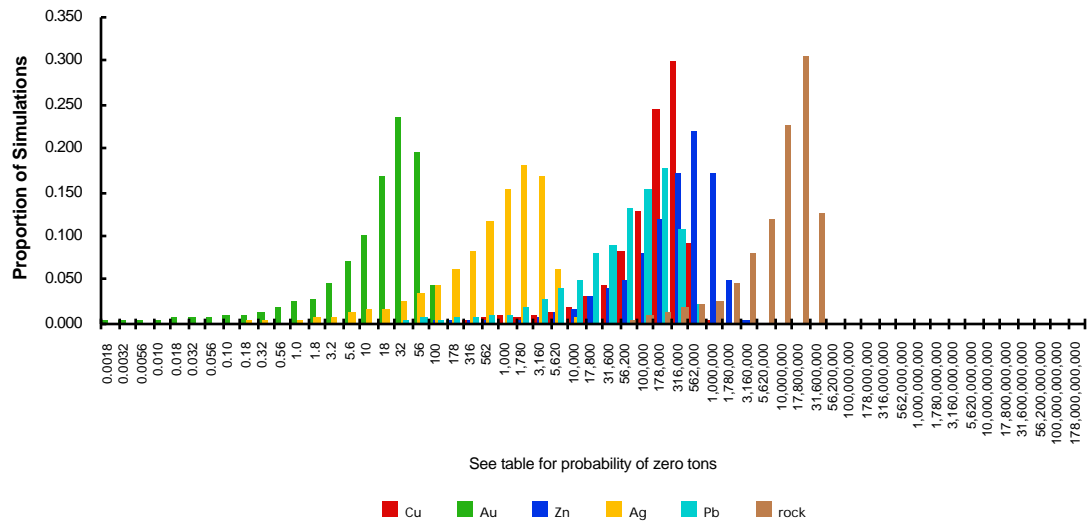
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	700	0	0	0	0	97,000
0.90	12,000	0	12,000	18	0	690,000
0.50	140,000	16	260,000	710	46,000	8,500,000
0.10	310,000	45	815,000	2,700	200,000	19,000,000
0.05	360,000	55	990,000	3,400	250,000	22,000,000
mean	160,000	20	340,000	1,100	76,000	9,200,000
Probability of mean	0.46	0.43	0.40	0.38	0.38	0.46
Probability of zero	0.04	0.06	0.06	0.05	0.10	0.04

The tract ID is PC17

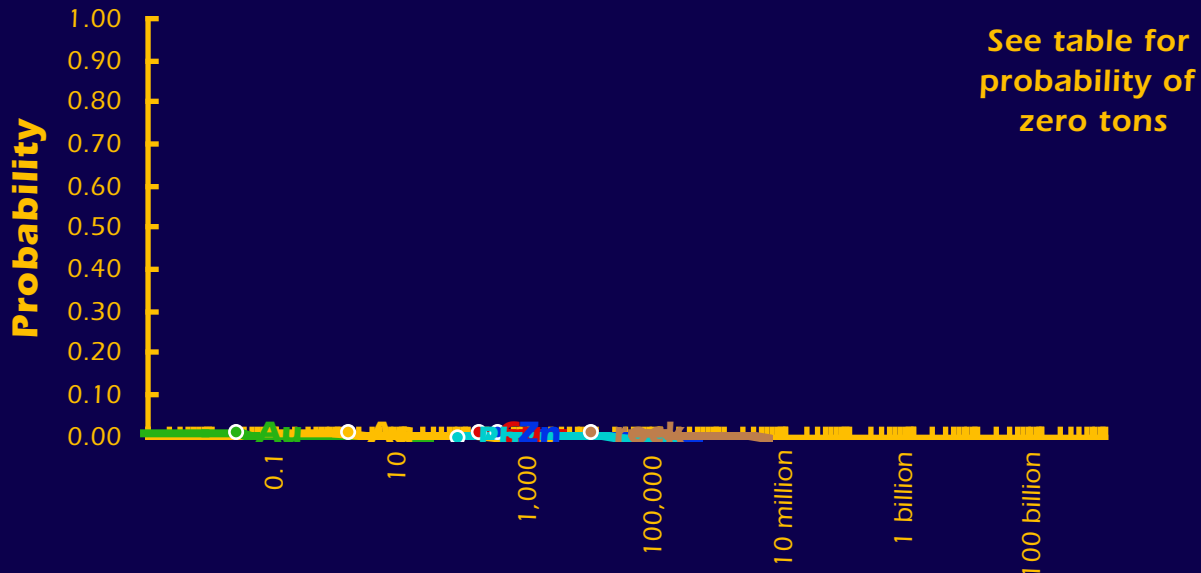
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

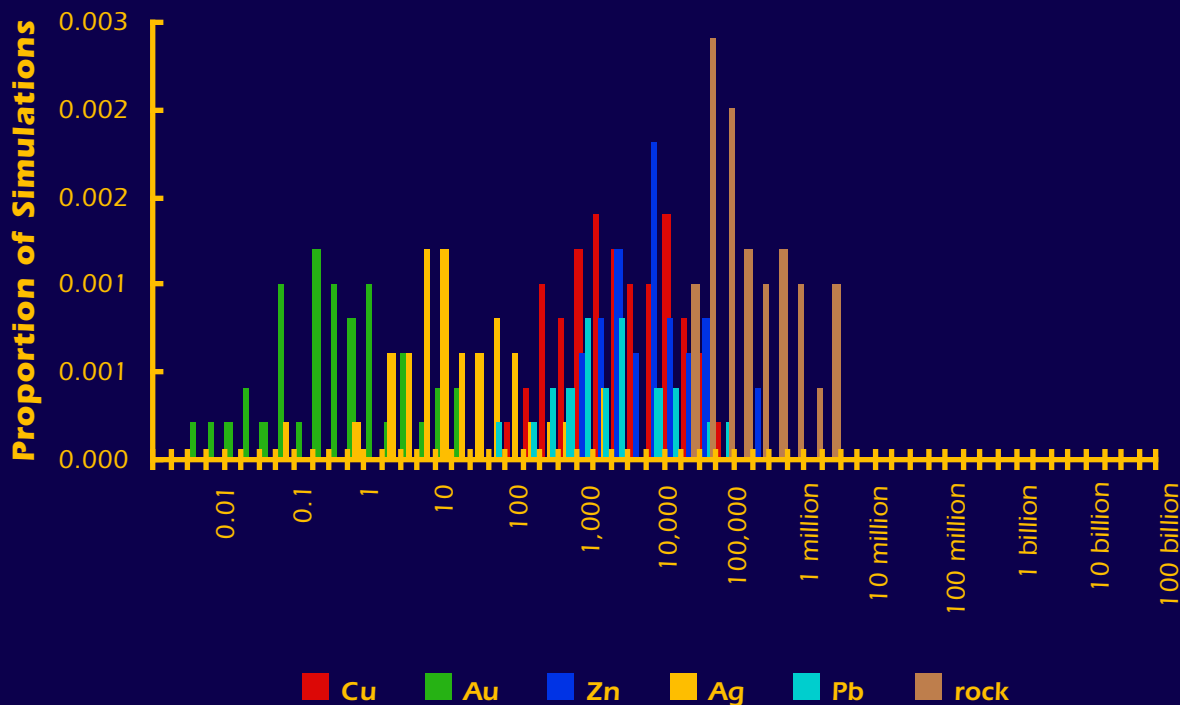


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC18

The Mark3 Index is 44:

Massive sulfide, Sierran kuroko

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	150	0	290	1	68	8,800
Probability of mean	0.01	0.01	0.01	0.01	0.00	0.01
Probability of zero	0.99	0.99	0.99	0.99	1.00	0.99

The tract ID is PC18The Mark3 Index is 44: **Massive sulfide, Sierran kuroko**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

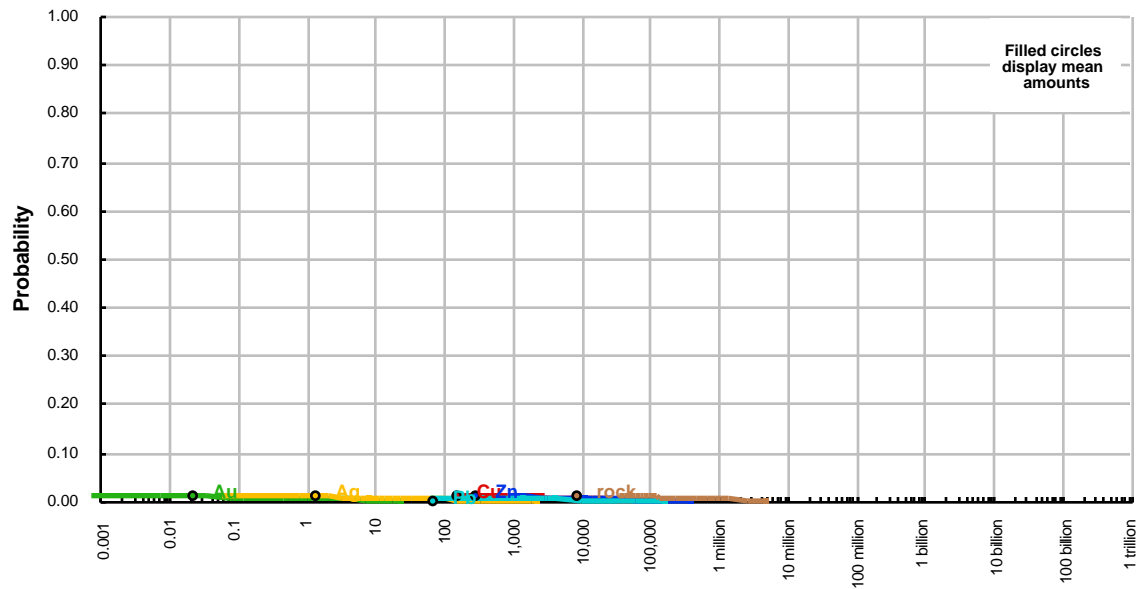
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

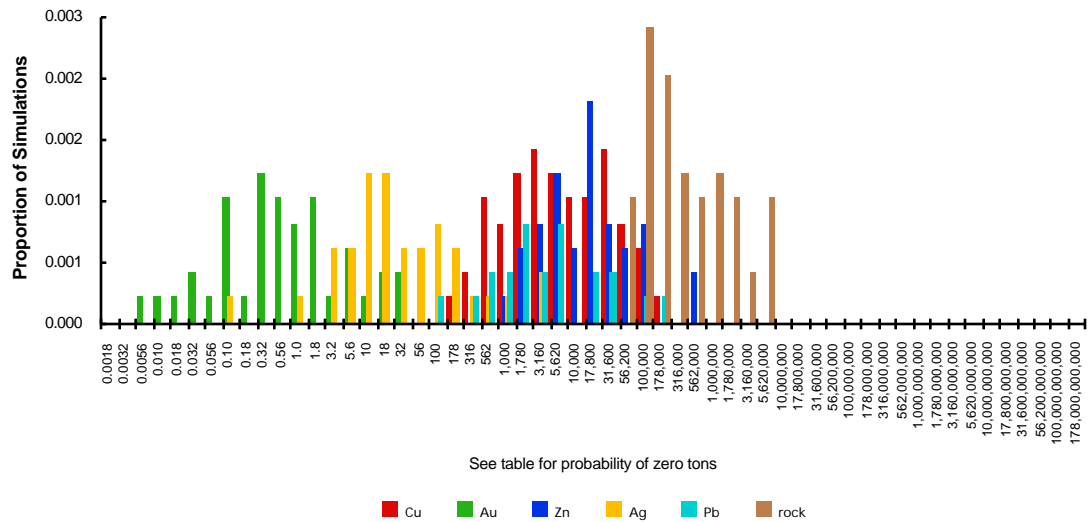
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	150	0	290	1	68	8,800
Probability of mean	0.01	0.01	0.01	0.01	0.00	0.01
Probability of zero	0.99	0.99	0.99	0.99	1.00	0.99

The tract ID is PC18

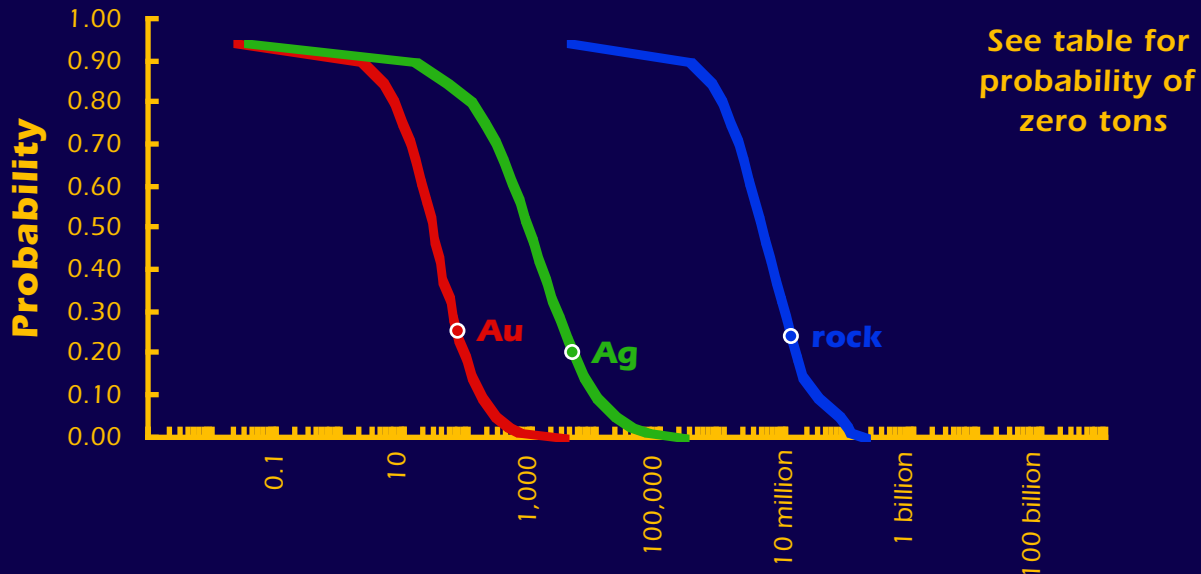
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

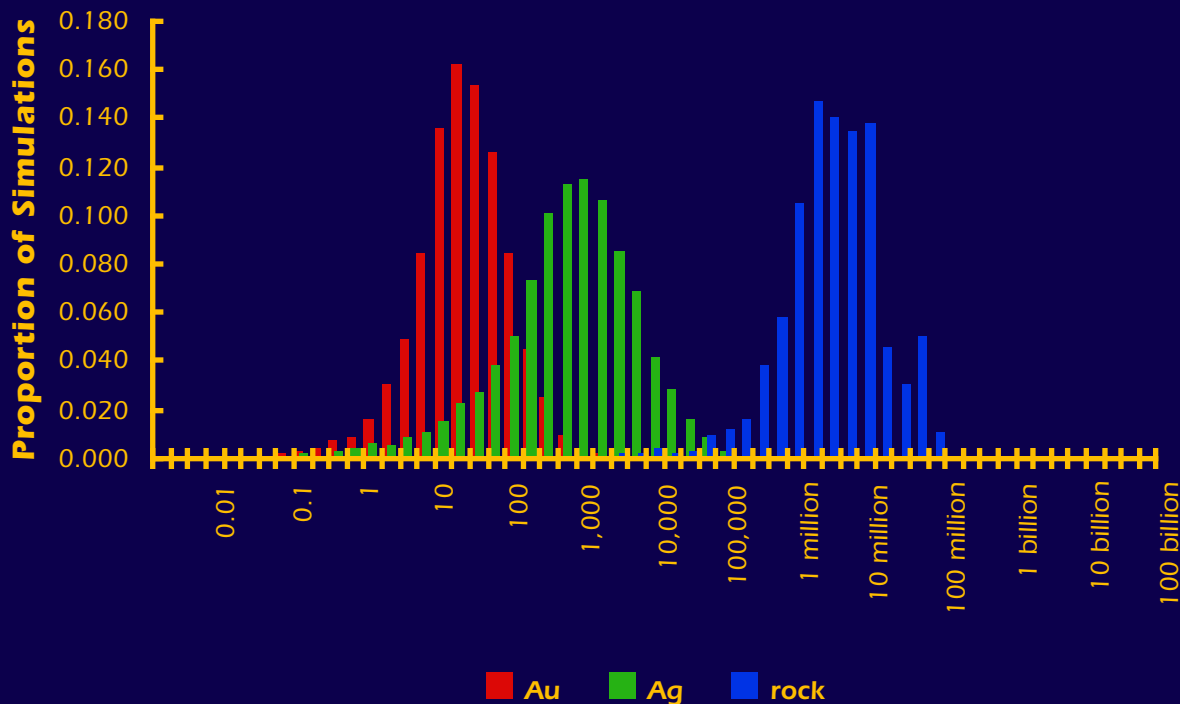


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC19

The Mark3 Index is 16:

Epithermal vein, Comstock

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	2	13	280,000
0.50	27	850	3,800,000
0.10	150	9,700	27,100,000
0.05	260	19,000	66,000,000
mean	66	4,300	11,000,000
Probability of mean	0.25	0.20	0.24
Probability of zero	0.06	0.06	0.06

The tract ID is PC19The Mark3 Index is 16: **Epithermal vein, Comstock**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

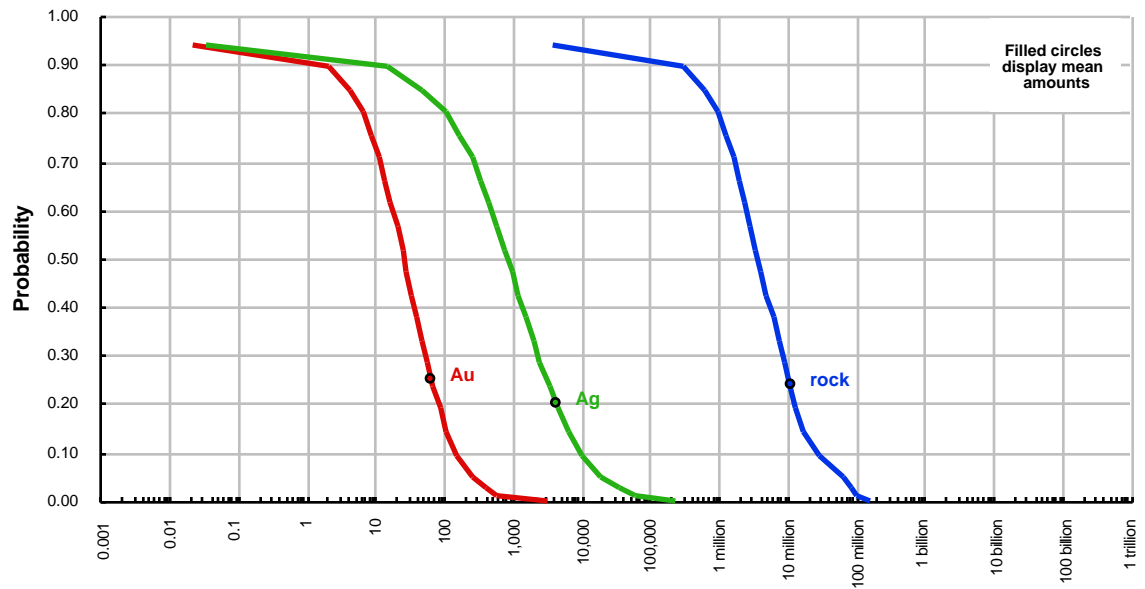
There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

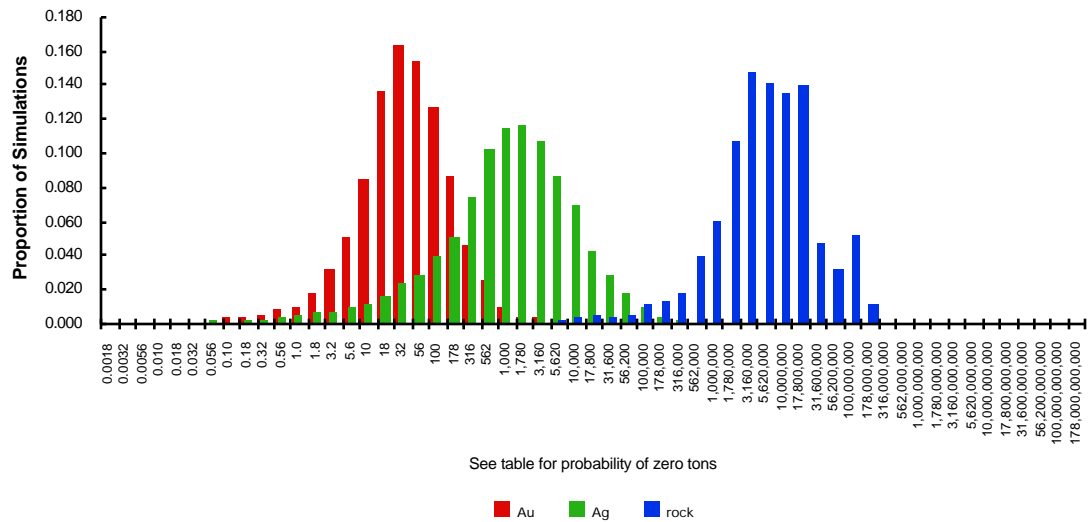
quantile	Au	Ag	rock
0.95	0	0	0
0.90	2	13	280,000
0.50	27	850	3,800,000
0.10	150	9,700	27,100,000
0.05	260	19,000	66,000,000
mean	66	4,300	11,000,000
Probability of mean	0.25	0.20	0.24
Probability of zero	0.06	0.06	0.06

The tract ID is PC19

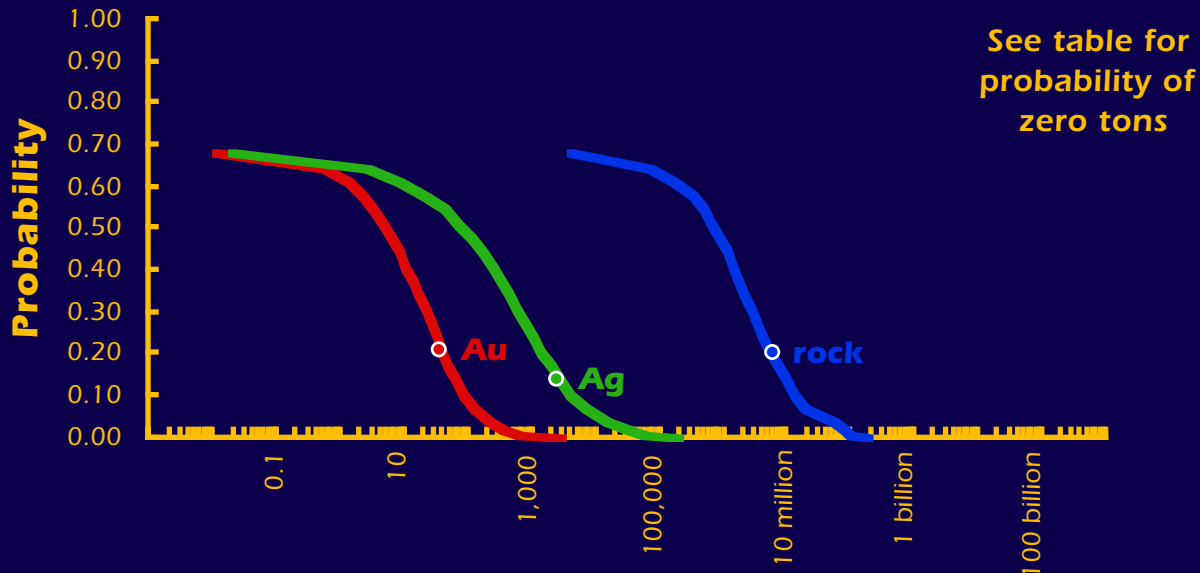
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

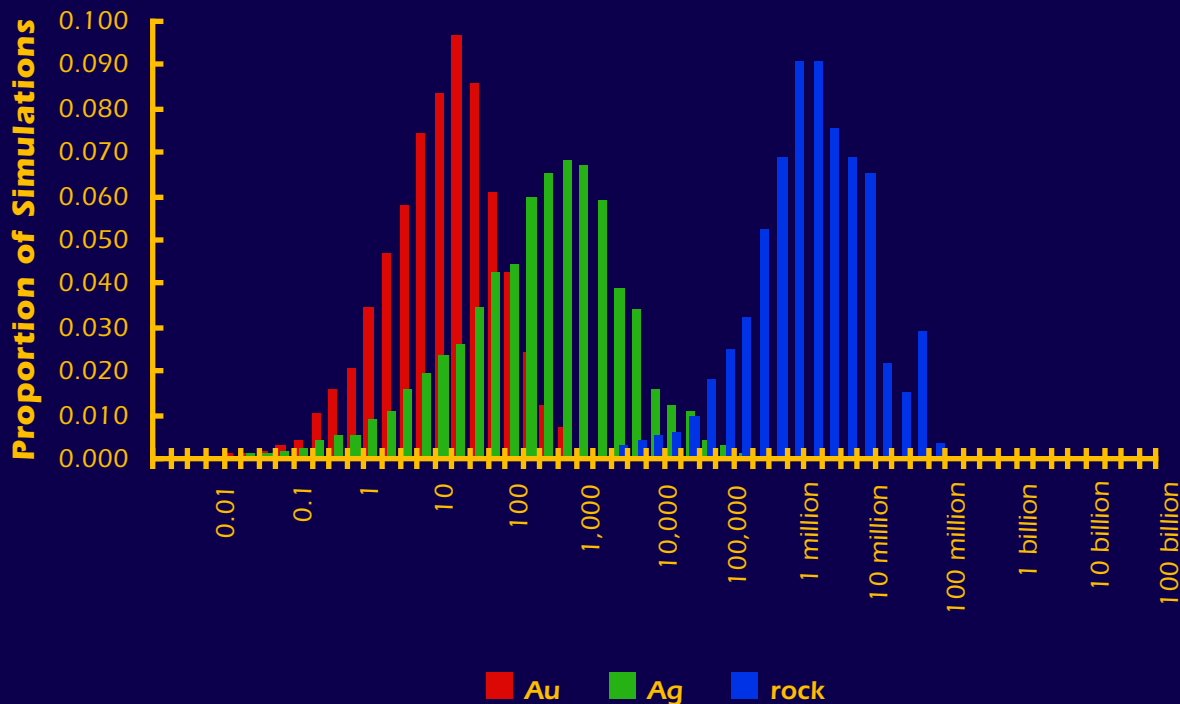


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC20

The Mark3 Index is 16:

Epithermal vein, Comstock

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	5	78	720,000
0.10	89	4,200	13,400,000
0.05	160	9,500	29,000,000
mean	36	2,500	6,000,000
Probability of mean	0.21	0.14	0.20
Probability of zero	0.32	0.32	0.32

The tract ID is PC20The Mark3 Index is 16: **Epithermal vein, Comstock**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

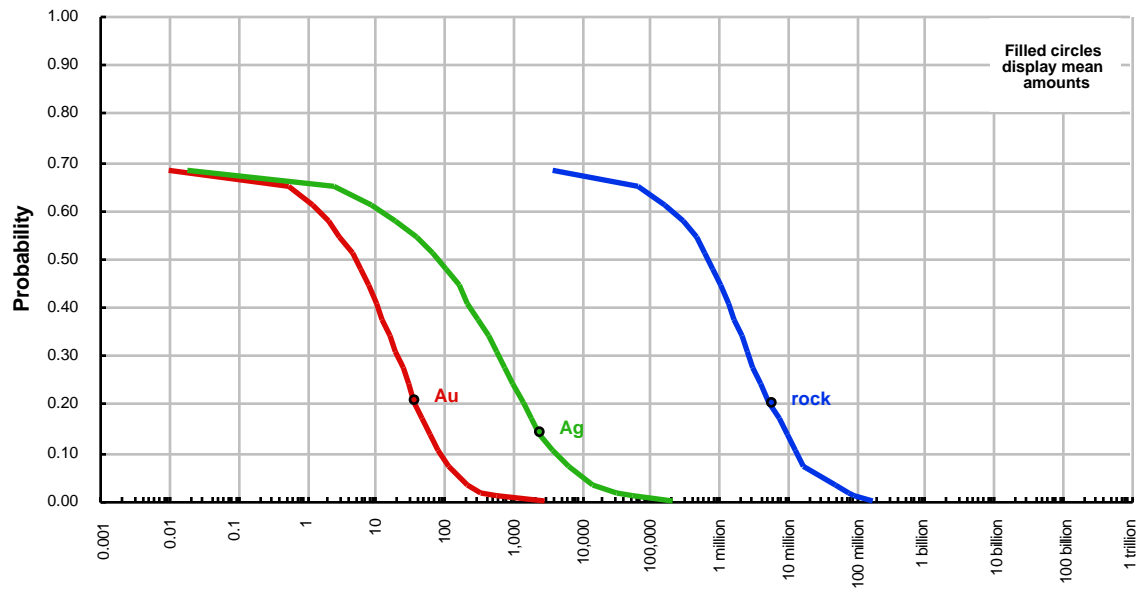
There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

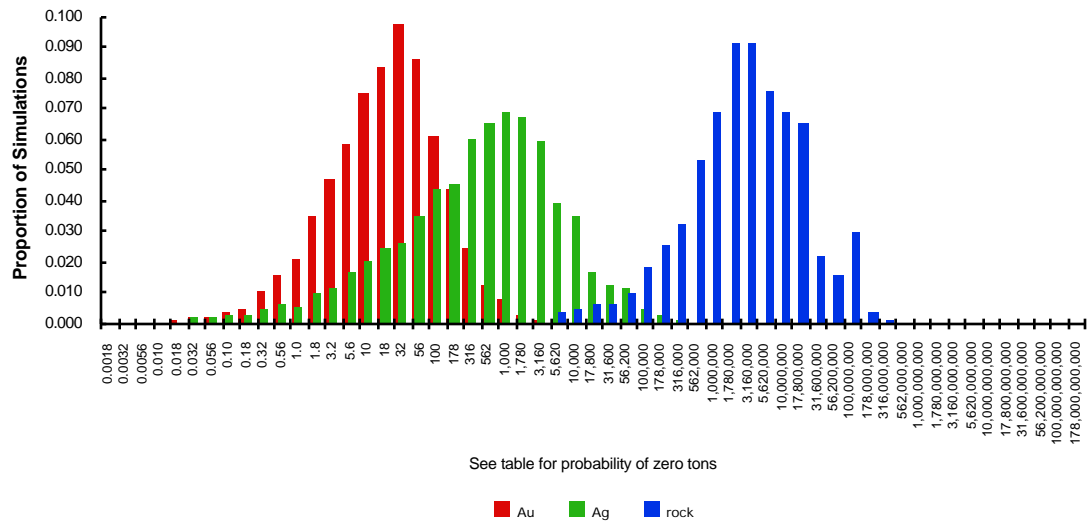
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	5	78	720,000
0.10	89	4,200	13,400,000
0.05	160	9,500	29,000,000
mean	36	2,500	6,000,000
Probability of mean	0.21	0.14	0.20
Probability of zero	0.32	0.32	0.32

The tract ID is PC20

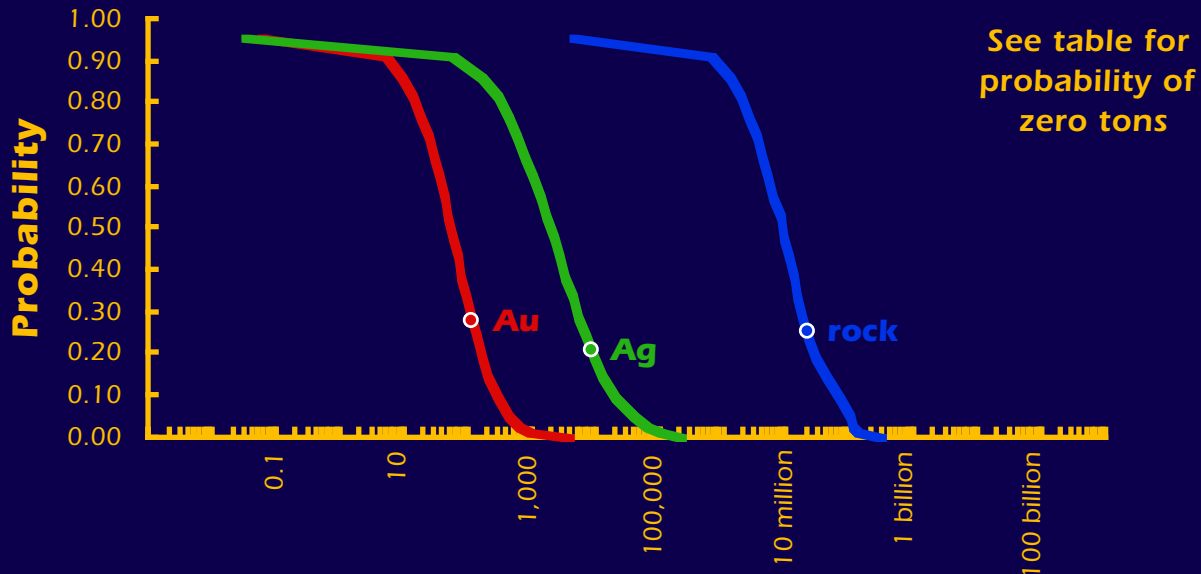
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

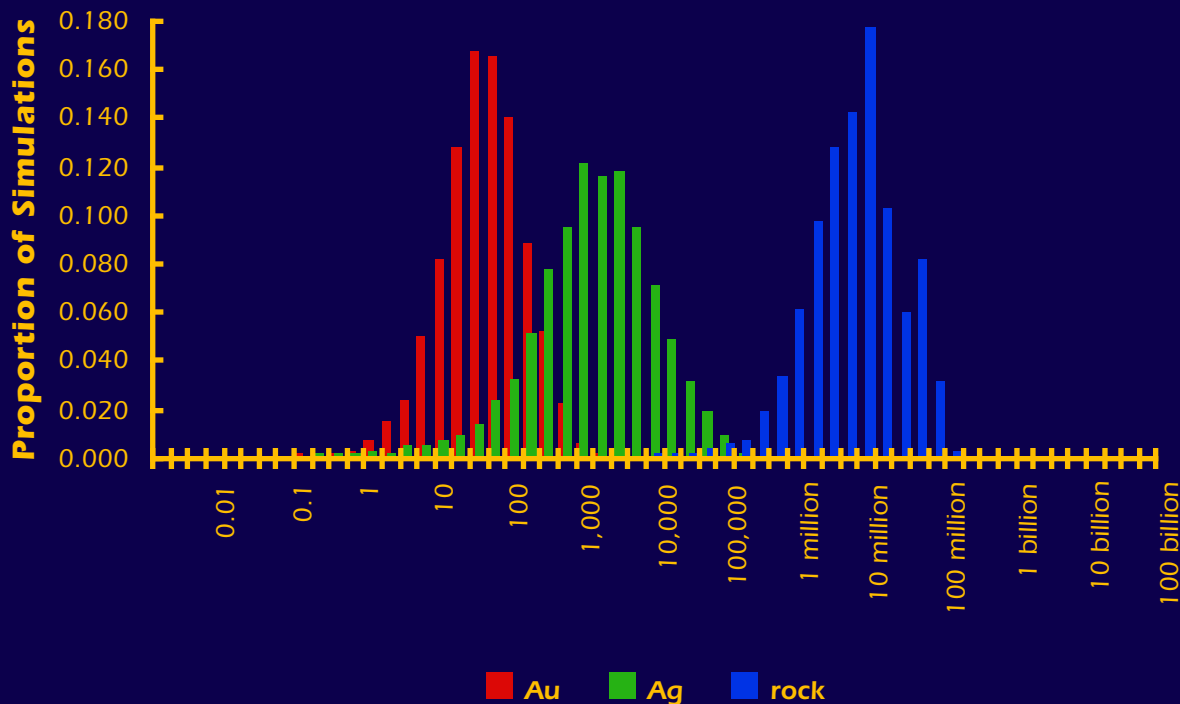


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC21

The Mark3 Index is 16:

Epithermal vein, Comstock

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 4 or more deposits.

There is a 10% or greater chance of 7 or more deposits.

There is a 5% or greater chance of 11 or more deposits.

There is a 1% or greater chance of 16 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	1	2	79,000
0.90	6	73	750,000
0.50	53	1,900	8,400,000
0.10	270	20,000	66,100,000
0.05	430	38,000	92,000,000
mean	110	8,100	20,000,000
Probability of mean	0.28	0.21	0.25
Probability of zero	0.04	0.04	0.04

The tract ID is PC21

The Mark3 Index is 16: **Epithermal vein, Comstock**

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 4 or more deposits.

There is a 10% or greater chance of 7 or more deposits.

There is a 5% or greater chance of 11 or more deposits.

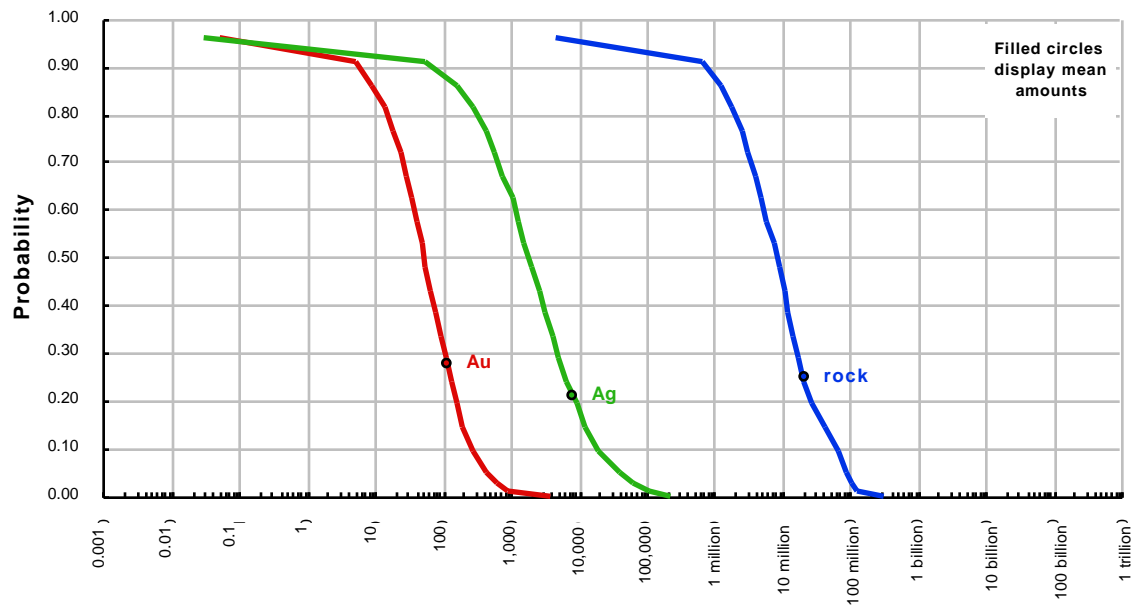
There is a 1% or greater chance of 16 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

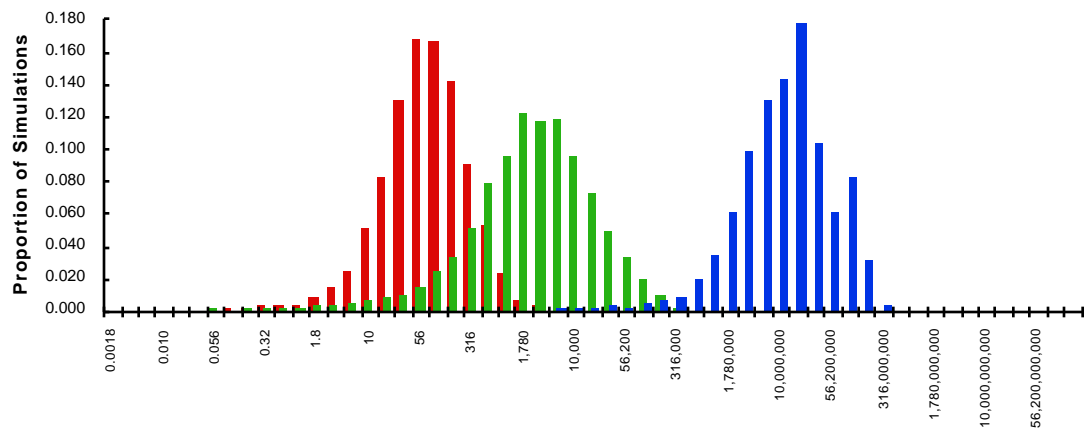
quantile	Au	Ag	rock
0.95	1	2	79,000
0.90	6	73	750,000
0.50	53	1,900	8,400,000
0.10	270	20,000	66,100,000
0.05	430	38,000	92,000,000
mean	110	8,100	20,000,000
Probability of mean	0.28	0.21	0.25
Probability of zero	0.04	0.04	0.04

The tract ID is PC21

Cumulative Distributions of Contained Metal and Mineralized Rock



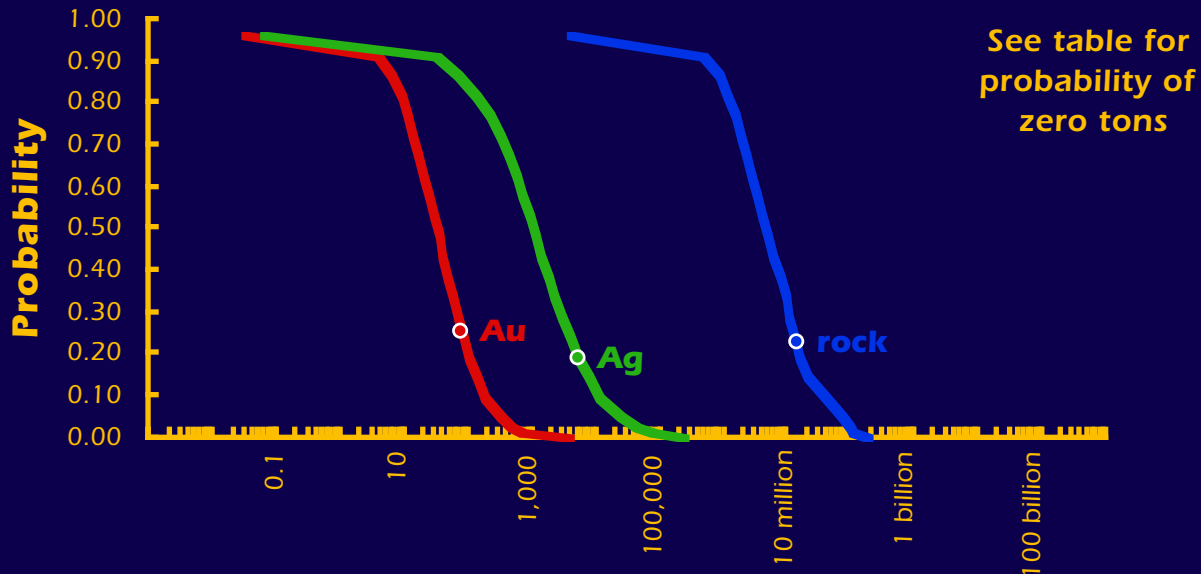
Histograms of Contained Metal and Mineralized Rock (metric tons)



See table for probability of zero tons

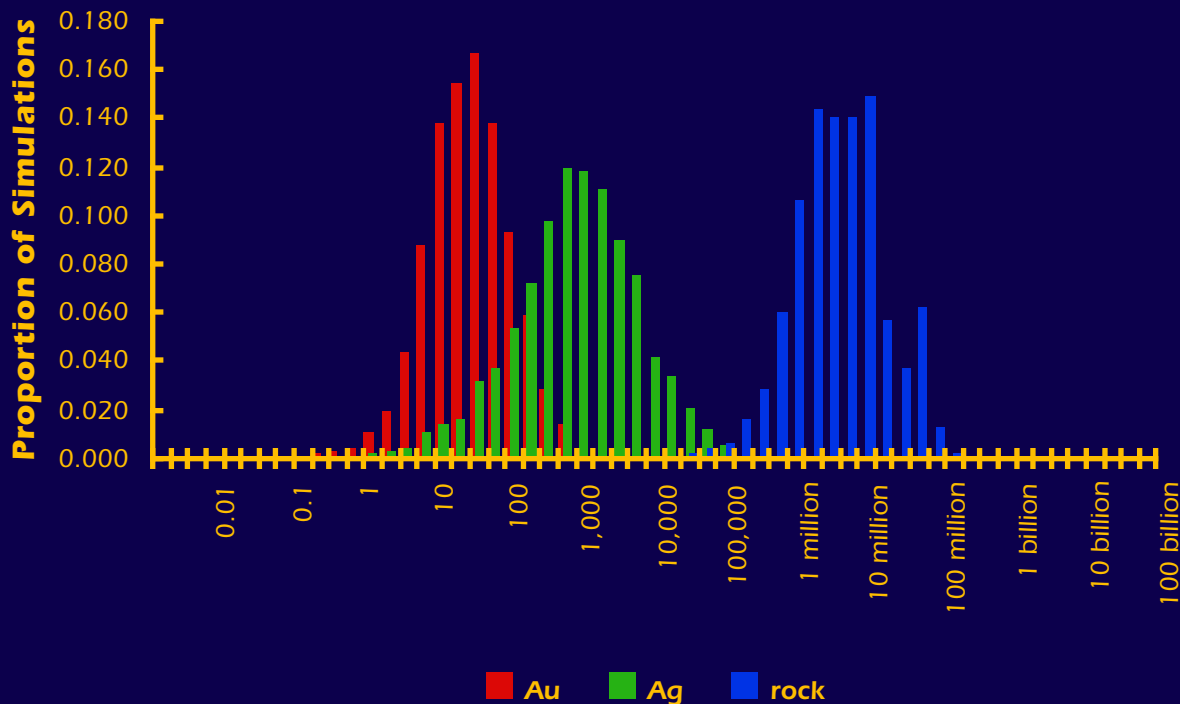
Au Ag rock

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC22

The Mark3 Index is 16:

Epithermal vein, Comstock

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	1	6	140,000
0.90	4	39	580,000
0.50	32	1,000	4,700,000
0.10	180	11,000	38,500,000
0.05	300	24,000	73,000,000
mean	76	5,200	13,000,000
Probability of mean	0.25	0.19	0.23
Probability of zero	0.04	0.04	0.04

The tract ID is PC22

The Mark3 Index is 16: **Epithermal vein, Comstock**

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

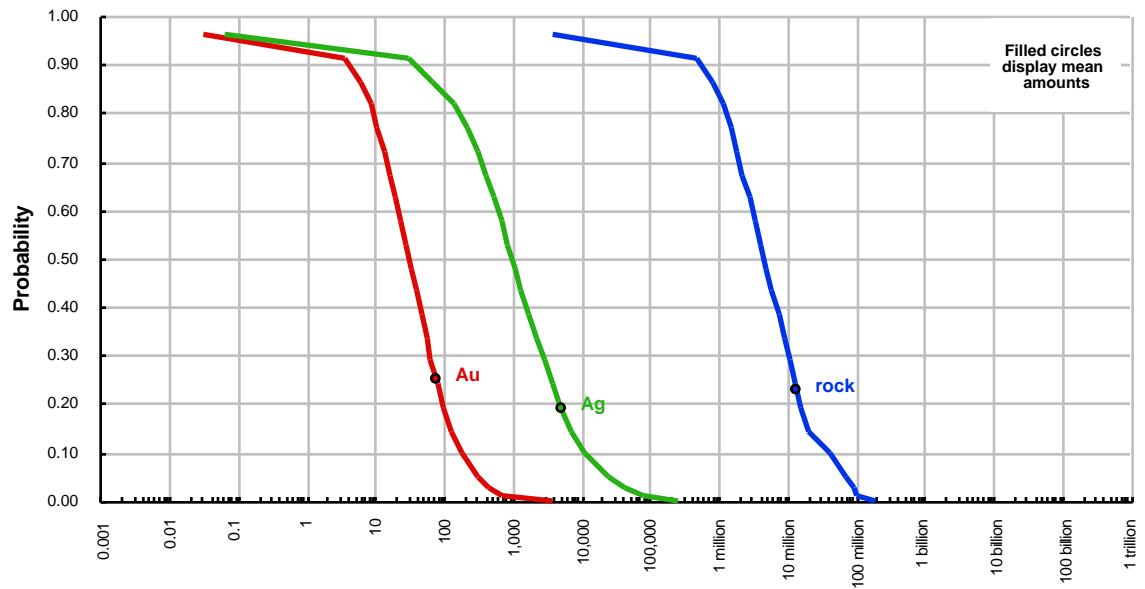
There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

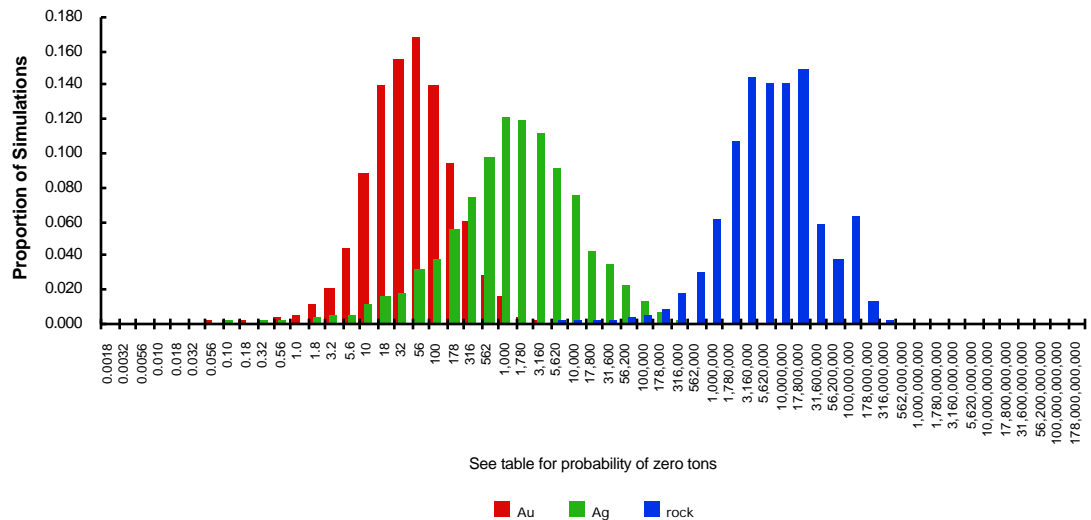
quantile	Au	Ag	rock
0.95	1	6	140,000
0.90	4	39	580,000
0.50	32	1,000	4,700,000
0.10	180	11,000	38,500,000
0.05	300	24,000	73,000,000
mean	76	5,200	13,000,000
Probability of mean	0.25	0.19	0.23
Probability of zero	0.04	0.04	0.04

The tract ID is PC22

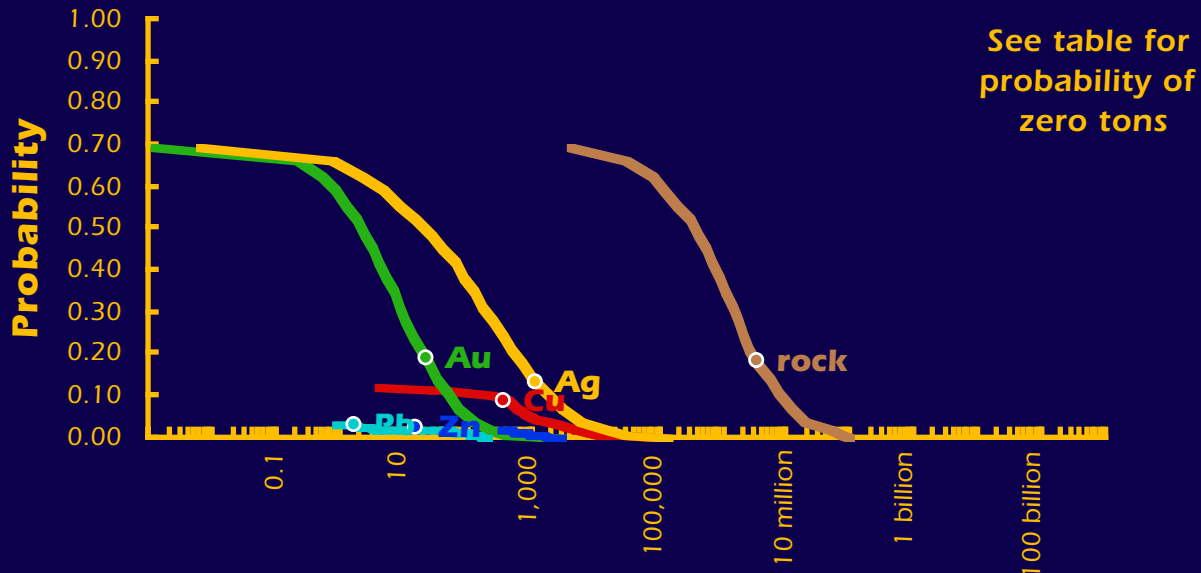
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

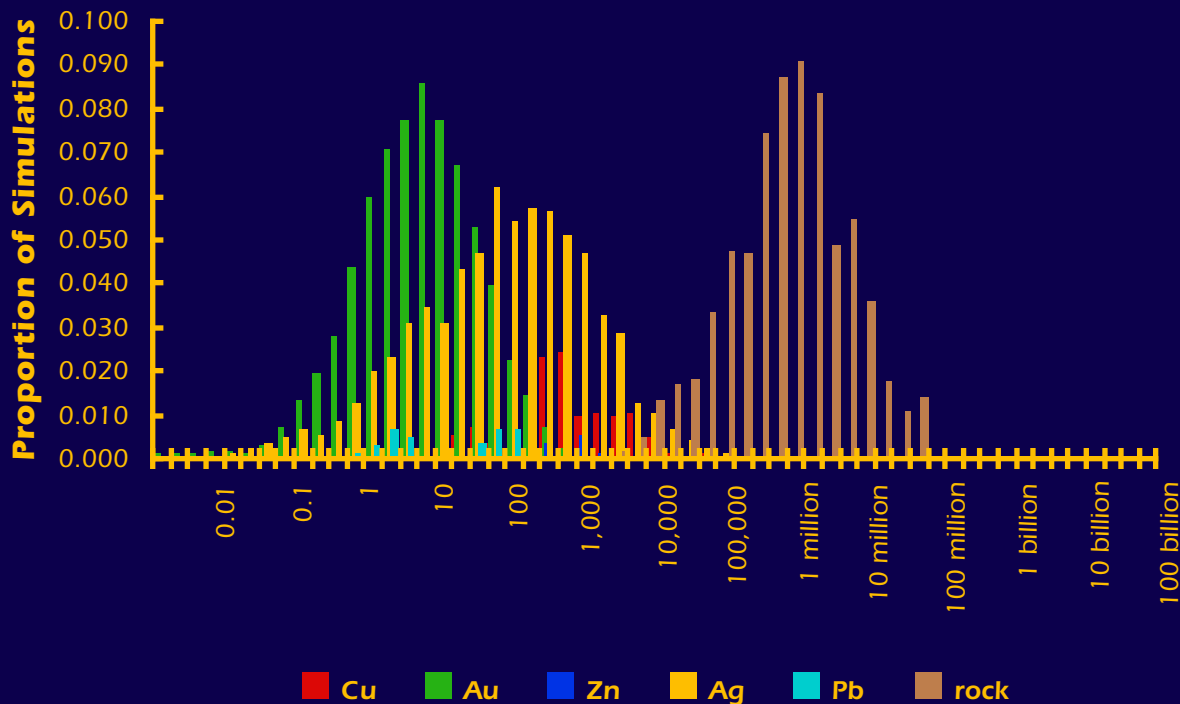


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC26

The Mark3 Index is 25:

Epithermal vein, quartz-adularia

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	2	0	21	0	360,000
0.10	180	48	0	1,700	0	7,700,000
0.05	890	94	0	4,100	0	14,000,000

The tract ID is PC26The Mark3 Index is 25: **Epithermal vein, quartz-adularia**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

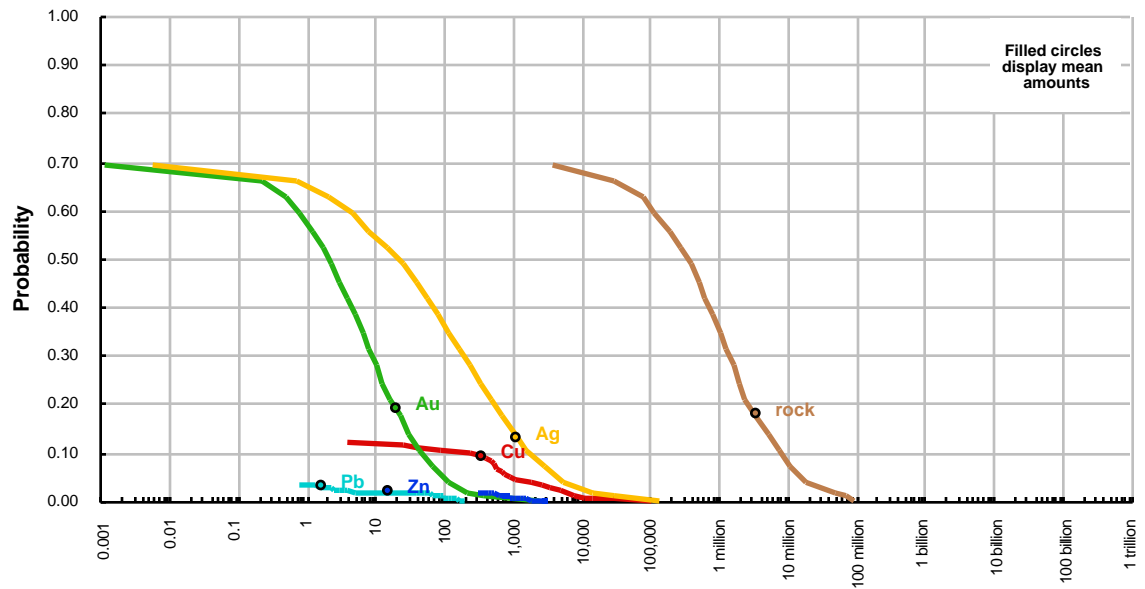
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

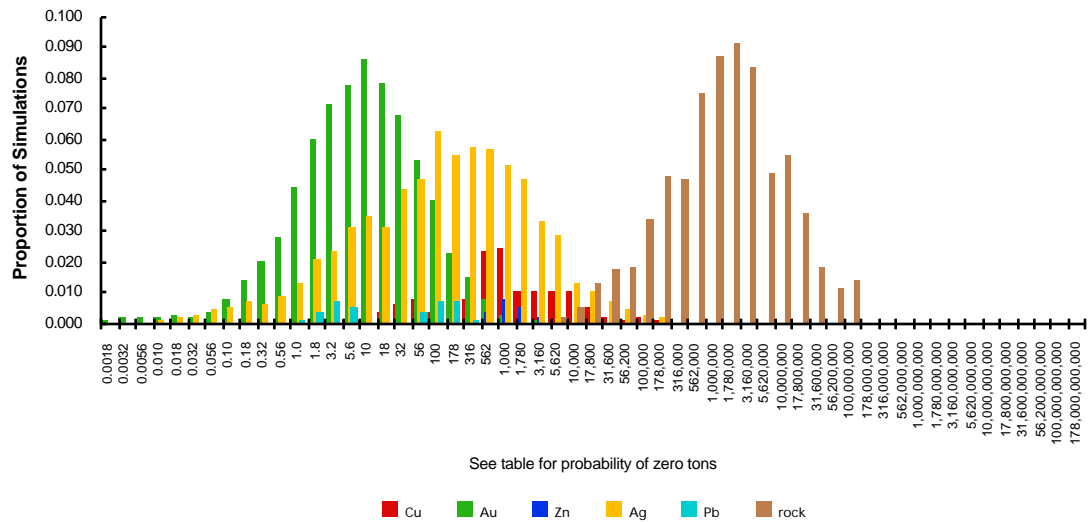
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	2	0	21	0	360,000
0.10	180	48	0	1,700	0	7,700,000
0.05	890	94	0	4,100	0	14,000,000
mean	350	21	15	1,100	2	3,300,000
Probability of mean	0.09	0.19	0.02	0.13	0.03	0.18
Probability of zero	0.88	0.31	0.98	0.31	0.97	0.31

The tract ID is PC26

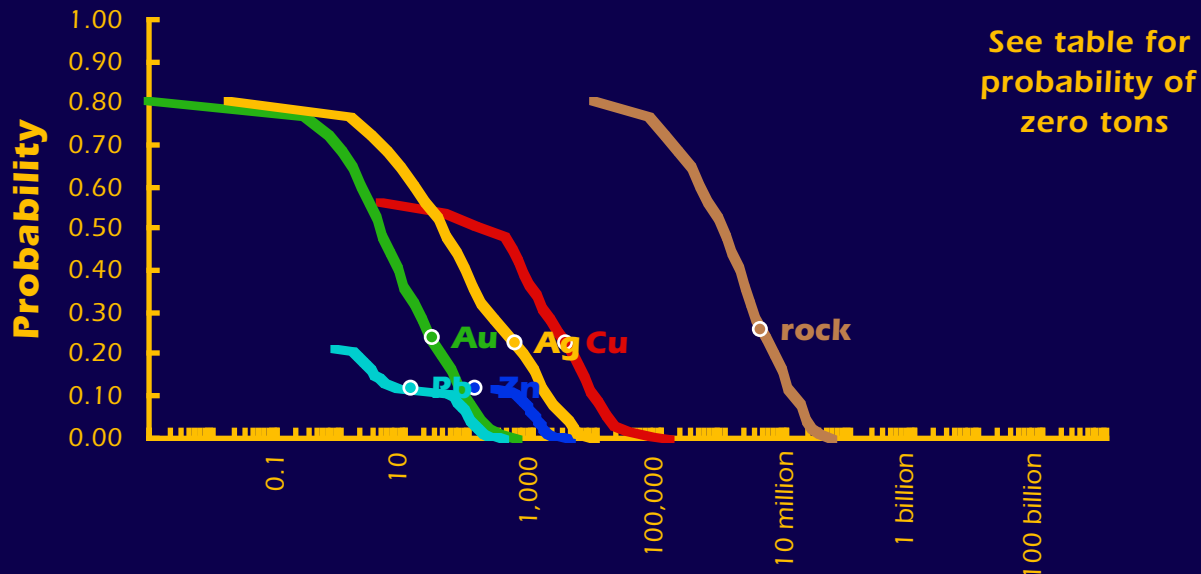
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)



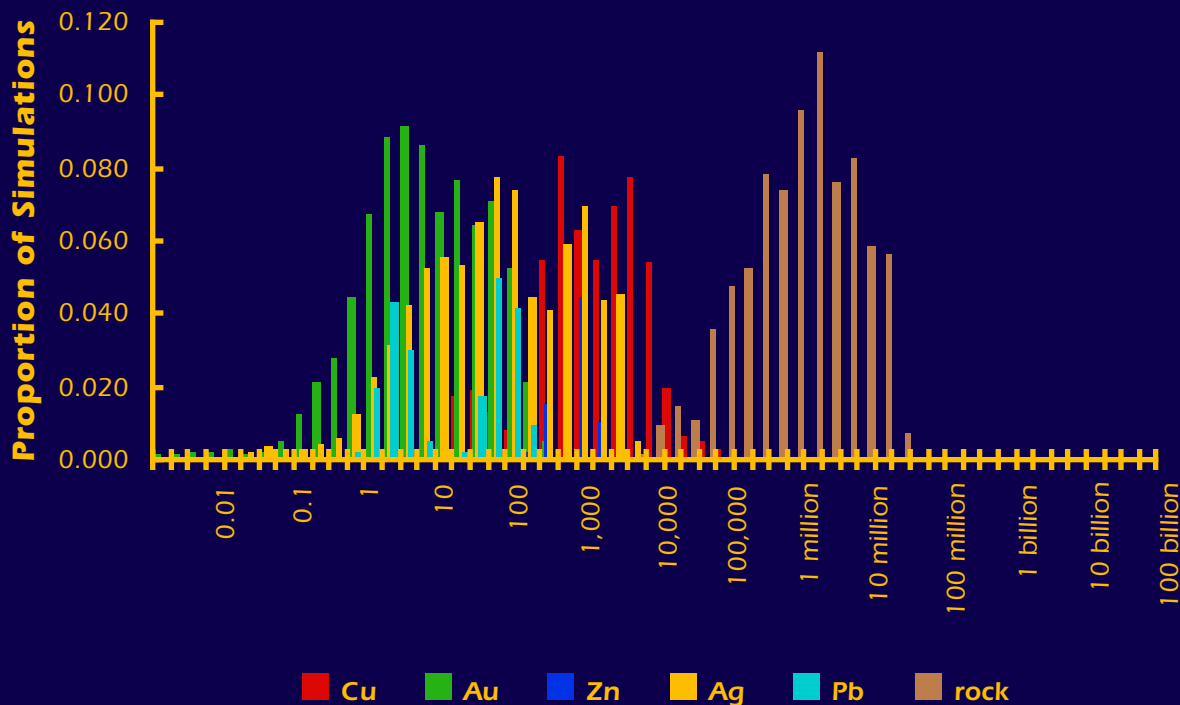
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



See table for
probability of
zero tons

Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC27

The Mark3 Index is 28:

Epithermal vein, Sado

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 8 or more deposits.

There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	230	4	0	39	0	910,000
0.10	8,900	83	592	1,600	56	12,000,000
0.05	14,000	130	1,100	3,100	100	19,000,000
mean	3,200	26	130	500	12	3,700,000
Probability of mean	0.23	0.24	0.12	0.23	0.12	0.26
Probability of zero	0.43	0.19	0.88	0.19	0.78	0.19

The tract ID is PC27The Mark3 Index is 28: **Epithermal vein, Sado**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 8 or more deposits.

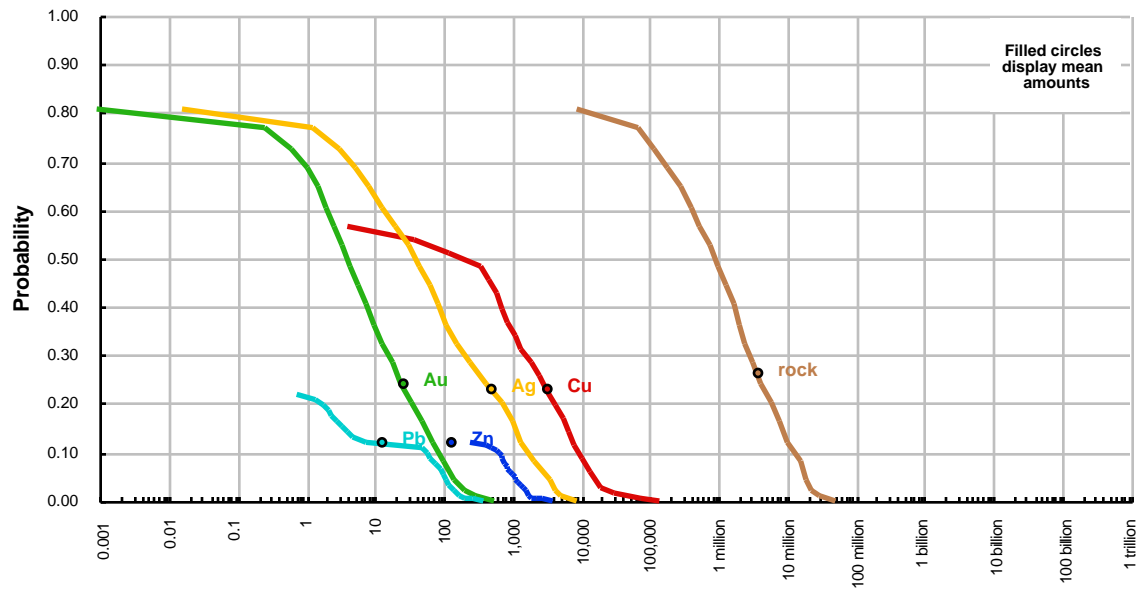
There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

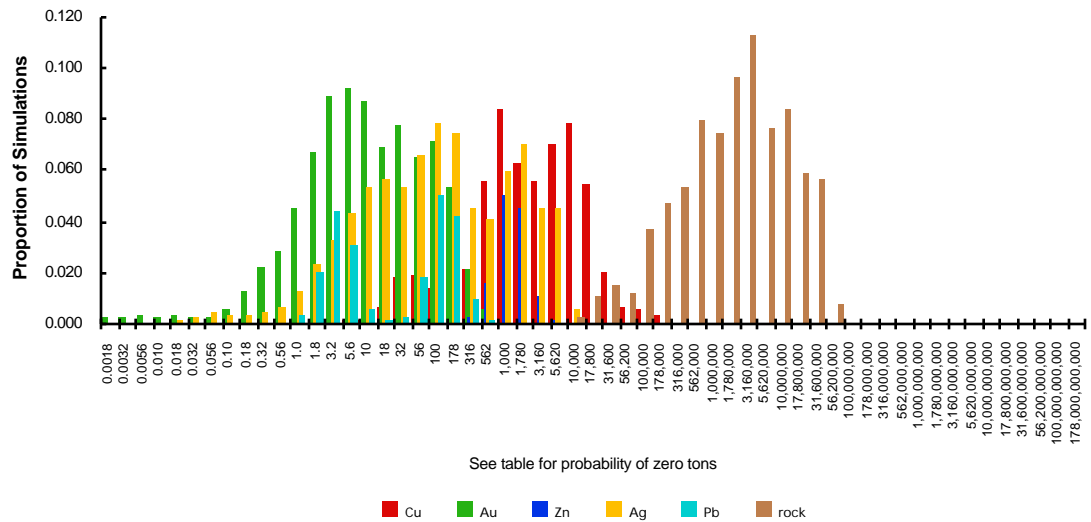
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	230	4	0	39	0	910,000
0.10	8,900	83	592	1,600	56	12,000,000
0.05	14,000	130	1,100	3,100	100	19,000,000
mean	3,200	26	130	500	12	3,700,000
Probability of mean	0.23	0.24	0.12	0.23	0.12	0.26
Probability of zero	0.43	0.19	0.88	0.19	0.78	0.19

The tract ID is PC27

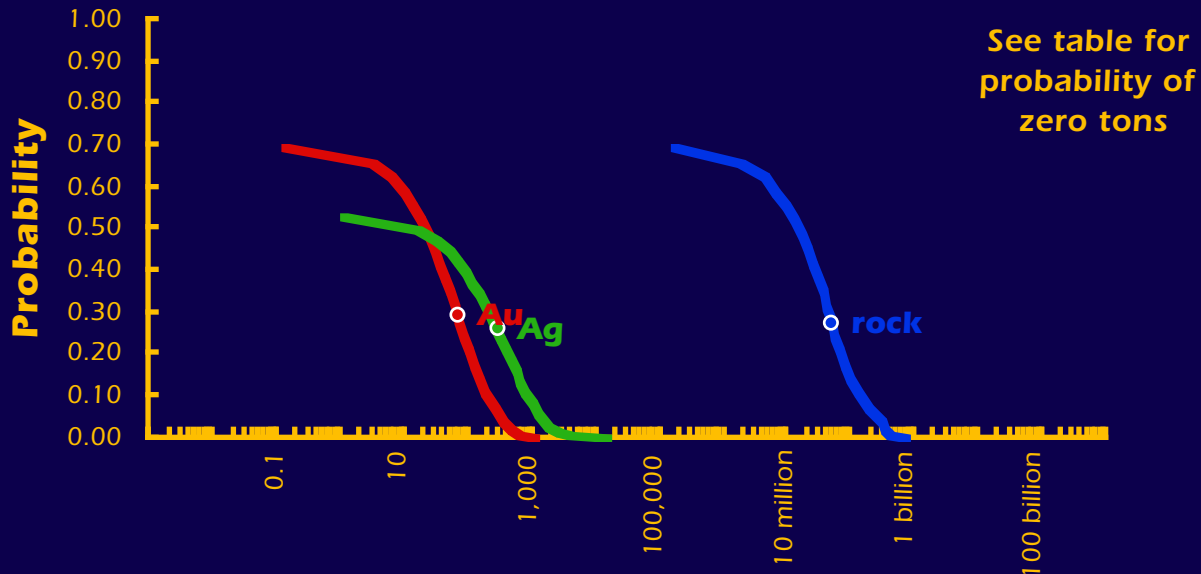
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

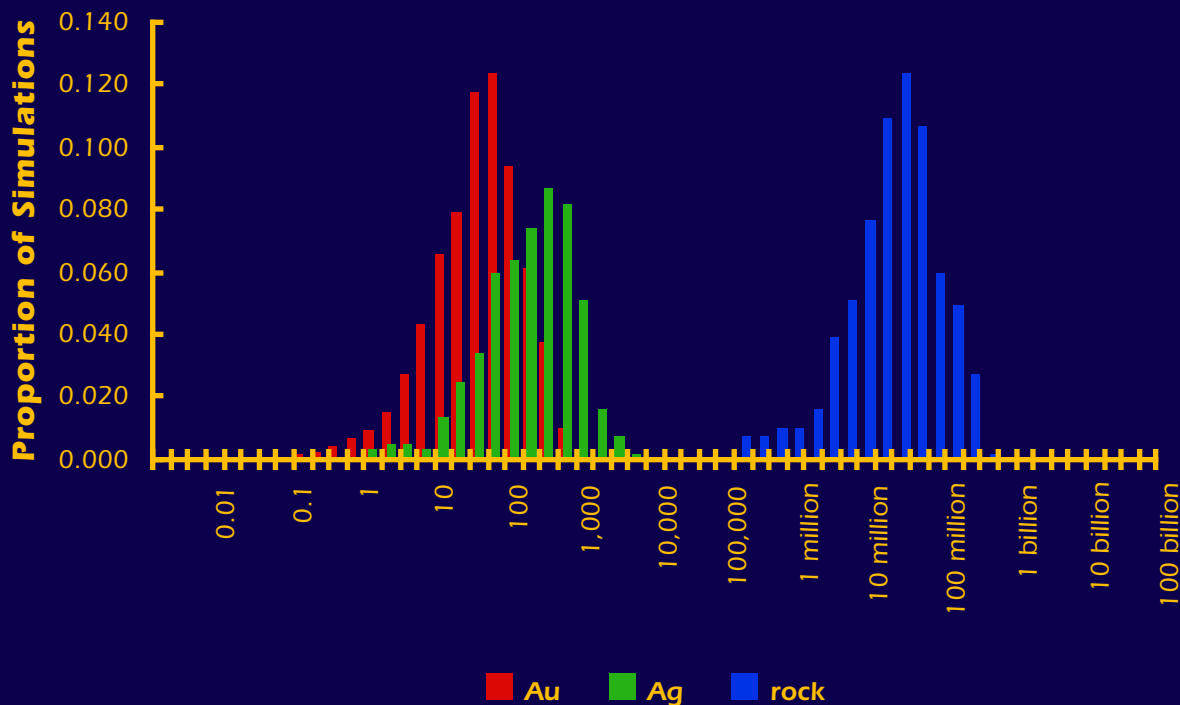


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC28

The Mark3 Index is 45:

Hot spring Au-Ag

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

There is a 1% or greater chance of 7 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	21	16	15,000,000
0.10	190	790	135,000,000
0.05	310	1,200	260,000,000
mean	68	280	48,000,000
Probability of mean	0.29	0.26	0.27
Probability of zero	0.31	0.47	0.31

The tract ID is PC28The Mark3 Index is 45: **Hot spring Au-Ag**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

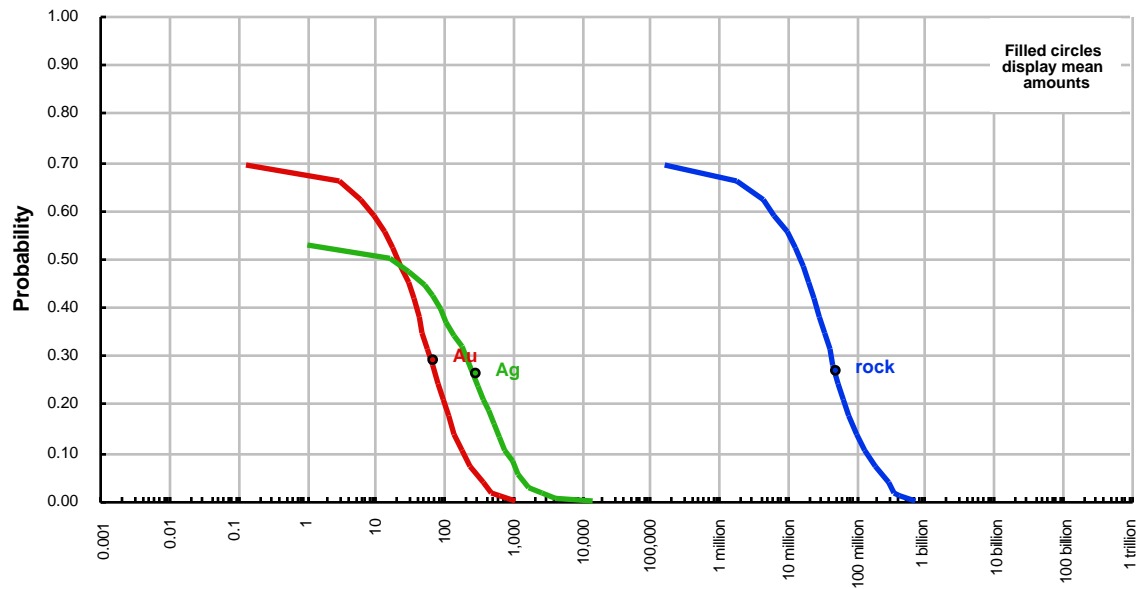
There is a 1% or greater chance of 7 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

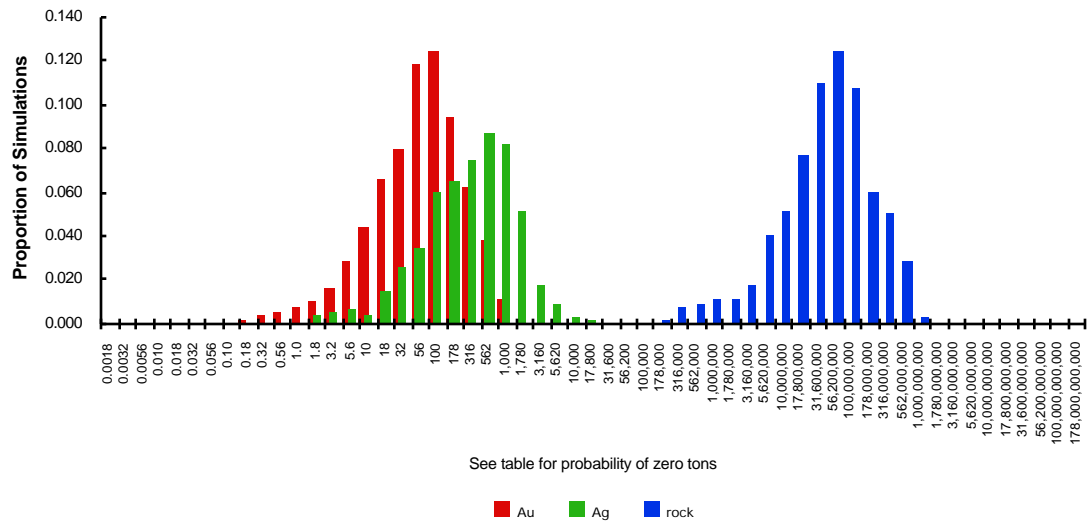
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	21	16	15,000,000
0.10	190	790	135,000,000
0.05	310	1,200	260,000,000
mean	68	280	48,000,000
Probability of mean	0.29	0.26	0.27
Probability of zero	0.31	0.47	0.31

The tract ID is PC28

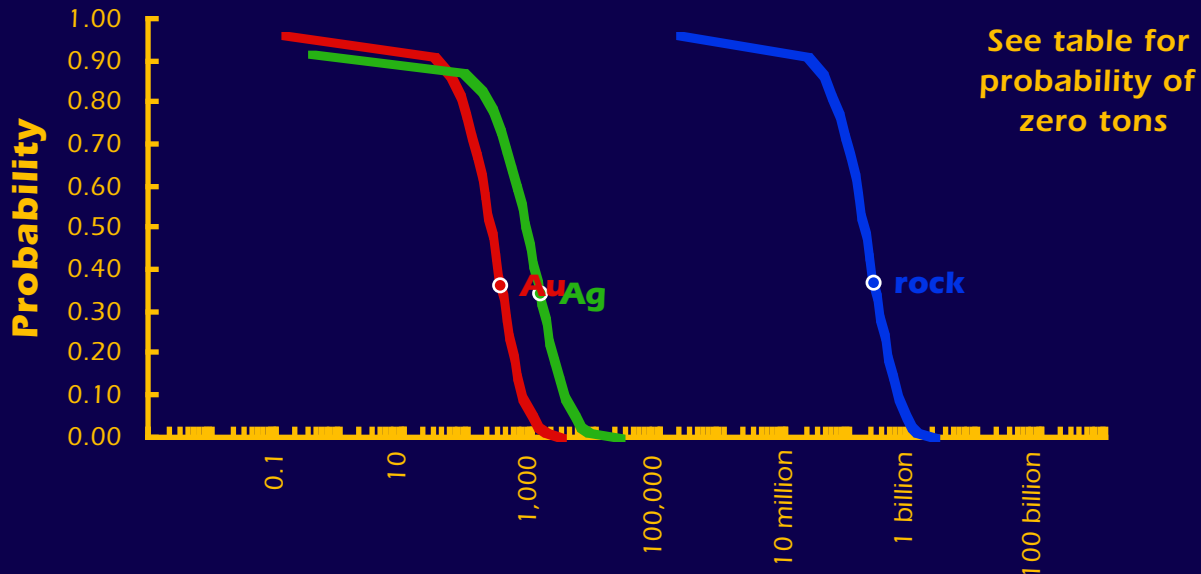
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

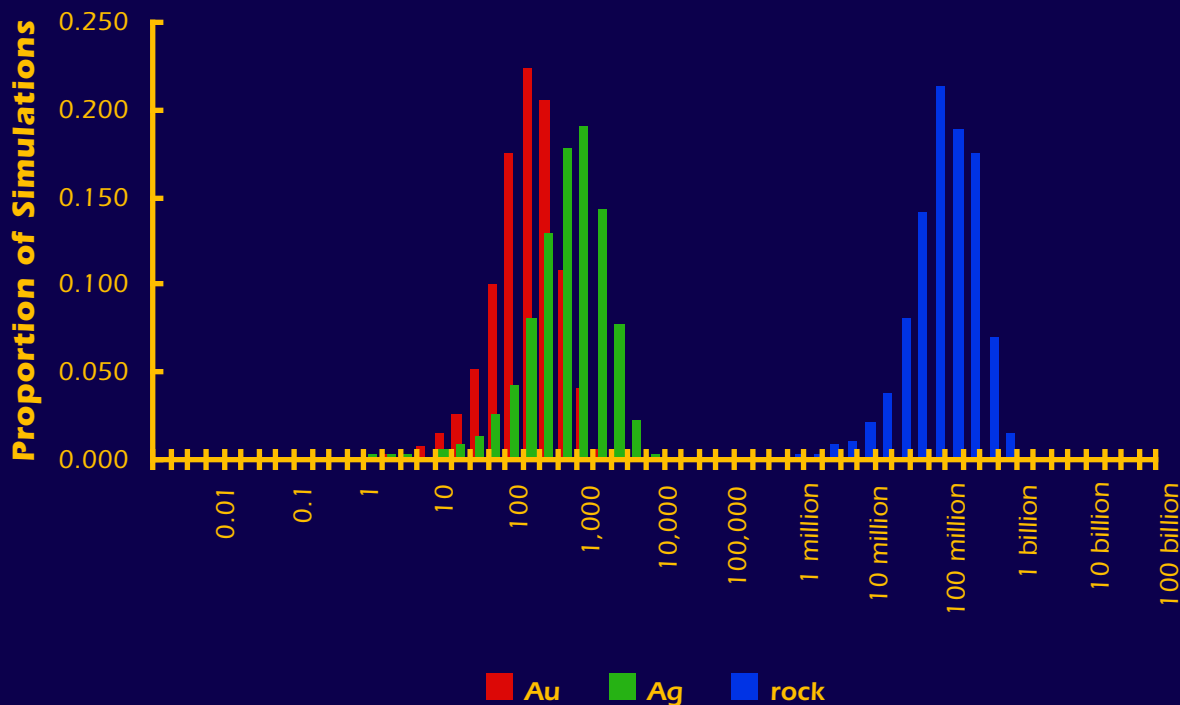


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC29

The Mark3 Index is 45:

Hot spring Au-Ag

There is a 90% or greater chance of 2 or more deposits.
There is a 50% or greater chance of 6 or more deposits.
There is a 10% or greater chance of 10 or more deposits.
There is a 5% or greater chance of 16 or more deposits.
There is a 1% or greater chance of 30 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	9	0	4,900,000
0.90	35	32	25,000,000
0.50	220	810	160,000,000
0.10	710	3,200	518,000,000
0.05	970	4,400	690,000,000
mean	320	1,300	230,000,000
Probability of mean	0.36	0.34	0.37
Probability of zero	0.04	0.08	0.04

The tract ID is PC29The Mark3 Index is 45: **Hot spring Au-Ag**

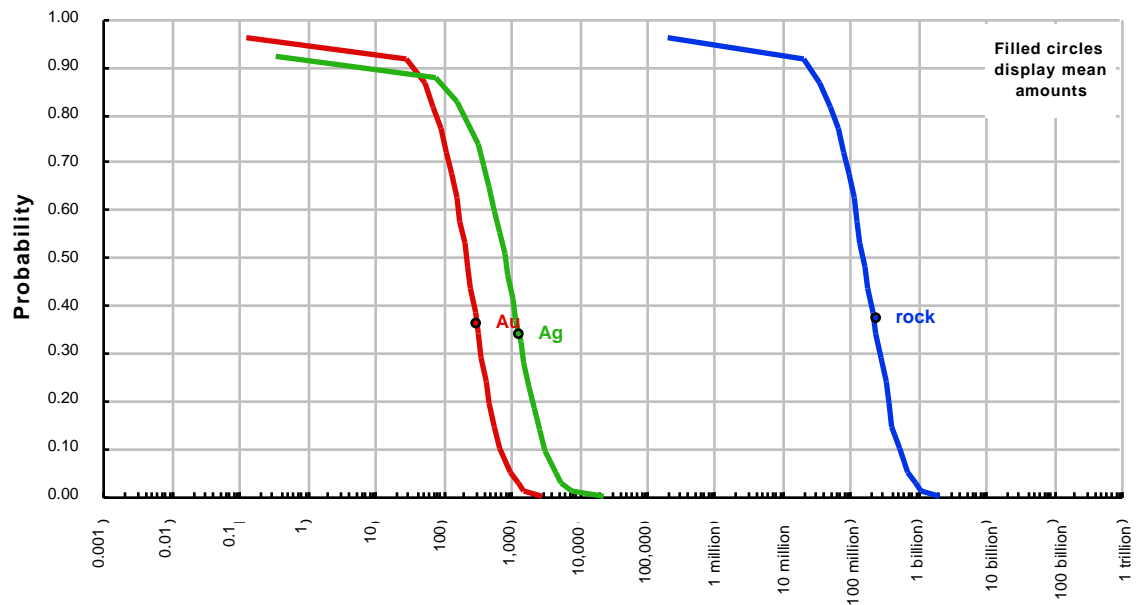
There is a 90% or greater chance of 2 or more deposits.
 There is a 50% or greater chance of 6 or more deposits.
 There is a 10% or greater chance of 10 or more deposits.
 There is a 5% or greater chance of 16 or more deposits.
 There is a 1% or greater chance of 30 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

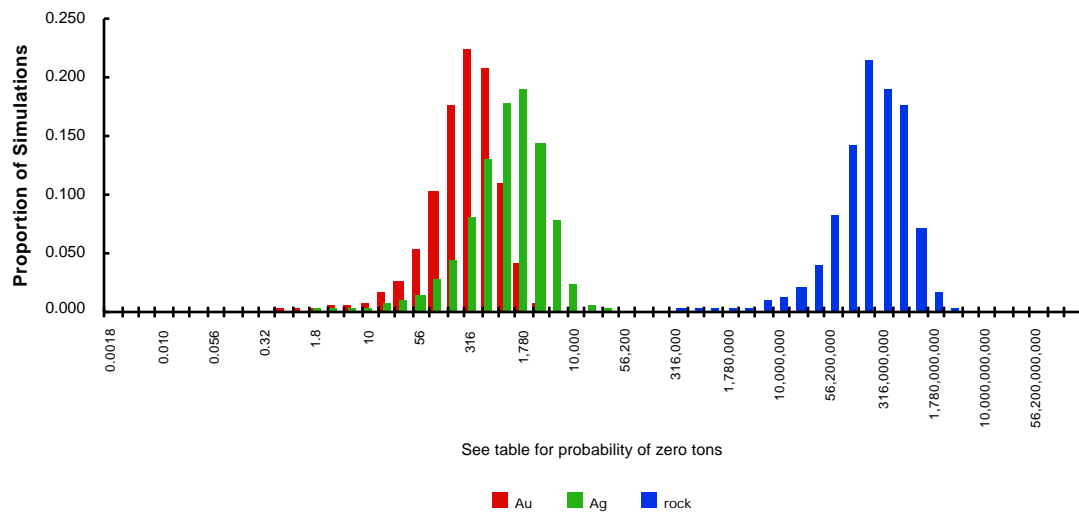
quantile	Au	Ag	rock
0.95	9	0	4,900,000
0.90	35	32	25,000,000
0.50	220	810	160,000,000
0.10	710	3,200	518,000,000
0.05	970	4,400	690,000,000
mean	320	1,300	230,000,000
Probability of mean	0.36	0.34	0.37
Probability of zero	0.04	0.08	0.04

The tract ID is PC29

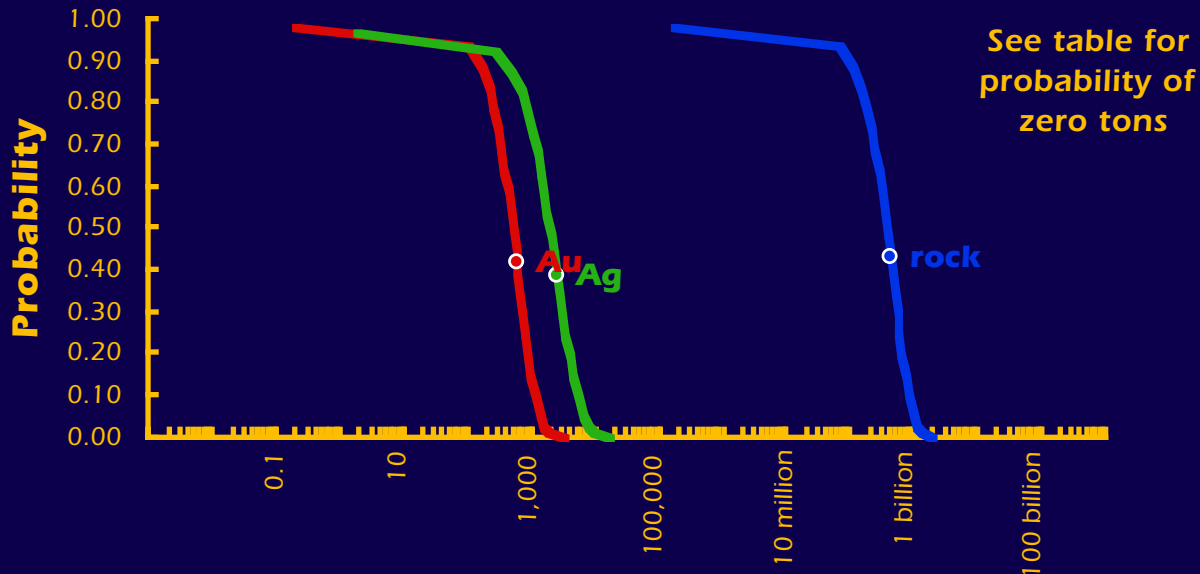
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

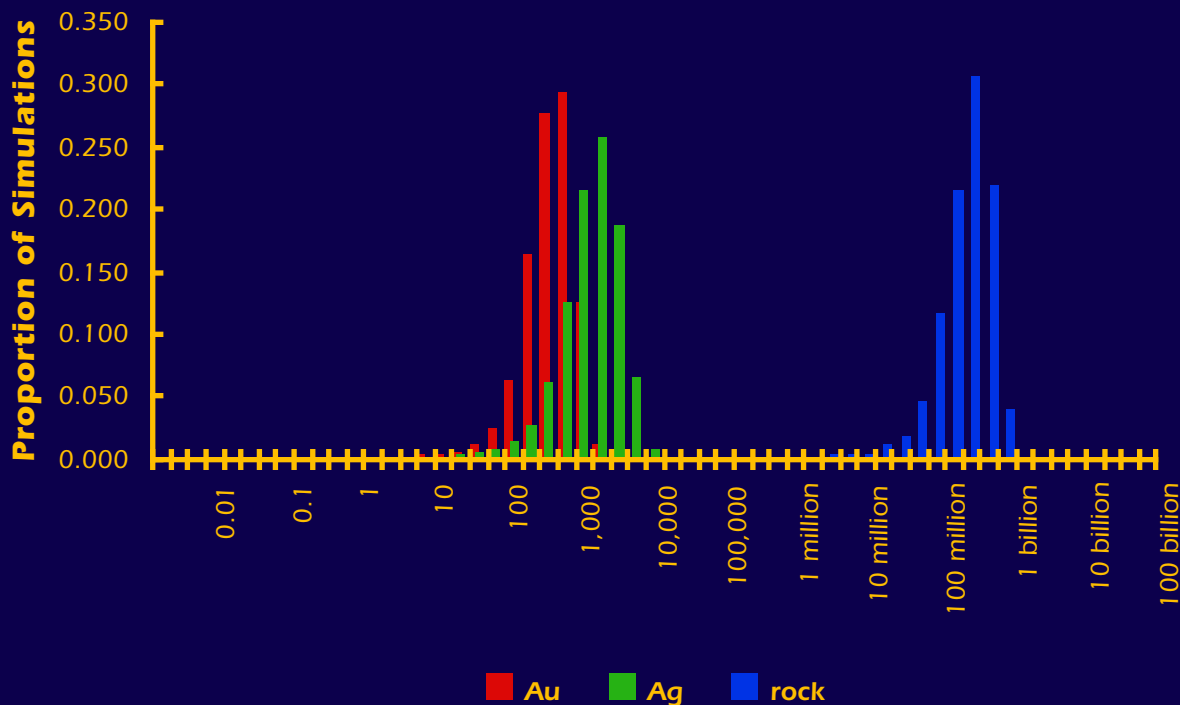


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC30

The Mark3 Index is 45:

Hot spring Au-Ag

There is a 90% or greater chance of 6 or more deposits.
There is a 50% or greater chance of 12 or more deposits.
There is a 10% or greater chance of 18 or more deposits.
There is a 5% or greater chance of 24 or more deposits.
There is a 1% or greater chance of 30 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	69	140	46,000,000
0.90	140	390	96,000,000
0.50	490	1,800	360,000,000
0.10	1,100	5,000	804,000,000
0.05	1,400	6,300	960,000,000
mean	570	2,400	410,000,000
Probability of mean	0.42	0.39	0.43
Probability of zero	0.02	0.03	0.02

The tract ID is PC30The Mark3 Index is 45: **Hot spring Au-Ag**

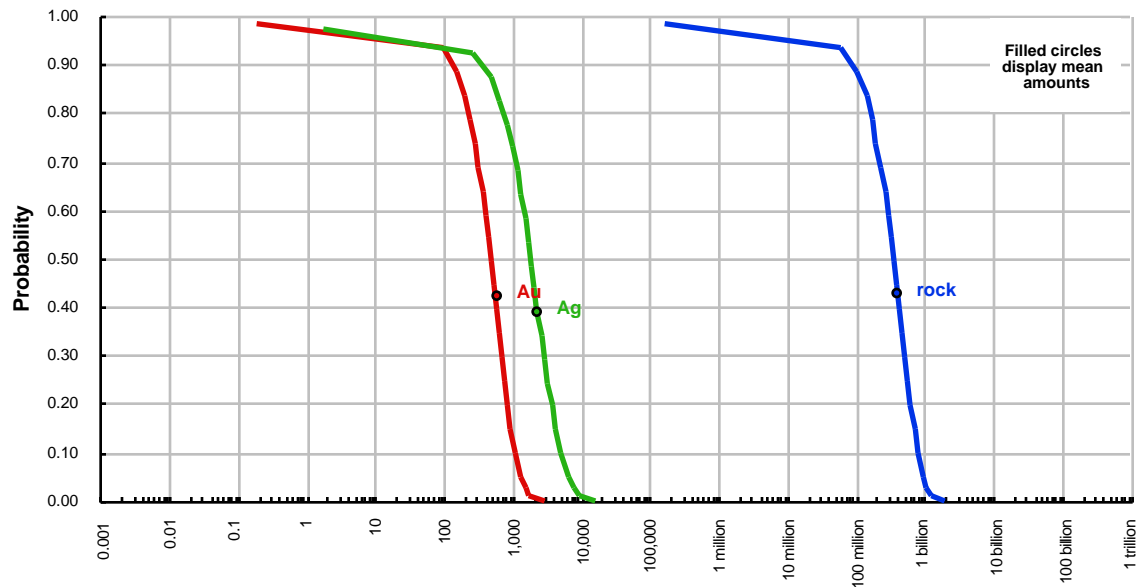
There is a 90% or greater chance of 6 or more deposits.
 There is a 50% or greater chance of 12 or more deposits.
 There is a 10% or greater chance of 18 or more deposits.
 There is a 5% or greater chance of 24 or more deposits.
 There is a 1% or greater chance of 30 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

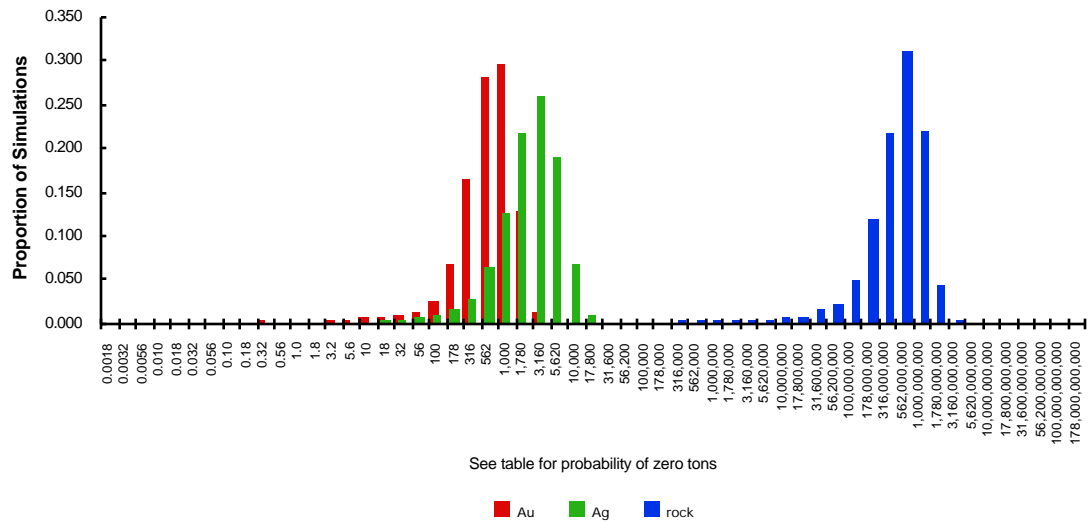
quantile	Au	Ag	rock
0.95	69	140	46,000,000
0.90	140	390	96,000,000
0.50	490	1,800	360,000,000
0.10	1,100	5,000	804,000,000
0.05	1,400	6,300	960,000,000
mean	570	2,400	410,000,000
Probability of mean	0.42	0.39	0.43
Probability of zero	0.02	0.03	0.02

The tract ID is PC30

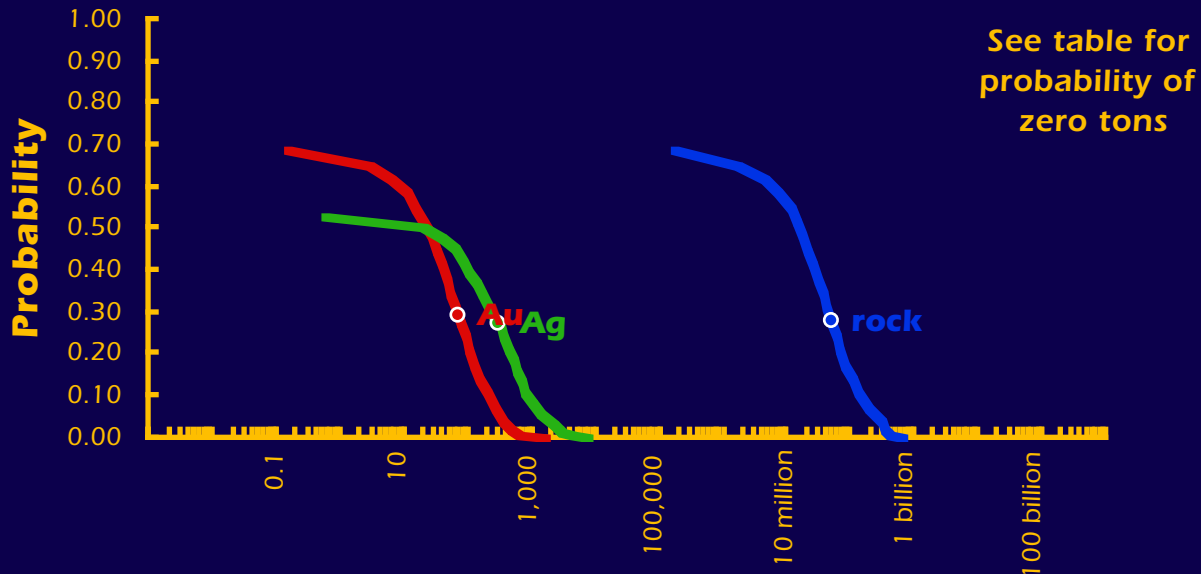
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

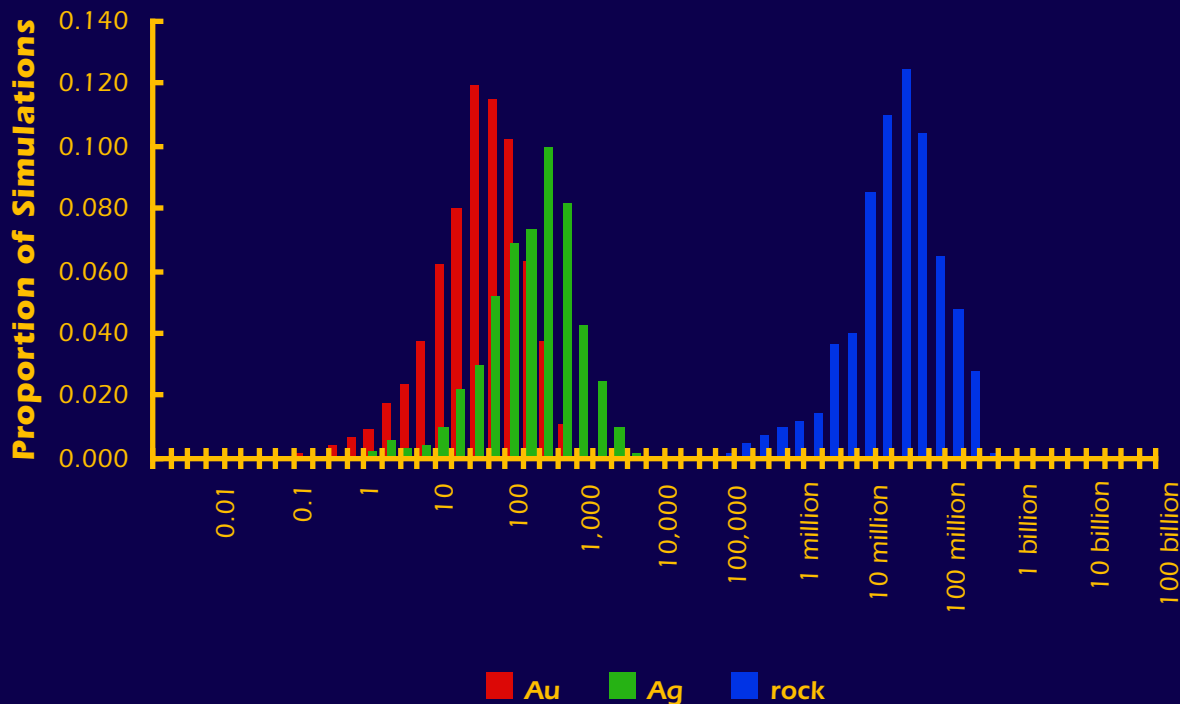


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC32

The Mark3 Index is 45:

Hot spring Au-Ag

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	22	21	15,000,000
0.10	200	830	137,000,000
0.05	310	1,400	250,000,000
mean	69	300	48,000,000
Probability of mean	0.29	0.27	0.28
Probability of zero	0.31	0.47	0.31

The tract ID is PC32The Mark3 Index is 45: **Hot spring Au-Ag**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

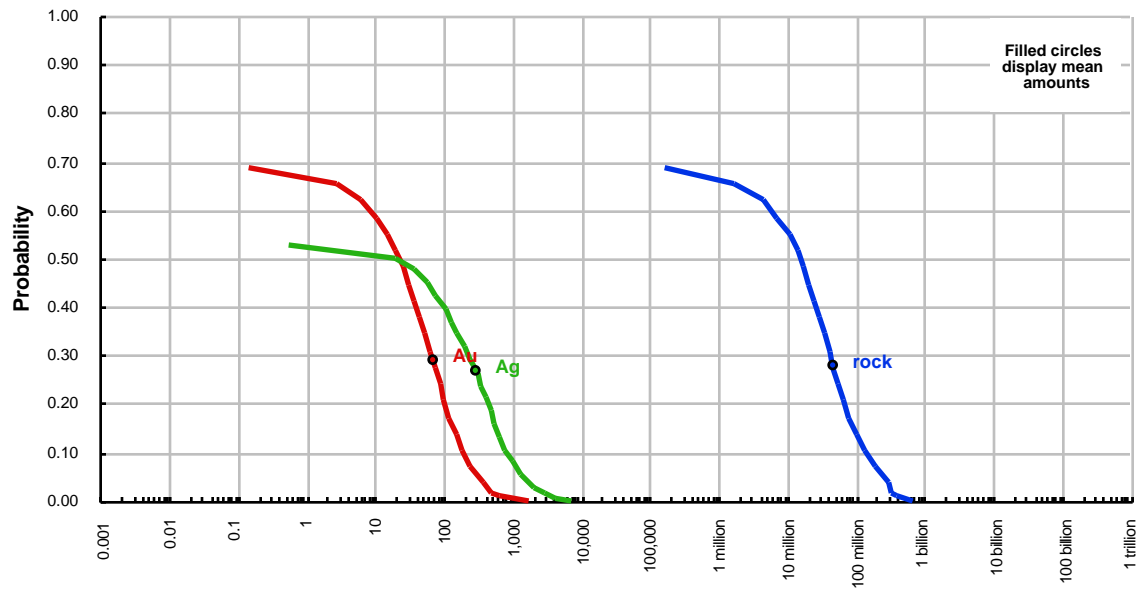
There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

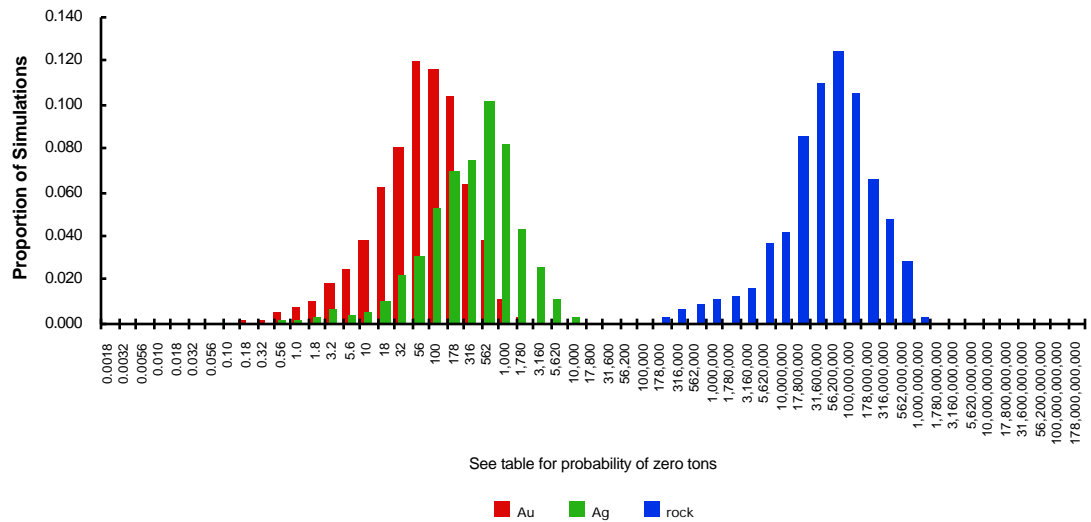
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	22	21	15,000,000
0.10	200	830	137,000,000
0.05	310	1,400	250,000,000
mean	69	300	48,000,000
Probability of mean	0.29	0.27	0.28
Probability of zero	0.31	0.47	0.31

The tract ID is PC32

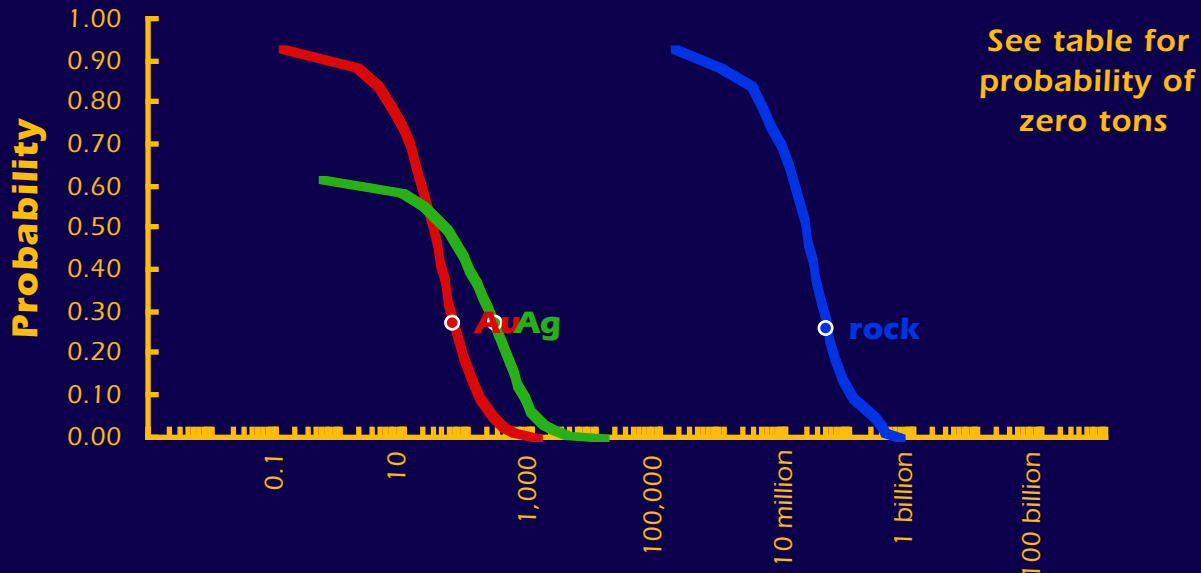
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

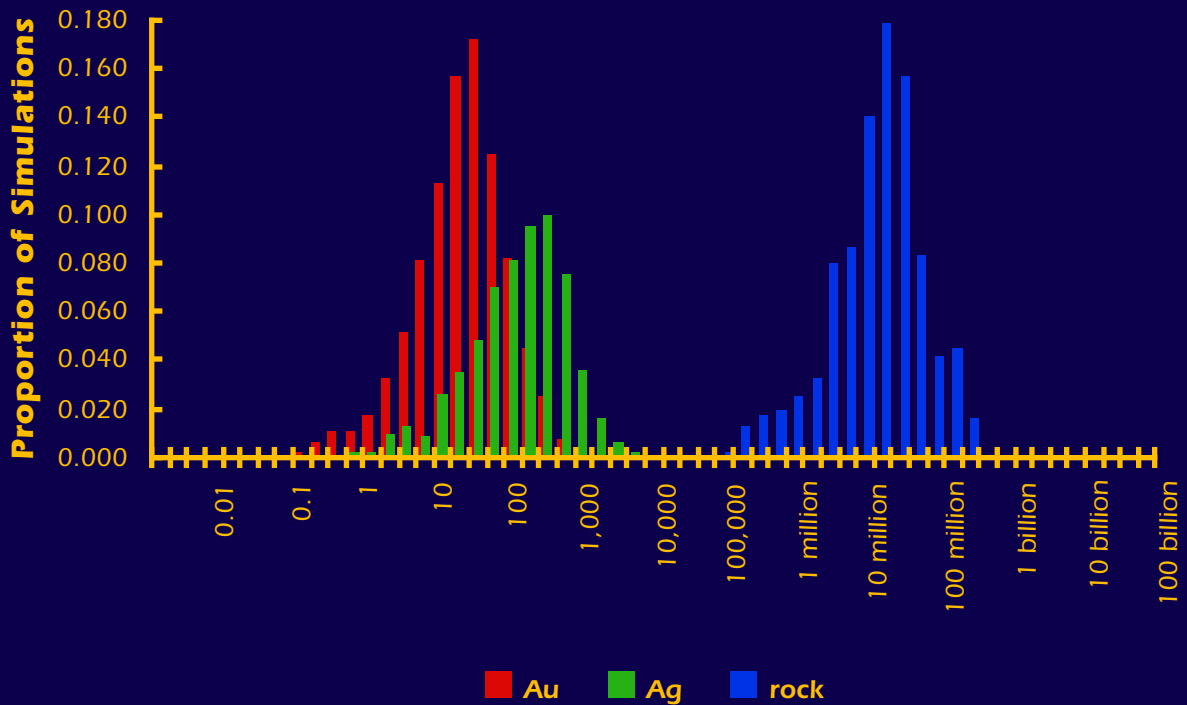


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC34

The Mark3 Index is 45:

Hot spring Au-Ag

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	1	0	580,000
0.50	27	46	19,000,000
0.10	140	710	101,000,000
0.05	240	1,100	220,000,000
mean	59	260	42,000,000
Probability of mean	0.27	0.27	0.26
Probability of zero	0.07	0.38	0.07

The tract ID is PC34The Mark3 Index is 45: **Hot spring Au-Ag**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

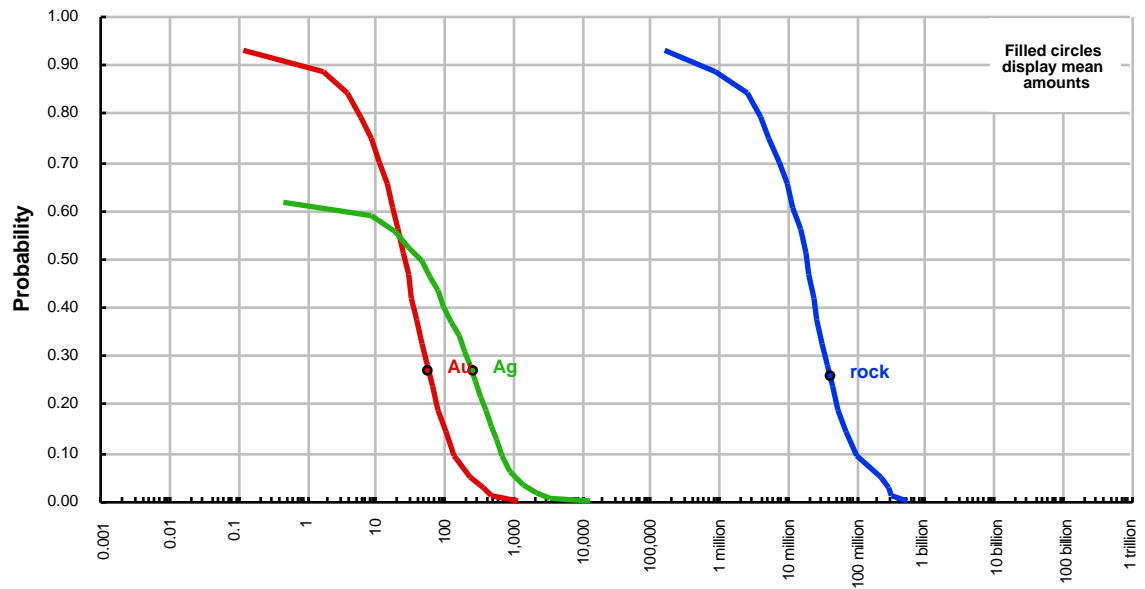
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

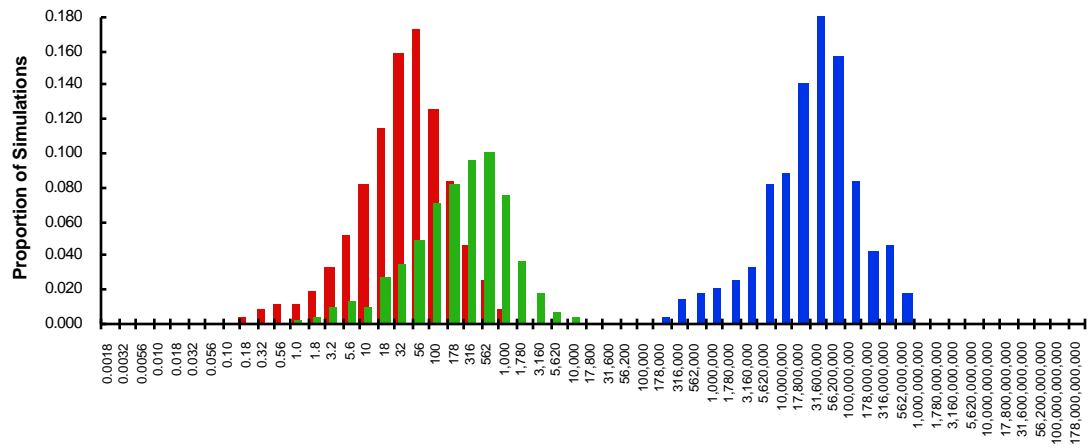
quantile	Au	Ag	rock
0.95	0	0	0
0.90	1	0	580,000
0.50	27	46	19,000,000
0.10	140	710	101,000,000
0.05	240	1,100	220,000,000
mean	59	260	42,000,000
Probability of mean	0.27	0.27	0.26
Probability of zero	0.07	0.38	0.07

The tract ID is PC34

Cumulative Distributions of Contained Metal and Mineralized Rock



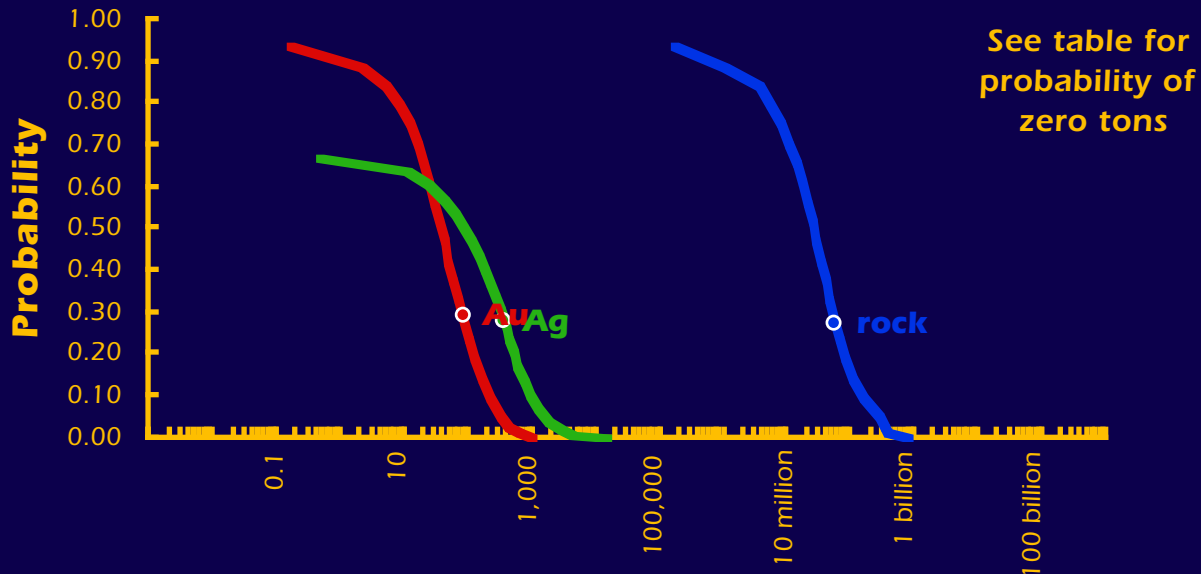
Histograms of Contained Metal and Mineralized Rock (metric tons)



See table for probability of zero tons

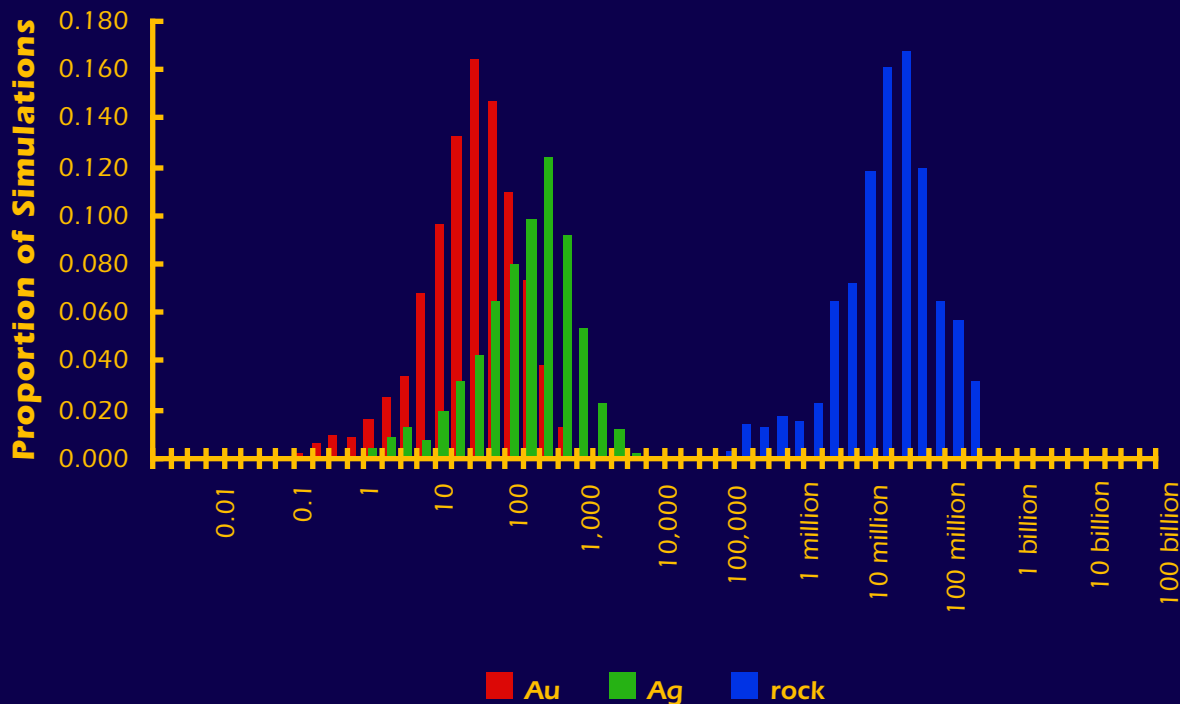
Au Ag rock

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC35

The Mark3 Index is 45:

Hot spring Au-Ag

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	2	0	740,000
0.50	37	86	26,000,000
0.10	210	930	152,000,000
0.05	320	1,400	270,000,000
mean	79	350	57,000,000
Probability of mean	0.29	0.28	0.27
Probability of zero	0.06	0.33	0.06

The tract ID is PC35The Mark3 Index is 45: **Hot spring Au-Ag**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

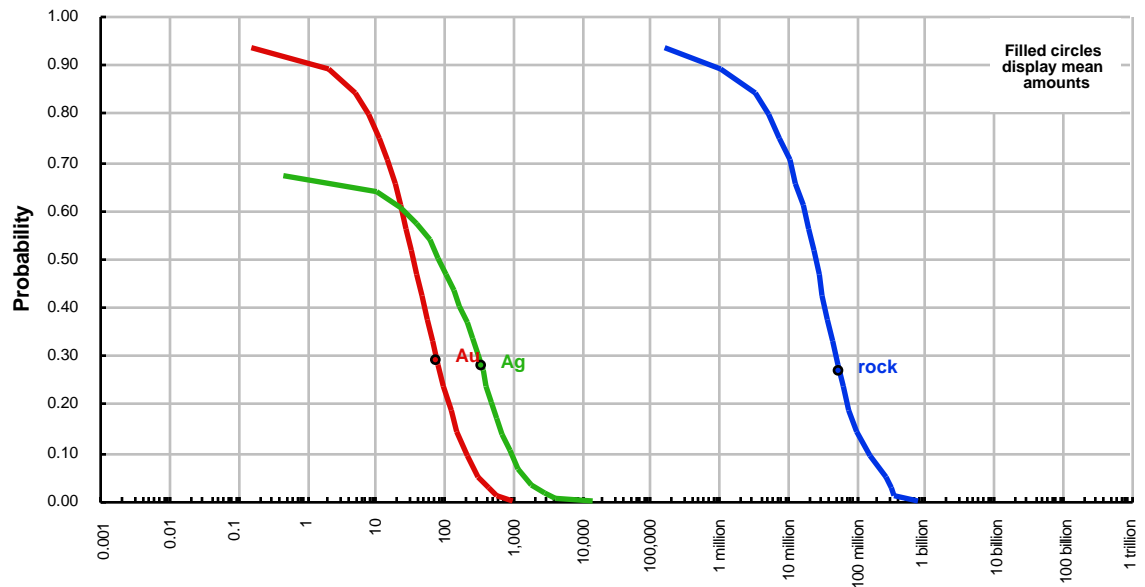
There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

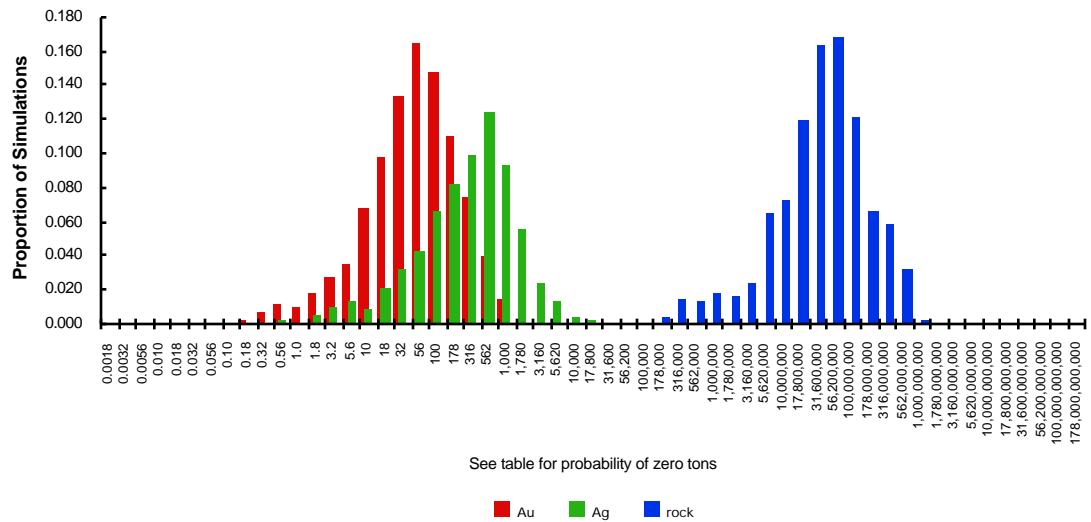
quantile	Au	Ag	rock
0.95	0	0	0
0.90	2	0	740,000
0.50	37	86	26,000,000
0.10	210	930	152,000,000
0.05	320	1,400	270,000,000
mean	79	350	57,000,000
Probability of mean	0.29	0.28	0.27
Probability of zero	0.06	0.33	0.06

The tract ID is PC35

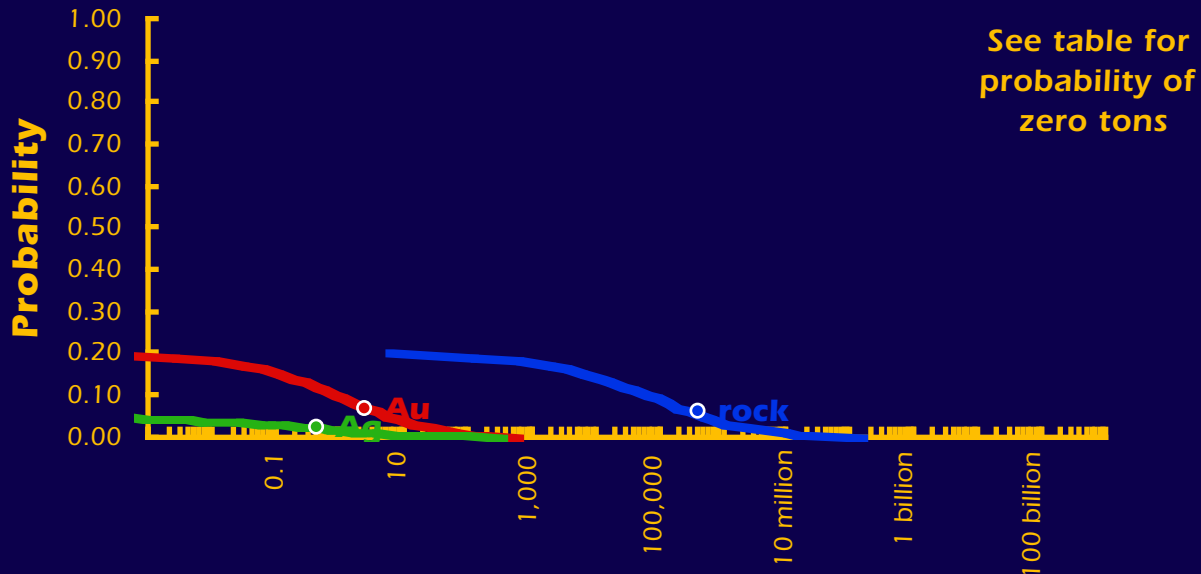
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

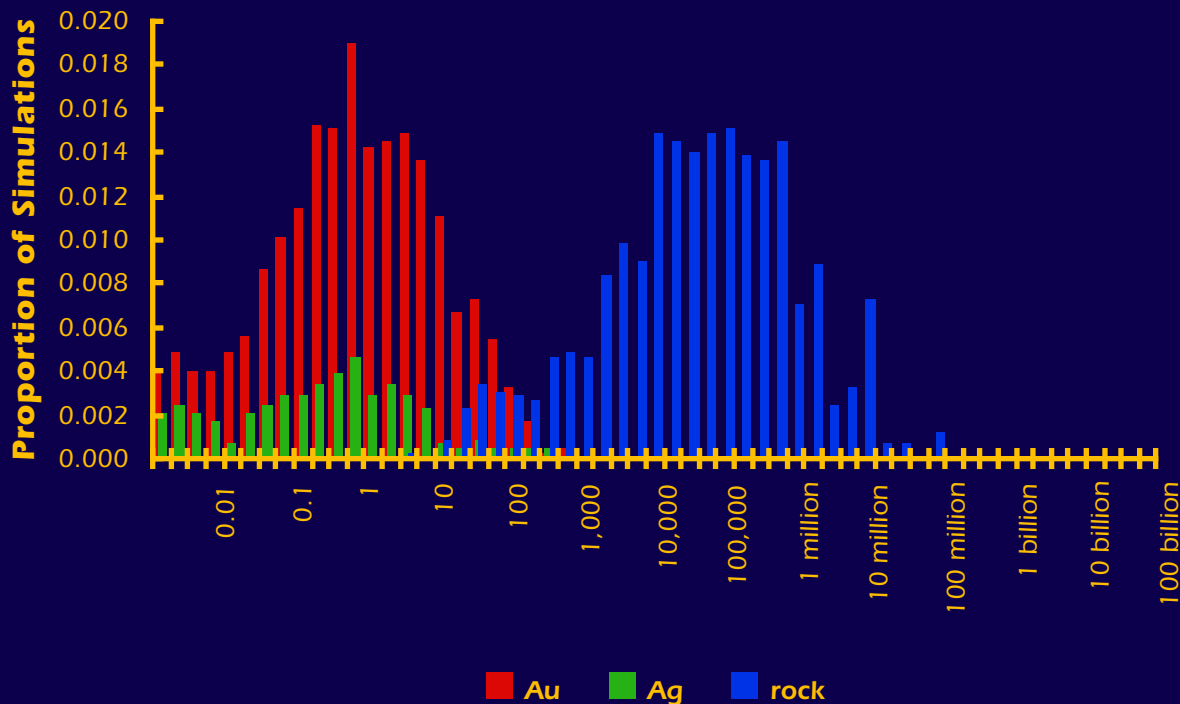


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC37

The Mark3 Index is 27:

Low sulfide Au-quartz vein

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

There is a 1% or greater chance of 7 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	1	0	65,400
0.05	5	0	480,000
mean	2	0	380,000
Probability of mean	0.07	0.02	0.06
Probability of zero	0.80	0.95	0.80

The tract ID is PC37The Mark3 Index is 27: **Low sulfide Au-quartz vein**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

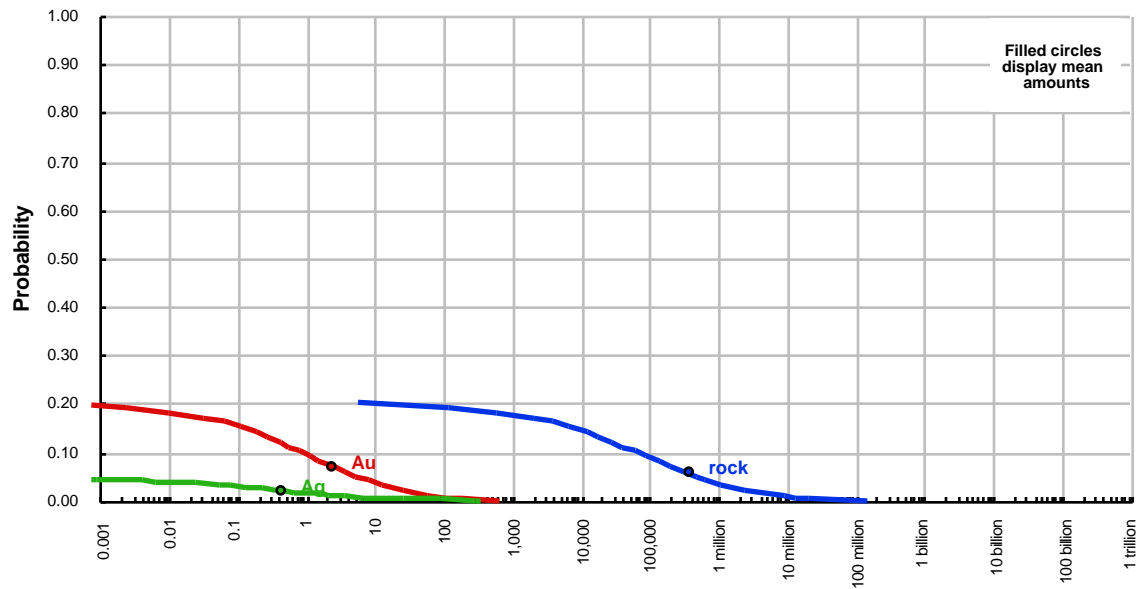
There is a 1% or greater chance of 7 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

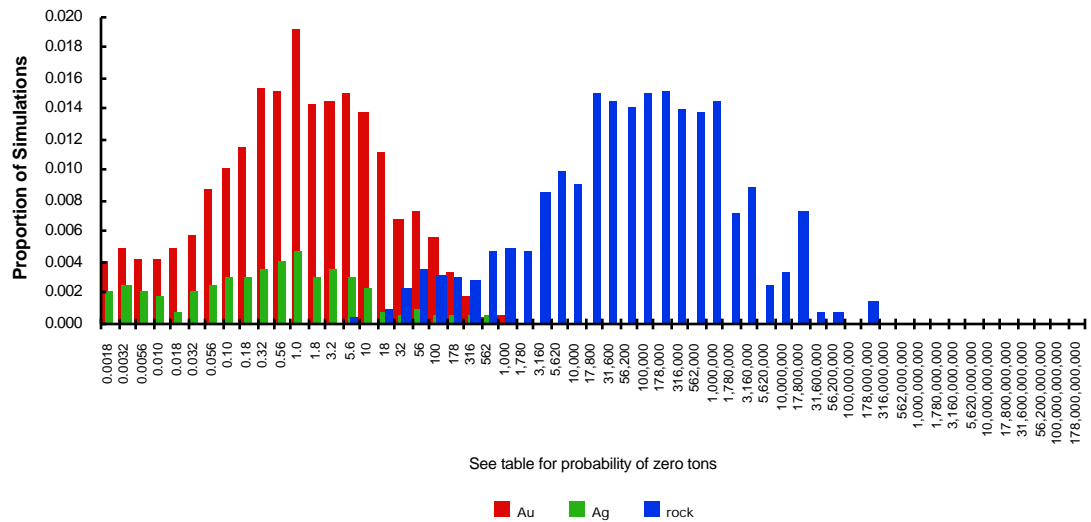
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	1	0	65,400
0.05	5	0	480,000
mean	2	0	380,000
Probability of mean	0.07	0.02	0.06
Probability of zero	0.80	0.95	0.80

The tract ID is PC37

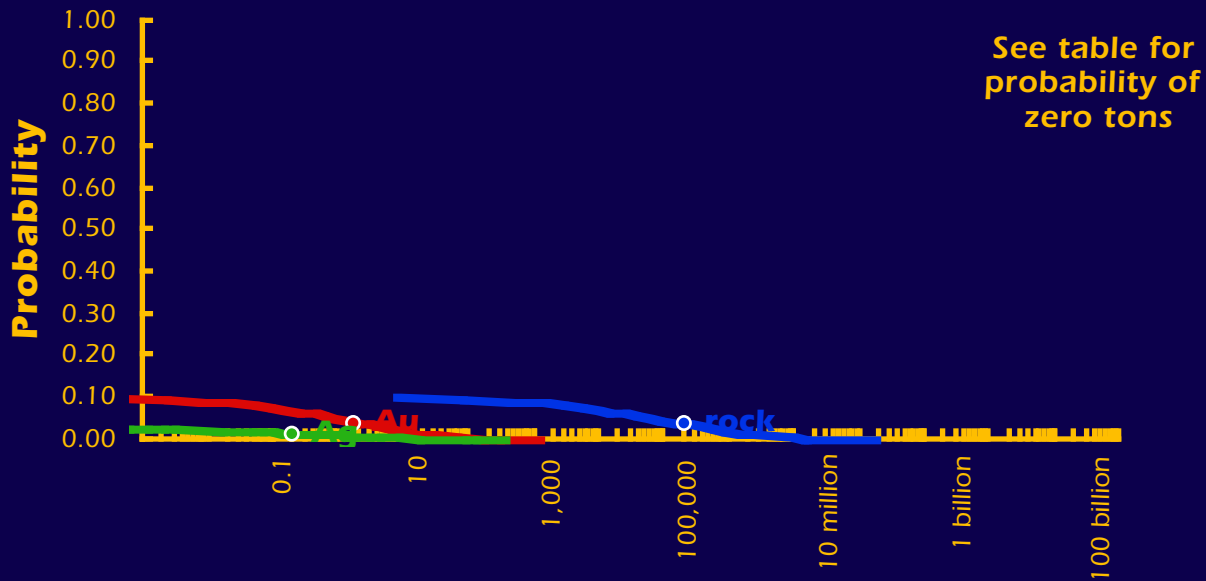
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

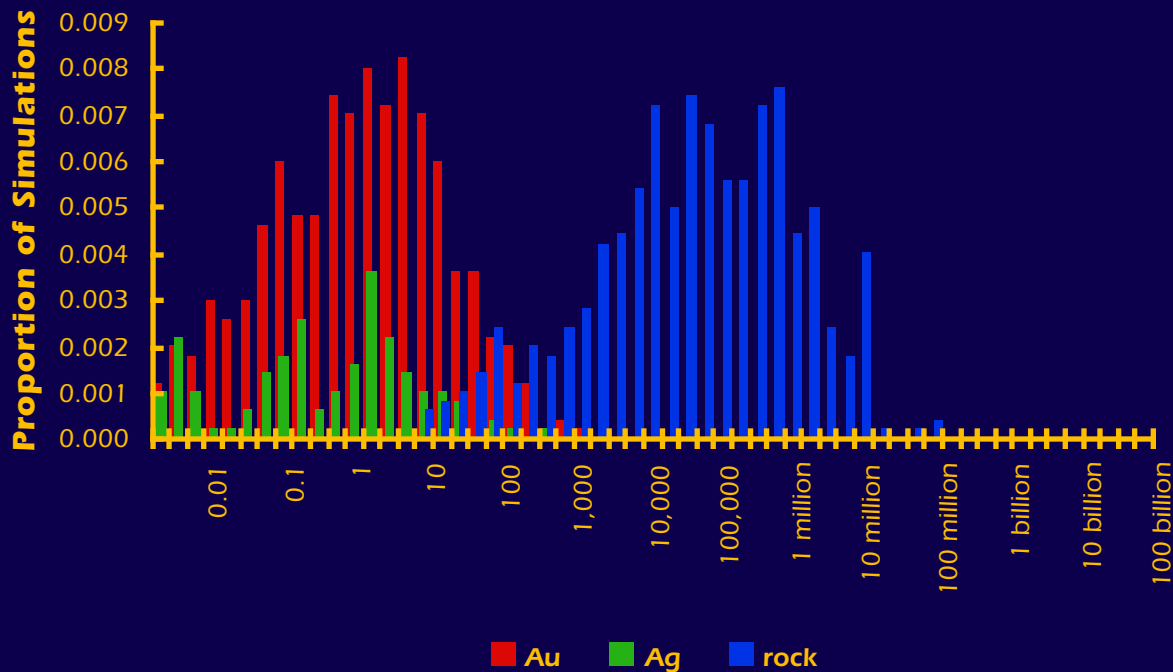


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC38

The Mark3 Index is 27:

Low sulfide Au-quartz vein

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	0	14
0.05	1	0	68,000
mean	2	0	200,000
Probability of mean	0.04	0.01	0.04
Probability of zero	0.90	0.97	0.90

The tract ID is PC38The Mark3 Index is 27: **Low sulfide Au-quartz vein**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

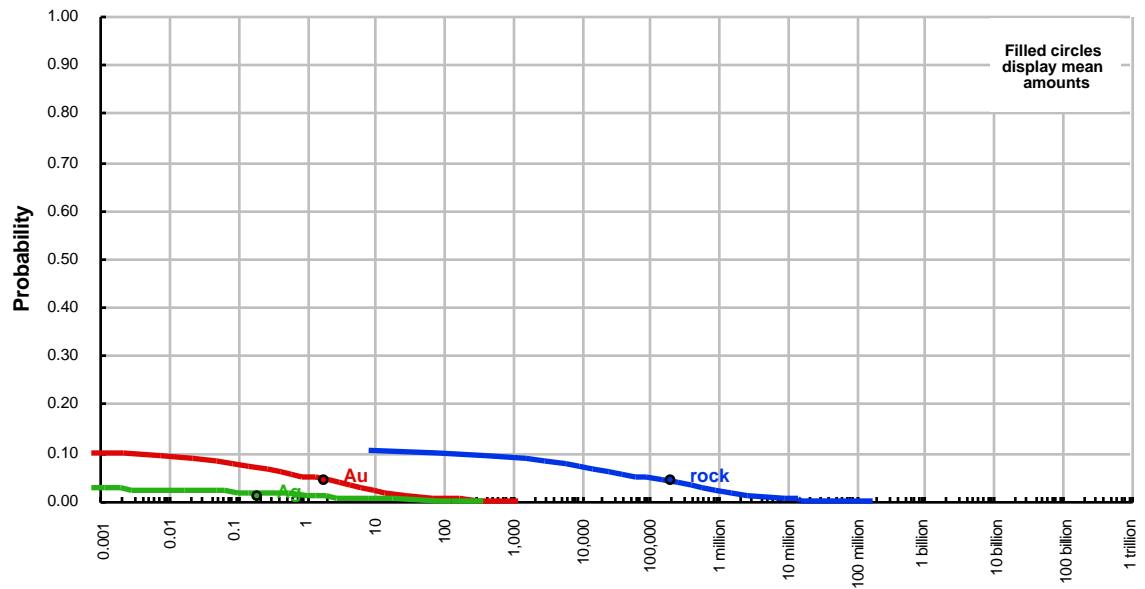
There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

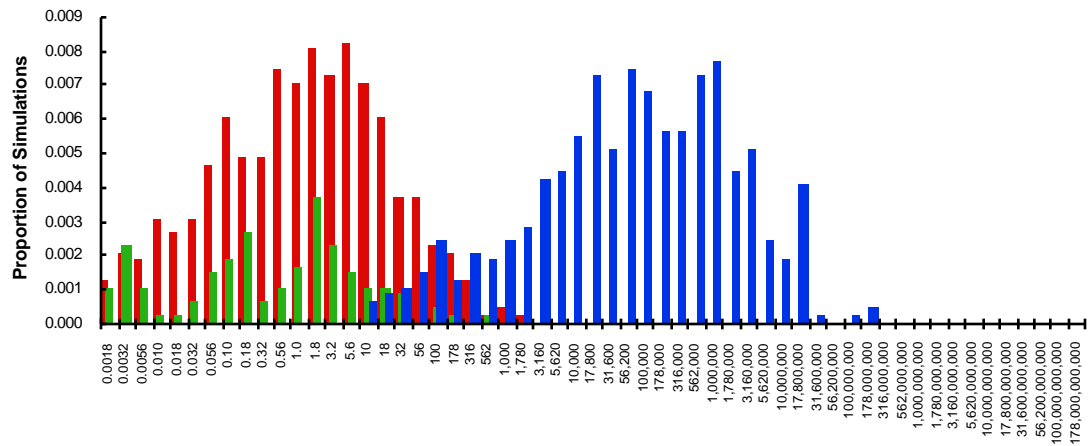
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	0	14
0.05	1	0	68,000
mean	2	0	200,000
Probability of mean	0.04	0.01	0.04
Probability of zero	0.90	0.97	0.90

The tract ID is PC38

Cumulative Distributions of Contained Metal and Mineralized Rock



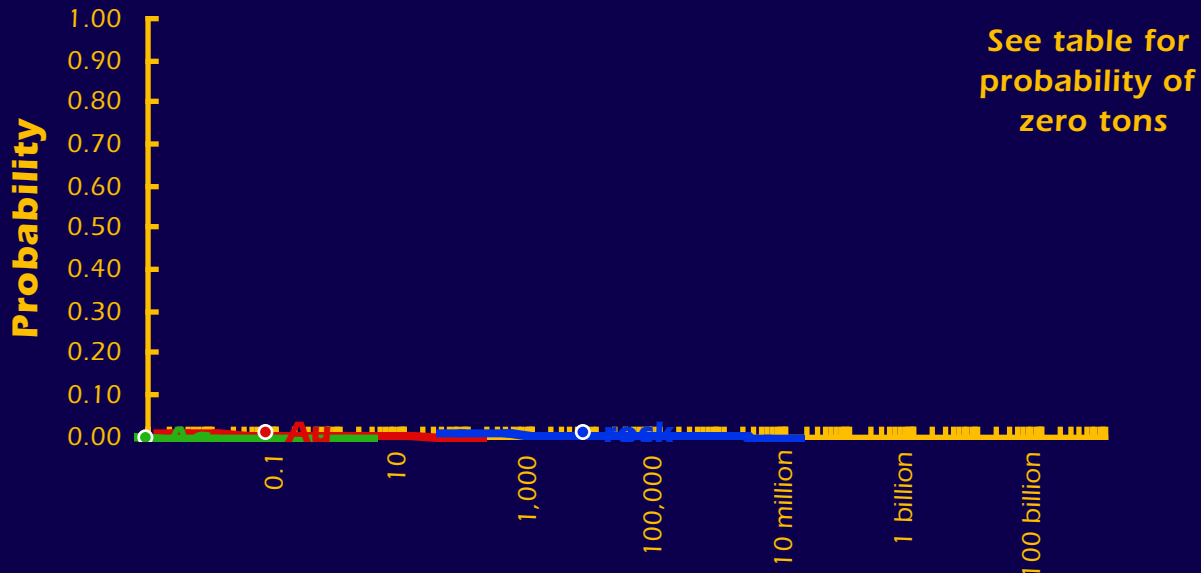
Histograms of Contained Metal and Mineralized Rock (metric tons)



See table for probability of zero tons

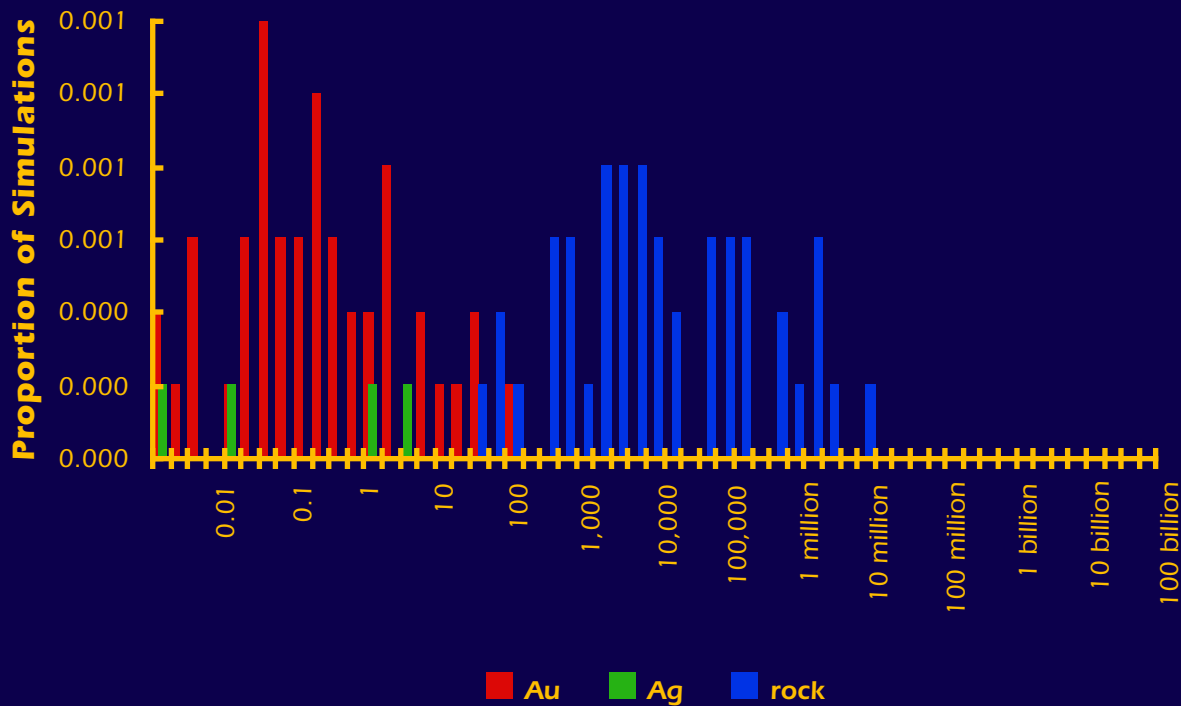
Au Ag rock

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC39

The Mark3 Index is 27:

Low sulfide Au-quartz vein

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	0	0
0.05	0	0	0
mean	0	0	6,300
Probability of mean	0.01	0.00	0.01
Probability of zero	0.99	1.00	0.99

The tract ID is PC39The Mark3 Index is 27: **Low sulfide Au-quartz vein**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

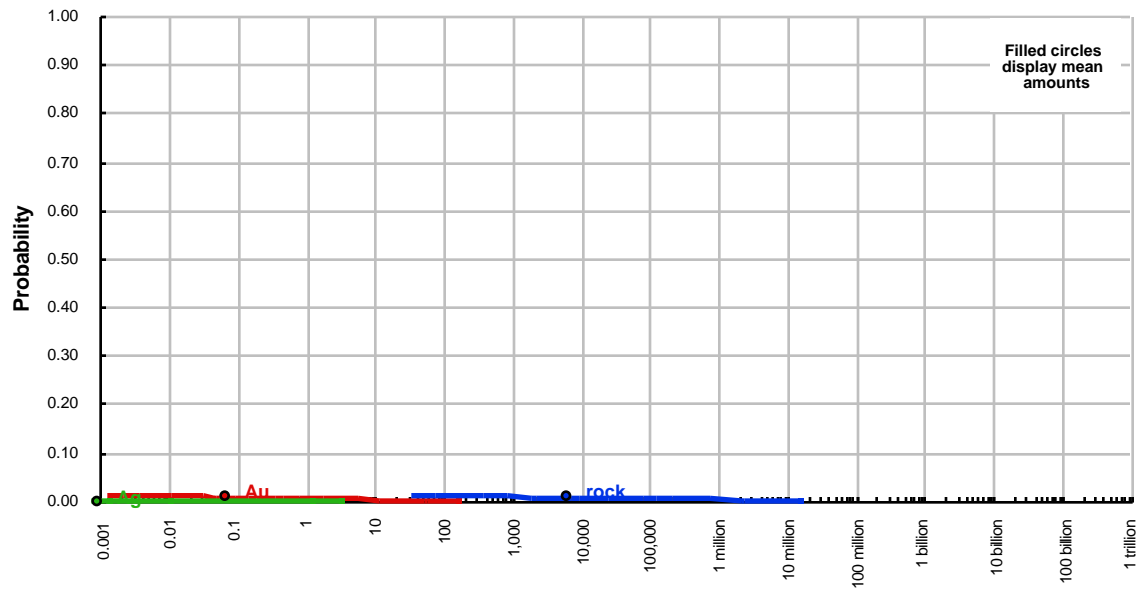
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

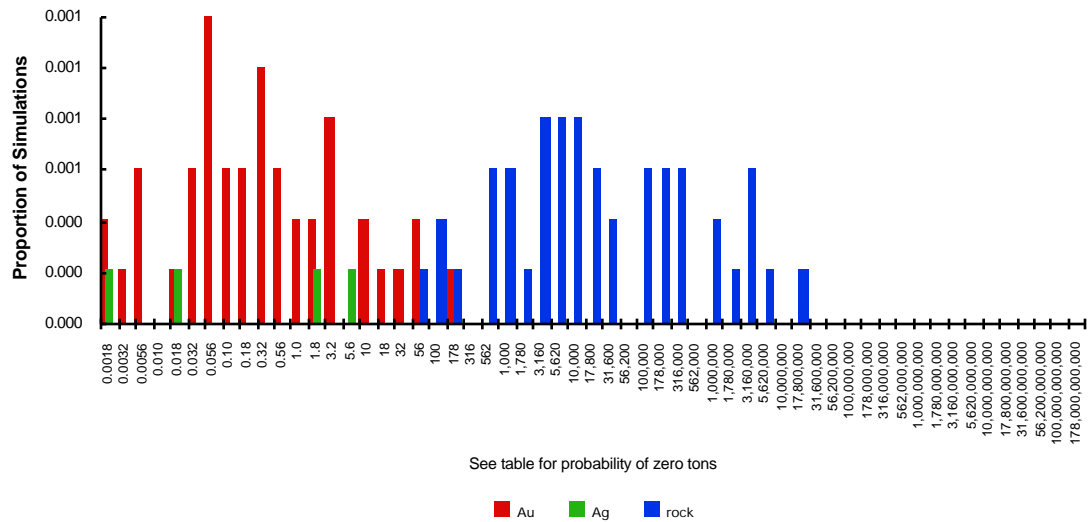
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	0	0
0.05	0	0	0
mean	0	0	6,300
Probability of mean	0.01	0.00	0.01
Probability of zero	0.99	1.00	0.99

The tract ID is PC39

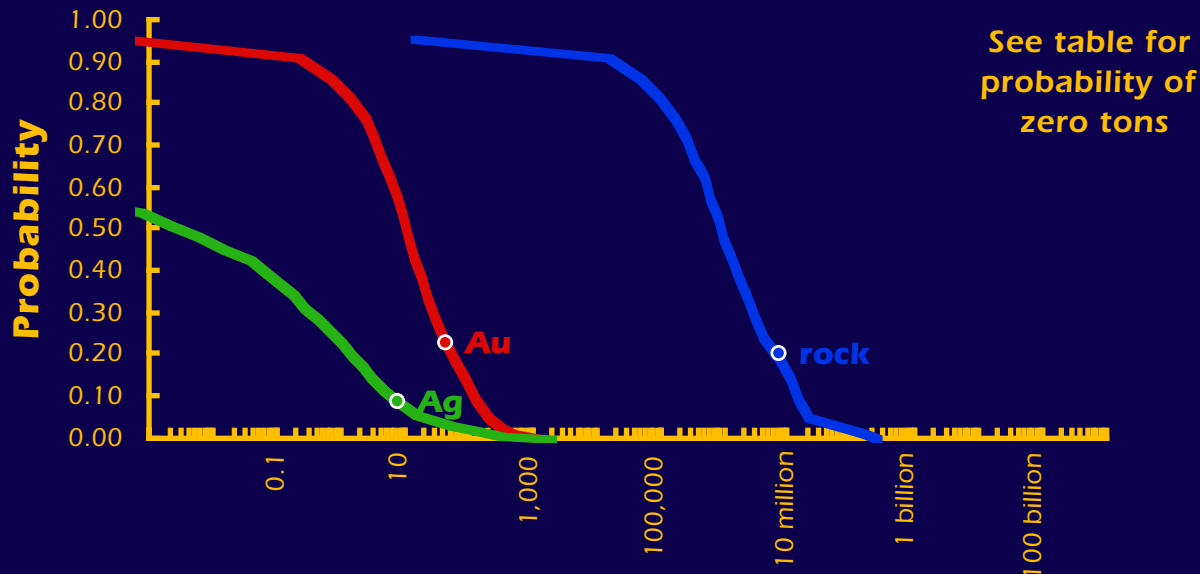
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

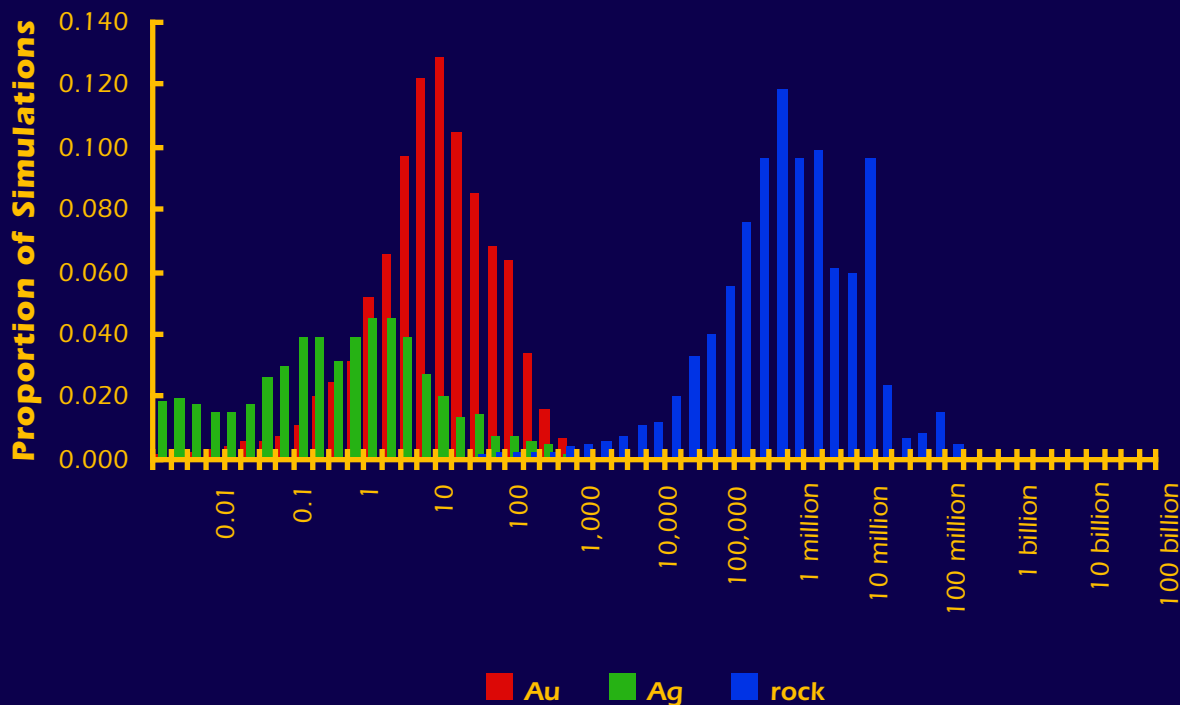


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is PC40

The Mark3 Index is 27:

Low sulfide Au-quartz vein

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 6 or more deposits.

There is a 10% or greater chance of 9 or more deposits.

There is a 5% or greater chance of 12 or more deposits.

There is a 1% or greater chance of 15 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	250
0.90	0	0	20,000
0.50	10	0	850,000
0.10	120	6	13,600,000
0.05	200	19	19,000,000
mean	42	7	6,900,000
Probability of mean	0.23	0.09	0.20
Probability of zero	0.04	0.43	0.04

The tract ID is PC40The Mark3 Index is 27: **Low sulfide Au-quartz vein**

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 6 or more deposits.

There is a 10% or greater chance of 9 or more deposits.

There is a 5% or greater chance of 12 or more deposits.

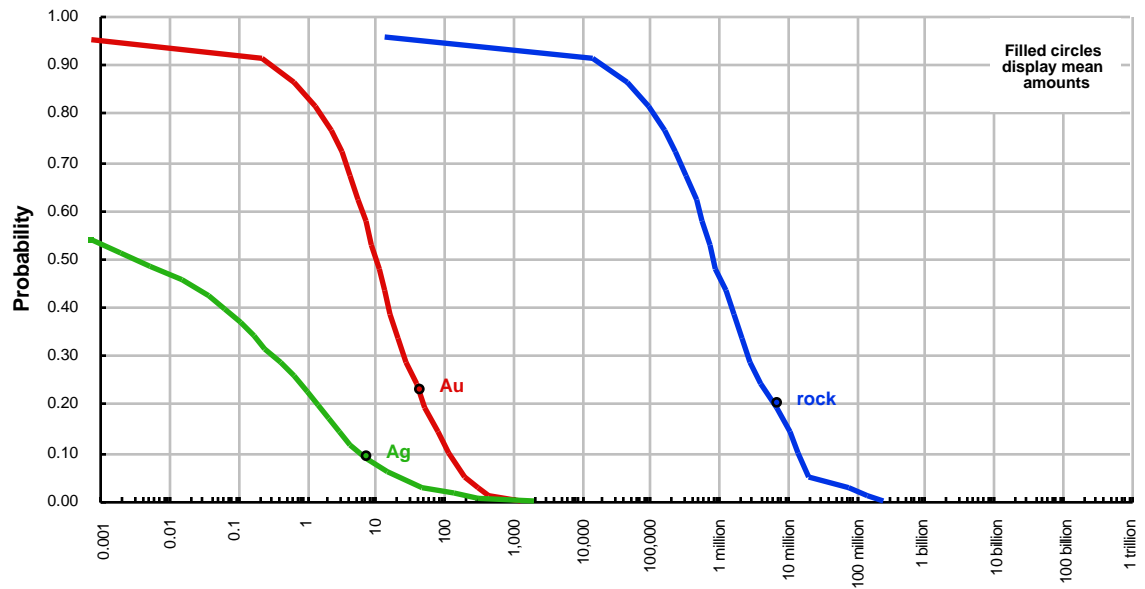
There is a 1% or greater chance of 15 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

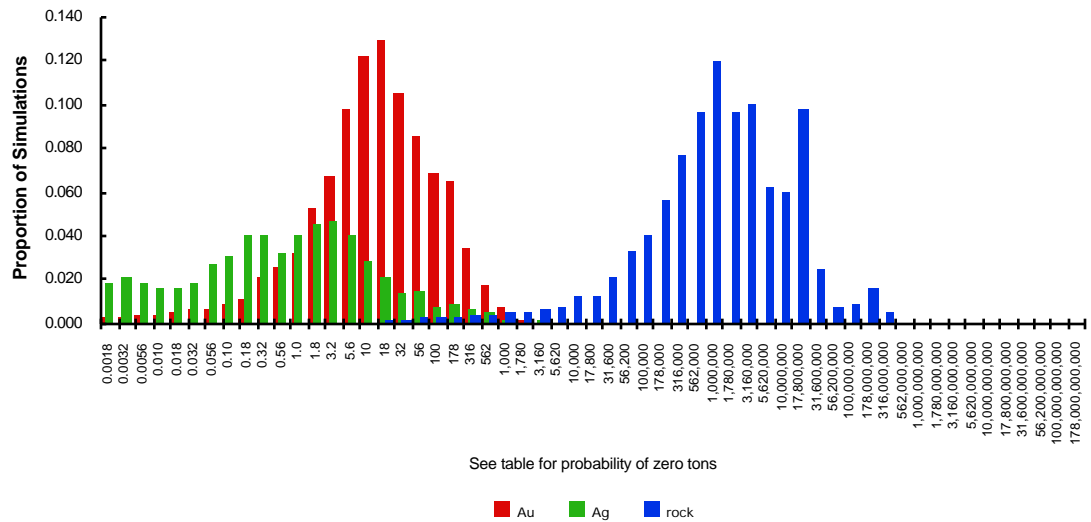
quantile	Au	Ag	rock
0.95	0	0	250
0.90	0	0	20,000
0.50	10	0	850,000
0.10	120	6	13,600,000
0.05	200	19	19,000,000
mean	42	7	6,900,000
Probability of mean	0.23	0.09	0.20
Probability of zero	0.04	0.43	0.04

The tract ID is PC40

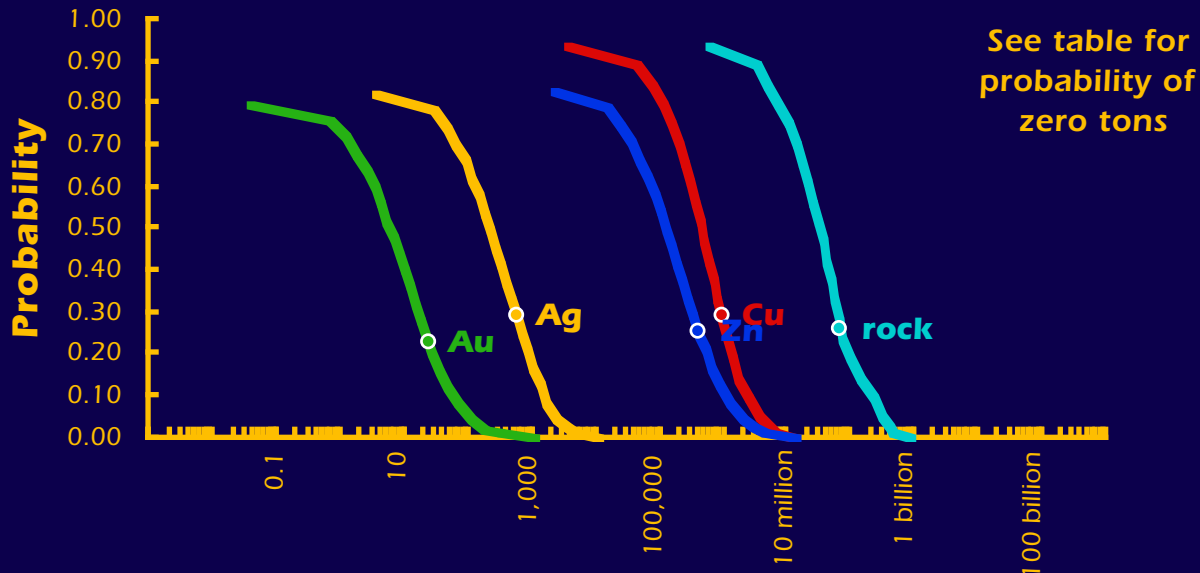
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

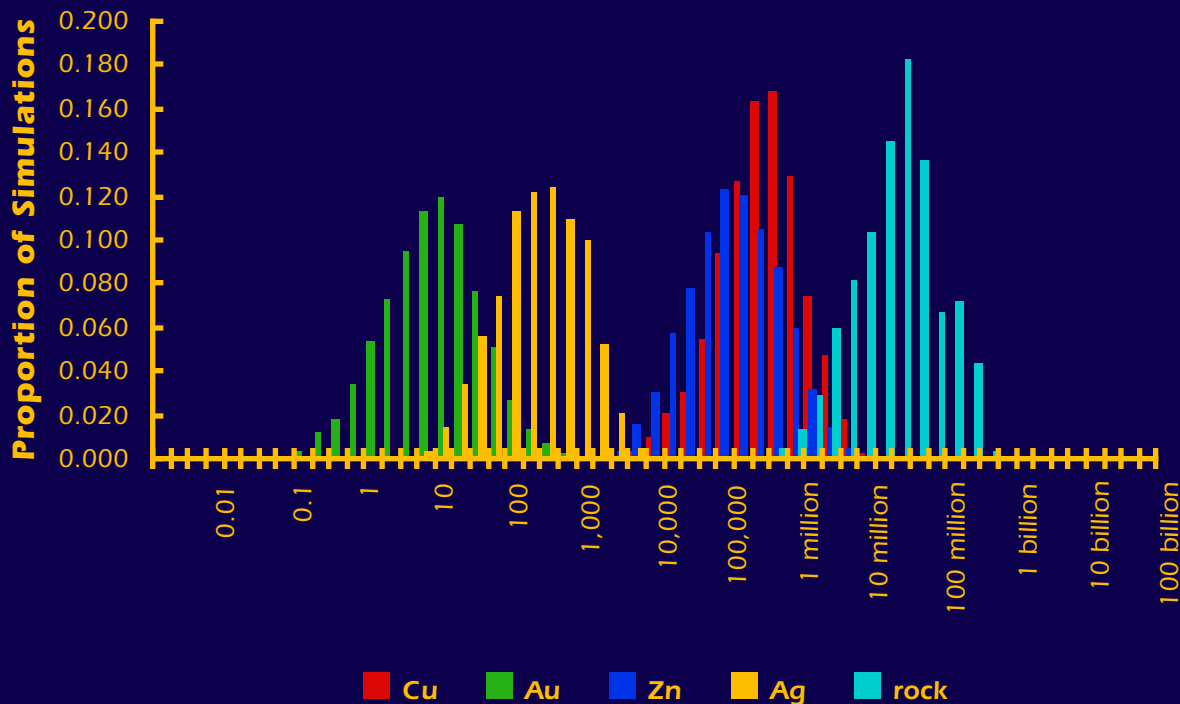


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SA01

The Mark3 Index is 98:

Massive sulfide, Besshi

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	rock
0.95	0	0	0	0	0
0.90	34,000	0	0	0	2,700,000
0.50	460,000	6	120,000	210	32,000,000
0.10	2,400,000	56	1,080,000	1,500	210,000,000
0.05	3,700,000	96	1,800,000	2,300	310,000,000
mean	920,000	23	420,000	560	69,000,000
Probability of mean	0.29	0.23	0.25	0.29	0.26
Probability of zero	0.06	0.20	0.17	0.18	0.06

The tract ID is SA01The Mark3 Index is 98: **Massive sulfide, Besshi**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

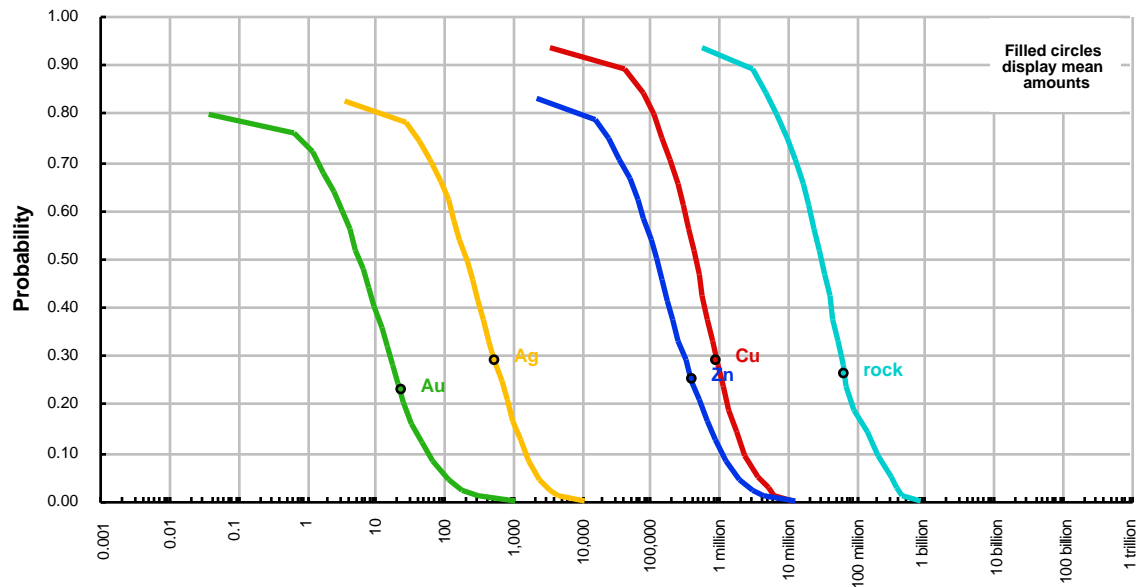
There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

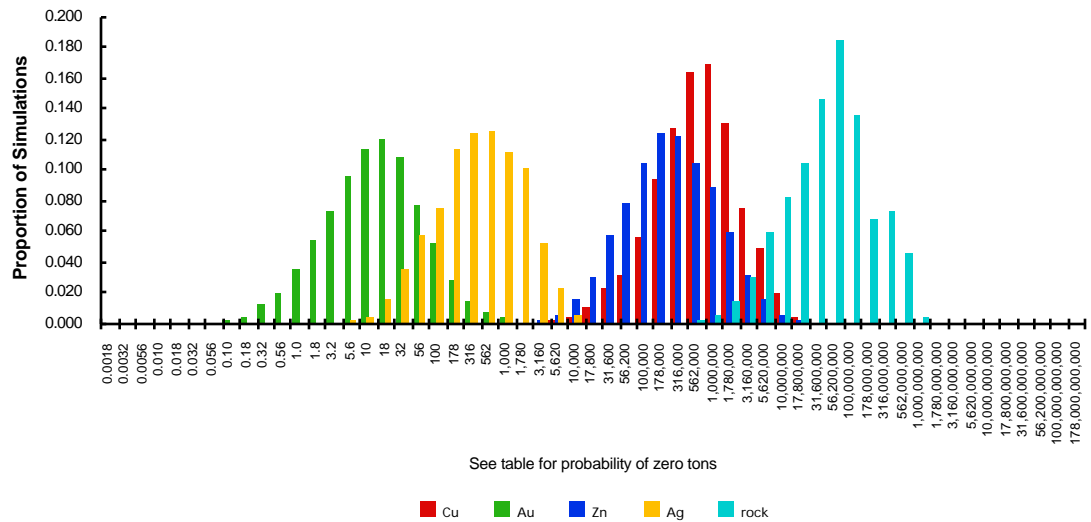
quantile	Cu	Au	Zn	Ag	rock
0.95	0	0	0	0	0
0.90	34,000	0	0	0	2,700,000
0.50	460,000	6	120,000	210	32,000,000
0.10	2,400,000	56	1,080,000	1,500	210,000,000
0.05	3,700,000	96	1,800,000	2,300	310,000,000
mean	920,000	23	420,000	560	69,000,000
Probability of mean	0.29	0.23	0.25	0.29	0.26
Probability of zero	0.06	0.20	0.17	0.18	0.06

The tract ID is SA01

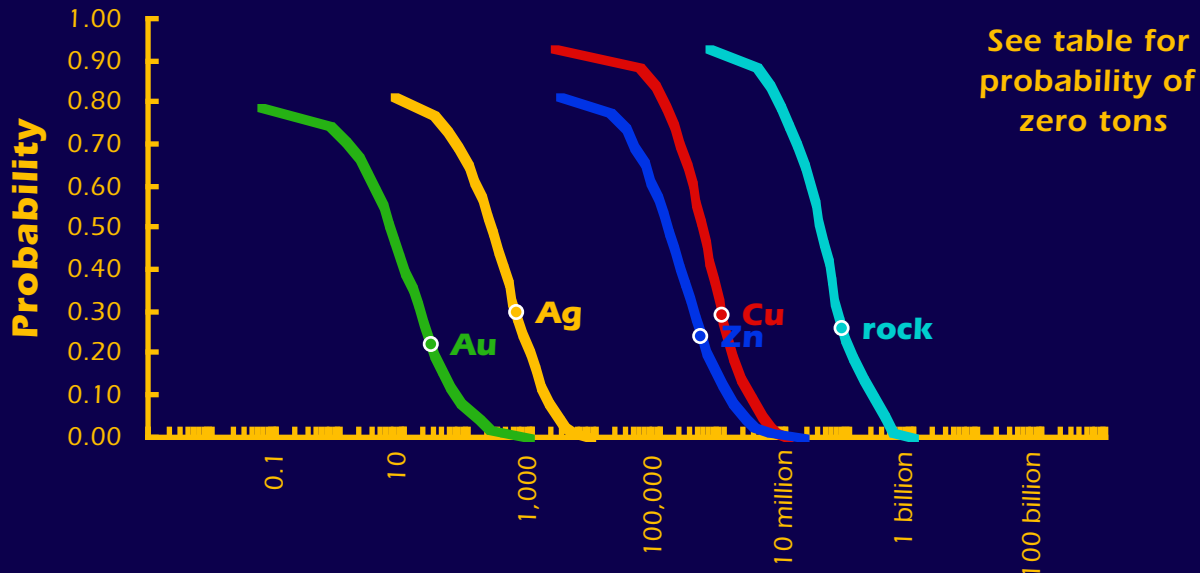
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

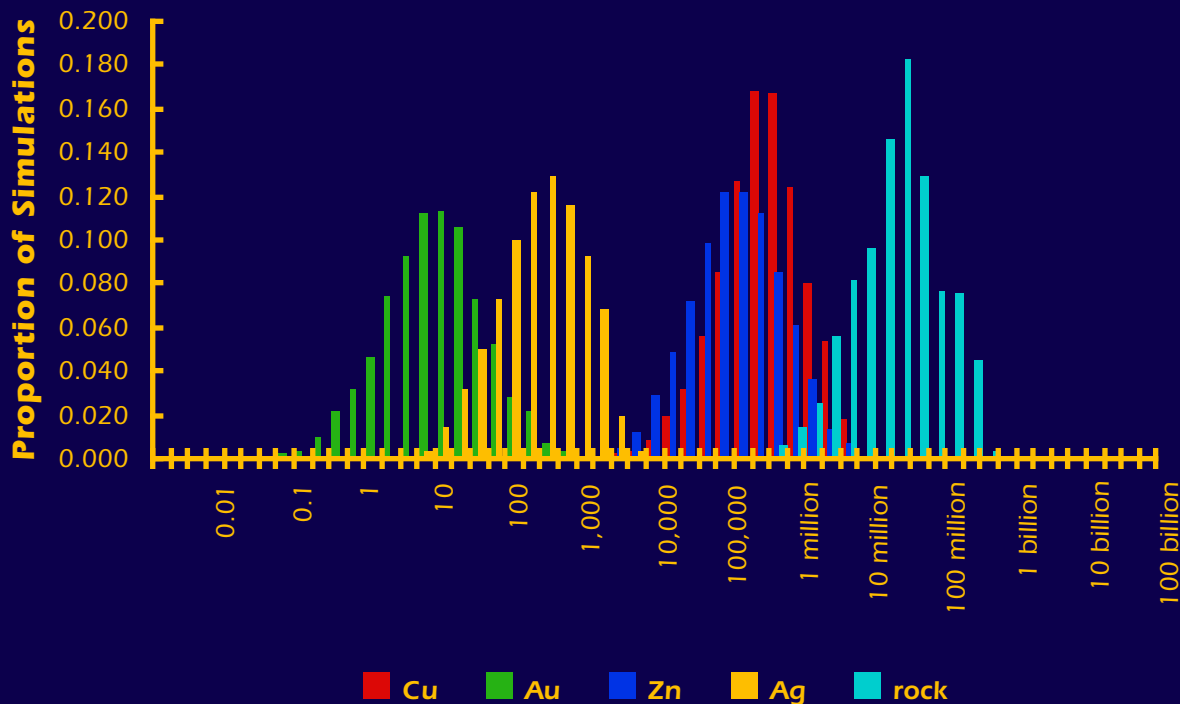


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SA03

The Mark3 Index is 98:

Massive sulfide, Besshi

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	rock
0.95	0	0	0	0	0
0.90	35,000	0	0	0	2,600,000
0.50	450,000	6	130,000	220	33,000,000
0.10	2,500,000	60	1,160,000	1,600	210,000,000
0.05	3,900,000	120	1,900,000	2,400	310,000,000
mean	940,000	26	450,000	570	71,000,000
Probability of mean	0.29	0.22	0.24	0.30	0.26
Probability of zero	0.07	0.21	0.18	0.19	0.07

The tract ID is SA03The Mark3 Index is 98: **Massive sulfide, Besshi**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

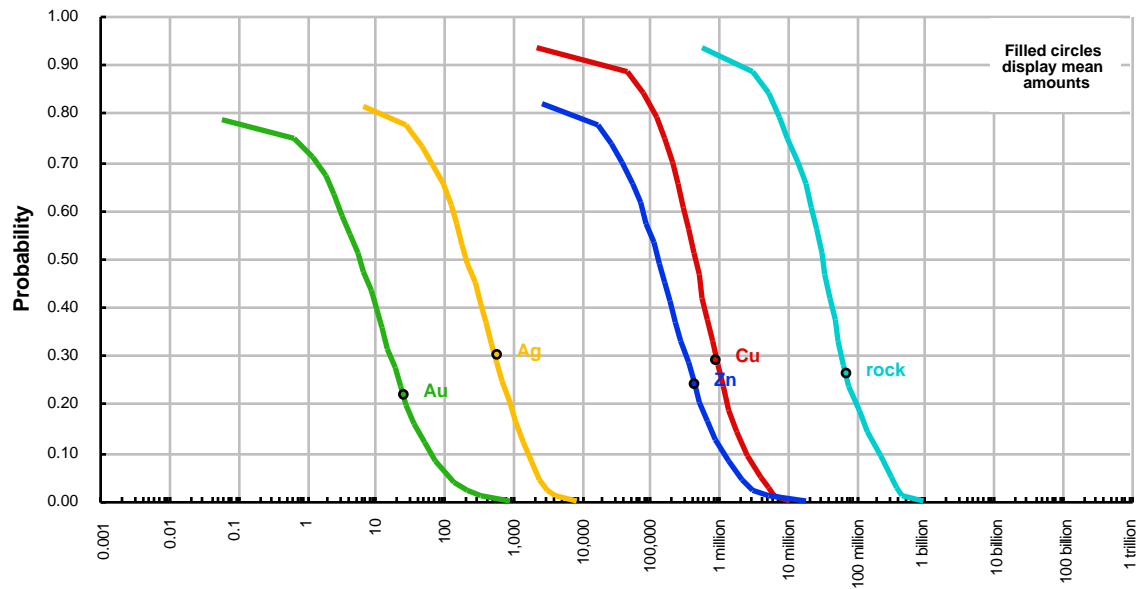
There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

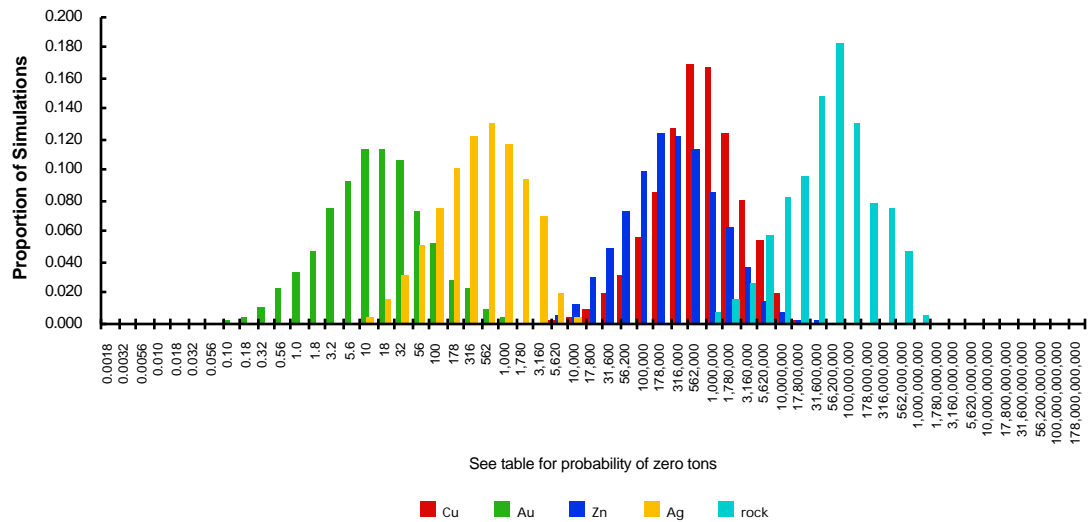
quantile	Cu	Au	Zn	Ag	rock
0.95	0	0	0	0	0
0.90	35,000	0	0	0	2,600,000
0.50	450,000	6	130,000	220	33,000,000
0.10	2,500,000	60	1,160,000	1,600	210,000,000
0.05	3,900,000	120	1,900,000	2,400	310,000,000
mean	940,000	26	450,000	570	71,000,000
Probability of mean	0.29	0.22	0.24	0.30	0.26
Probability of zero	0.07	0.21	0.18	0.19	0.07

The tract ID is SA03

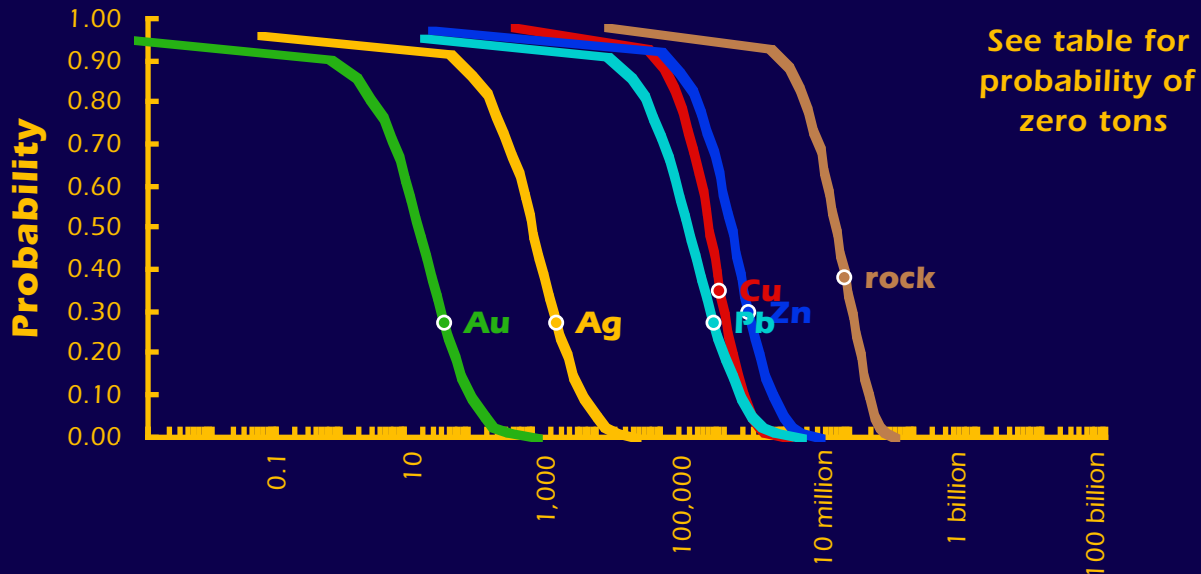
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

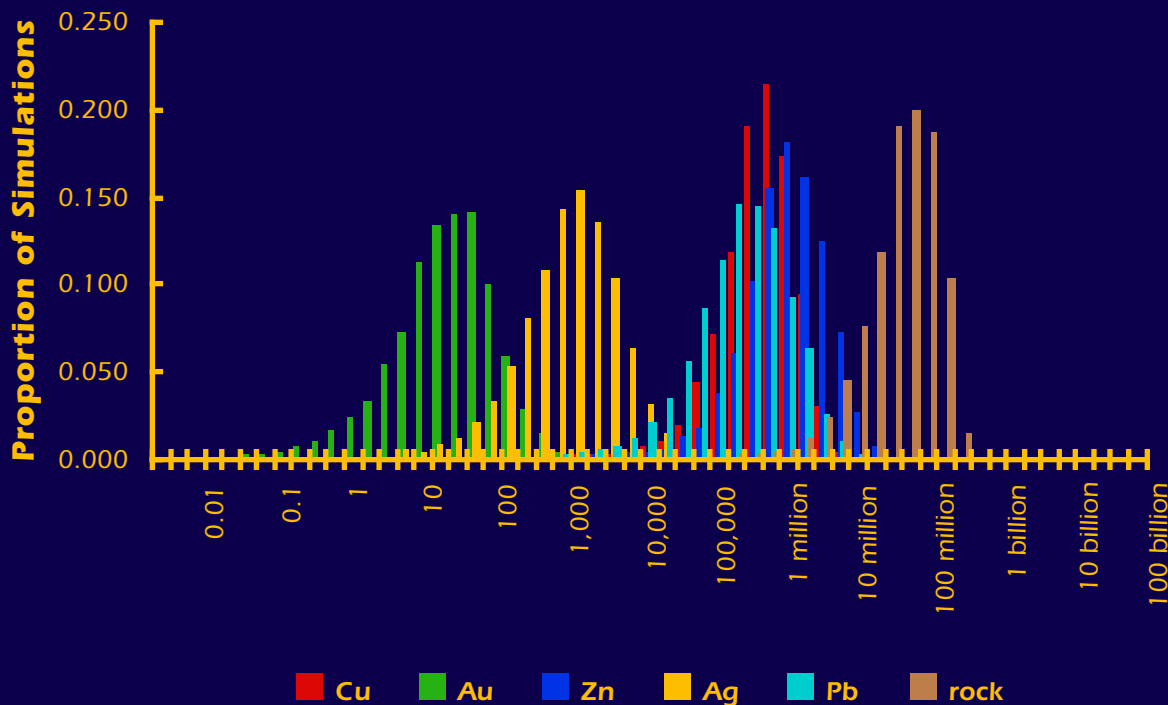


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SA04

The Mark3 Index is 104:

Massive sulfide, kuroko (Phanerozoic)

There is a 90% or greater chance of 4 or more deposits.
There is a 50% or greater chance of 8 or more deposits.
There is a 10% or greater chance of 12 or more deposits.
There is a 5% or greater chance of 12 or more deposits.
There is a 1% or greater chance of 12 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	39,000	0	46,000	12	1,400	3,500,000
0.90	93,000	1	160,000	76	19,000	8,500,000
0.50	590,000	17	1,300,000	1,000	280,000	57,000,000
0.10	2,000,000	100	5,930,000	6,100	1,800,000	190,000,000
0.05	2,800,000	160	8,500,000	9,800	2,700,000	230,000,000
mean	880,000	42	2,400,000	2,400	700,000	81,000,000
Probability of mean	0.35	0.27	0.30	0.27	0.27	0.38
Probability of zero	0.02	0.05	0.03	0.03	0.04	0.02

The tract ID is SA04

The Mark3 Index is 104: **Massive sulfide, kuroko (Phanerozoic)**

There is a 90% or greater chance of 4 or more deposits.

There is a 50% or greater chance of 8 or more deposits.

There is a 10% or greater chance of 12 or more deposits.

There is a 5% or greater chance of 12 or more deposits.

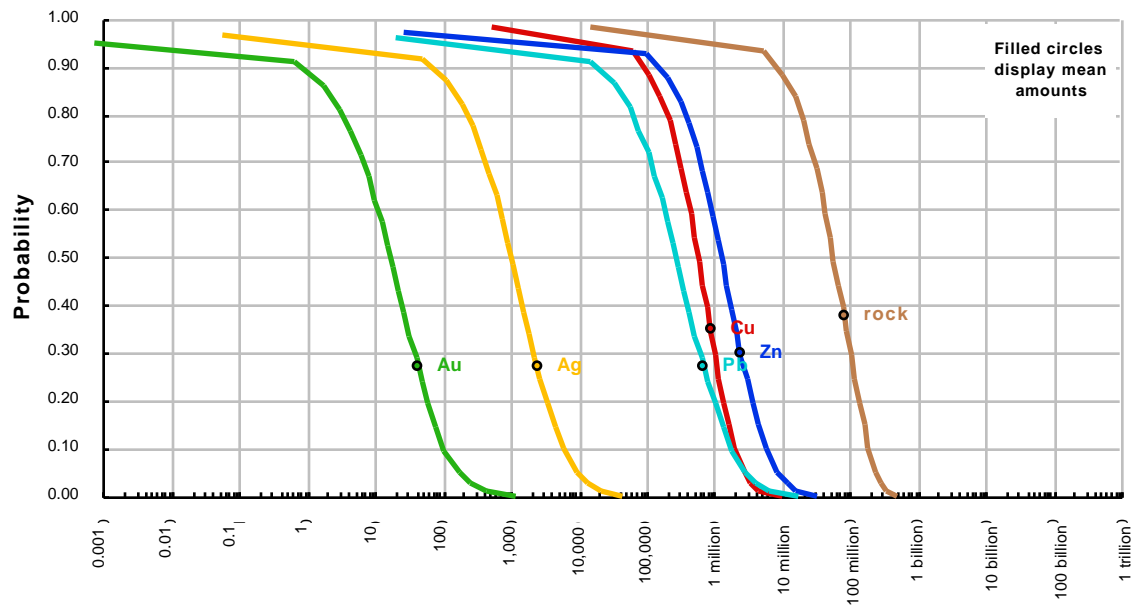
There is a 1% or greater chance of 12 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

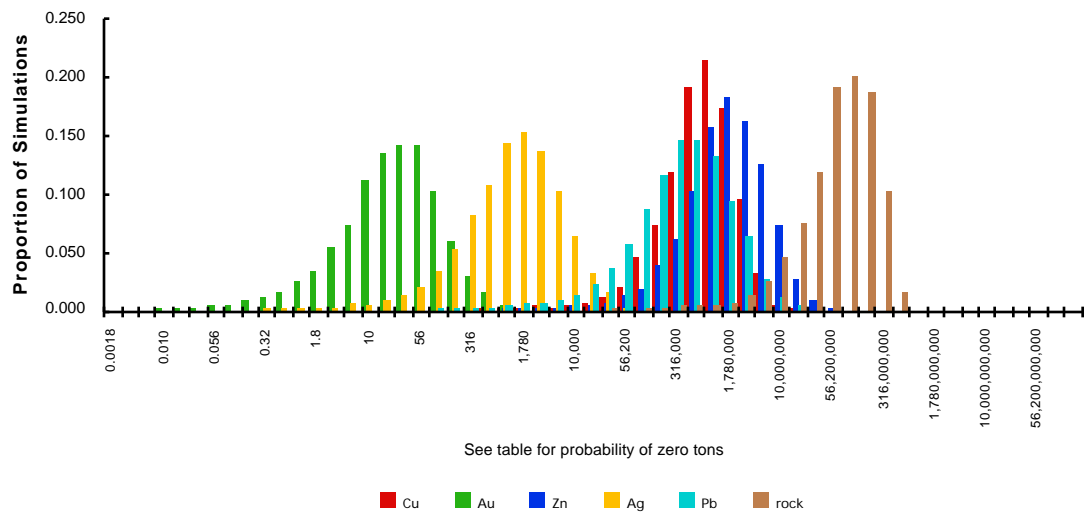
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	39,000	0	46,000	12	1,400	3,500,000
0.90	93,000	1	160,000	76	19,000	8,500,000
0.50	590,000	17	1,300,000	1,000	280,000	57,000,000
0.10	2,000,000	100	5,930,000	6,100	1,800,000	190,000,000
0.05	2,800,000	160	8,500,000	9,800	2,700,000	230,000,000
mean	880,000	42	2,400,000	2,400	700,000	81,000,000
Probability of mean	0.35	0.27	0.30	0.27	0.27	0.38
Probability of zero	0.02	0.05	0.03	0.03	0.04	0.02

The tract ID is SA04

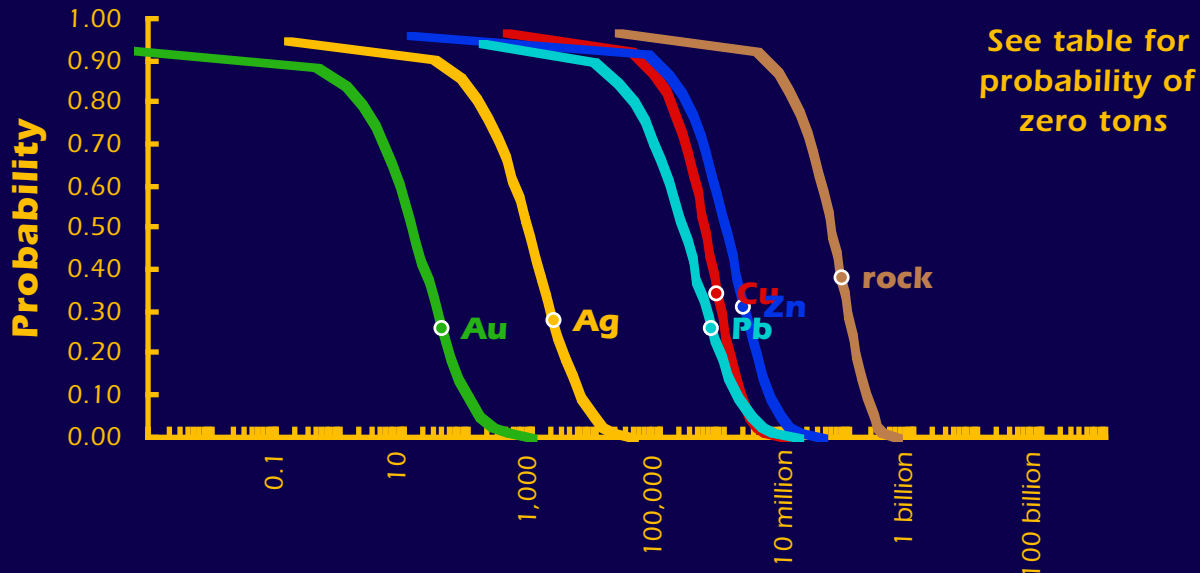
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)



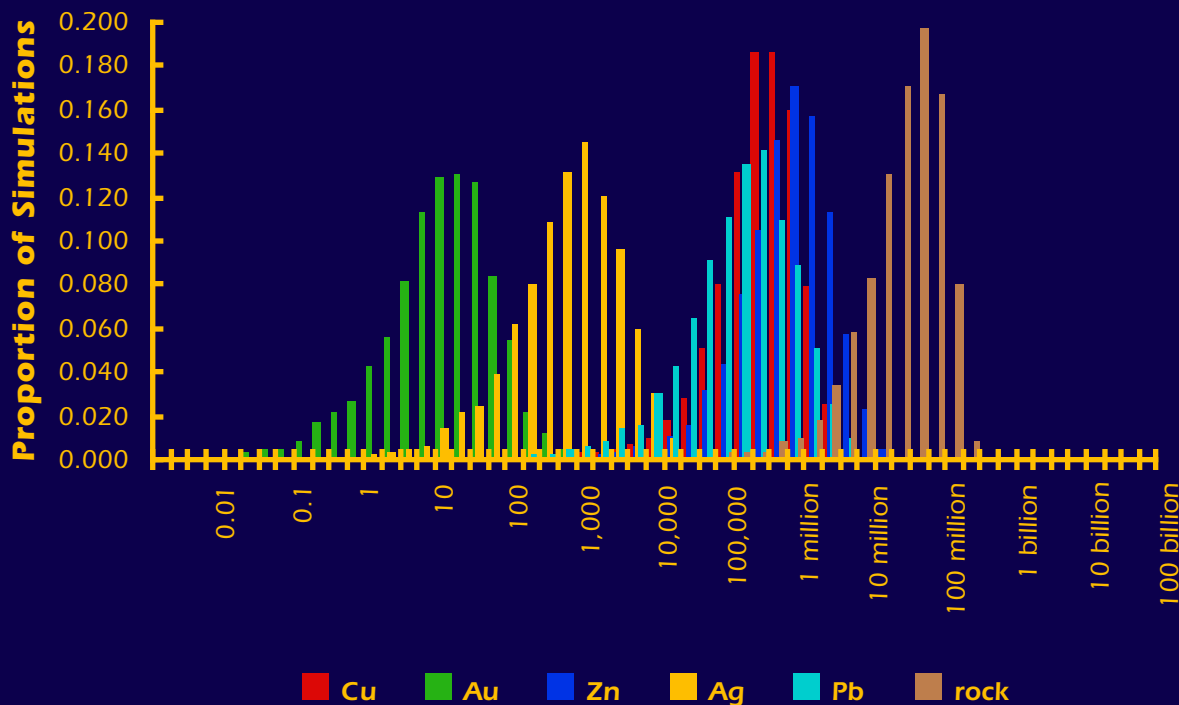
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



See table for
probability of
zero tons

Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SA07

The Mark3 Index is 104:

Massive sulfide, kuroko (Phanerozoic)

There is a 90% or greater chance of 3 or more deposits.
 There is a 50% or greater chance of 7 or more deposits.
 There is a 10% or greater chance of 12 or more deposits.
 There is a 5% or greater chance of 12 or more deposits.
 There is a 1% or greater chance of 12 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	14,000	0	13,000	2	0	1,300,000
0.90	56,000	0	85,000	32	7,800	5,200,000
0.50	500,000	13	1,100,000	850	230,000	48,000,000
0.10	1,800,000	94	5,100,000	5,500	1,600,000	170,000,000
0.05	2,600,000	150	7,600,000	8,800	2,600,000	220,000,000
mean	780,000	38	2,100,000	2,100	620,000	71,000,000
Probability of mean	0.34	0.26	0.31	0.28	0.26	0.38
Probability of zero	0.03	0.07	0.04	0.05	0.06	0.03

The tract ID is SA07The Mark3 Index is 104: **Massive sulfide, kuroko (Phanerozoic)**

There is a 90% or greater chance of 3 or more deposits.

There is a 50% or greater chance of 7 or more deposits.

There is a 10% or greater chance of 12 or more deposits.

There is a 5% or greater chance of 12 or more deposits.

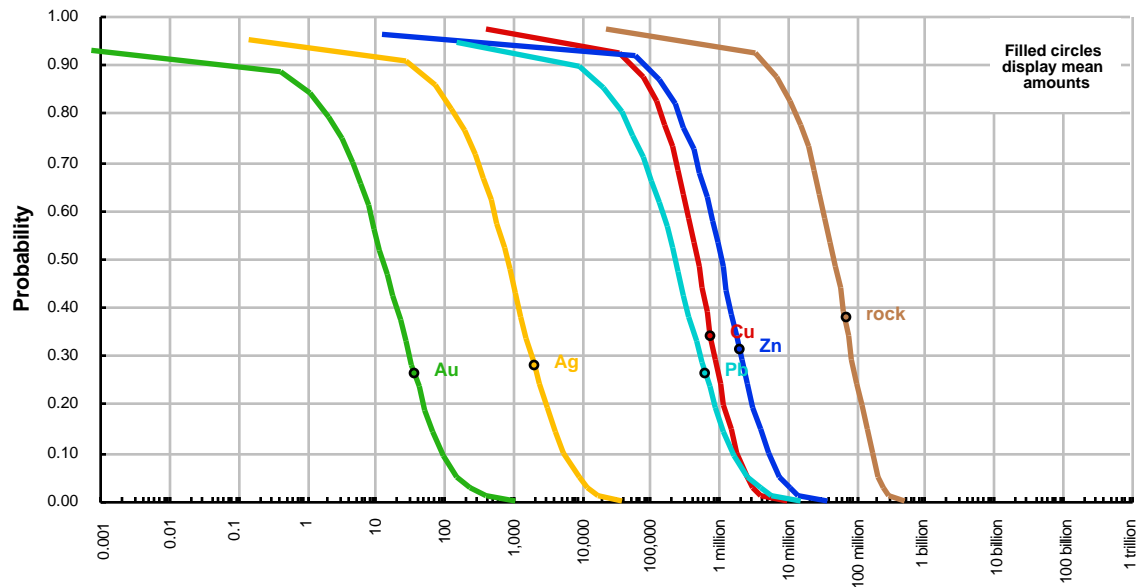
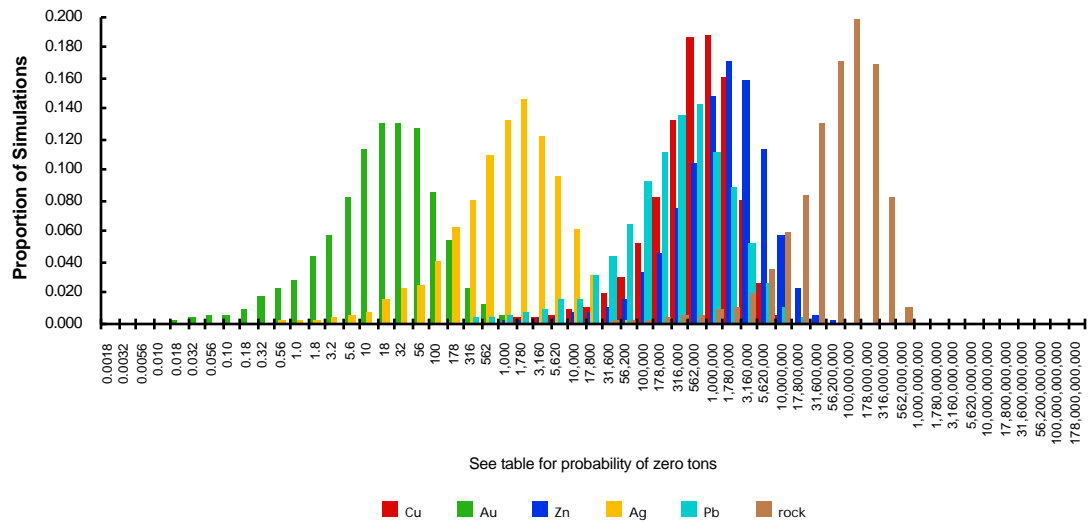
There is a 1% or greater chance of 12 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

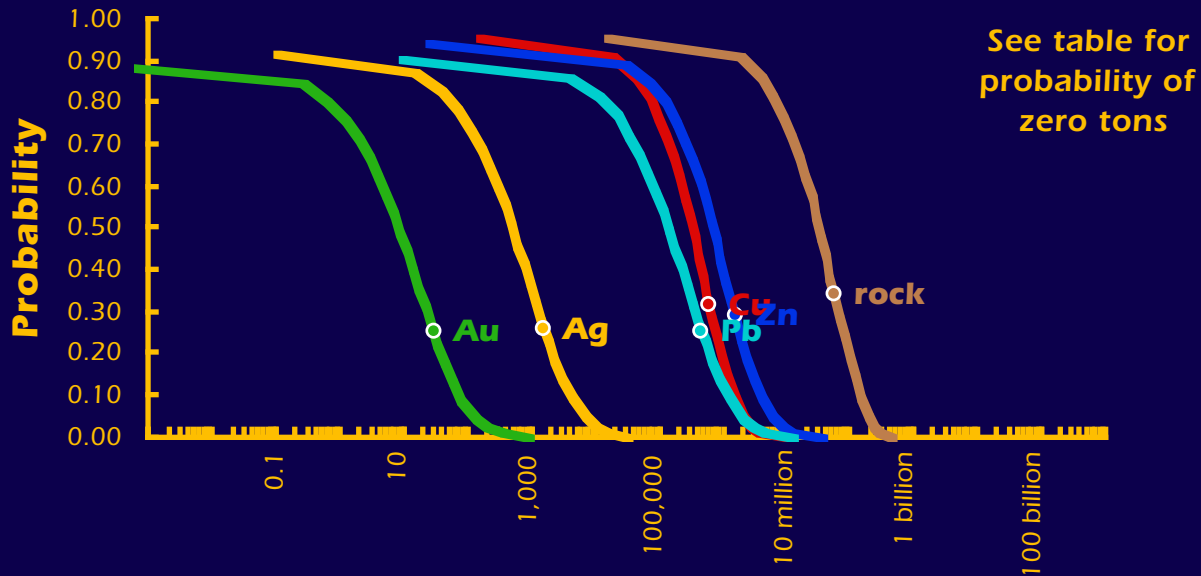
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	14,000	0	13,000	2	0	1,300,000
0.90	56,000	0	85,000	32	7,800	5,200,000
0.50	500,000	13	1,100,000	850	230,000	48,000,000
0.10	1,800,000	94	5,100,000	5,500	1,600,000	170,000,000
0.05	2,600,000	150	7,600,000	8,800	2,600,000	220,000,000
mean	780,000	38	2,100,000	2,100	620,000	71,000,000
Probability of mean	0.34	0.26	0.31	0.28	0.26	0.38
Probability of zero	0.03	0.07	0.04	0.05	0.06	0.03

The tract ID is SA07

Cumulative Distributions of Contained Metal and Mineralized Rock

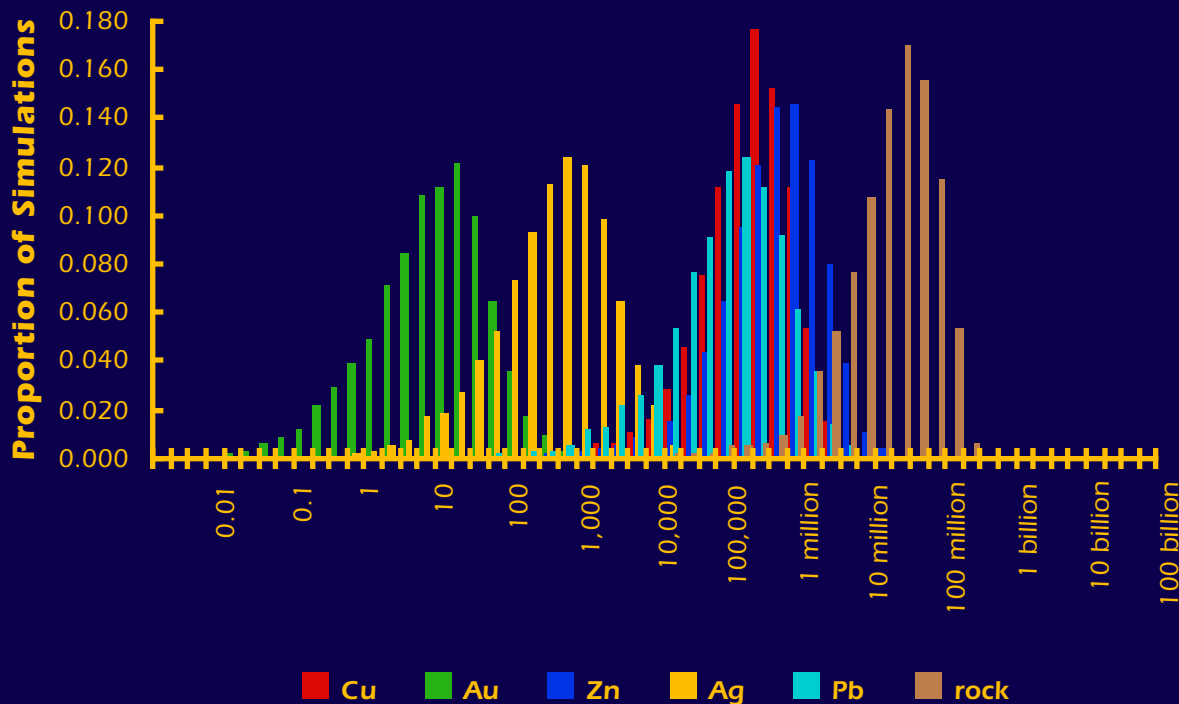
Histograms of Contained Metal and Mineralized Rock
(metric tons)

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SA08

The Mark3 Index is 104:

Massive sulfide, kuroko (Phanerozoic)

There is a 90% or greater chance of 2 or more deposits.
 There is a 50% or greater chance of 5 or more deposits.
 There is a 10% or greater chance of 10 or more deposits.
 There is a 5% or greater chance of 10 or more deposits.
 There is a 1% or greater chance of 10 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	2,300	0	0	0	0	150,000
0.90	25,000	0	26,000	7	230	2,200,000
0.50	330,000	8	670,000	470	130,000	31,000,000
0.10	1,500,000	70	3,830,000	3,900	1,100,000	140,000,000
0.05	2,000,000	120	5,900,000	6,700	1,900,000	190,000,000
mean	580,000	29	1,500,000	1,500	450,000	54,000,000
Probability of mean	0.32	0.25	0.29	0.26	0.25	0.34
Probability of zero	0.04	0.11	0.06	0.08	0.10	0.04

The tract ID is SA08The Mark3 Index is 104: **Massive sulfide, kuroko (Phanerozoic)**

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 5 or more deposits.

There is a 10% or greater chance of 10 or more deposits.

There is a 5% or greater chance of 10 or more deposits.

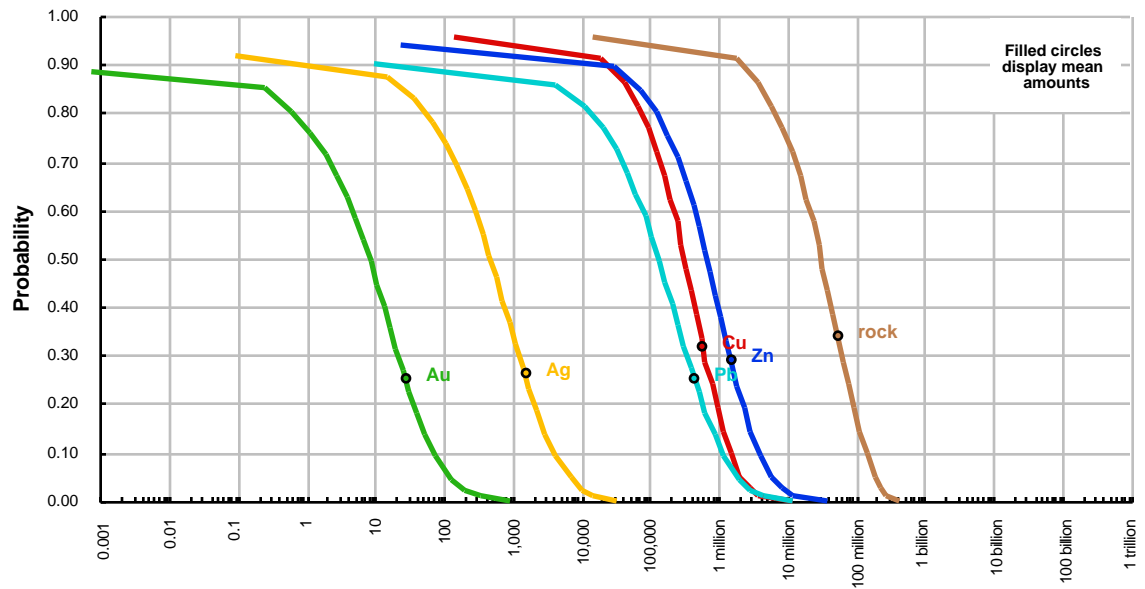
There is a 1% or greater chance of 10 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

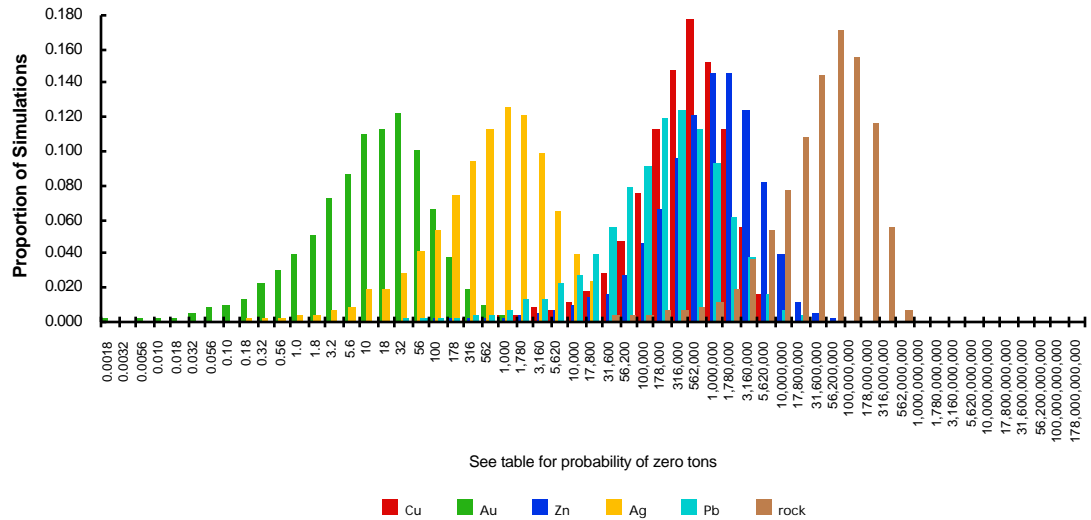
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	2,300	0	0	0	0	150,000
0.90	25,000	0	26,000	7	230	2,200,000
0.50	330,000	8	670,000	470	130,000	31,000,000
0.10	1,500,000	70	3,830,000	3,900	1,100,000	140,000,000
0.05	2,000,000	120	5,900,000	6,700	1,900,000	190,000,000
mean	580,000	29	1,500,000	1,500	450,000	54,000,000
Probability of mean	0.32	0.25	0.29	0.26	0.25	0.34
Probability of zero	0.04	0.11	0.06	0.08	0.10	0.04

The tract ID is SA08

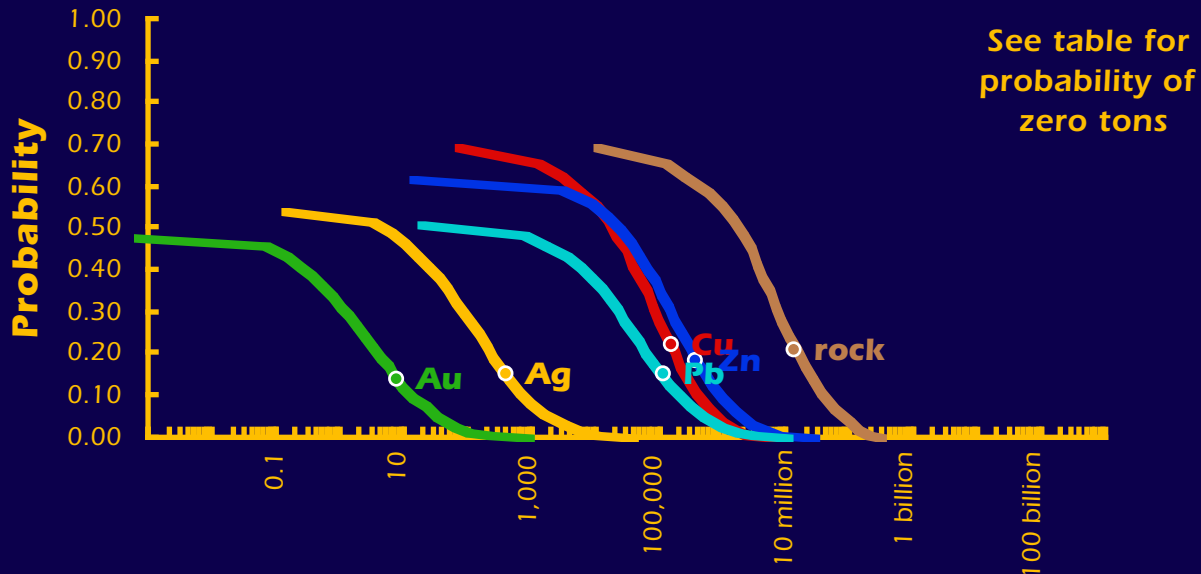
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

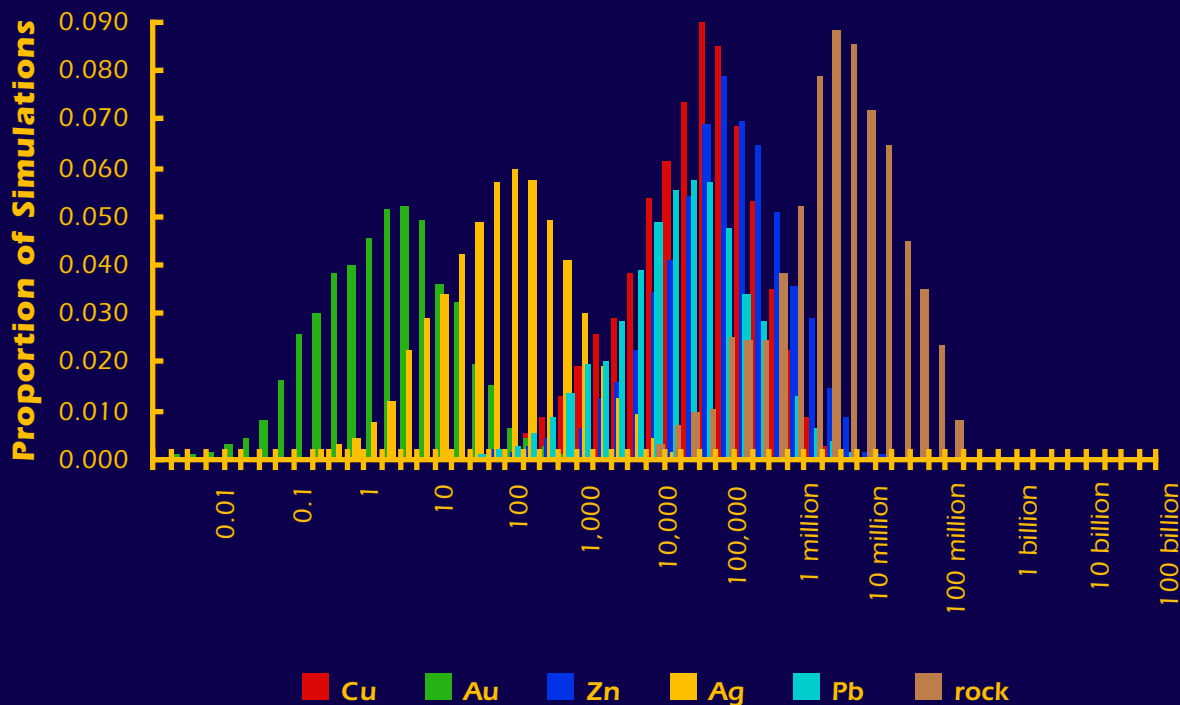


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SA09

The Mark3 Index is 104:

Massive sulfide, kuroko (Phanerozoic)

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	18,000	0	23,000	5	310	1,800,000
0.10	390,000	12	851,000	710	200,000	36,000,000
0.05	740,000	30	1,900,000	1,600	490,000	71,000,000
mean	150,000	7	370,000	370	110,000	13,000,000
Probability of mean	0.22	0.14	0.18	0.15	0.15	0.21
Probability of zero	0.31	0.52	0.38	0.46	0.49	0.31

The tract ID is SA09The Mark3 Index is 104: **Massive sulfide, kuroko (Phanerozoic)**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

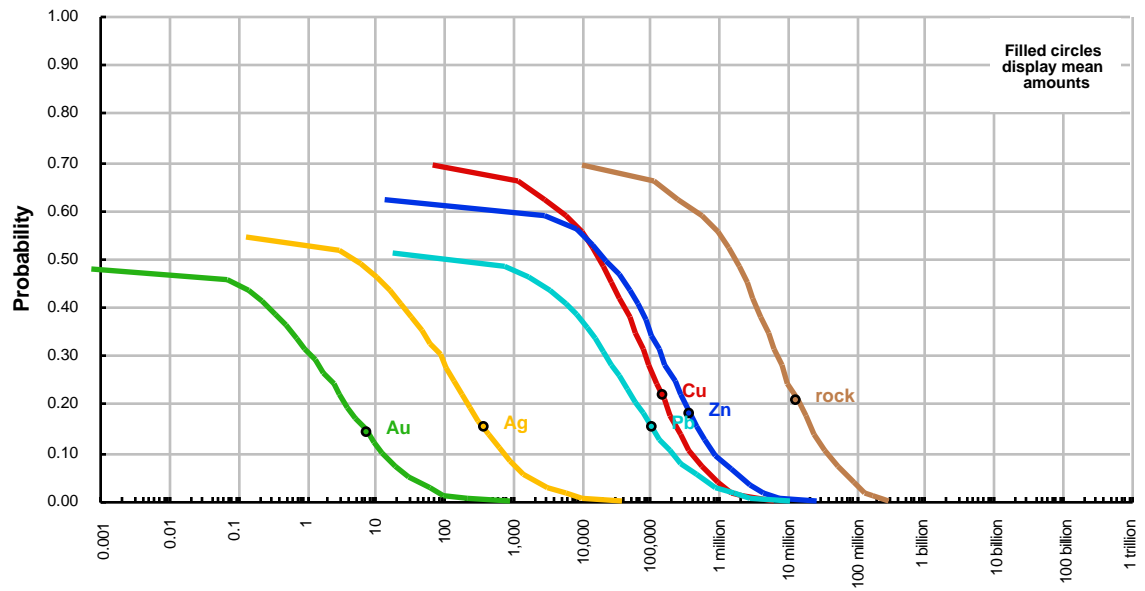
There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

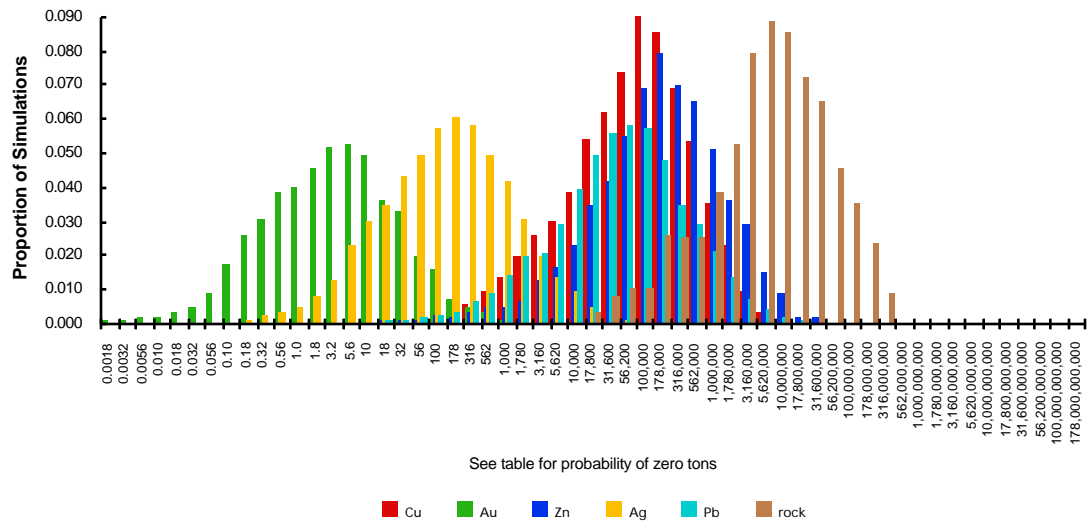
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	18,000	0	23,000	5	310	1,800,000
0.10	390,000	12	851,000	710	200,000	36,000,000
0.05	740,000	30	1,900,000	1,600	490,000	71,000,000
mean	150,000	7	370,000	370	110,000	13,000,000
Probability of mean	0.22	0.14	0.18	0.15	0.15	0.21
Probability of zero	0.31	0.52	0.38	0.46	0.49	0.31

The tract ID is SA09

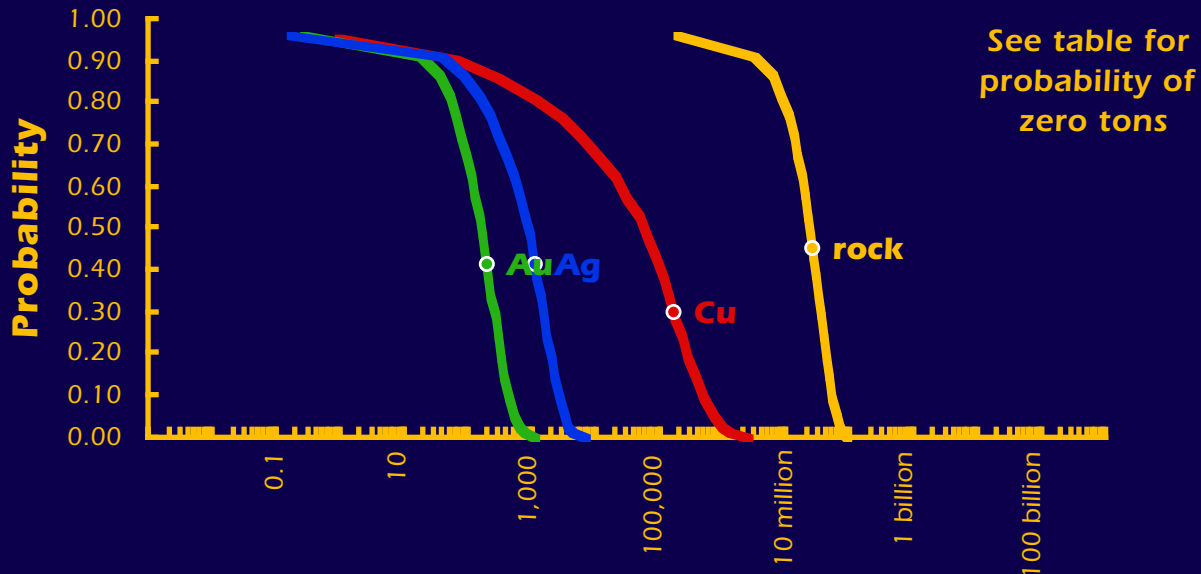
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

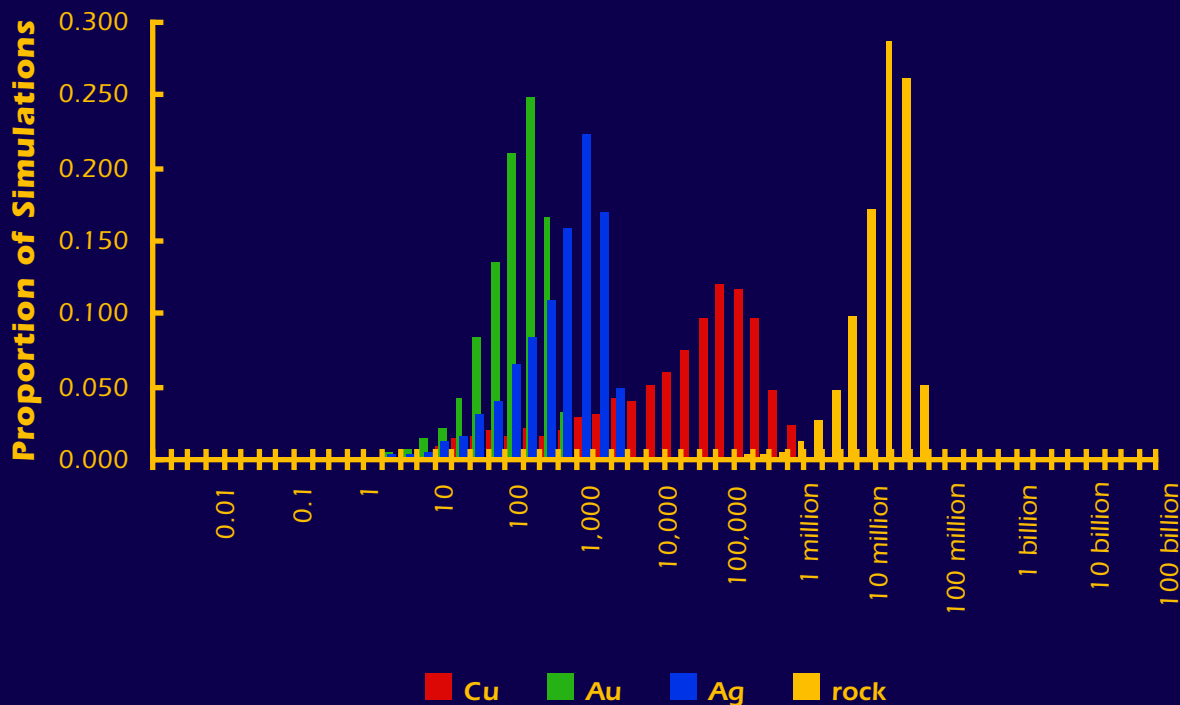


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SA10

The Mark3 Index is 38:

Epithermal vein, quartz-alunite

There is a 90% or greater chance of 2 or more deposits.
There is a 50% or greater chance of 5 or more deposits.
There is a 10% or greater chance of 10 or more deposits.
There is a 5% or greater chance of 10 or more deposits.
There is a 1% or greater chance of 10 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Ag	rock
0.95	7	5	10	1,100,000
0.90	78	24	52	3,800,000
0.50	55,000	160	840	22,000,000
0.10	450,000	420	2,510	49,000,000
0.05	690,000	520	3,200	56,000,000
mean	160,000	190	1,100	25,000,000
Probability of mean	0.30	0.41	0.41	0.45
Probability of zero	0.04	0.04	0.04	0.04

The tract ID is SA10The Mark3 Index is 38: **Epithermal vein, quartz-alunite**

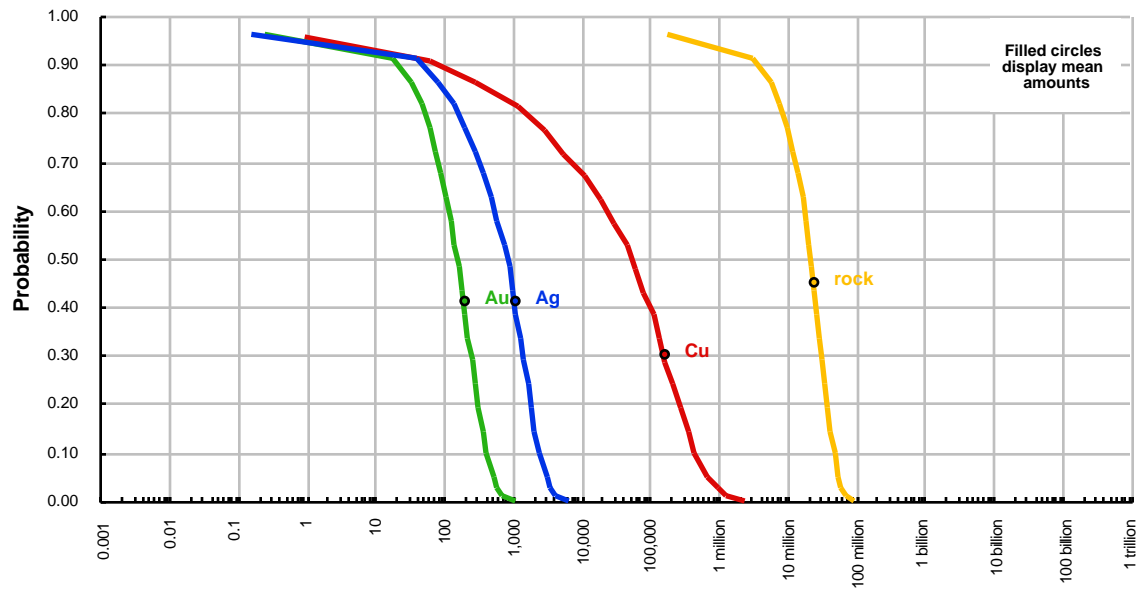
There is a 90% or greater chance of 2 or more deposits.
 There is a 50% or greater chance of 5 or more deposits.
 There is a 10% or greater chance of 10 or more deposits.
 There is a 5% or greater chance of 10 or more deposits.
 There is a 1% or greater chance of 10 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

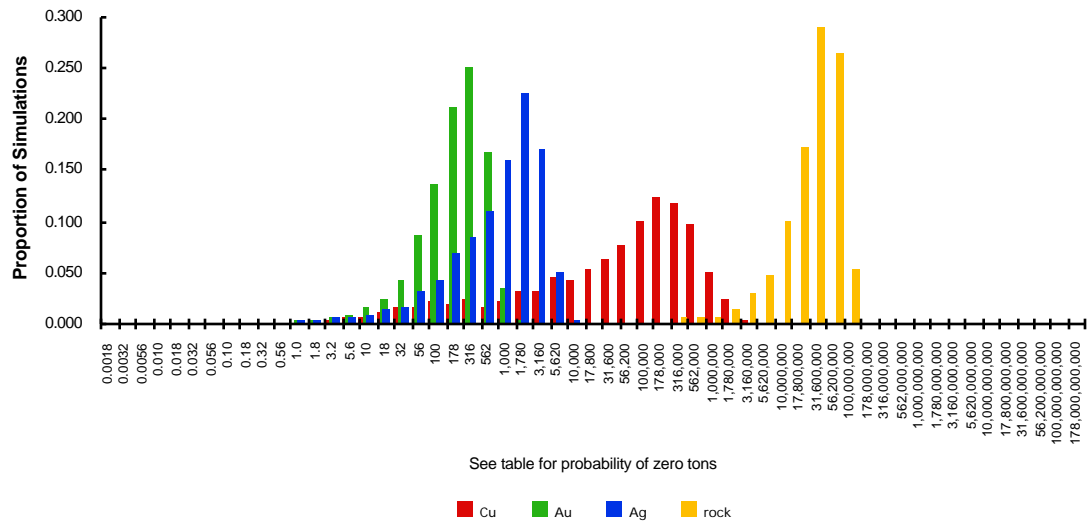
quantile	Cu	Au	Ag	rock
0.95	7	5	10	1,100,000
0.90	78	24	52	3,800,000
0.50	55,000	160	840	22,000,000
0.10	450,000	420	2,510	49,000,000
0.05	690,000	520	3,200	56,000,000
mean	160,000	190	1,100	25,000,000
Probability of mean	0.30	0.41	0.41	0.45
Probability of zero	0.04	0.04	0.04	0.04

The tract ID is SA10

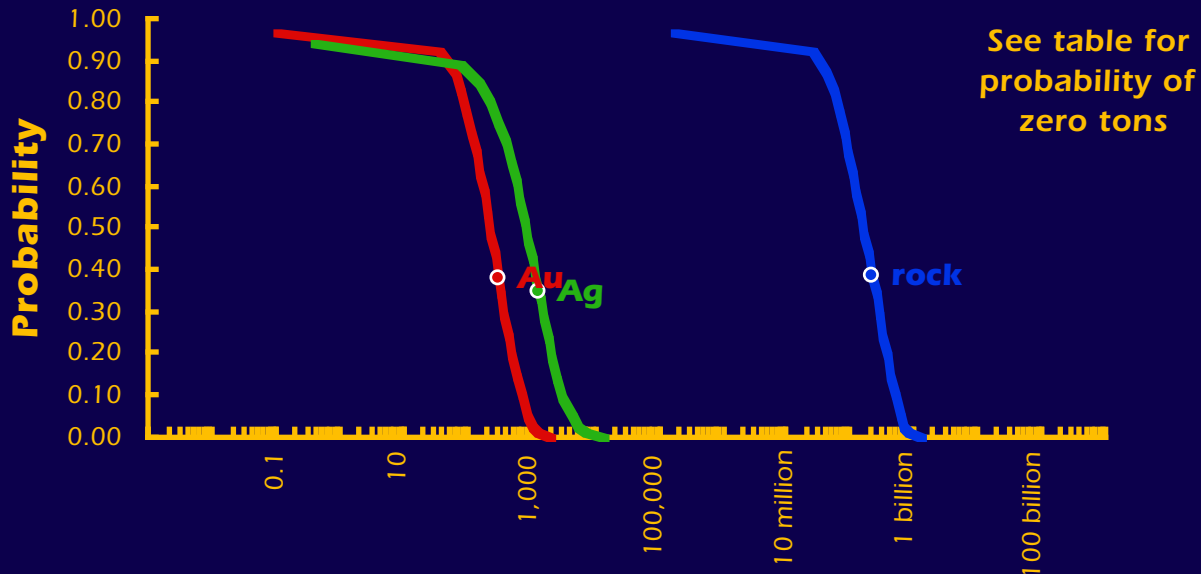
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

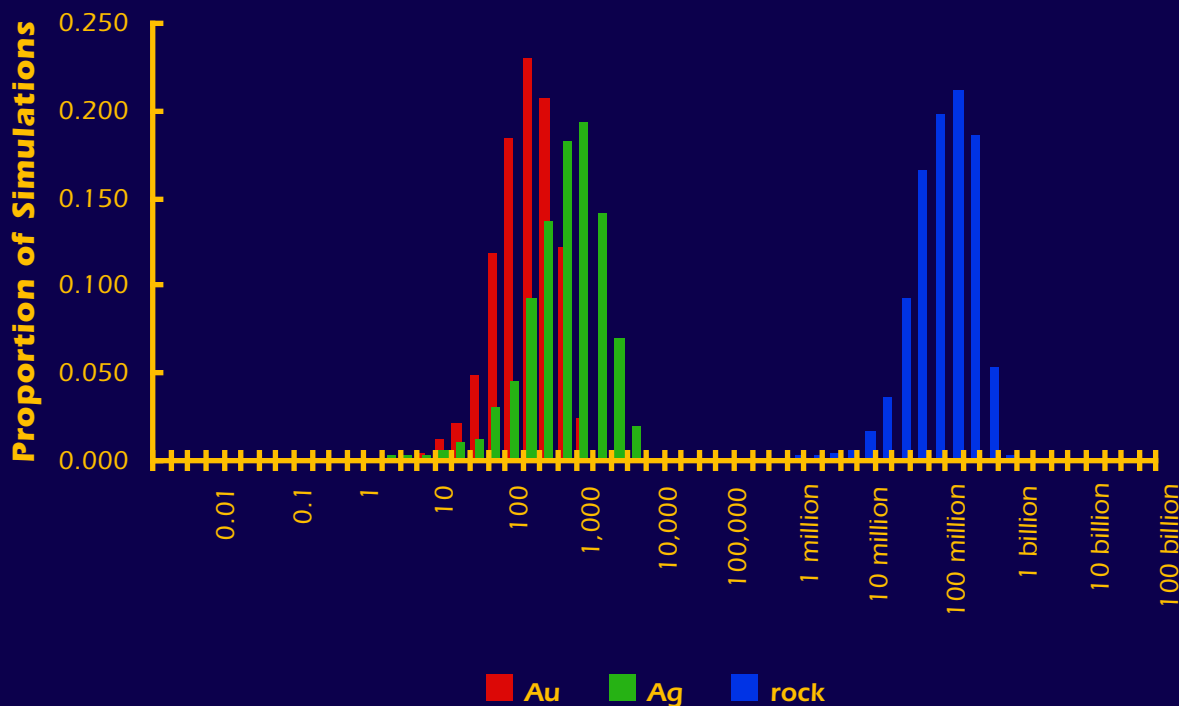


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SA15

The Mark3 Index is 45:

Hot spring Au-Ag

There is a 90% or greater chance of 3 or more deposits.
There is a 50% or greater chance of 5 or more deposits.
There is a 10% or greater chance of 12 or more deposits.
There is a 5% or greater chance of 12 or more deposits.
There is a 1% or greater chance of 12 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	19	0	14,000,000
0.90	48	66	34,000,000
0.50	220	780	150,000,000
0.10	670	3,000	472,000,000
0.05	830	4,000	570,000,000
mean	300	1,200	210,000,000
Probability of mean	0.38	0.35	0.39
Probability of zero	0.03	0.06	0.03

The tract ID is SA15The Mark3 Index is 45: **Hot spring Au-Ag**

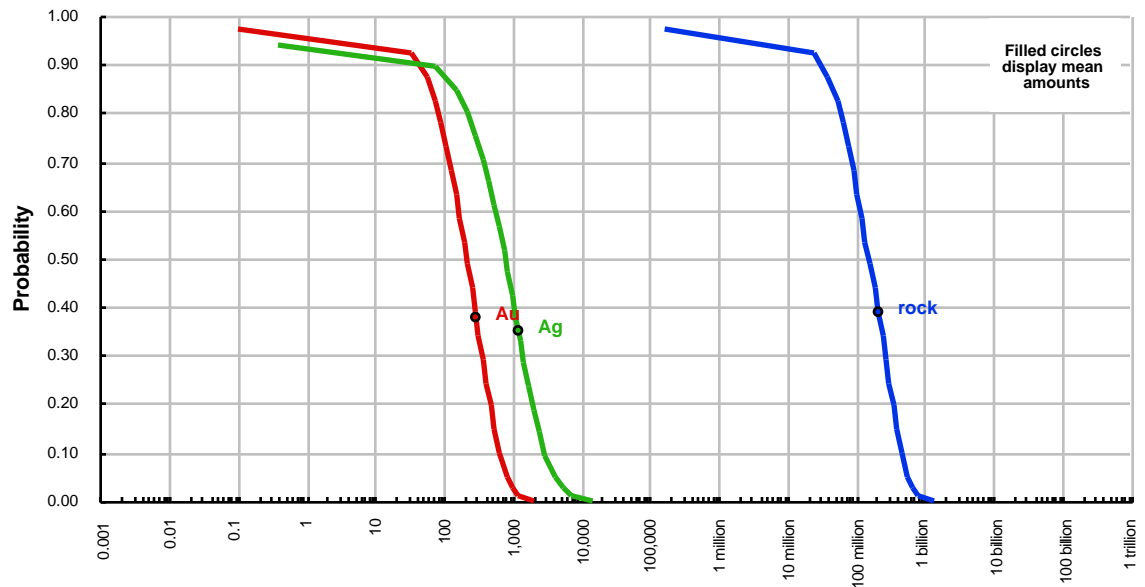
There is a 90% or greater chance of 3 or more deposits.
 There is a 50% or greater chance of 5 or more deposits.
 There is a 10% or greater chance of 12 or more deposits.
 There is a 5% or greater chance of 12 or more deposits.
 There is a 1% or greater chance of 12 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

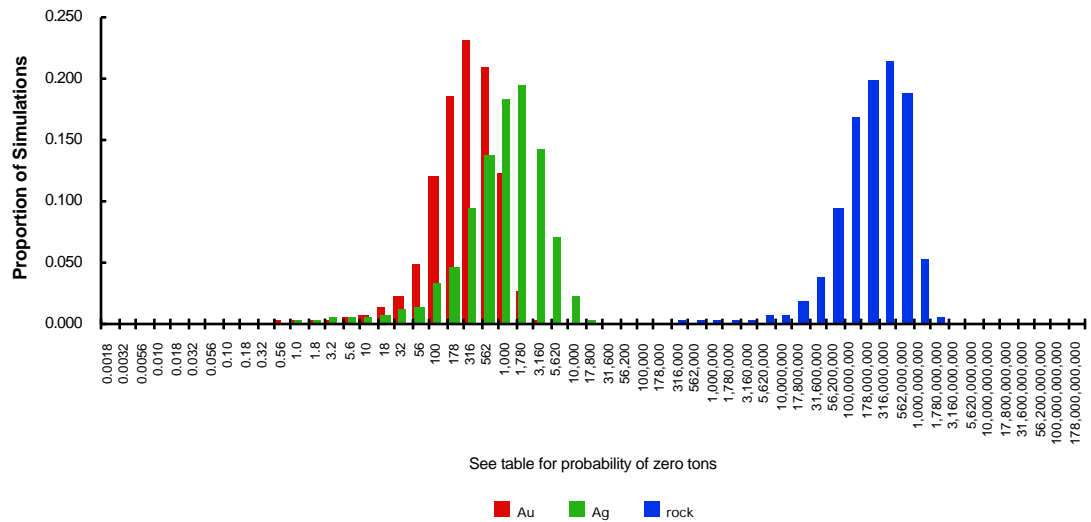
quantile	Au	Ag	rock
0.95	19	0	14,000,000
0.90	48	66	34,000,000
0.50	220	780	150,000,000
0.10	670	3,000	472,000,000
0.05	830	4,000	570,000,000
mean	300	1,200	210,000,000
Probability of mean	0.38	0.35	0.39
Probability of zero	0.03	0.06	0.03

The tract ID is SA15

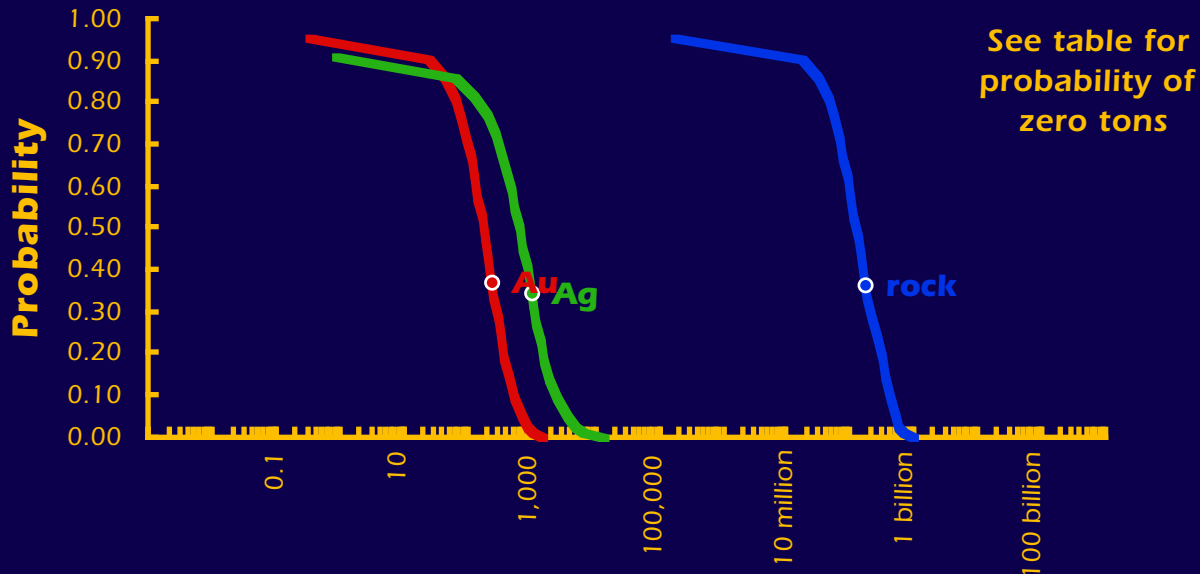
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

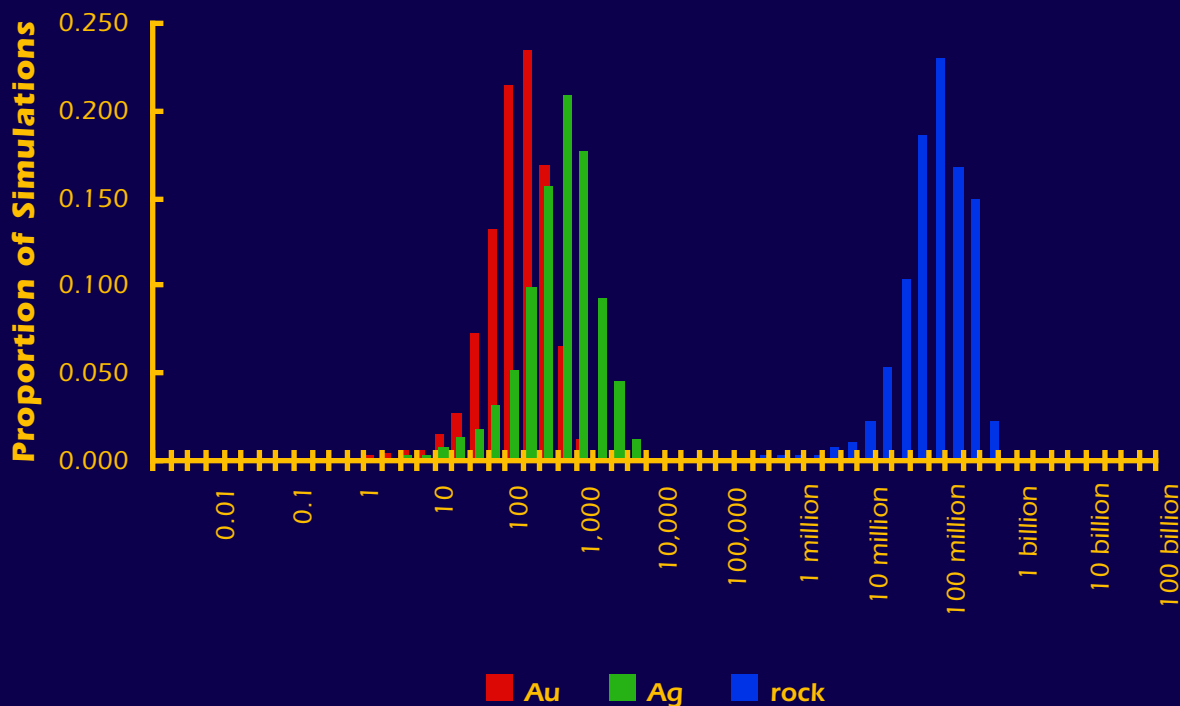


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SA16

The Mark3 Index is 45:

Hot spring Au-Ag

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 5 or more deposits.

There is a 10% or greater chance of 8 or more deposits.

There is a 5% or greater chance of 8 or more deposits.

There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	3	0	1,400,000
0.90	30	15	20,000,000
0.50	170	610	120,000,000
0.10	500	2,300	389,000,000
0.05	660	3,400	470,000,000
mean	230	970	170,000,000
Probability of mean	0.37	0.34	0.36
Probability of zero	0.04	0.09	0.04

The tract ID is SA16The Mark3 Index is 45: **Hot spring Au-Ag**

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 5 or more deposits.

There is a 10% or greater chance of 8 or more deposits.

There is a 5% or greater chance of 8 or more deposits.

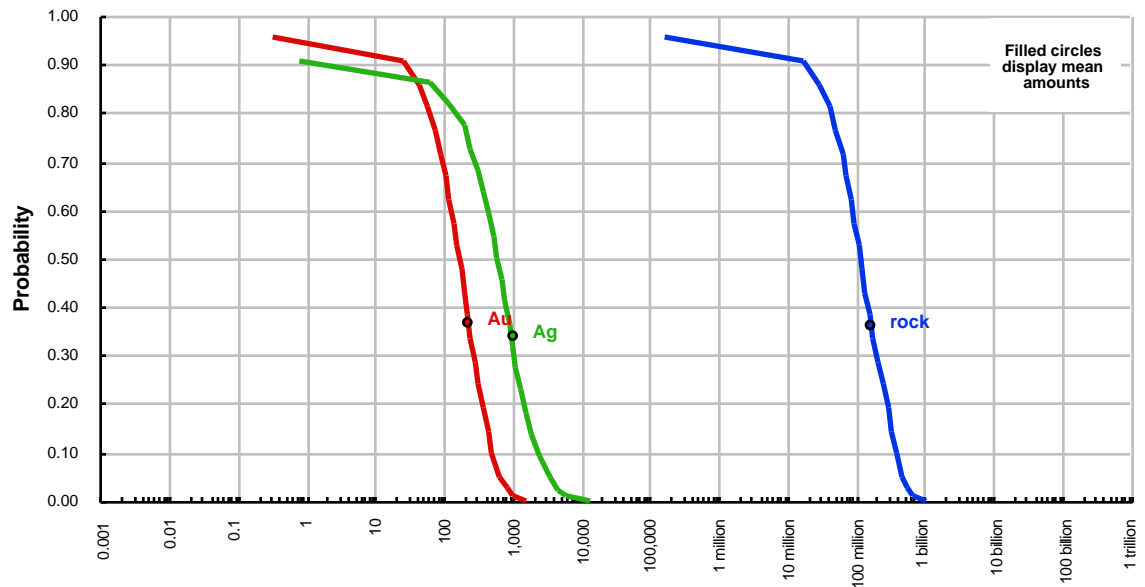
There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

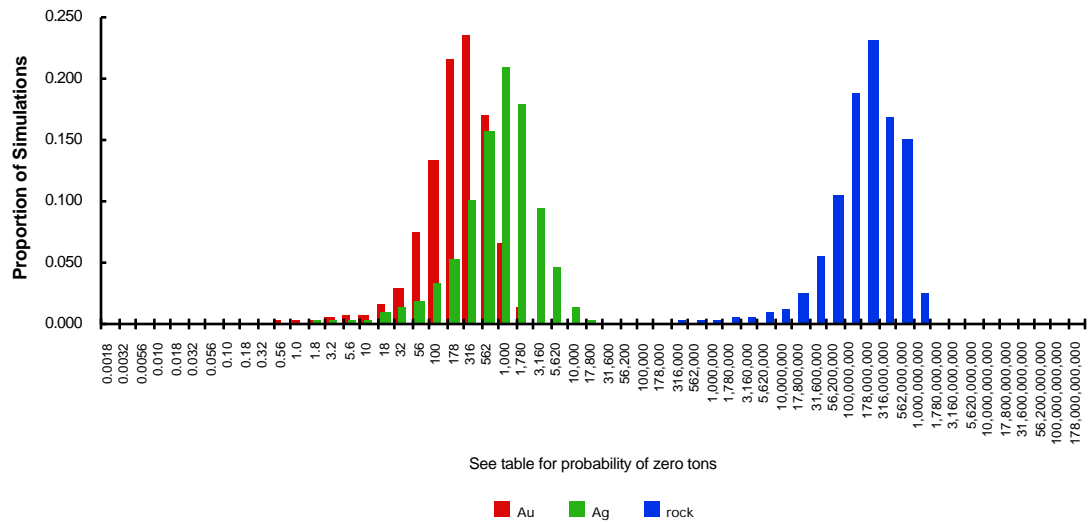
quantile	Au	Ag	rock
0.95	3	0	1,400,000
0.90	30	15	20,000,000
0.50	170	610	120,000,000
0.10	500	2,300	389,000,000
0.05	660	3,400	470,000,000
mean	230	970	170,000,000
Probability of mean	0.37	0.34	0.36
Probability of zero	0.04	0.09	0.04

The tract ID is SA16

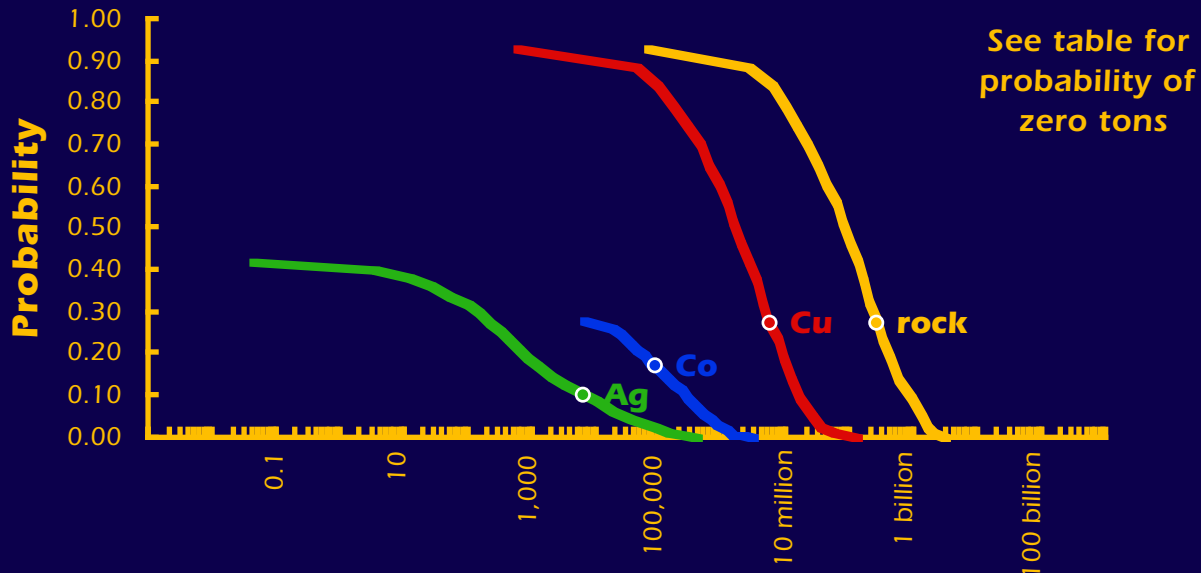
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

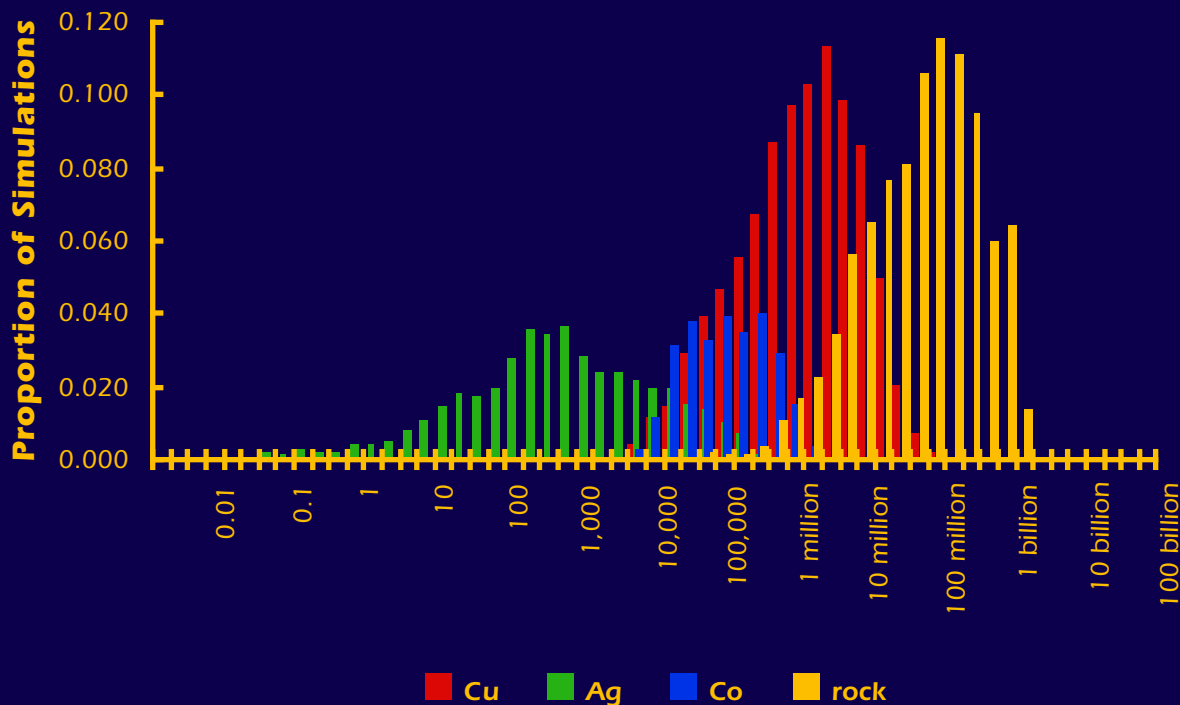


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SA18

The Mark3 Index is 63:
Sediment-hosted Cu

There is a 90% or greater chance of 1 or more deposits.
 There is a 50% or greater chance of 2 or more deposits.
 There is a 10% or greater chance of 3 or more deposits.
 There is a 5% or greater chance of 3 or more deposits.
 There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Ag	Co	rock
0.95	0	0	0	0
0.90	29,000	0	0	1,700,000
0.50	1,600,000	0	0	81,000,000
0.10	15,000,000	6,500	255,000	810,000,000
0.05	23,000,000	28,000	550,000	1,300,000,000
mean	5,500,000	6,100	84,000	260,000,000
Probability of mean	0.27	0.10	0.17	0.27
Probability of zero	0.07	0.58	0.72	0.07

The tract ID is SA18The Mark3 Index is 63: **Sediment-hosted Cu**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

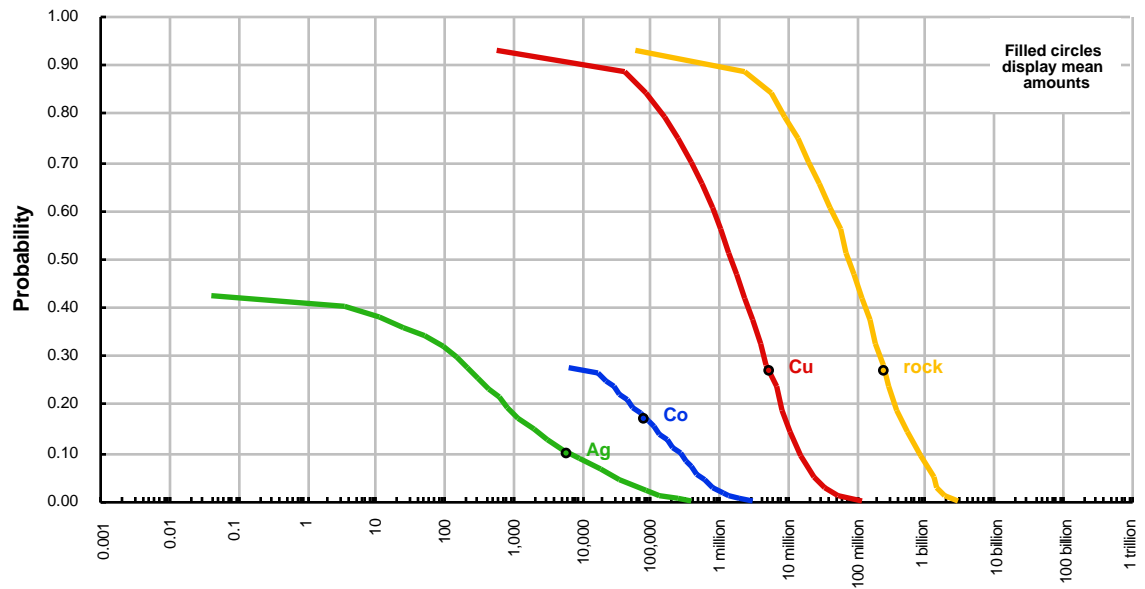
There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

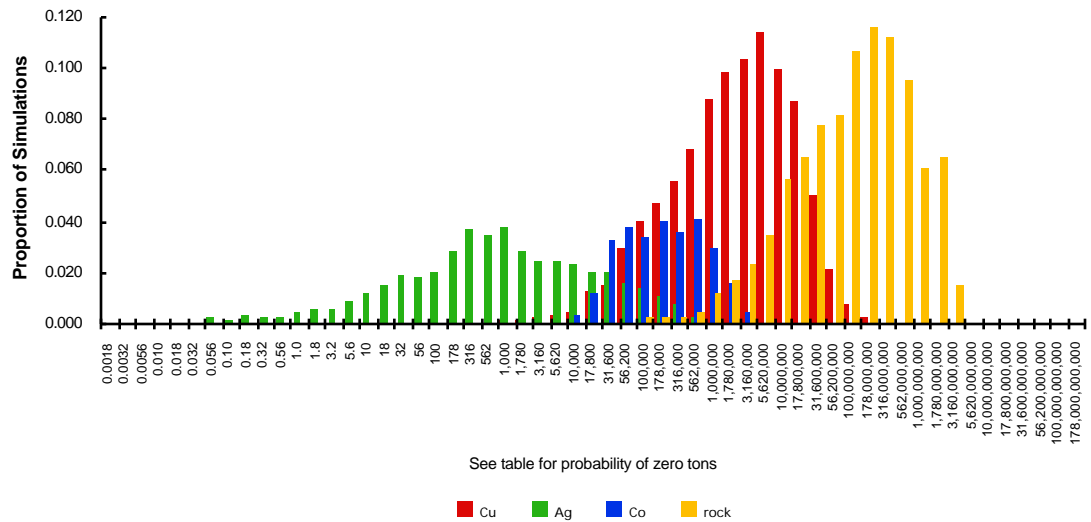
quantile	Cu	Ag	Co	rock
0.95	0	0	0	0
0.90	29,000	0	0	1,700,000
0.50	1,600,000	0	0	81,000,000
0.10	15,000,000	6,500	255,000	810,000,000
0.05	23,000,000	28,000	550,000	1,300,000,000
mean	5,500,000	6,100	84,000	260,000,000
Probability of mean	0.27	0.10	0.17	0.27
Probability of zero	0.07	0.58	0.72	0.07

The tract ID is SA18

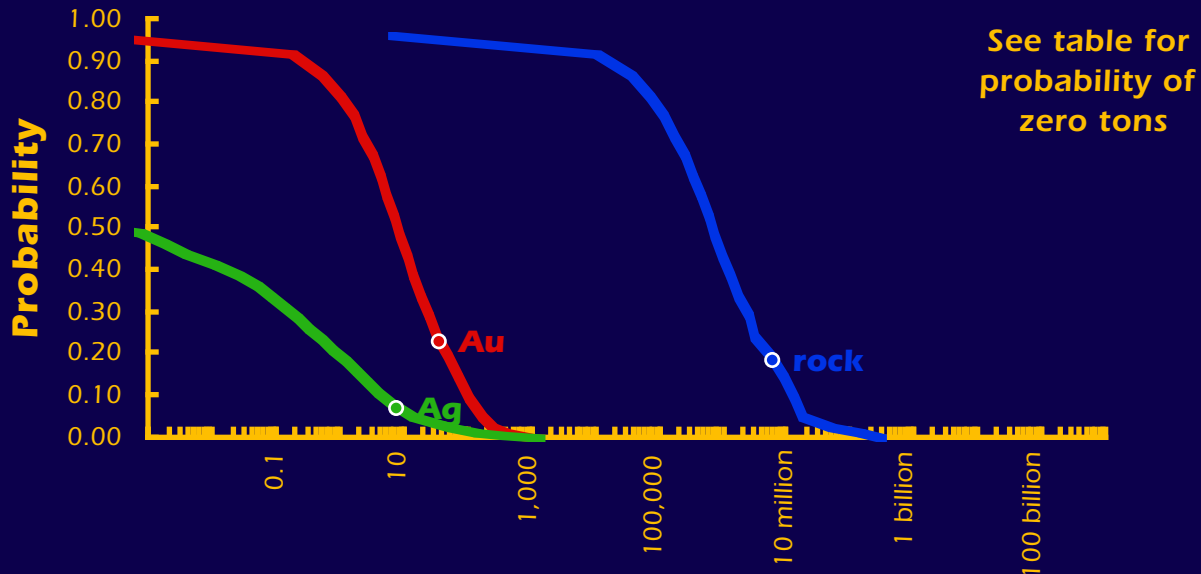
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

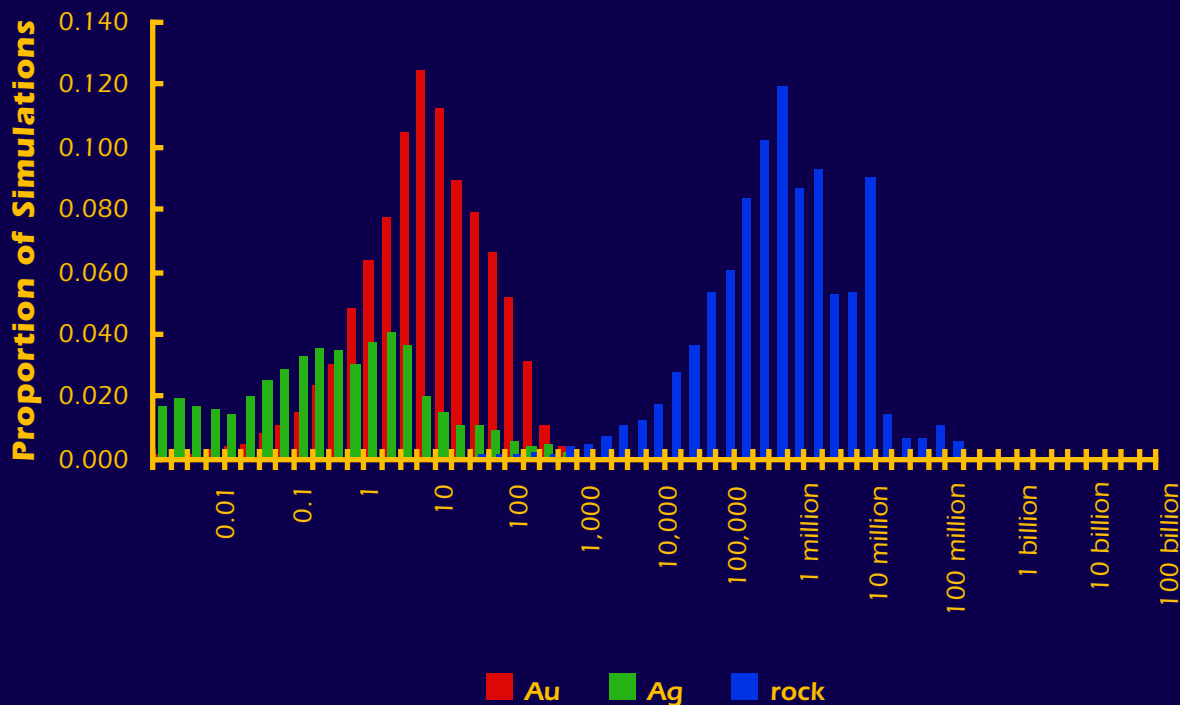


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SA21

The Mark3 Index is 27:

Low sulfide Au-quartz vein

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 5 or more deposits.

There is a 10% or greater chance of 8 or more deposits.

There is a 5% or greater chance of 8 or more deposits.

There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	1,200
0.90	0	0	17,000
0.50	8	0	670,000
0.10	97	4	12,200,000
0.05	170	15	16,000,000
mean	34	7	5,800,000
Probability of mean	0.23	0.07	0.18
Probability of zero	0.04	0.48	0.04

The tract ID is SA21

The Mark3 Index is 27: **Low sulfide Au-quartz vein**

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 5 or more deposits.

There is a 10% or greater chance of 8 or more deposits.

There is a 5% or greater chance of 8 or more deposits.

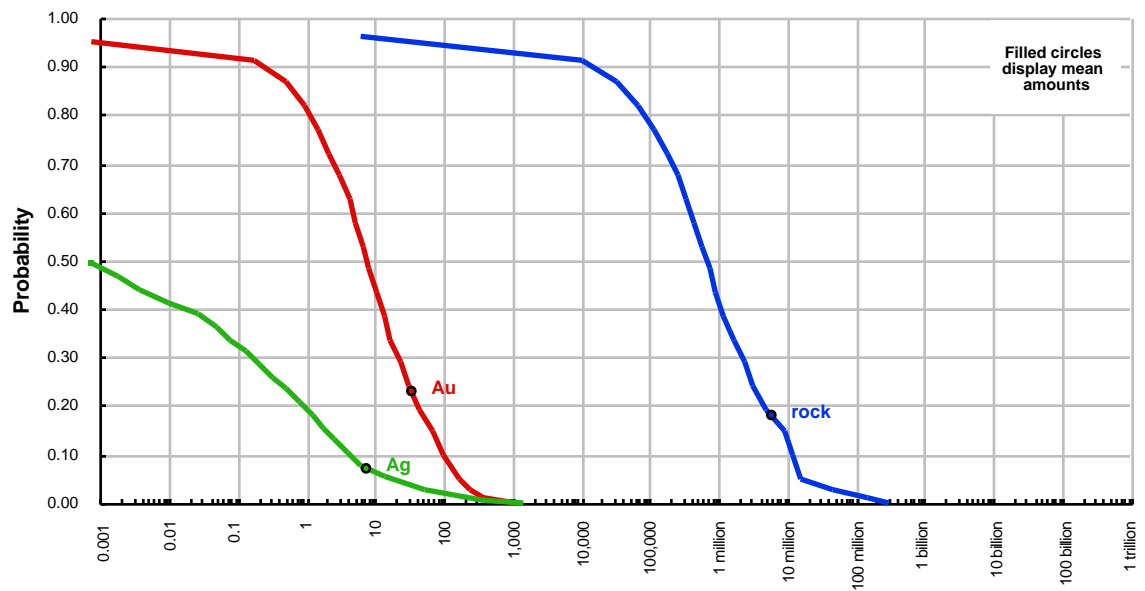
There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

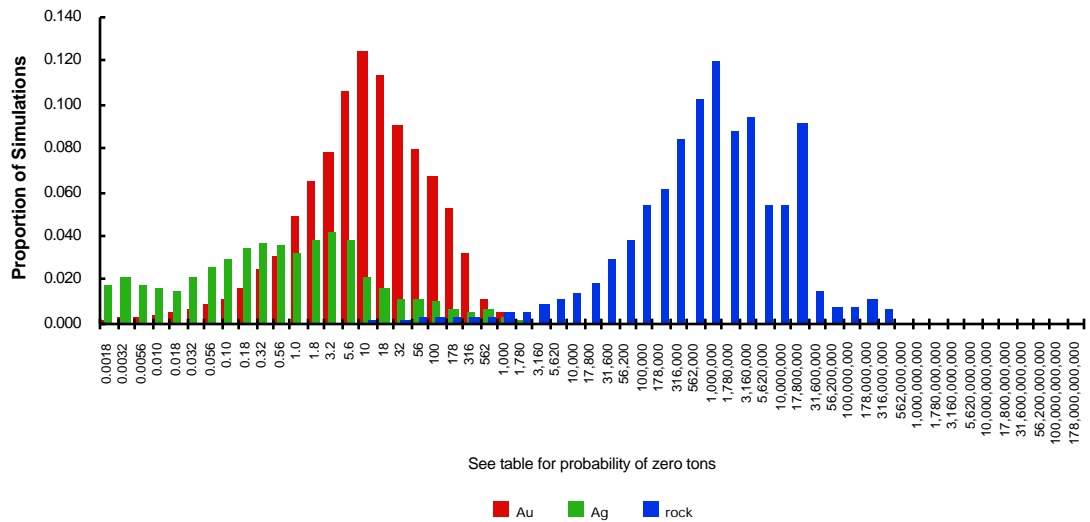
quantile	Au	Ag	rock
0.95	0	0	1,200
0.90	0	0	17,000
0.50	8	0	670,000
0.10	97	4	12,200,000
0.05	170	15	16,000,000
mean	34	7	5,800,000
Probability of mean	0.23	0.07	0.18
Probability of zero	0.04	0.48	0.04

The tract ID is SA21

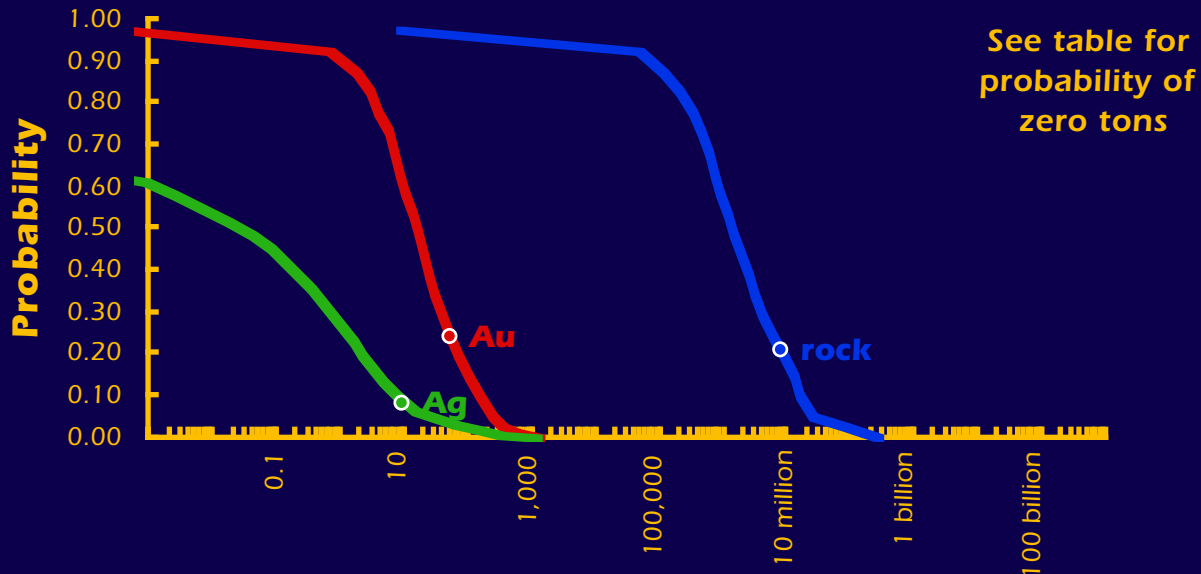
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

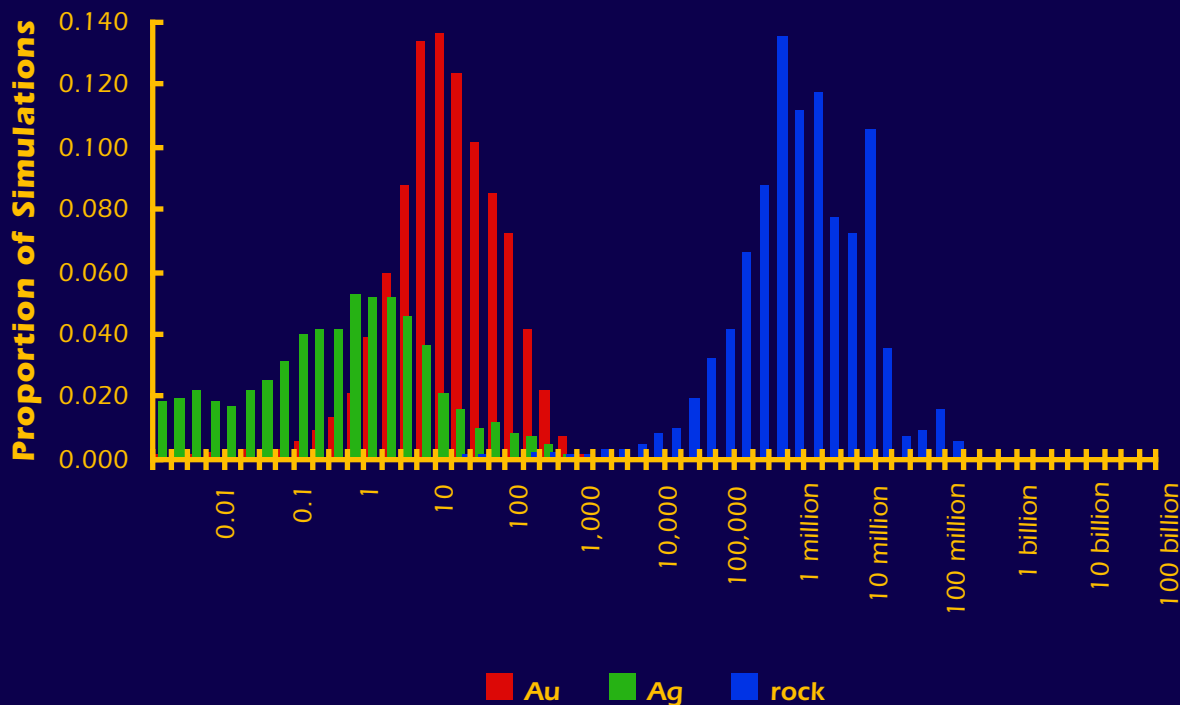


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SA22

The Mark3 Index is 27:

Low sulfide Au-quartz vein

There is a 90% or greater chance of 4 or more deposits.
There is a 50% or greater chance of 7 or more deposits.
There is a 10% or greater chance of 11 or more deposits.
There is a 5% or greater chance of 13 or more deposits.
There is a 1% or greater chance of 13 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	14,000
0.90	1	0	78,000
0.50	15	0	1,300,000
0.10	140	7	15,400,000
0.05	230	25	24,000,000
mean	52	9	7,900,000
Probability of mean	0.24	0.08	0.21
Probability of zero	0.03	0.35	0.03

The tract ID is SA22The Mark3 Index is 27: **Low sulfide Au-quartz vein**

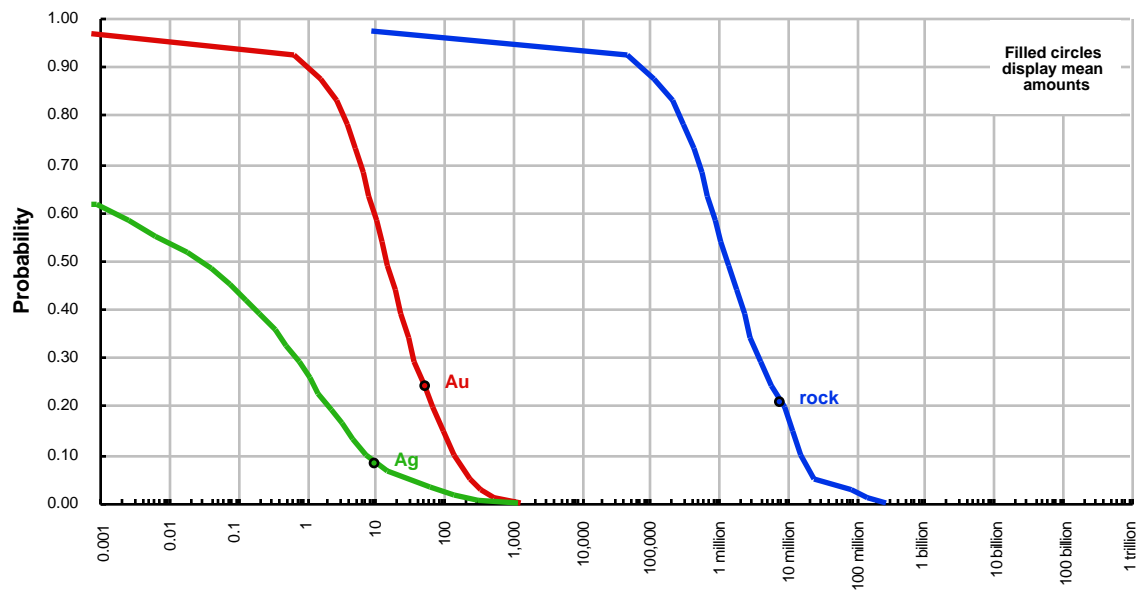
There is a 90% or greater chance of 4 or more deposits.
 There is a 50% or greater chance of 7 or more deposits.
 There is a 10% or greater chance of 11 or more deposits.
 There is a 5% or greater chance of 13 or more deposits.
 There is a 1% or greater chance of 13 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

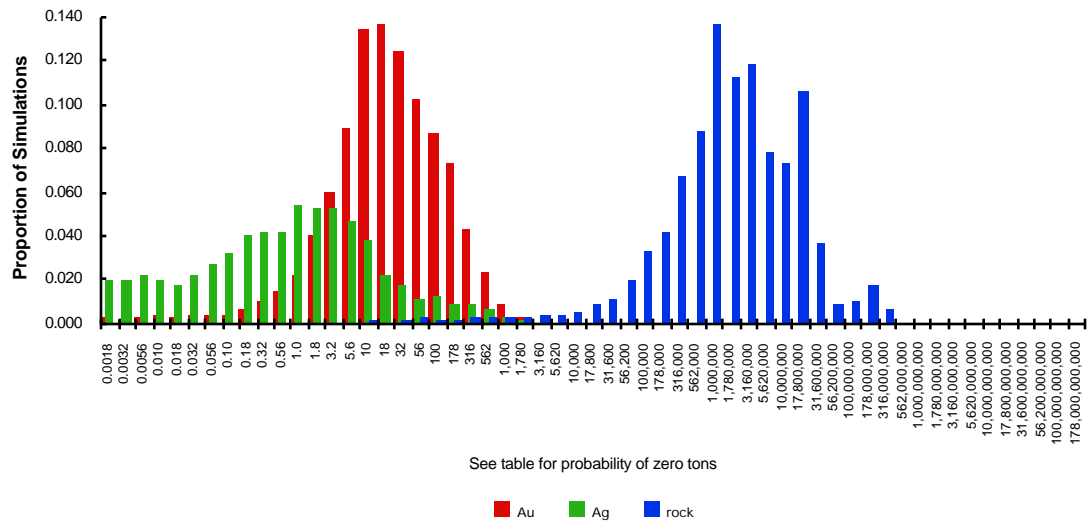
quantile	Au	Ag	rock
0.95	0	0	14,000
0.90	1	0	78,000
0.50	15	0	1,300,000
0.10	140	7	15,400,000
0.05	230	25	24,000,000
mean	52	9	7,900,000
Probability of mean	0.24	0.08	0.21
Probability of zero	0.03	0.35	0.03

The tract ID is SA22

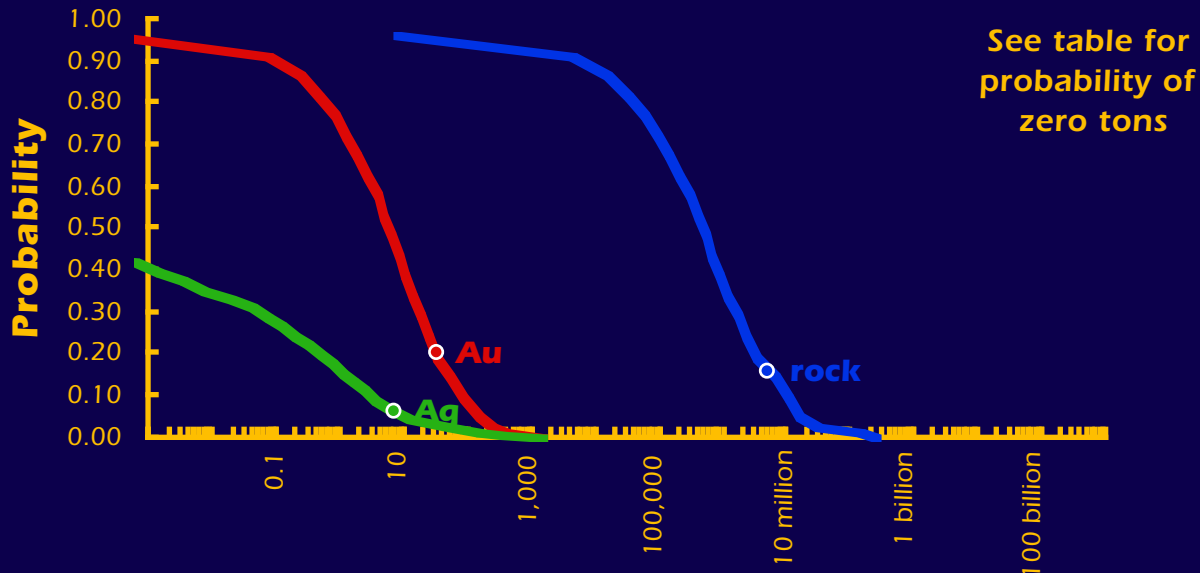
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

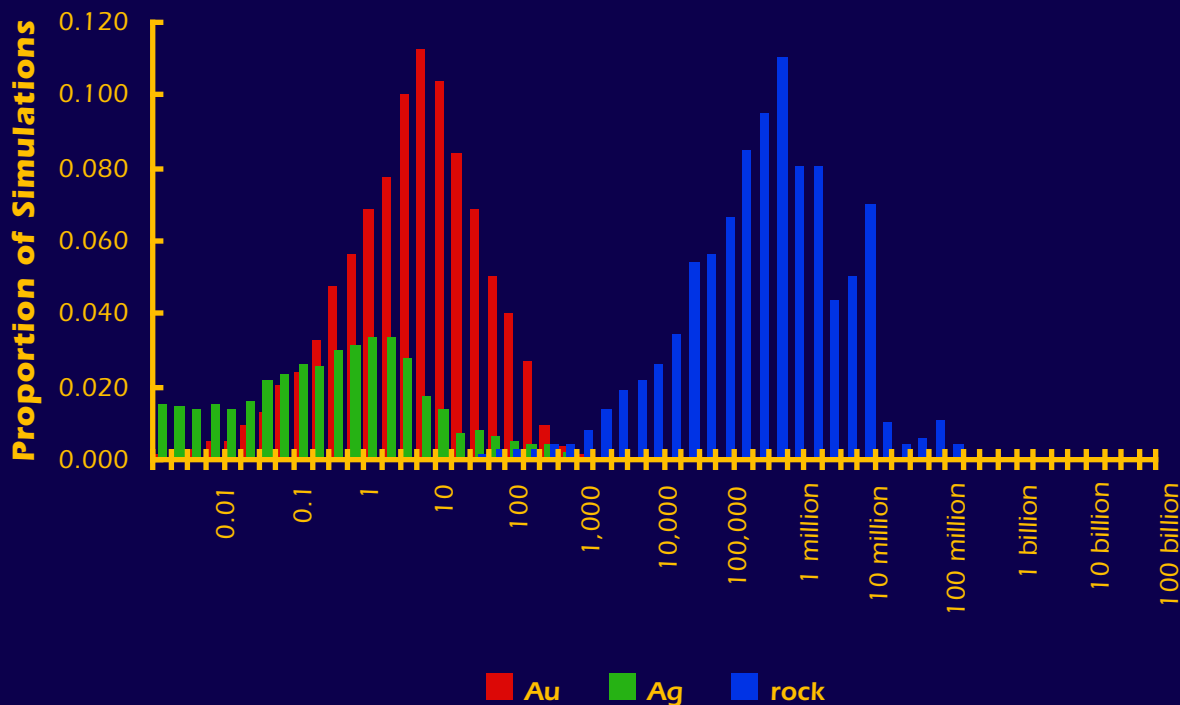


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SA23

The Mark3 Index is 27:

Low sulfide Au-quartz vein

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 8 or more deposits.

There is a 5% or greater chance of 8 or more deposits.

There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	530
0.90	0	0	6,900
0.50	6	0	470,000
0.10	77	3	10,700,000
0.05	150	10	15,000,000
mean	30	7	5,100,000
Probability of mean	0.20	0.06	0.16
Probability of zero	0.04	0.56	0.04

The tract ID is SA23The Mark3 Index is 27: **Low sulfide Au-quartz vein**

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 8 or more deposits.

There is a 5% or greater chance of 8 or more deposits.

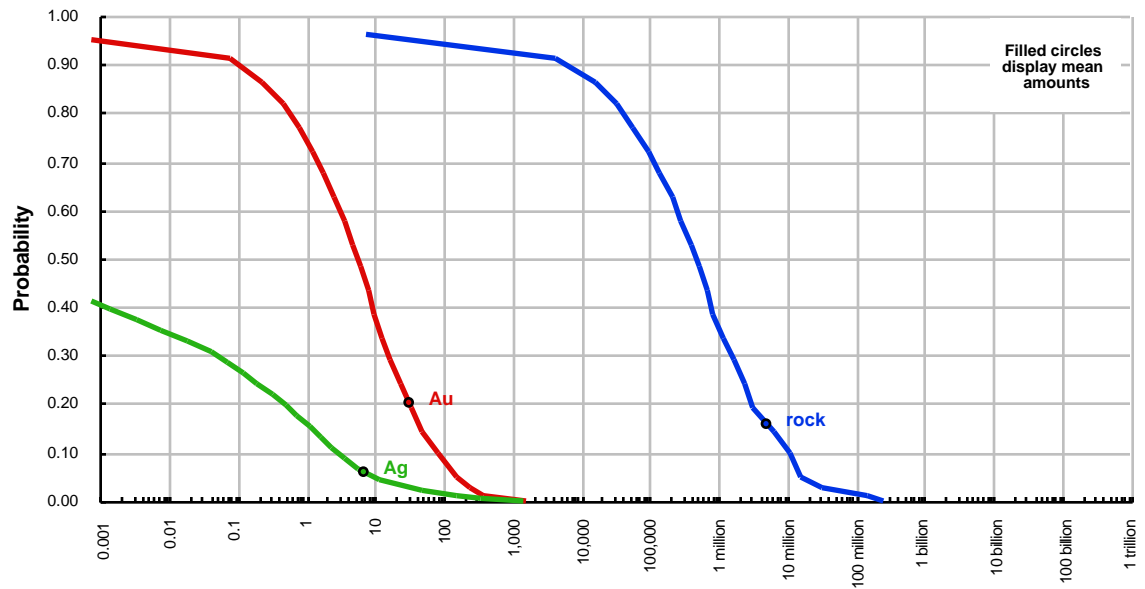
There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

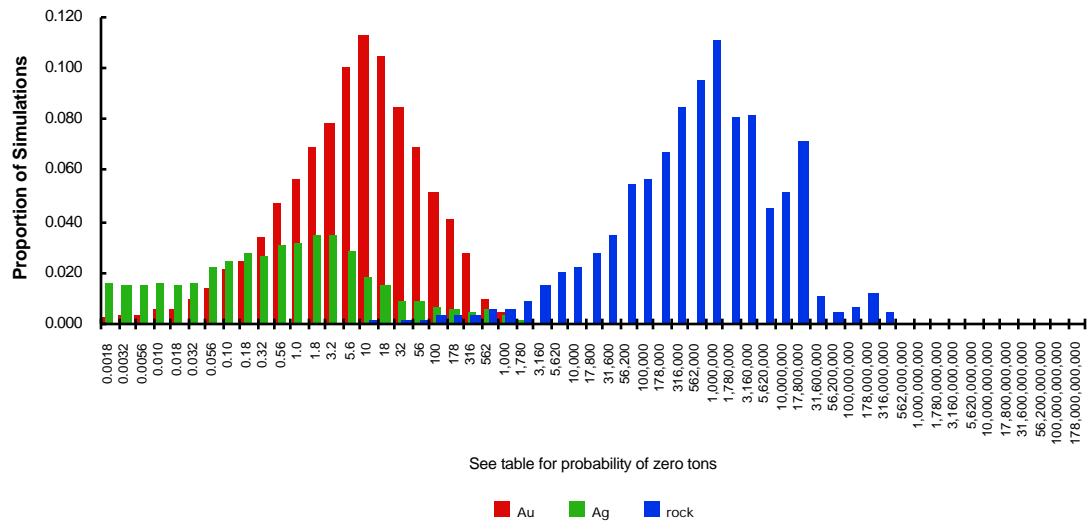
quantile	Au	Ag	rock
0.95	0	0	530
0.90	0	0	6,900
0.50	6	0	470,000
0.10	77	3	10,700,000
0.05	150	10	15,000,000
mean	30	7	5,100,000
Probability of mean	0.20	0.06	0.16
Probability of zero	0.04	0.56	0.04

The tract ID is SA23

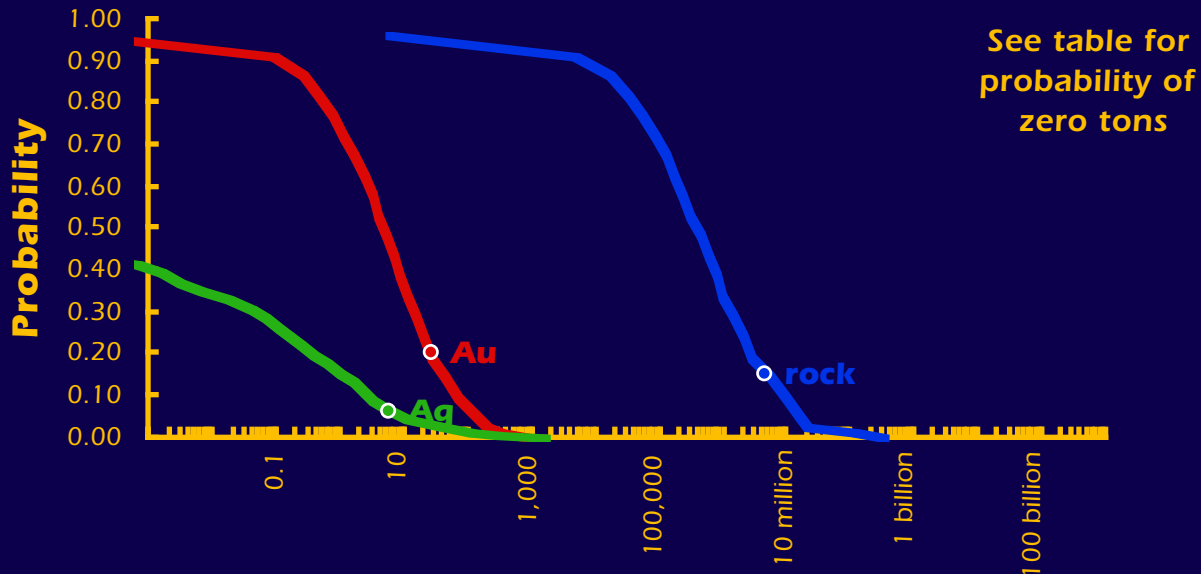
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

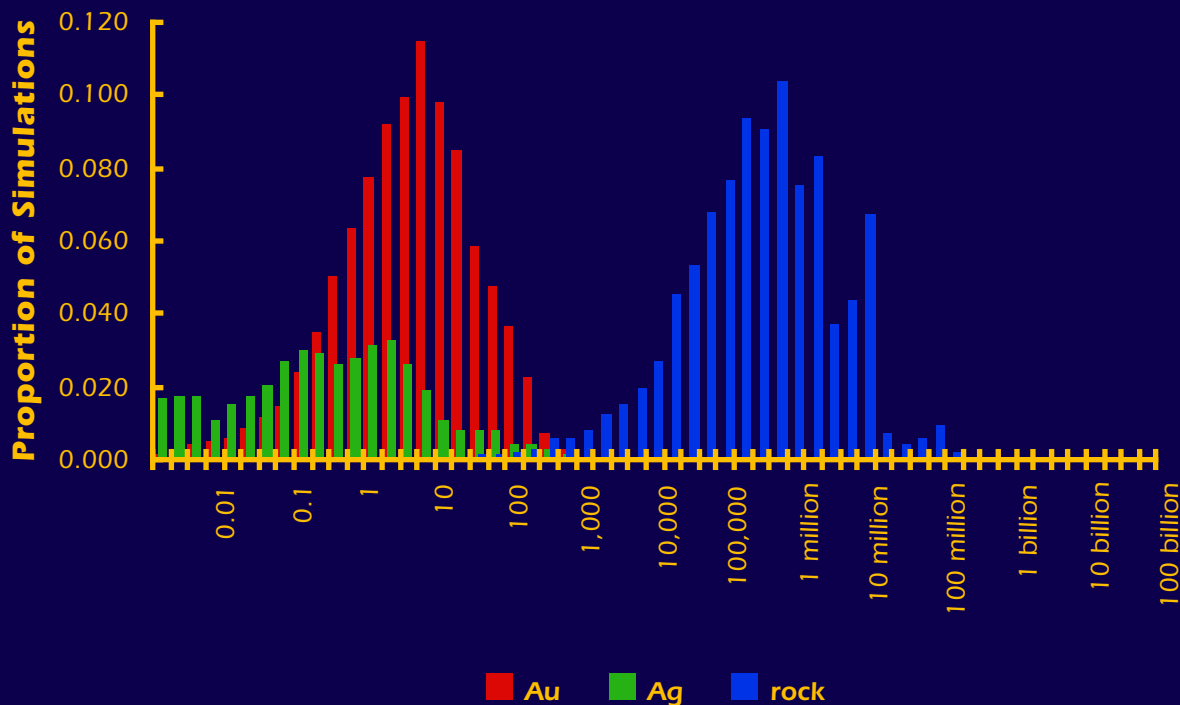


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SA24

The Mark3 Index is 27:

Low sulfide Au-quartz vein

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 7 or more deposits.

There is a 5% or greater chance of 7 or more deposits.

There is a 1% or greater chance of 7 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	510
0.90	0	0	7,000
0.50	5	0	380,000
0.10	66	3	9,440,000
0.05	130	8	15,000,000
mean	25	6	4,300,000
Probability of mean	0.20	0.06	0.15
Probability of zero	0.04	0.56	0.04

The tract ID is SA24The Mark3 Index is 27: **Low sulfide Au-quartz vein**

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 7 or more deposits.

There is a 5% or greater chance of 7 or more deposits.

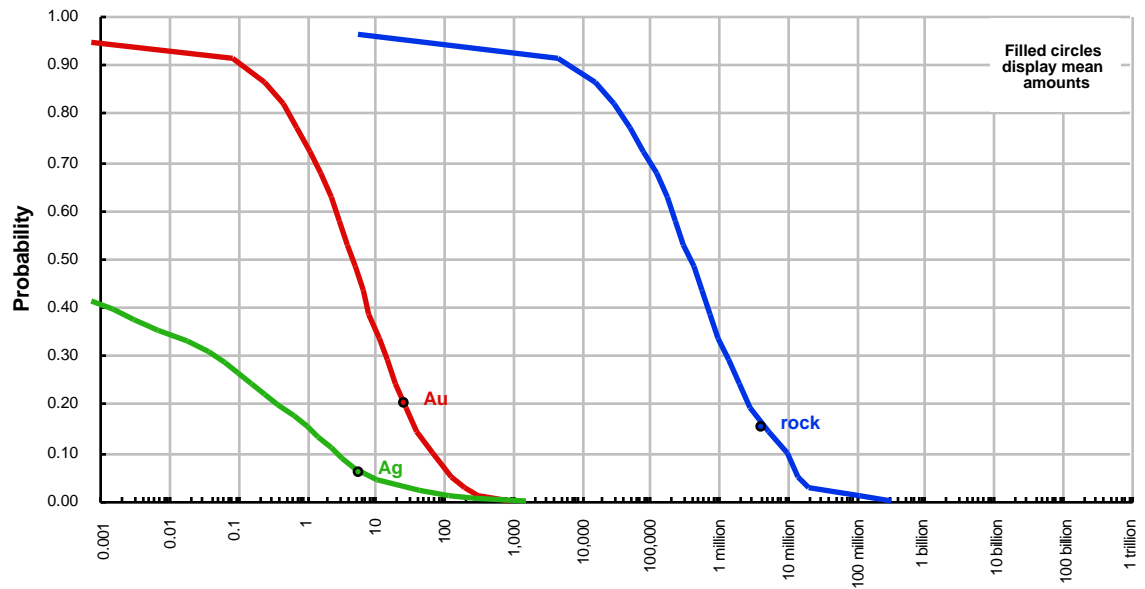
There is a 1% or greater chance of 7 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

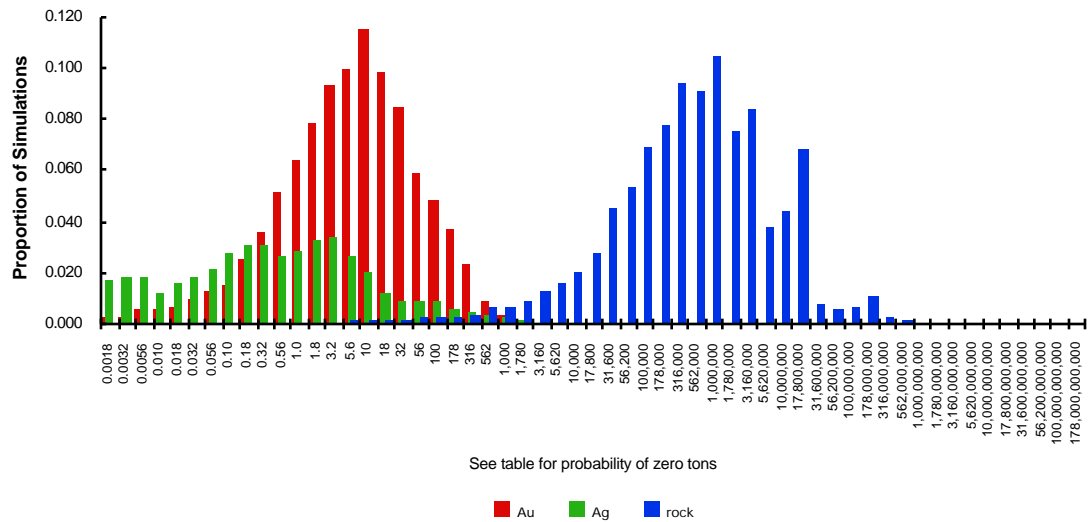
quantile	Au	Ag	rock
0.95	0	0	510
0.90	0	0	7,000
0.50	5	0	380,000
0.10	66	3	9,440,000
0.05	130	8	15,000,000
mean	25	6	4,300,000
Probability of mean	0.20	0.06	0.15
Probability of zero	0.04	0.56	0.04

The tract ID is SA24

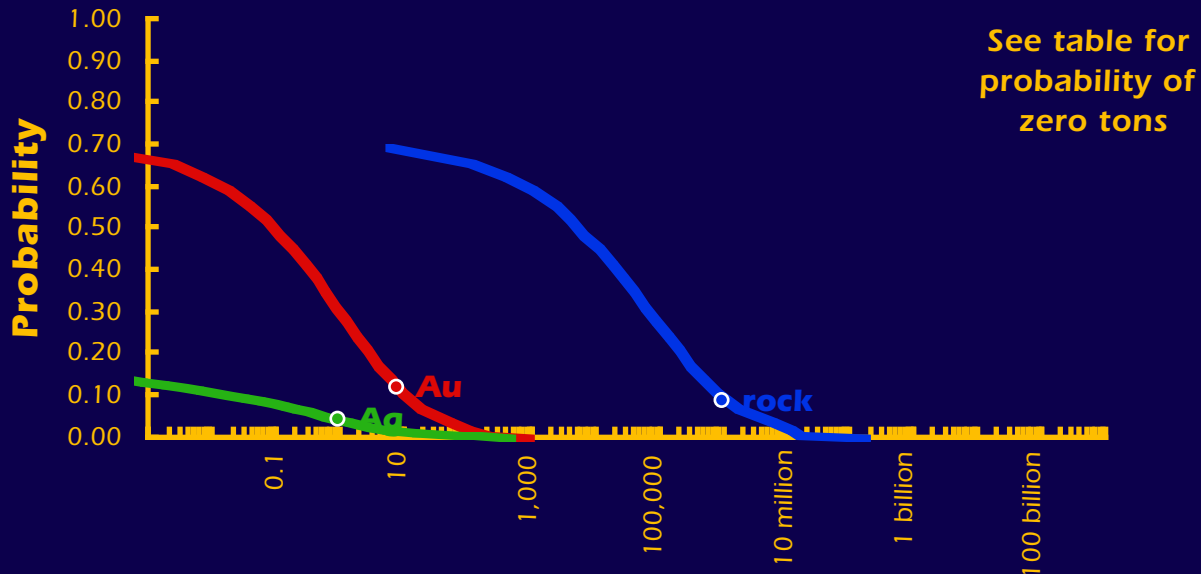
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

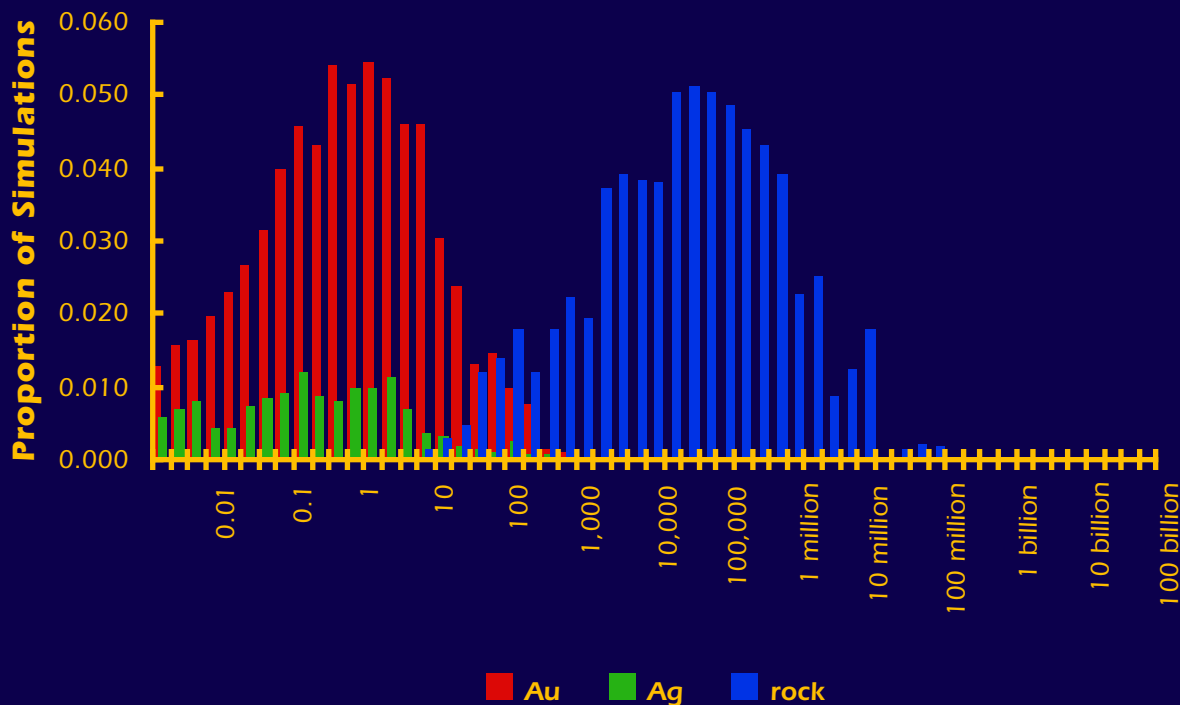


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SA25

The Mark3 Index is 27:

Low sulfide Au-quartz vein

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	5,300
0.10	10	0	824,000
0.05	30	1	2,600,000
mean	8	1	960,000
Probability of mean	0.12	0.04	0.09
Probability of zero	0.31	0.85	0.31

The tract ID is SA25The Mark3 Index is 27: **Low sulfide Au-quartz vein**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

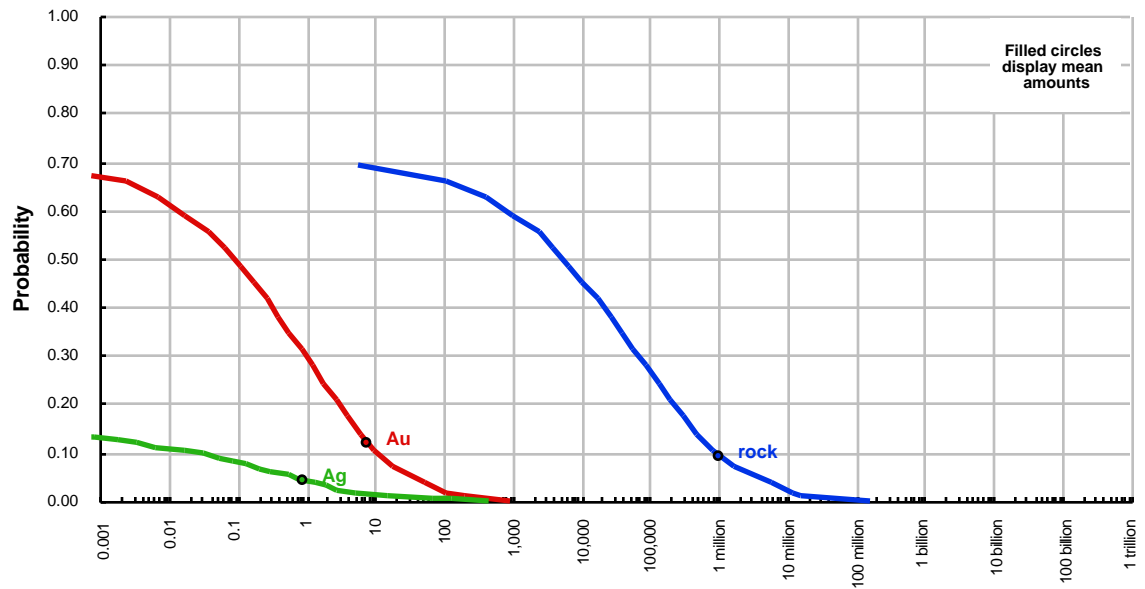
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

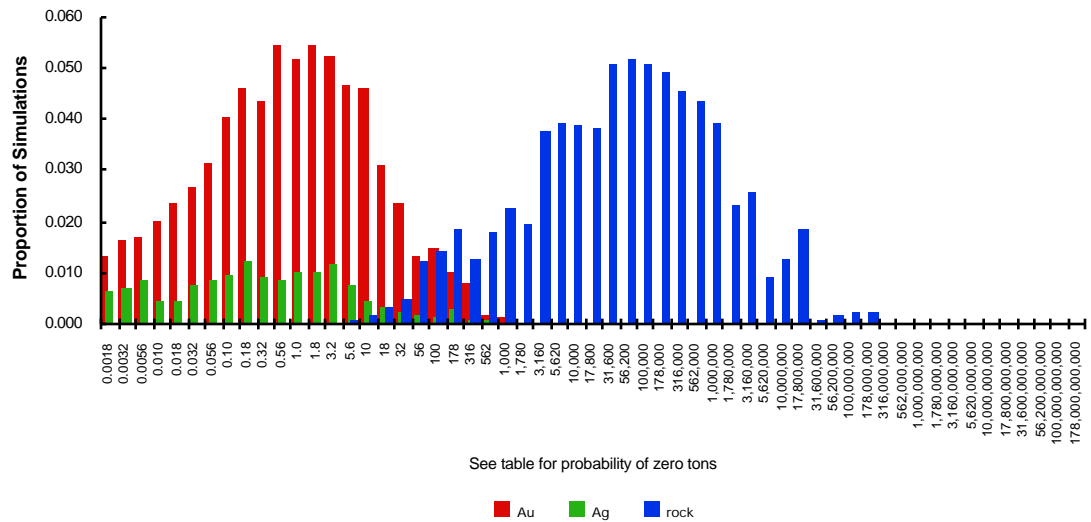
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	5,300
0.10	10	0	824,000
0.05	30	1	2,600,000
mean	8	1	960,000
Probability of mean	0.12	0.04	0.09
Probability of zero	0.31	0.85	0.31

The tract ID is SA25

Cumulative Distributions of Contained Metal and Mineralized Rock



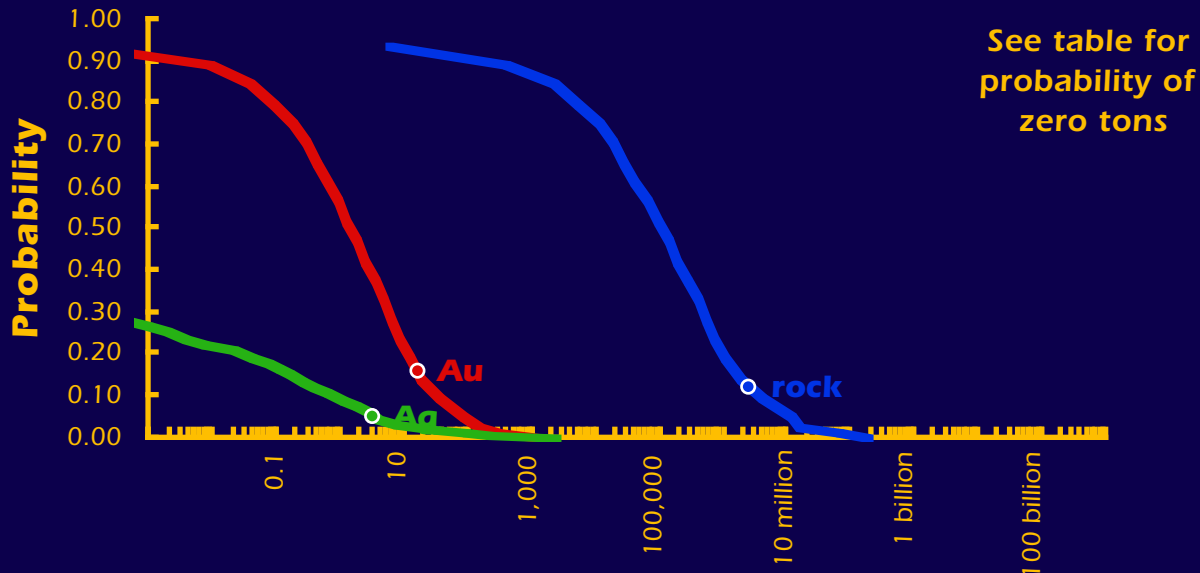
Histograms of Contained Metal and Mineralized Rock (metric tons)



See table for probability of zero tons

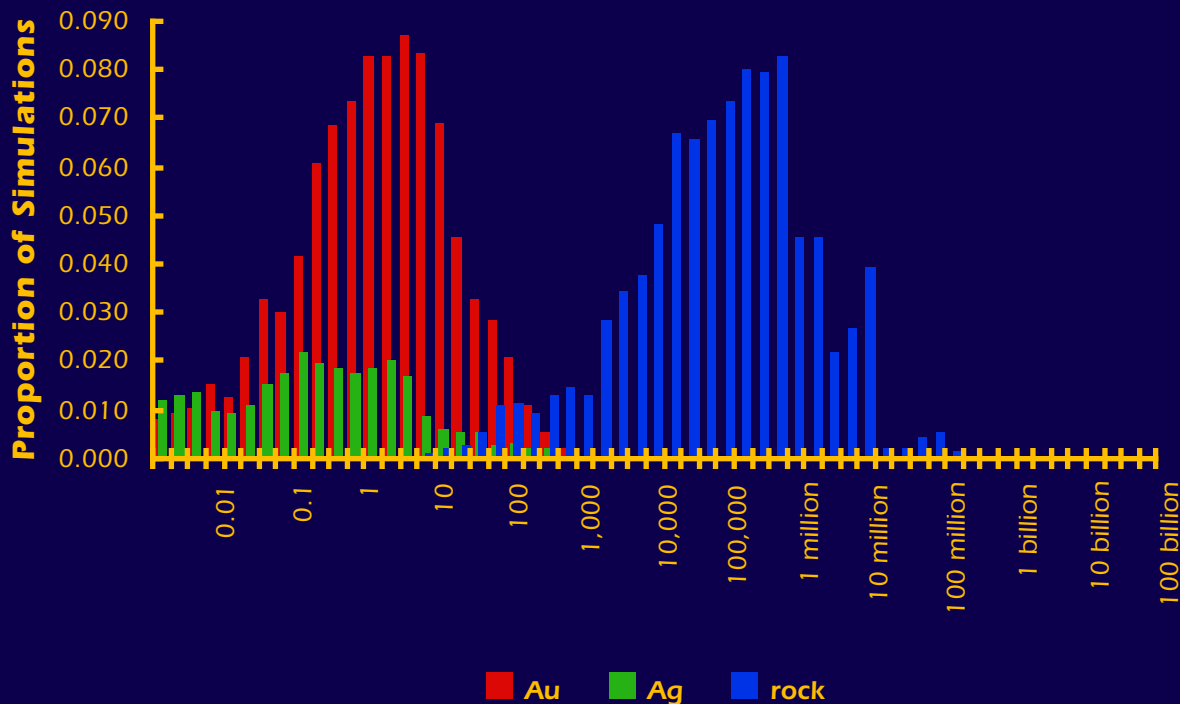
Au Ag rock

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SA26

The Mark3 Index is 27:

Low sulfide Au-quartz vein

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	280
0.50	1	0	110,000
0.10	31	1	3,240,000
0.05	79	3	11,000,000
mean	16	3	2,600,000
Probability of mean	0.16	0.05	0.12
Probability of zero	0.06	0.70	0.06

The tract ID is SA26The Mark3 Index is 27: **Low sulfide Au-quartz vein**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

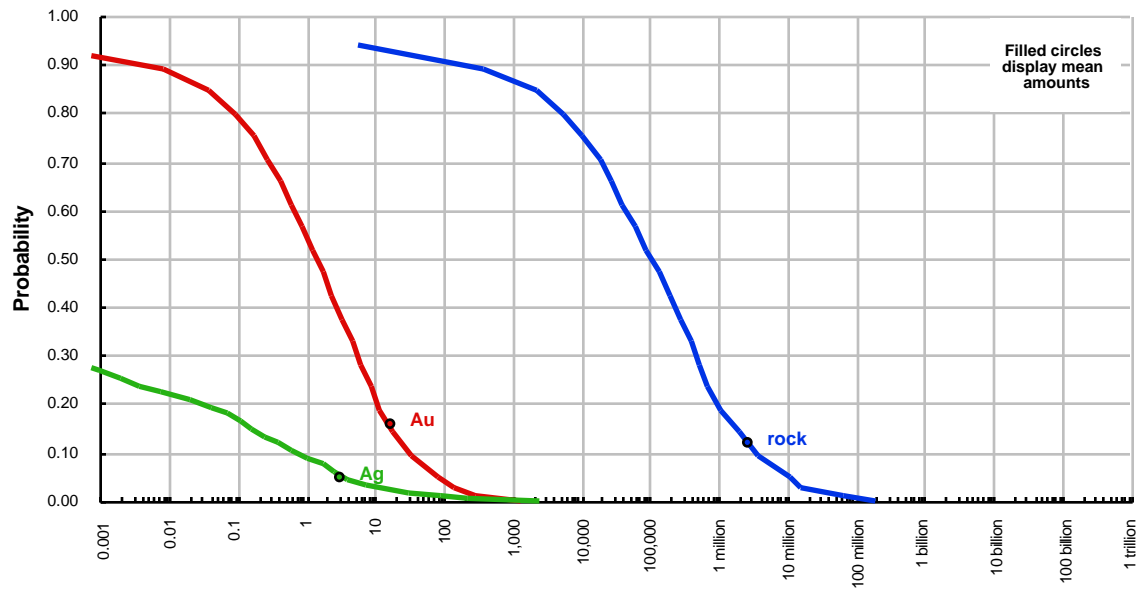
There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

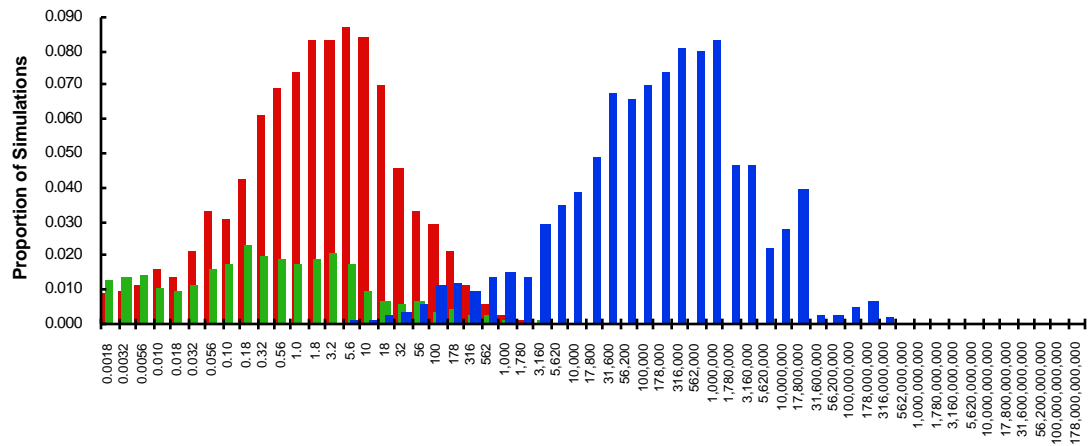
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	280
0.50	1	0	110,000
0.10	31	1	3,240,000
0.05	79	3	11,000,000
mean	16	3	2,600,000
Probability of mean	0.16	0.05	0.12
Probability of zero	0.06	0.70	0.06

The tract ID is SA26

Cumulative Distributions of Contained Metal and Mineralized Rock



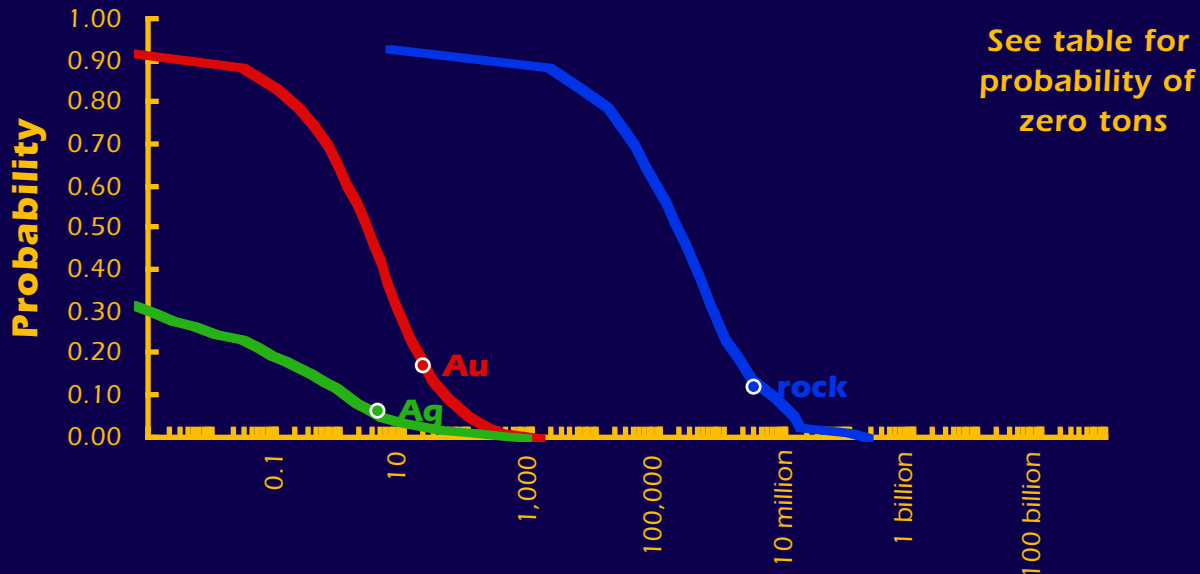
Histograms of Contained Metal and Mineralized Rock (metric tons)



See table for probability of zero tons

Au Ag rock

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Figure 1 is a histogram showing the distribution of the number of simulations per size class for three materials: Au (red), Ag (green), and rock (blue). The x-axis represents the size class on a logarithmic scale, ranging from 0.001 to 100 billion. The y-axis represents the proportion of simulations, ranging from 0.000 to 0.100. The distribution for Au is centered around size class 10, Ag is centered around size class 1, and rock is centered around size class 100,000.

Size Class	Au (Proportion)	Ag (Proportion)	rock (Proportion)
0.001	0.005	0.015	0.000
0.002	0.008	0.012	0.000
0.003	0.005	0.010	0.000
0.005	0.008	0.012	0.000
0.007	0.005	0.010	0.000
0.01	0.008	0.012	0.000
0.015	0.005	0.010	0.000
0.02	0.008	0.012	0.000
0.03	0.005	0.010	0.000
0.05	0.008	0.012	0.000
0.07	0.005	0.010	0.000
0.1	0.008	0.012	0.000
0.15	0.005	0.010	0.000
0.2	0.008	0.012	0.000
0.3	0.005	0.010	0.000
0.5	0.008	0.012	0.000
0.7	0.005	0.010	0.000
1	0.008	0.012	0.000
1.5	0.005	0.010	0.000
2	0.008	0.012	0.000
3	0.005	0.010	0.000
5	0.008	0.012	0.000
7	0.005	0.010	0.000
10	0.008	0.012	0.000
15	0.005	0.010	0.000
20	0.008	0.012	0.000
30	0.005	0.010	0.000
50	0.008	0.012	0.000
70	0.005	0.010	0.000
100	0.008	0.012	0.000
150	0.005	0.010	0.000
200	0.008	0.012	0.000
300	0.005	0.010	0.000
500	0.008	0.012	0.000
700	0.005	0.010	0.000
1000	0.008	0.012	0.000
1500	0.005	0.010	0.000
2000	0.008	0.012	0.000
3000	0.005	0.010	0.000
5000	0.008	0.012	0.000
7000	0.005	0.010	0.000
10000	0.008	0.012	0.000
15000	0.005	0.010	0.000
20000	0.008	0.012	0.000
30000	0.005	0.010	0.000
50000	0.008	0.012	0.000
70000	0.005	0.010	0.000
100000	0.008	0.012	0.000
150000	0.005	0.010	0.000
200000	0.008	0.012	0.000
300000	0.005	0.010	0.000
500000	0.008	0.012	0.000
700000	0.005	0.010	0.000
1000000	0.008	0.012	0.000
1500000	0.005	0.010	0.000
2000000	0.008	0.012	0.000
3000000	0.005	0.010	0.000
5000000	0.008	0.012	0.000
7000000	0.005	0.010	0.000
10000000	0.008	0.012	0.000
15000000	0.005	0.010	0.000
20000000	0.008	0.012	0.000
30000000	0.005	0.010	0.000
50000000	0.008	0.012	0.000
70000000	0.005	0.010	0.000
100000000	0.008	0.012	0.000
150000000	0.005	0.010	0.000
200000000	0.008	0.012	0.000
300000000	0.005	0.010	0.000
500000000	0.008	0.012	0.000
700000000	0.005	0.010	0.000
1000000000	0.008	0.012	0.000
1500000000	0.005	0.010	0.000
2000000000	0.008	0.012	0.000
3000000000	0.005	0.010	0.000
5000000000	0.008	0.012	0.000
7000000000	0.005	0.010	0.000
10000000000	0.008	0.012	0.000

The tract ID is SA27

The Mark3 Index is 27:

Low sulfide Au-quartz vein

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	680
0.50	2	0	190,000
0.10	42	1	5,180,000
0.05	98	4	12,000,000
mean	20	4	3,100,000
Probability of mean	0.17	0.06	0.12
Probability of zero	0.07	0.67	0.07

The tract ID is SA27The Mark3 Index is 27: **Low sulfide Au-quartz vein**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

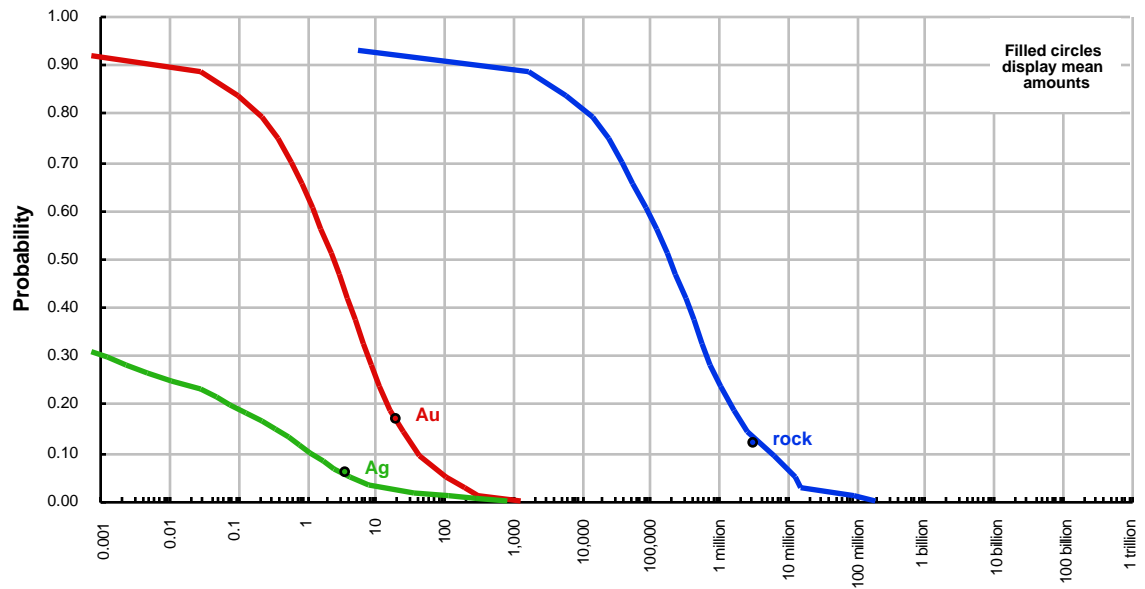
There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

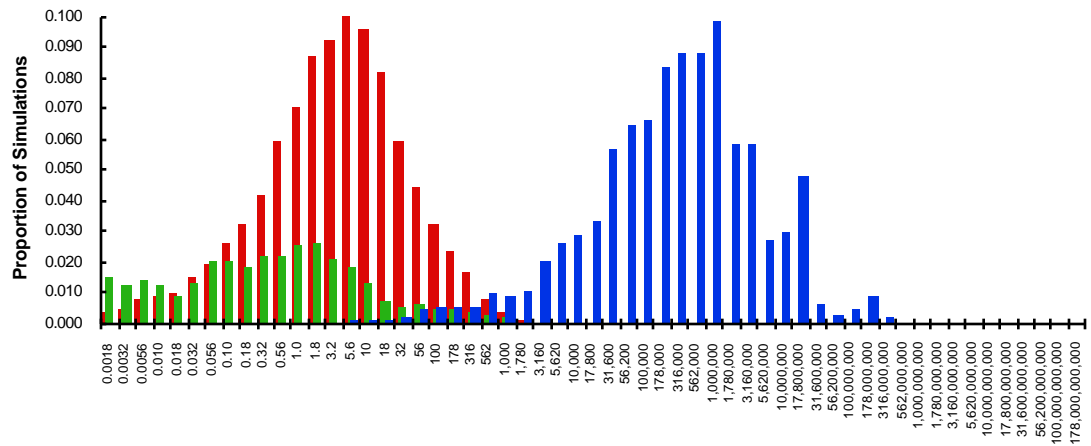
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	680
0.50	2	0	190,000
0.10	42	1	5,180,000
0.05	98	4	12,000,000
mean	20	4	3,100,000
Probability of mean	0.17	0.06	0.12
Probability of zero	0.07	0.67	0.07

The tract ID is SA27

Cumulative Distributions of Contained Metal and Mineralized Rock



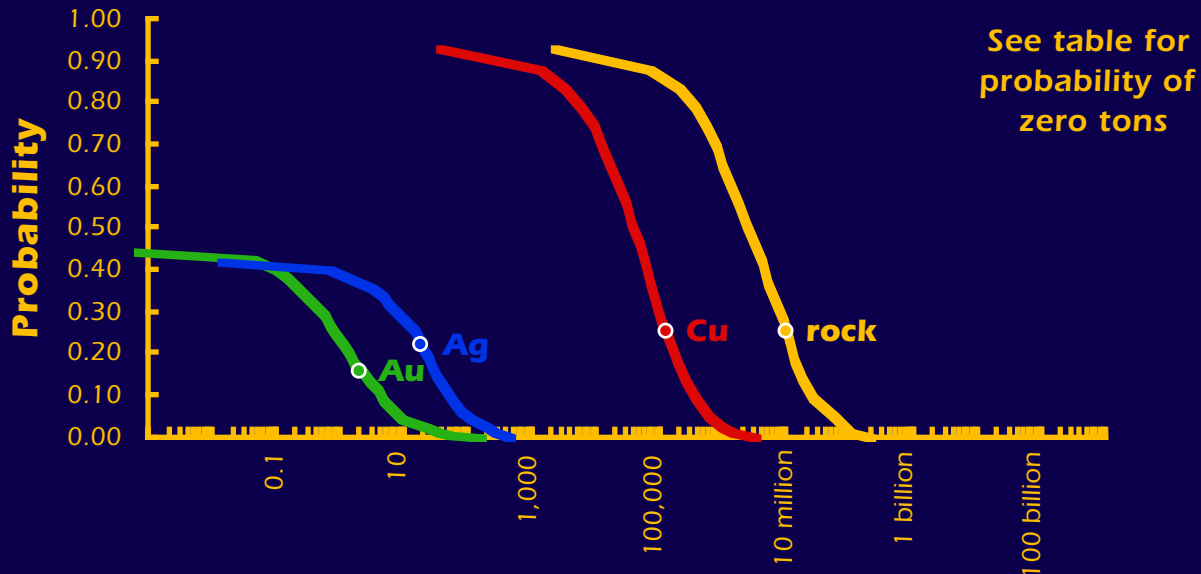
Histograms of Contained Metal and Mineralized Rock (metric tons)



See table for probability of zero tons

Au Ag rock

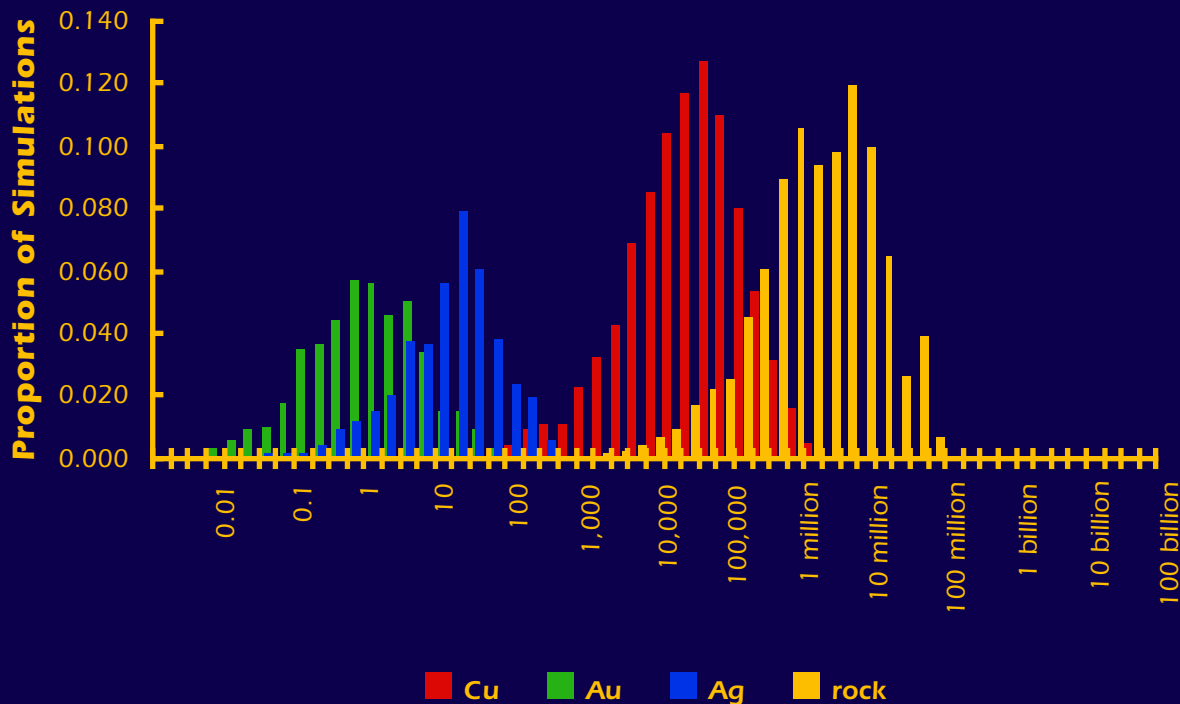
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



See table for
probability of
zero tons

Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB01

The Mark3 Index is 8:

Skarn Cu

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	650	0	0	37,000
0.50	38,000	0	0	2,300,000
0.10	330,000	4	48	24,000,000
0.05	570,000	8	96	50,000,000
mean	130,000	2	18	9,500,000
Probability of mean	0.25	0.16	0.22	0.25
Probability of zero	0.07	0.55	0.58	0.07

The tract ID is SB01The Mark3 Index is 8: **Skarn Cu**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

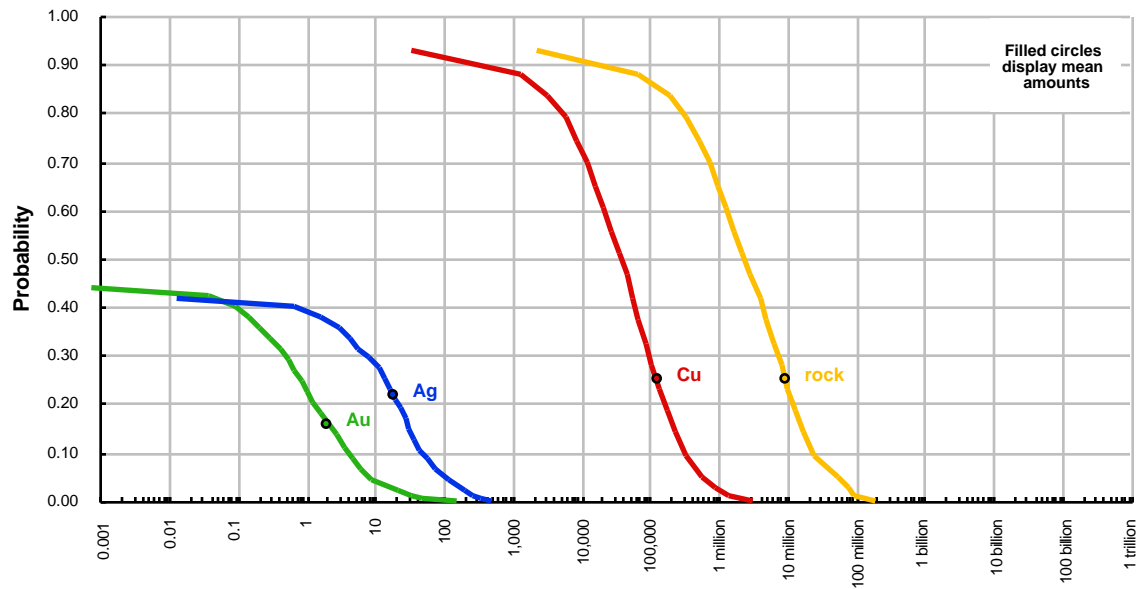
There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

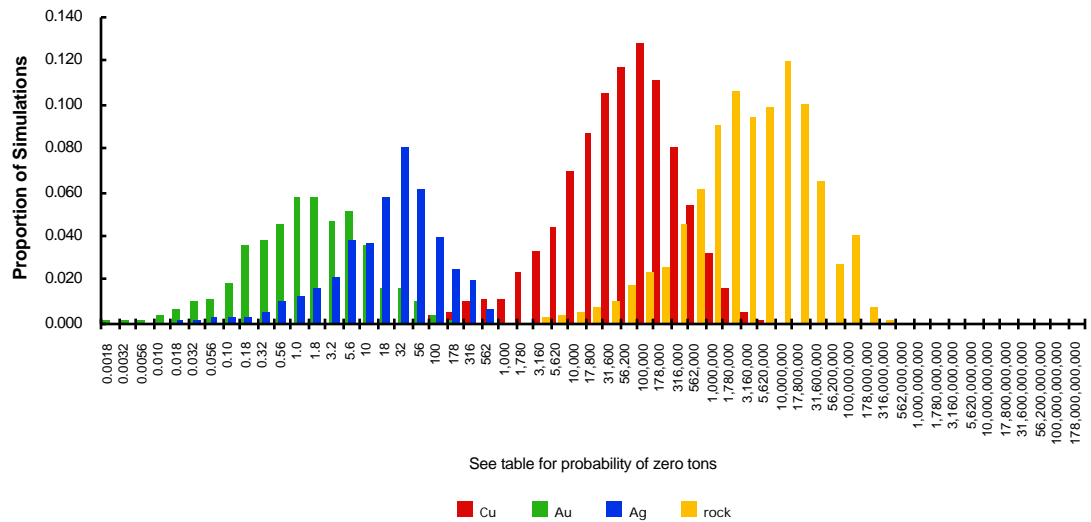
quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	650	0	0	37,000
0.50	38,000	0	0	2,300,000
0.10	330,000	4	48	24,000,000
0.05	570,000	8	96	50,000,000
mean	130,000	2	18	9,500,000
Probability of mean	0.25	0.16	0.22	0.25
Probability of zero	0.07	0.55	0.58	0.07

The tract ID is SB01

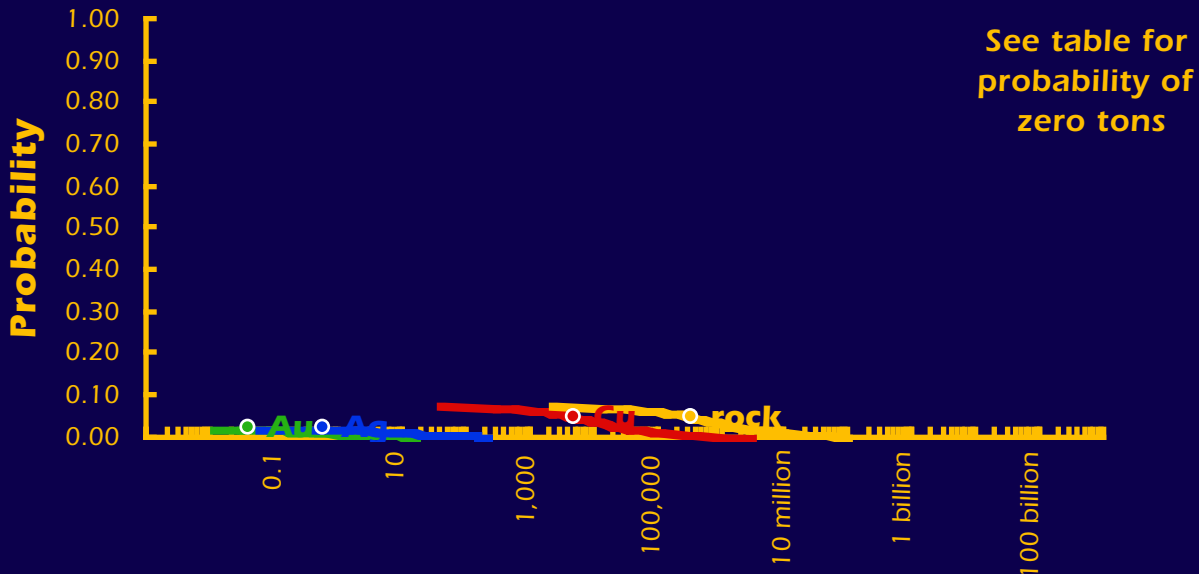
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

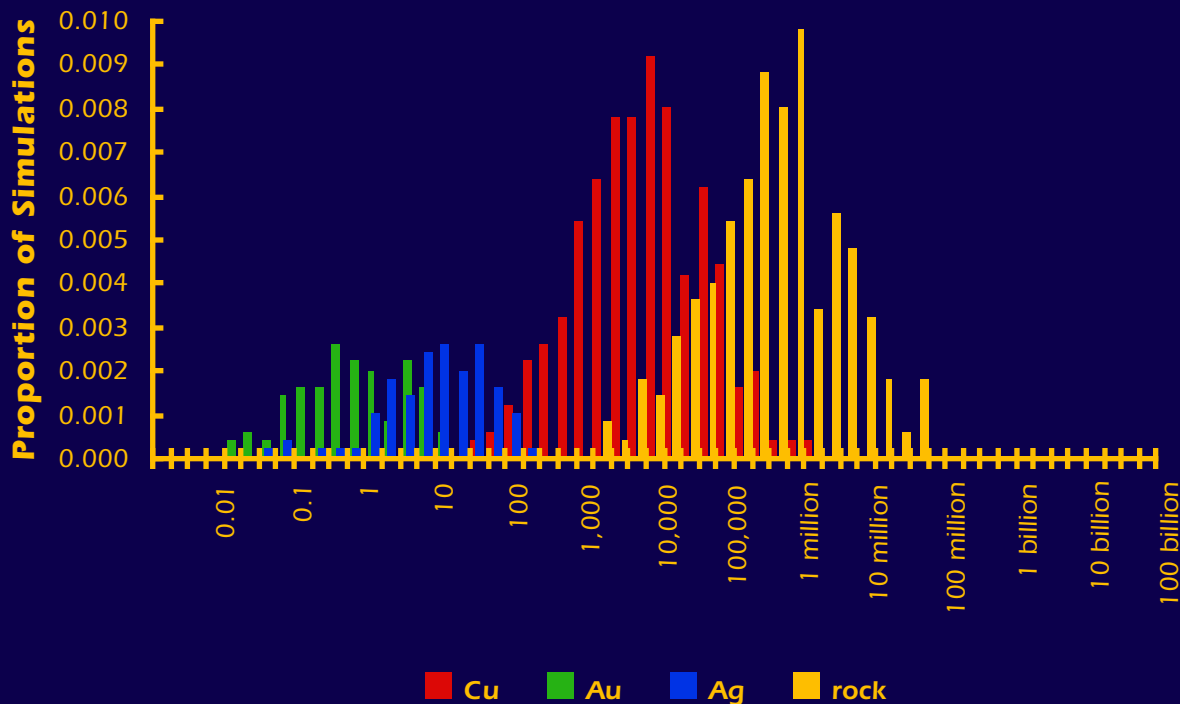


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB02

The Mark3 Index is 8:

Skarn Cu

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	3,700	0	0	270,000
mean	4,700	0	1	330,000
Probability of mean	0.05	0.02	0.02	0.05
Probability of zero	0.93	0.98	0.98	0.93

The tract ID is SB02The Mark3 Index is 8: **Skarn Cu**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

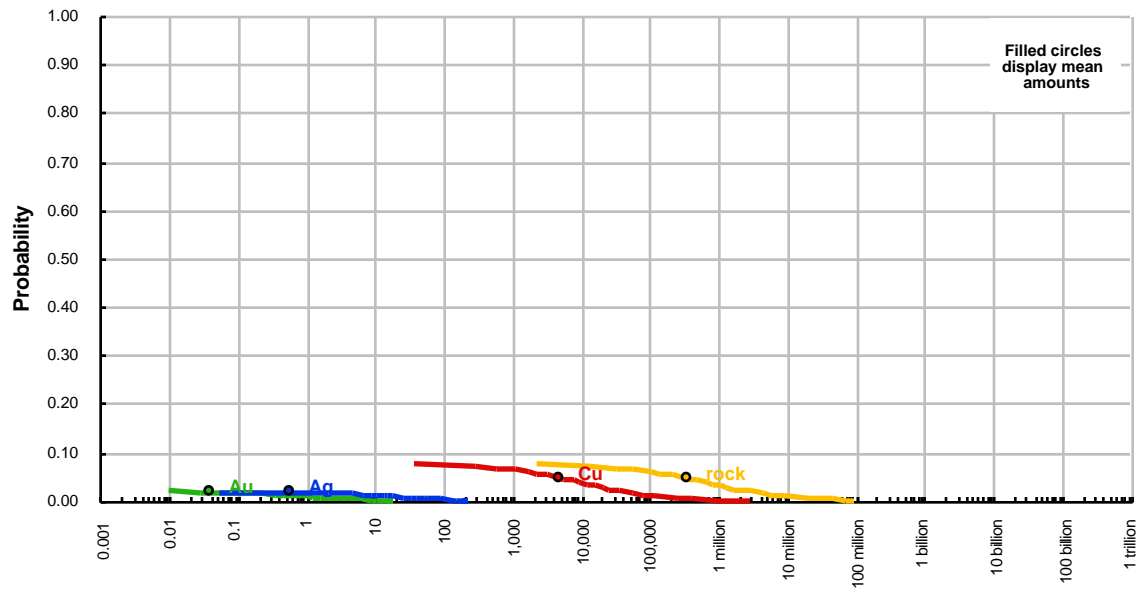
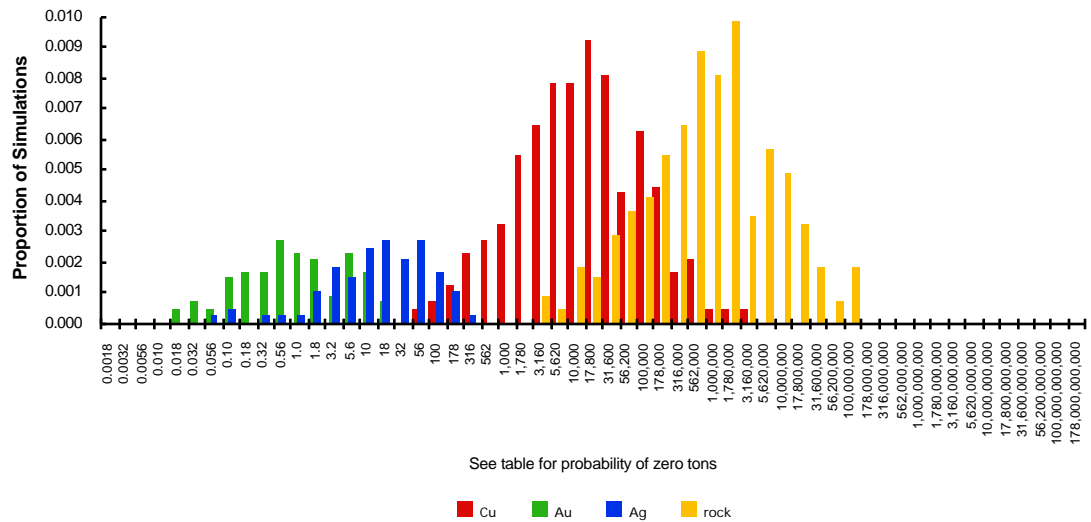
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

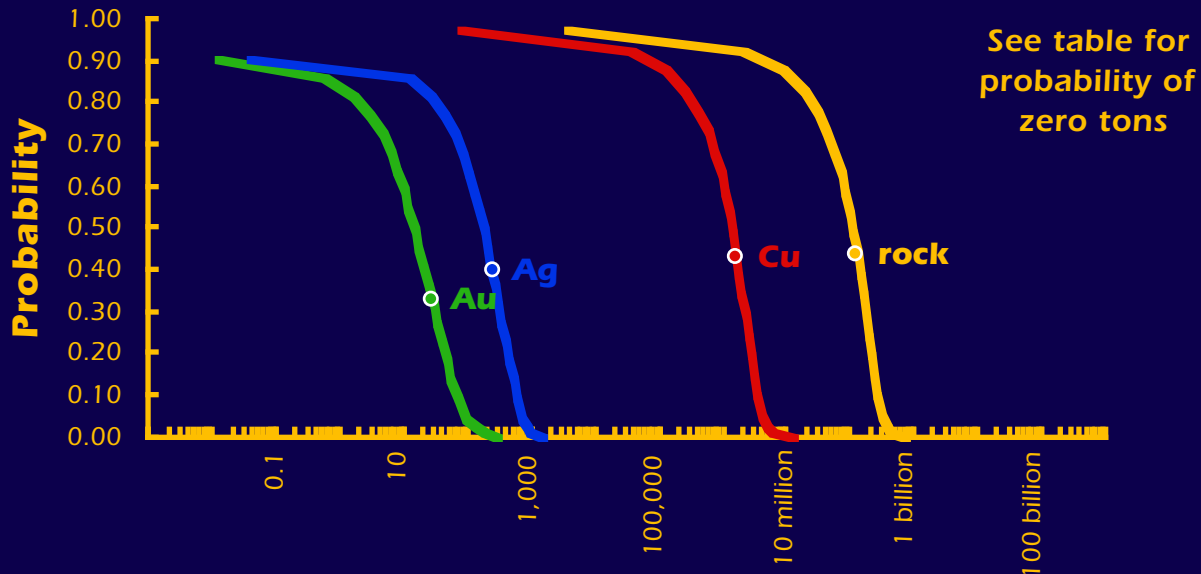
quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	3,700	0	0	270,000
mean	4,700	0	1	330,000
Probability of mean	0.05	0.02	0.02	0.05
Probability of zero	0.93	0.98	0.98	0.93

The tract ID is SB02

Cumulative Distributions of Contained Metal and Mineralized Rock

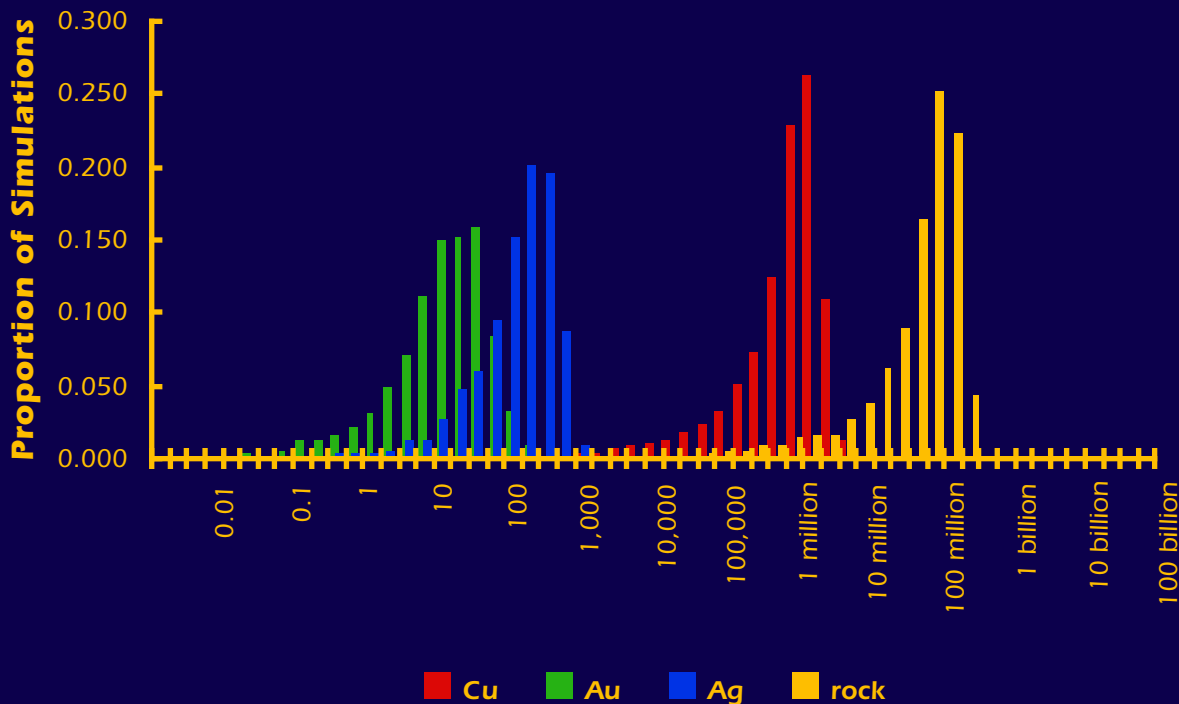
Histograms of Contained Metal and Mineralized Rock
(metric tons)

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB03

The Mark3 Index is 8:

Skarn Cu

There is a 90% or greater chance of 3 or more deposits.
There is a 50% or greater chance of 30 or more deposits.
There is a 10% or greater chance of 50 or more deposits.
There is a 5% or greater chance of 60 or more deposits.
There is a 1% or greater chance of 60 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Ag	rock
0.95	11,000	0	0	640,000
0.90	80,000	0	1	5,200,000
0.50	1,400,000	14	170	110,000,000
0.10	3,300,000	63	554	260,000,000
0.05	4,100,000	90	690	310,000,000
mean	1,600,000	26	230	120,000,000
Probability of mean	0.43	0.33	0.40	0.44
Probability of zero	0.03	0.09	0.10	0.03

The tract ID is SB03The Mark3 Index is 8: **Skarn Cu**

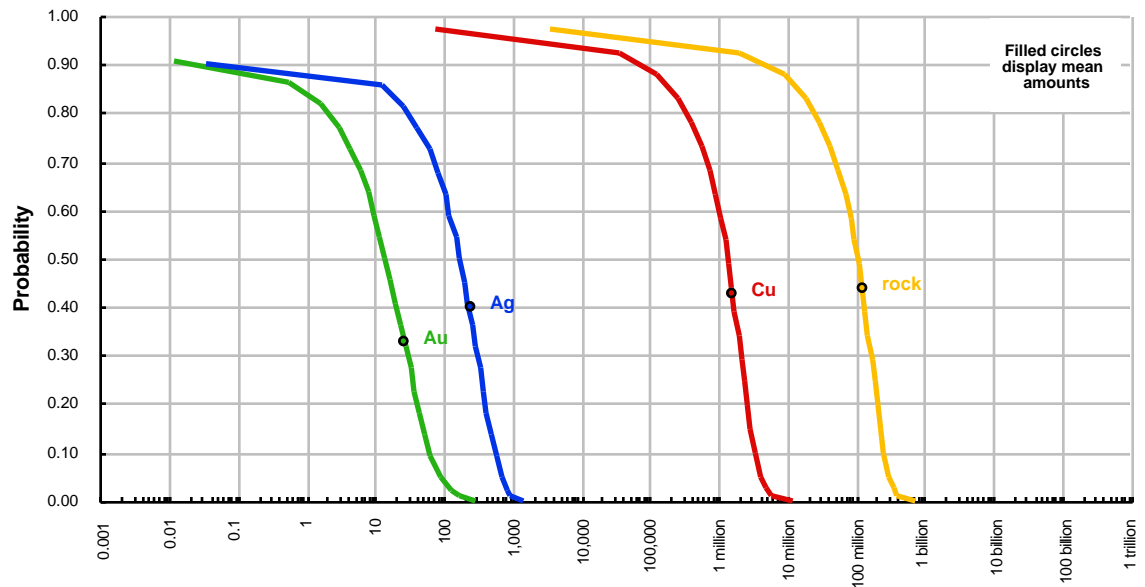
There is a 90% or greater chance of 3 or more deposits.
 There is a 50% or greater chance of 30 or more deposits.
 There is a 10% or greater chance of 50 or more deposits.
 There is a 5% or greater chance of 60 or more deposits.
 There is a 1% or greater chance of 60 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

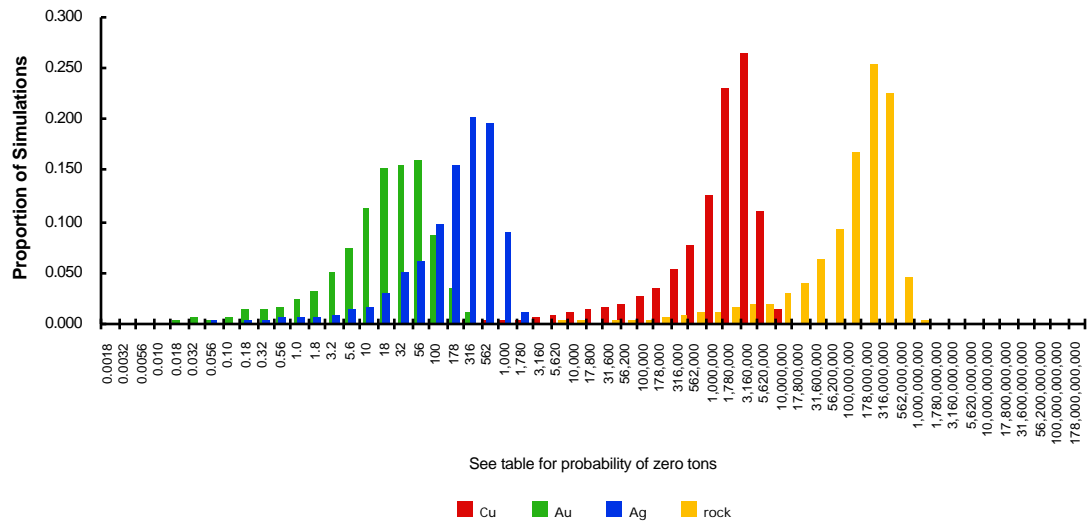
quantile	Cu	Au	Ag	rock
0.95	11,000	0	0	640,000
0.90	80,000	0	1	5,200,000
0.50	1,400,000	14	170	110,000,000
0.10	3,300,000	63	554	260,000,000
0.05	4,100,000	90	690	310,000,000
mean	1,600,000	26	230	120,000,000
Probability of mean	0.43	0.33	0.40	0.44
Probability of zero	0.03	0.09	0.10	0.03

The tract ID is SB03

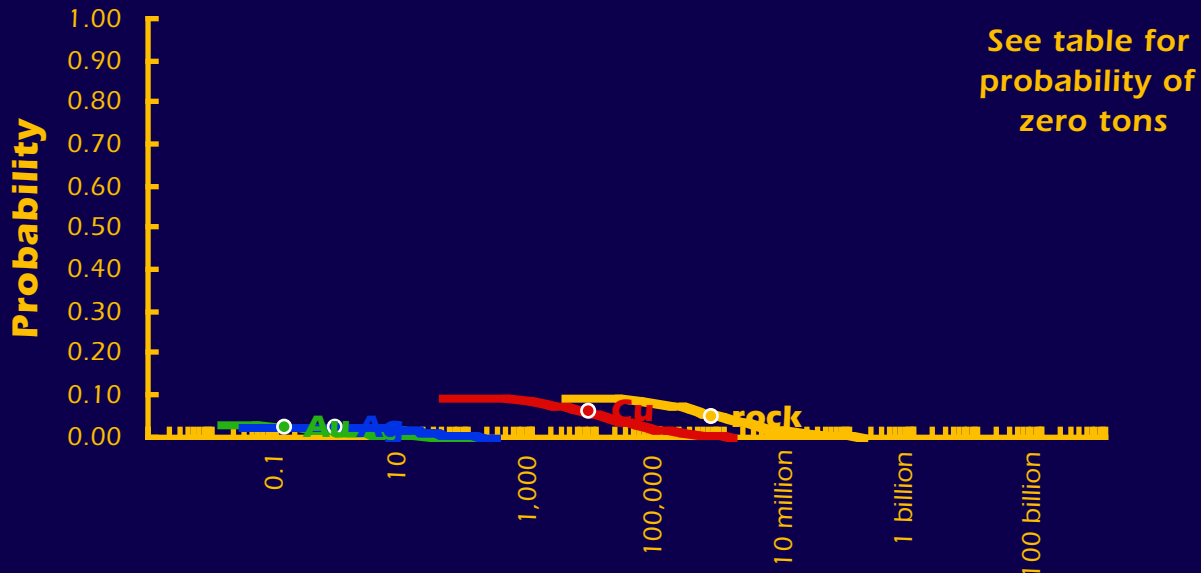
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

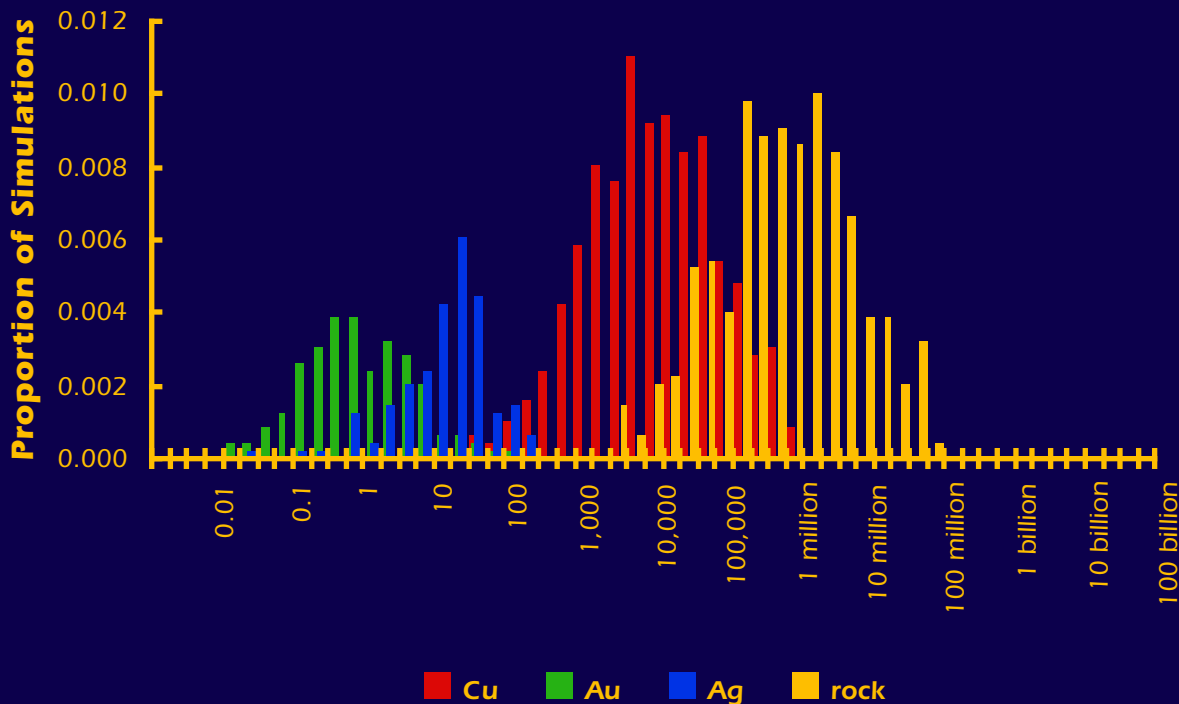


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB04

The Mark3 Index is 8:

Skarn Cu

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	12,000	0	0	780,000
mean	8,000	0	1	660,000
Probability of mean	0.06	0.02	0.02	0.05
Probability of zero	0.90	0.97	0.97	0.90

The tract ID is SB04The Mark3 Index is 8: **Skarn Cu**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

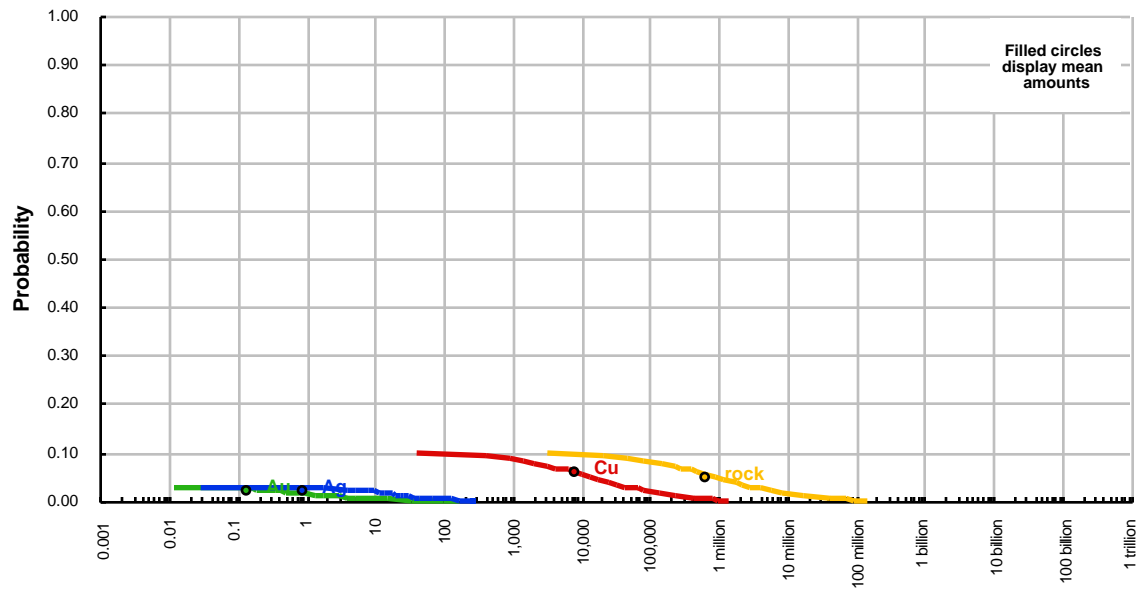
There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

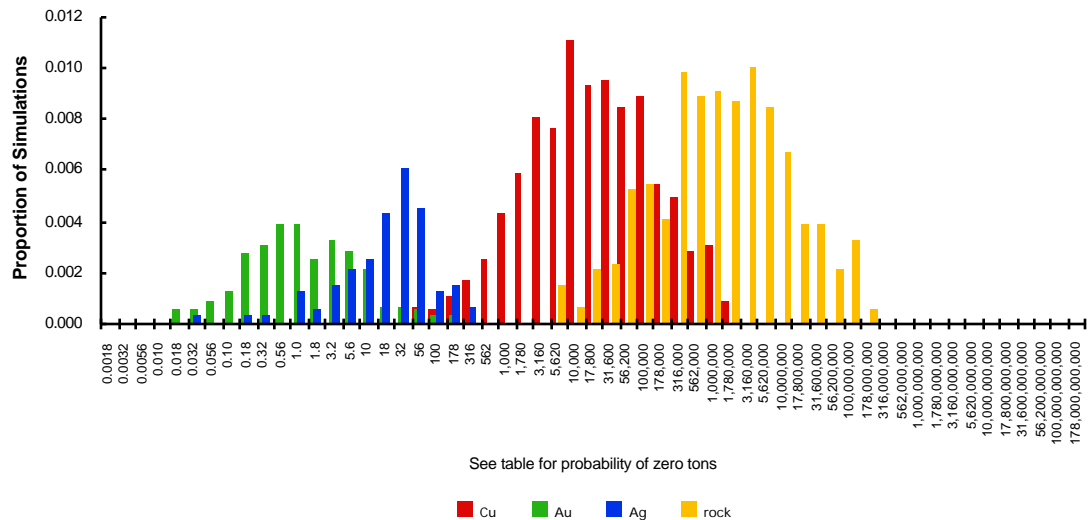
quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	12,000	0	0	780,000
mean	8,000	0	1	660,000
Probability of mean	0.06	0.02	0.02	0.05
Probability of zero	0.90	0.97	0.97	0.90

The tract ID is SB04

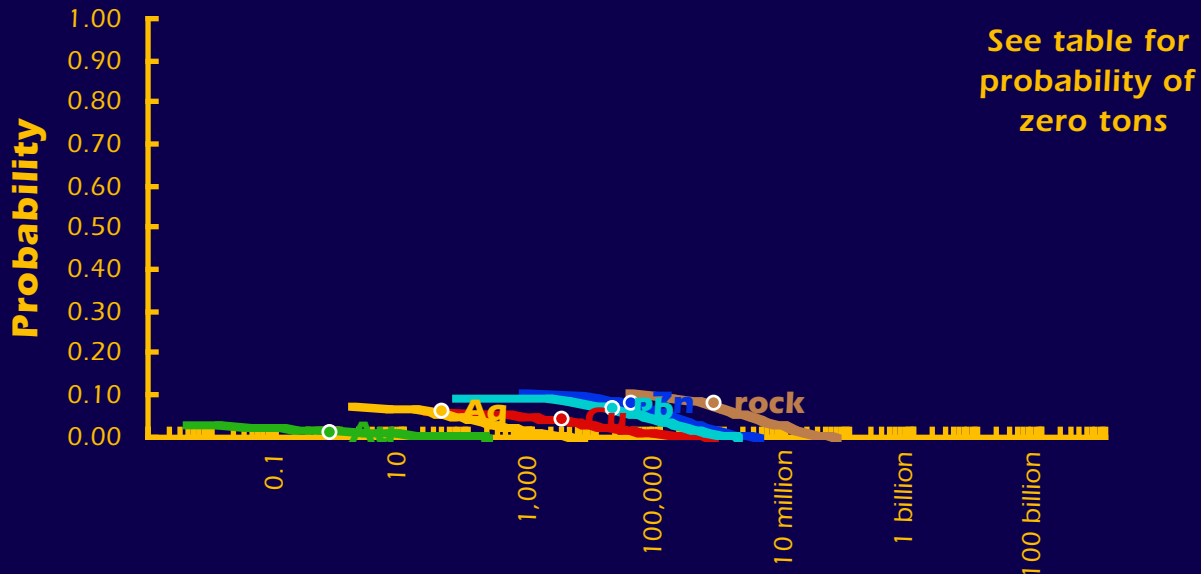
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

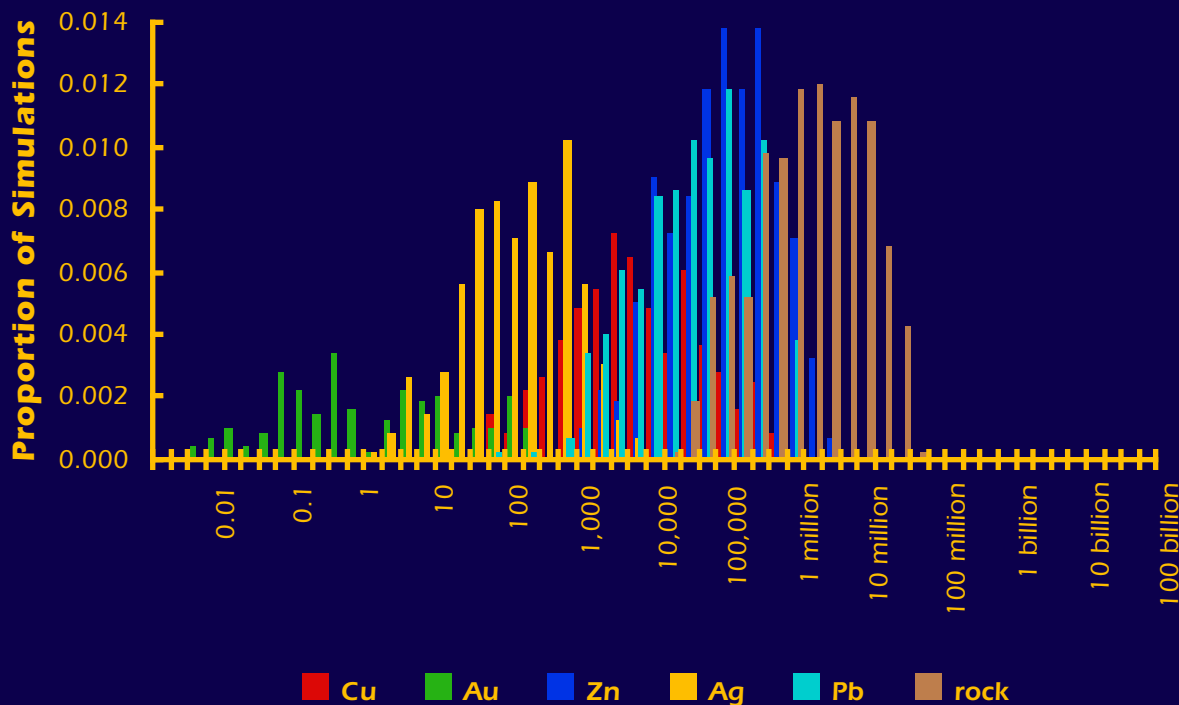


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB05

The Mark3 Index is 22:

Skarn Zn-Pb

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	6,100	0	0	83,000
0.05	850	0	150,000	63	55,000	2,300,000
mean	3,100	1	36,000	37	19,000	680,000
Probability of mean	0.04	0.01	0.08	0.06	0.07	0.08
Probability of zero	0.94	0.97	0.89	0.93	0.90	0.89

The tract ID is SB05The Mark3 Index is 22: **Skarn Zn-Pb**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

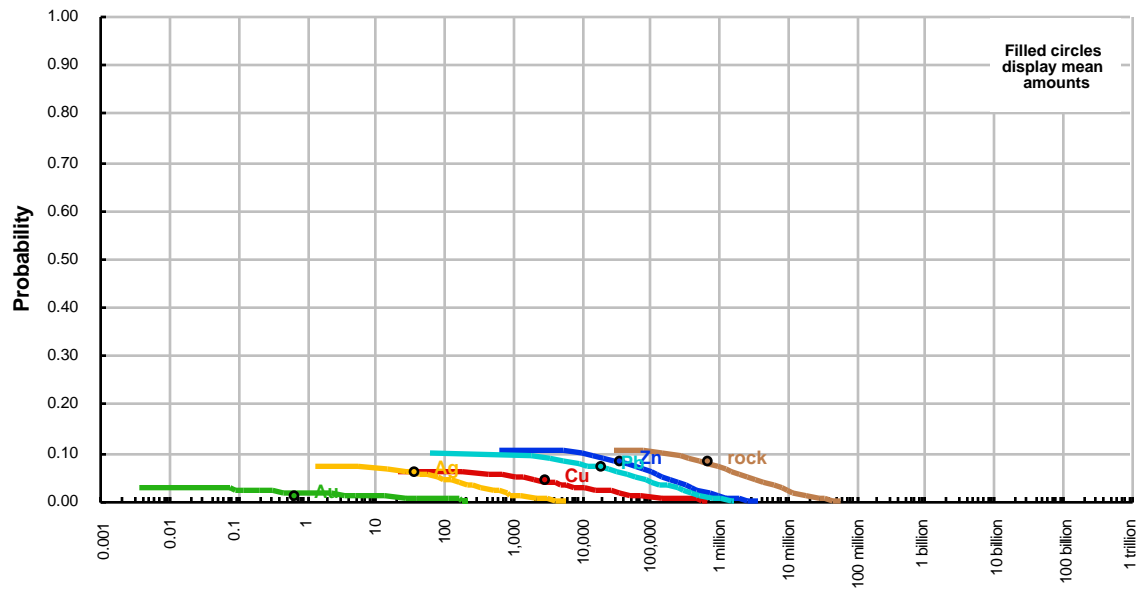
There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

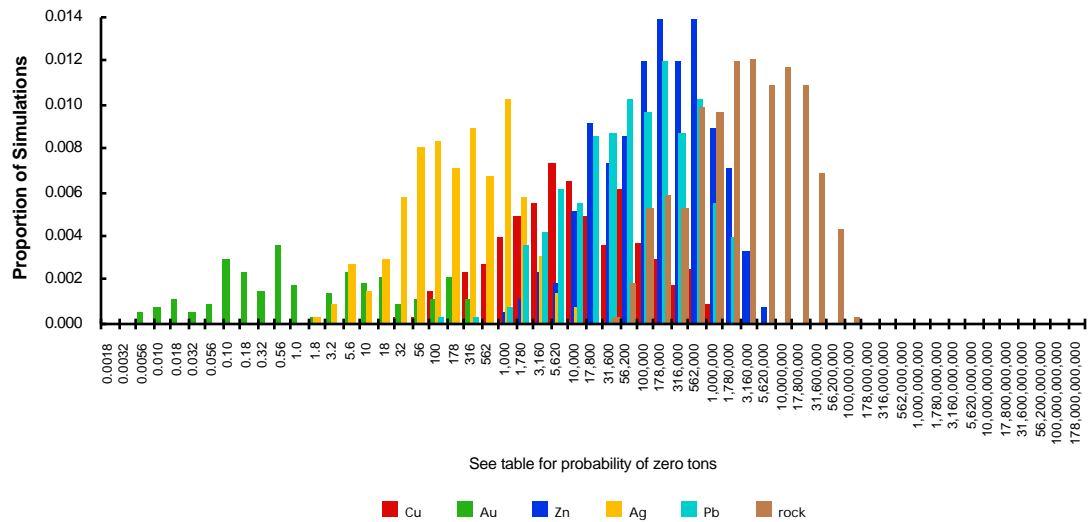
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	6,100	0	0	83,000
0.05	850	0	150,000	63	55,000	2,300,000
mean	3,100	1	36,000	37	19,000	680,000
Probability of mean	0.04	0.01	0.08	0.06	0.07	0.08
Probability of zero	0.94	0.97	0.89	0.93	0.90	0.89

The tract ID is SB05

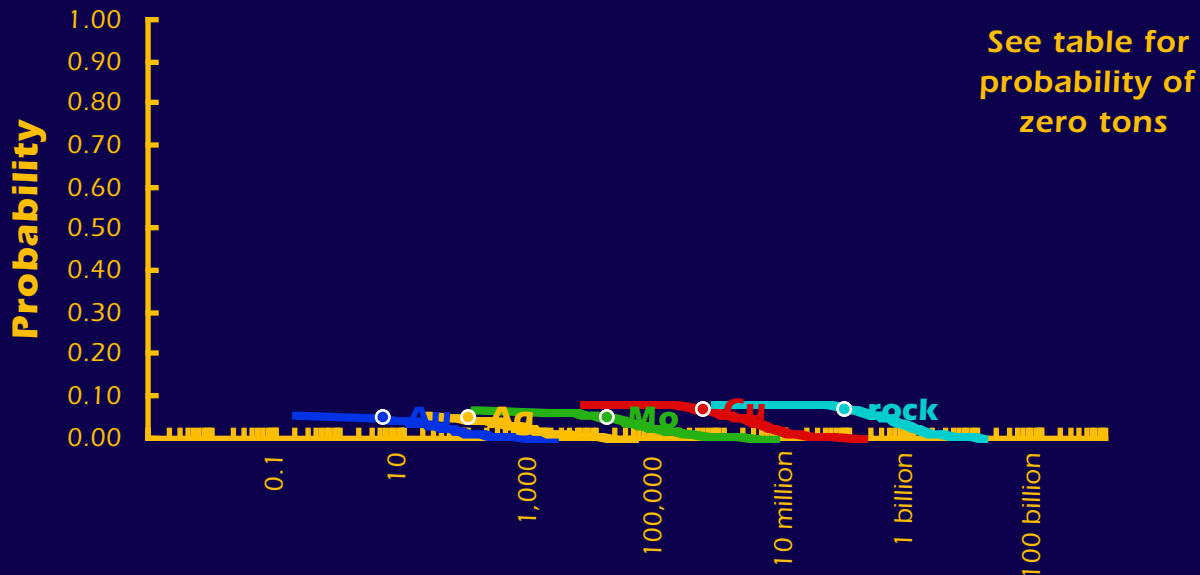
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

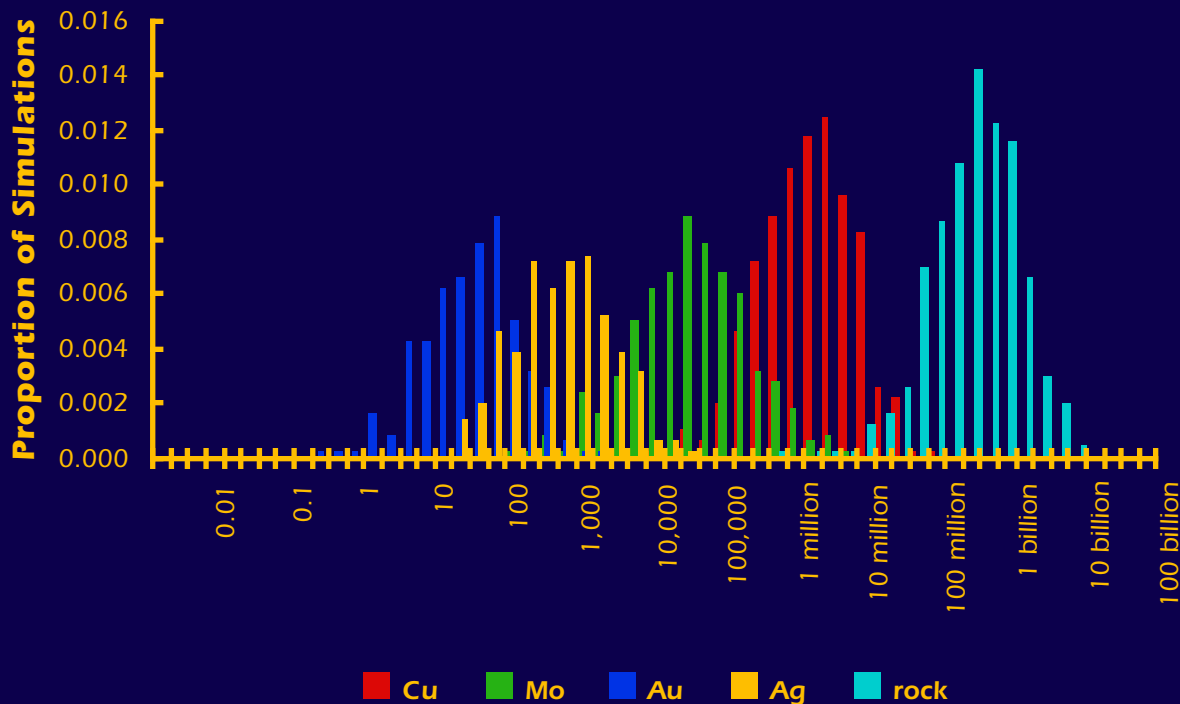


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB06

The Mark3 Index is 4:

Porphyry Cu

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	1,600,000	12,000	3	58	320,000,000
mean	490,000	15,000	5	100	82,000,000
Probability of mean	0.07	0.05	0.05	0.05	0.07
Probability of zero	0.92	0.93	0.95	0.95	0.92

The tract ID is SB06The Mark3 Index is 4: **Porphyry Cu**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

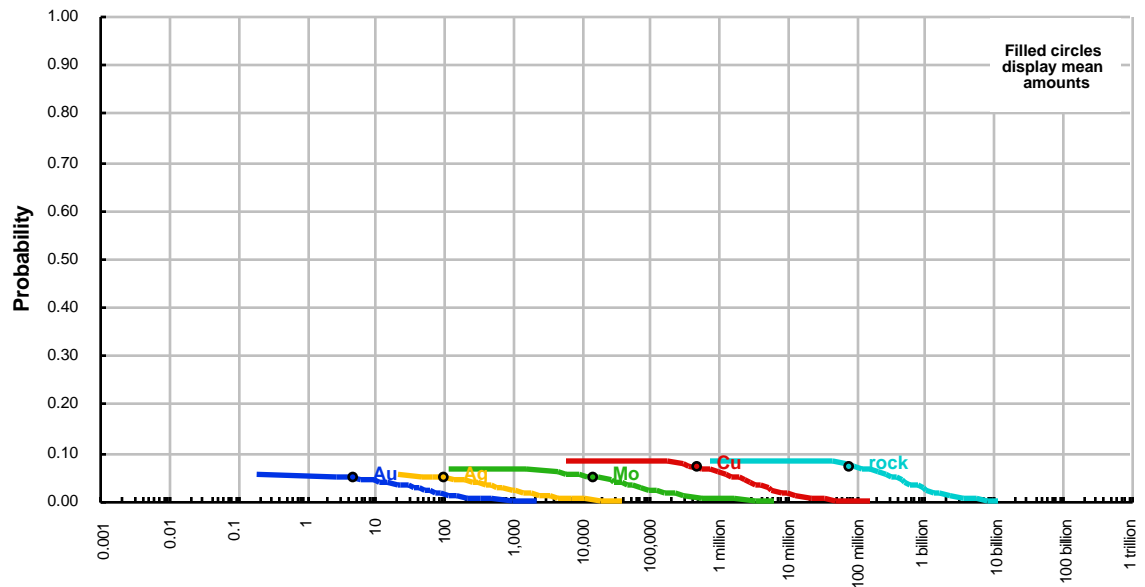
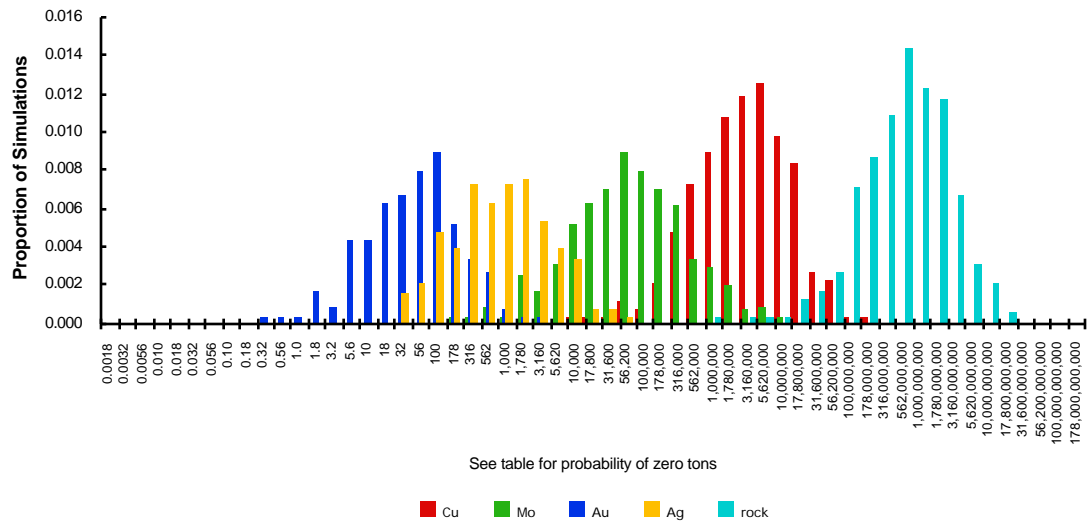
There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

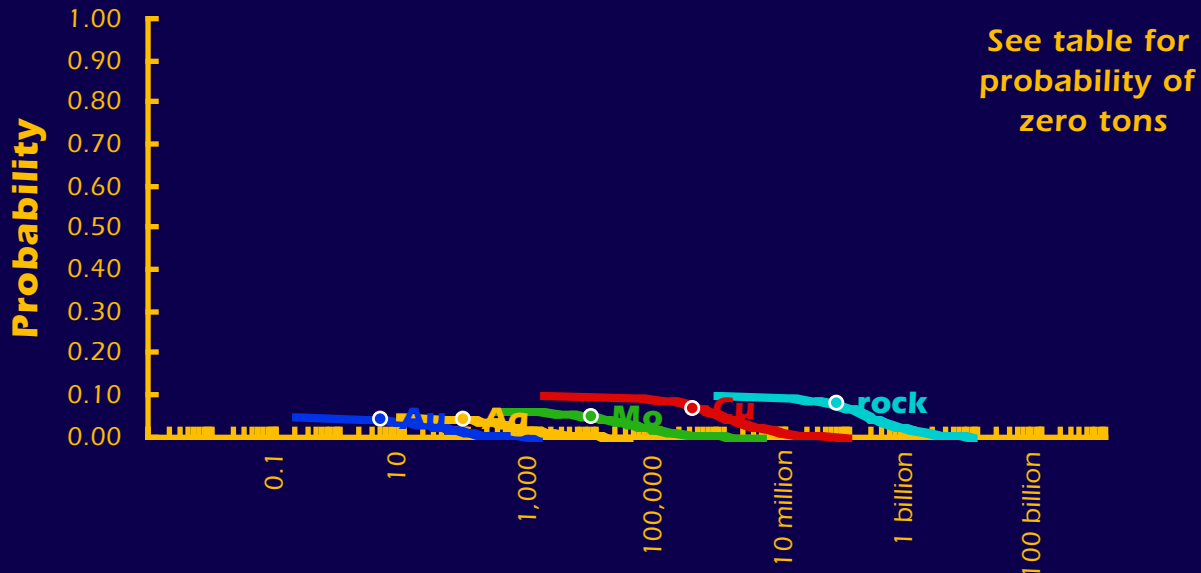
quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	1,600,000	12,000	3	58	320,000,000
mean	490,000	15,000	5	100	82,000,000
Probability of mean	0.07	0.05	0.05	0.05	0.07
Probability of zero	0.92	0.93	0.95	0.95	0.92

The tract ID is SB06

Cumulative Distributions of Contained Metal and Mineralized Rock

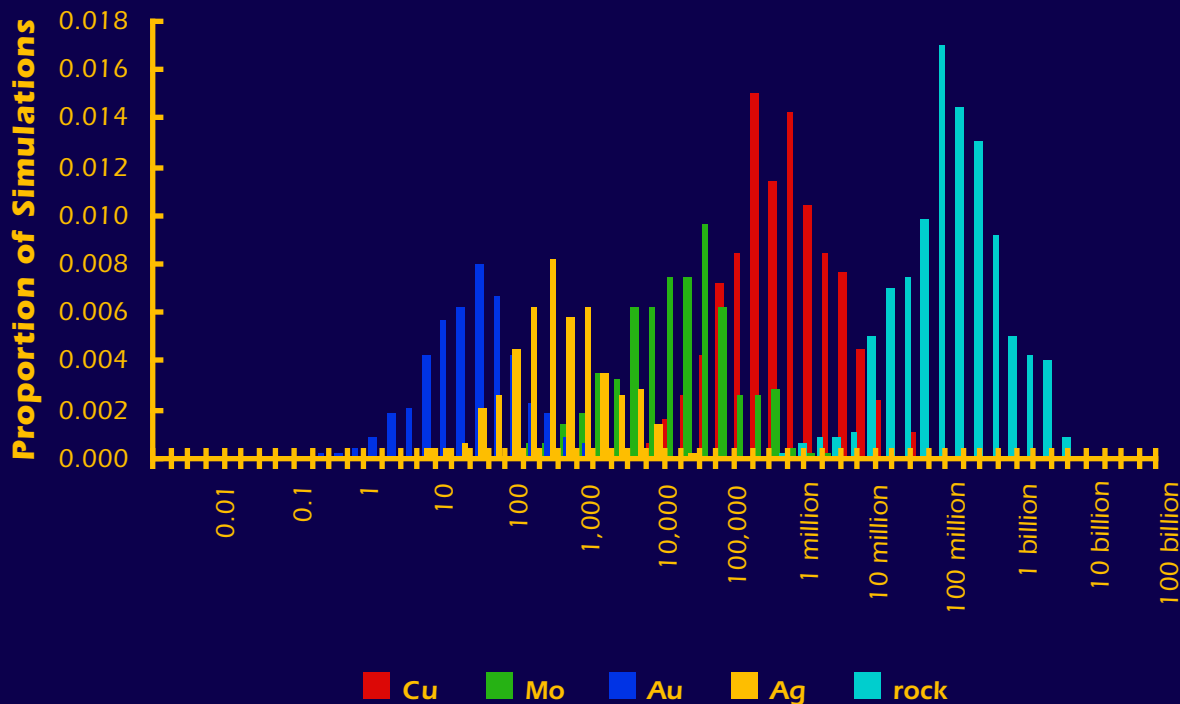
Histograms of Contained Metal and Mineralized Rock
(metric tons)

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB07

The Mark3 Index is 4:

Porphry Cu

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	2,400	0	0	0	1,100,000
0.05	960,000	6,200	0	0	190,000,000
mean	330,000	8,100	4	80	58,000,000
Probability of mean	0.07	0.05	0.04	0.04	0.08
Probability of zero	0.90	0.94	0.95	0.95	0.90

The tract ID is SB07The Mark3 Index is 4: **Porphyry Cu**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

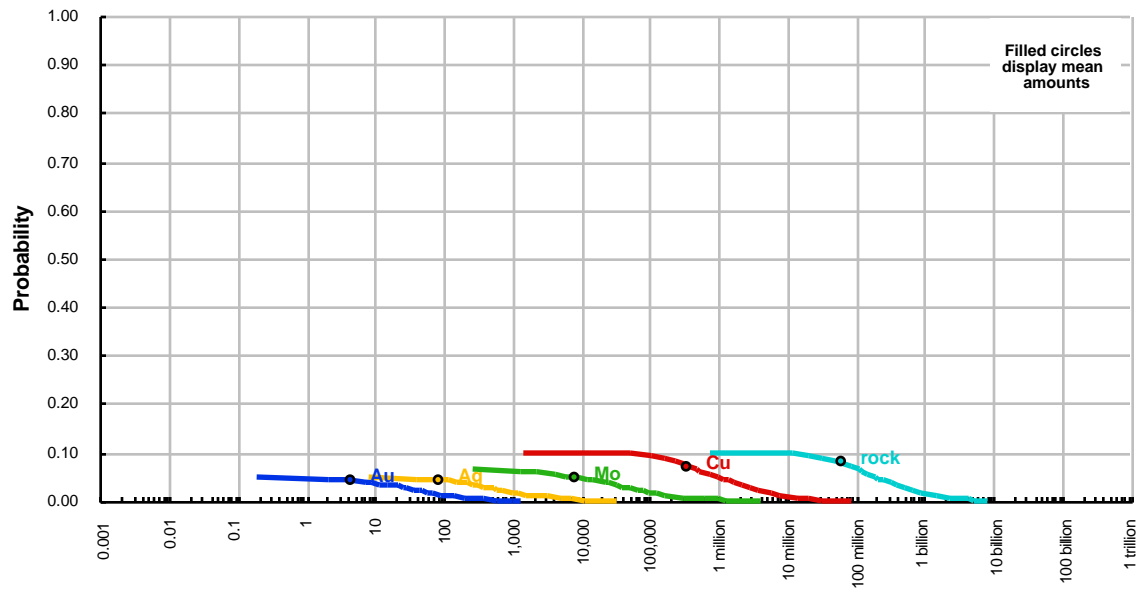
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

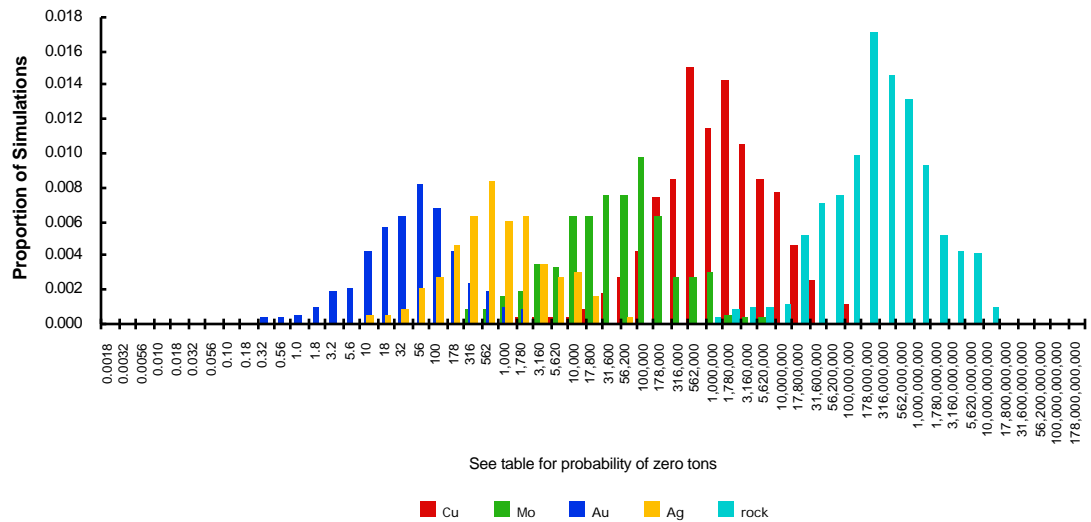
quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	2,400	0	0	0	1,100,000
0.05	960,000	6,200	0	0	190,000,000
mean	330,000	8,100	4	80	58,000,000
Probability of mean	0.07	0.05	0.04	0.04	0.08
Probability of zero	0.90	0.94	0.95	0.95	0.90

The tract ID is SB07

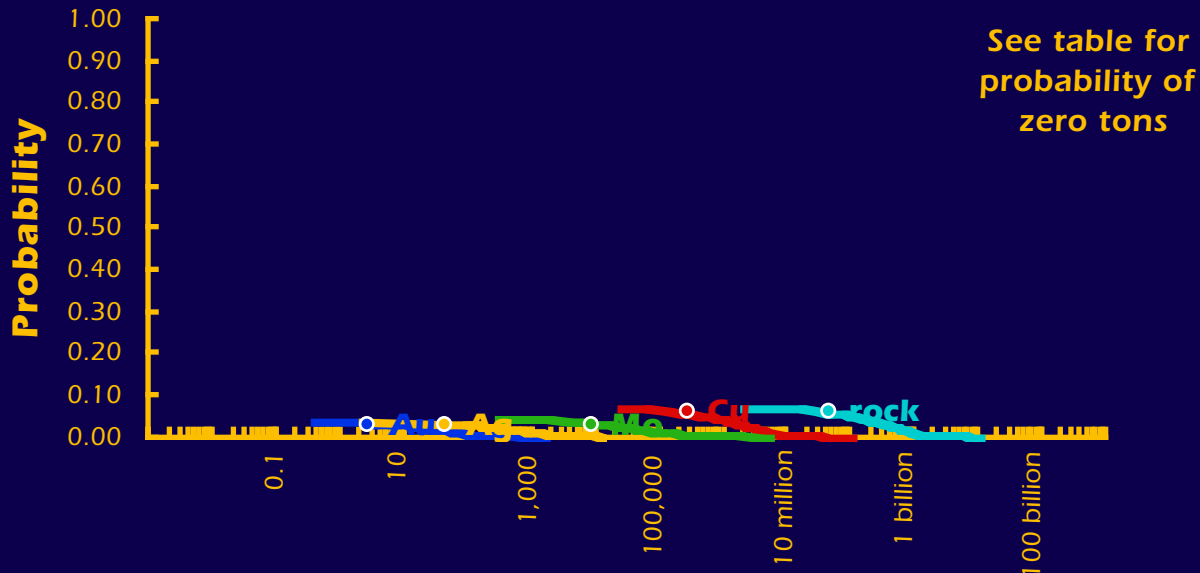
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

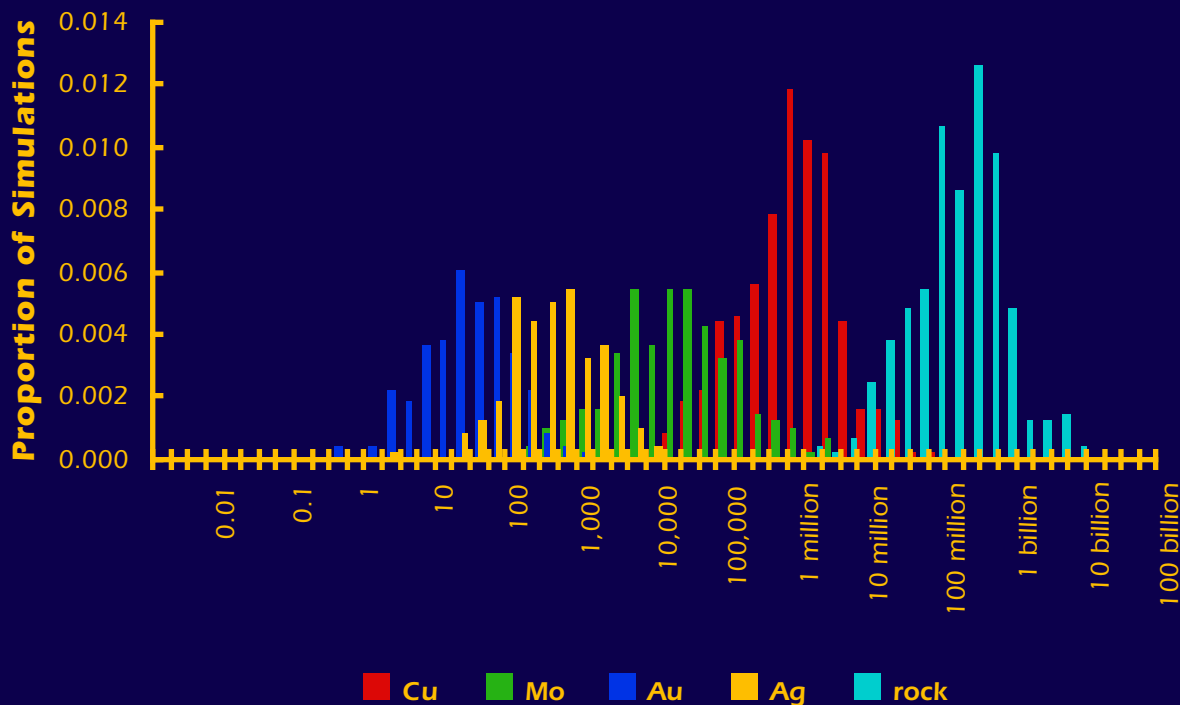


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB08

The Mark3 Index is 4:

Porphry Cu

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	490,000	0	0	0	110,000,000
mean	270,000	8,100	3	44	44,000,000
Probability of mean	0.06	0.03	0.03	0.03	0.06
Probability of zero	0.93	0.96	0.96	0.97	0.93

The tract ID is SB08The Mark3 Index is 4: **Porphyry Cu**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

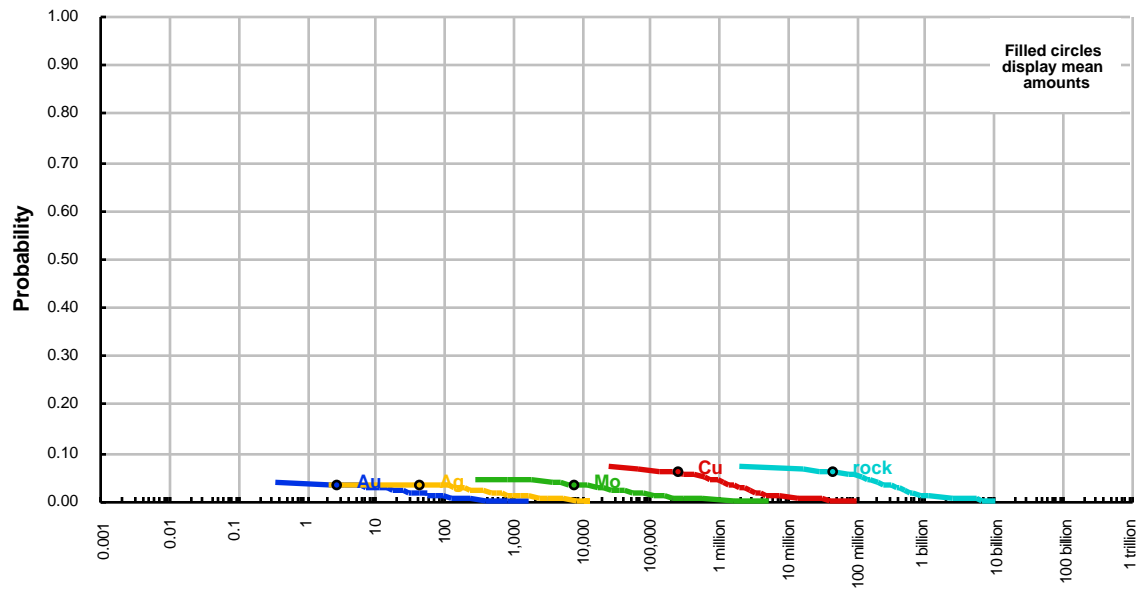
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

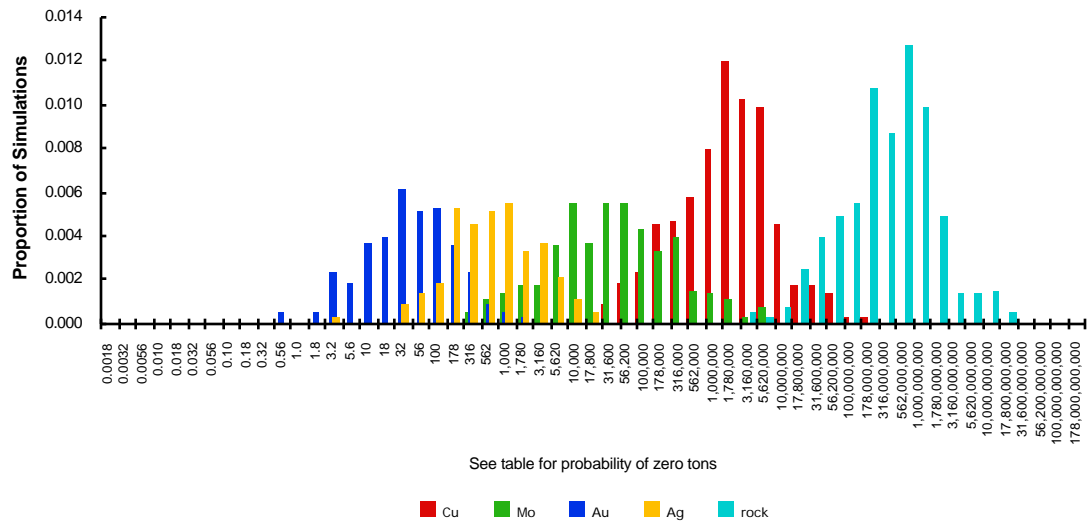
quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	490,000	0	0	0	110,000,000
mean	270,000	8,100	3	44	44,000,000
Probability of mean	0.06	0.03	0.03	0.03	0.06
Probability of zero	0.93	0.96	0.96	0.97	0.93

The tract ID is SB08

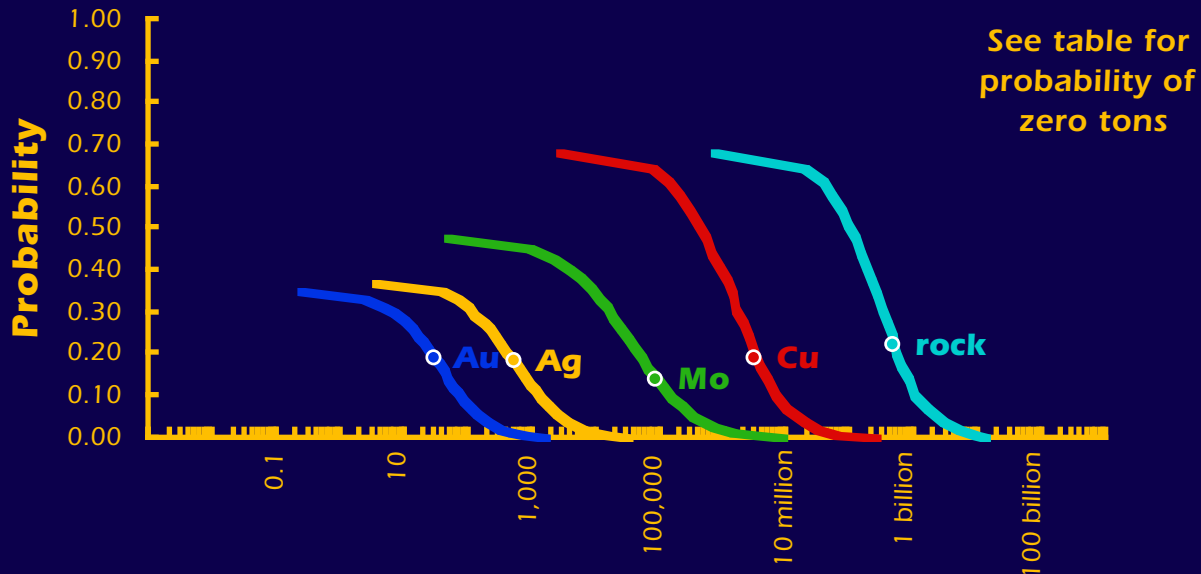
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

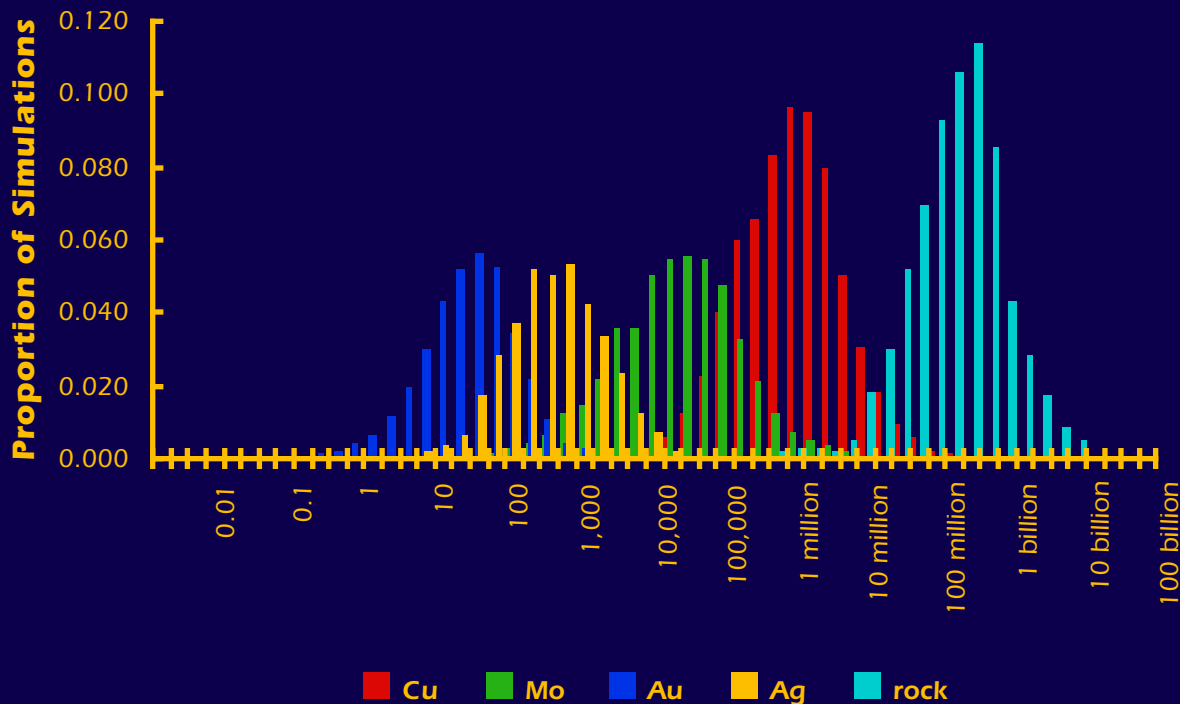


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB09

The Mark3 Index is 4:

Porphyry Cu

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	450,000	0	0	0	99,000,000
0.10	6,500,000	140,000	73	1,200	1,000,000,000
0.05	13,000,000	310,000	140	2,800	2,000,000,000
mean	3,100,000	88,000	29	540	470,000,000
Probability of mean	0.19	0.14	0.19	0.18	0.22
Probability of zero	0.32	0.53	0.65	0.63	0.32

The tract ID is SB09The Mark3 Index is 4: **Porphyry Cu**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

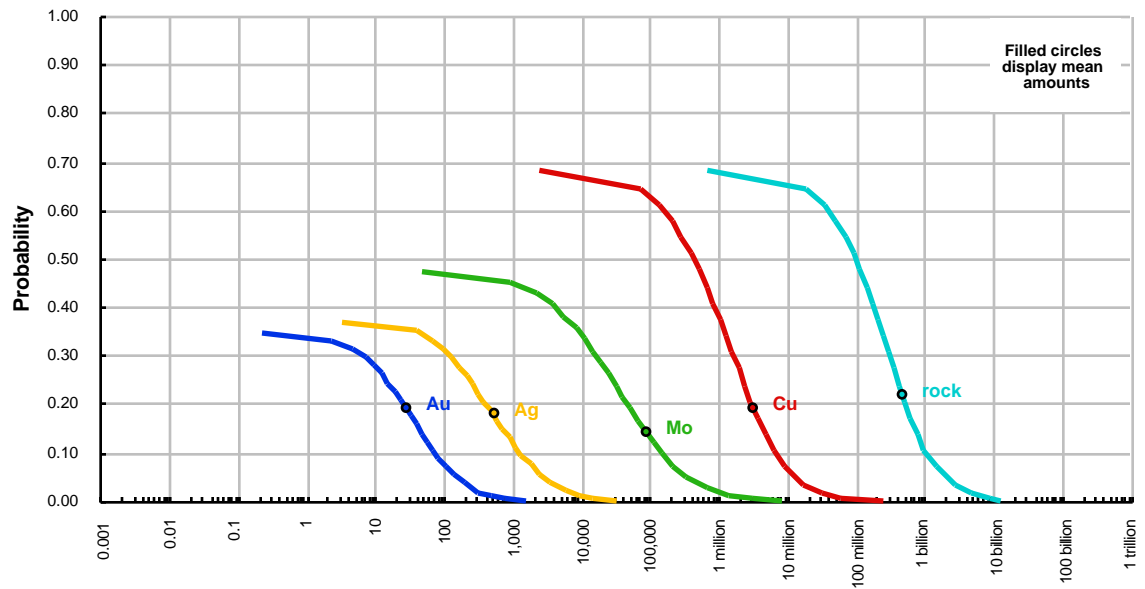
There is a 1% or greater chance of 3 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

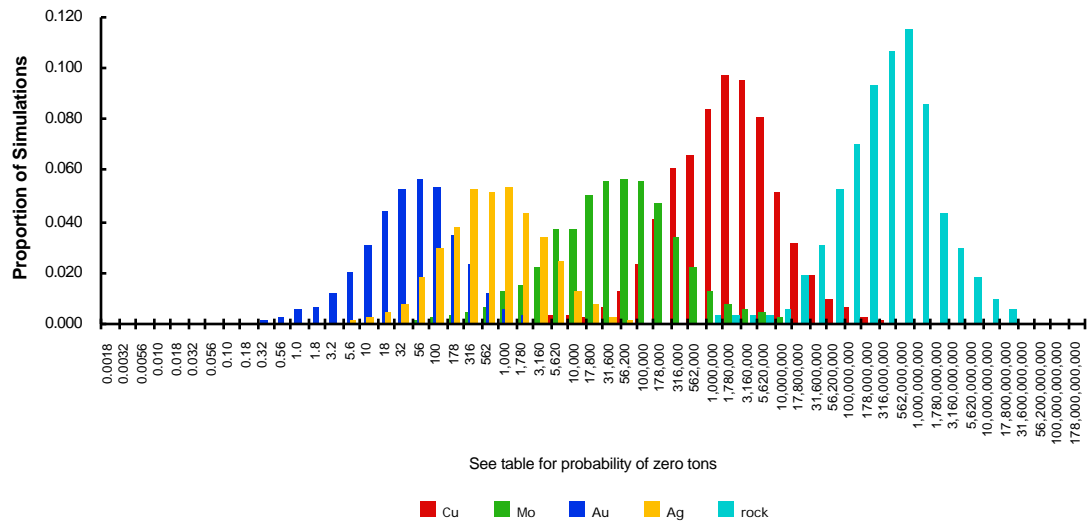
quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	450,000	0	0	0	99,000,000
0.10	6,500,000	140,000	73	1,200	1,000,000,000
0.05	13,000,000	310,000	140	2,800	2,000,000,000
mean	3,100,000	88,000	29	540	470,000,000
Probability of mean	0.19	0.14	0.19	0.18	0.22
Probability of zero	0.32	0.53	0.65	0.63	0.32

The tract ID is SB09

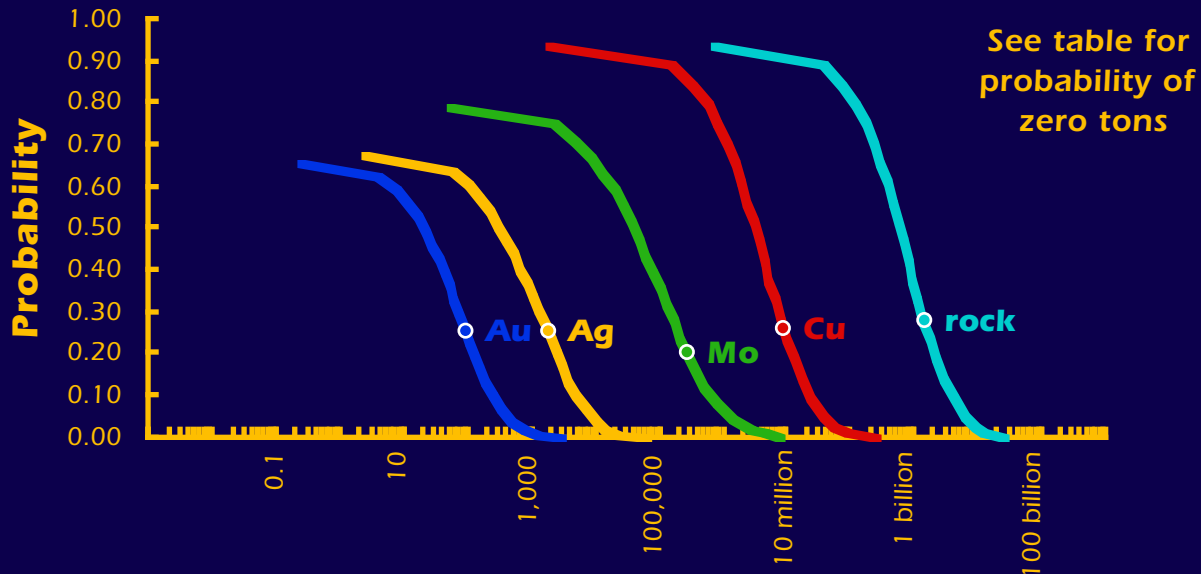
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

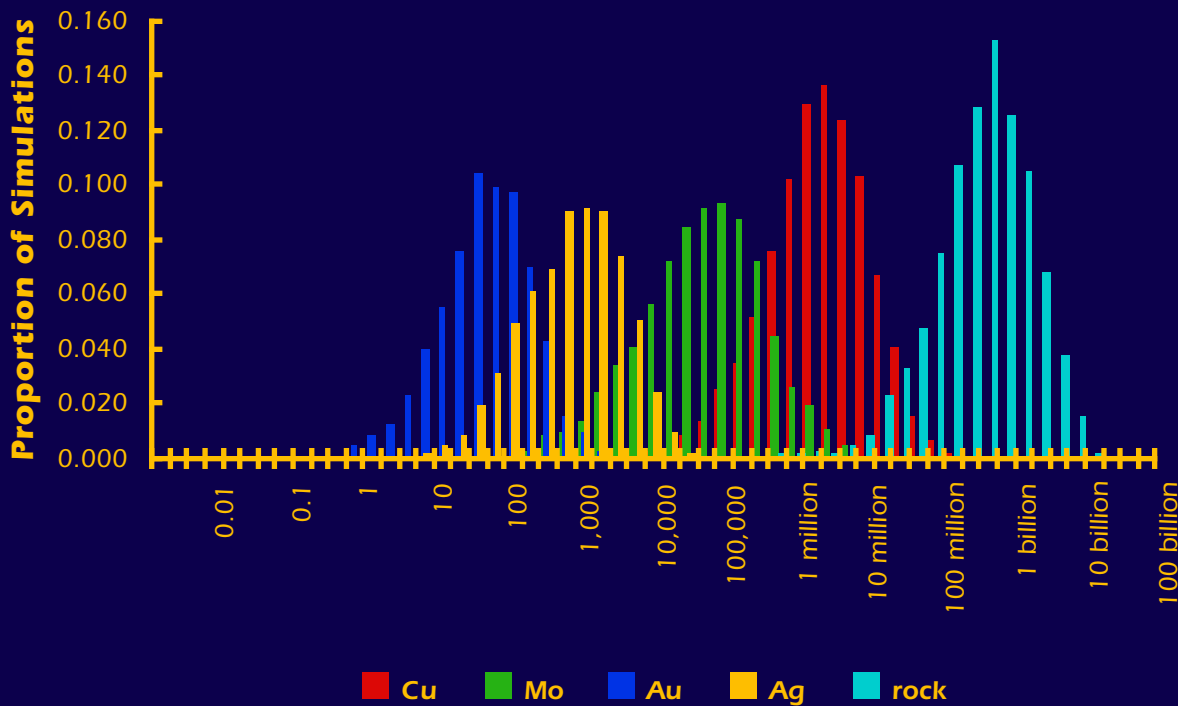


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB10

The Mark3 Index is 4:

Porphyry Cu

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 10 or more deposits.

There is a 1% or greater chance of 10 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	120,000	0	0	0	28,000,000
0.50	3,100,000	40,000	20	310	580,000,000
0.10	22,000,000	580,000	236	4,900	3,800,000,000
0.05	36,000,000	1,100,000	380	7,900	5,900,000,000
mean	8,800,000	260,000	90	1,700	1,400,000,000
Probability of mean	0.26	0.20	0.25	0.25	0.28
Probability of zero	0.06	0.21	0.34	0.33	0.06

The tract ID is SB10The Mark3 Index is 4: **Porphyry Cu**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 10 or more deposits.

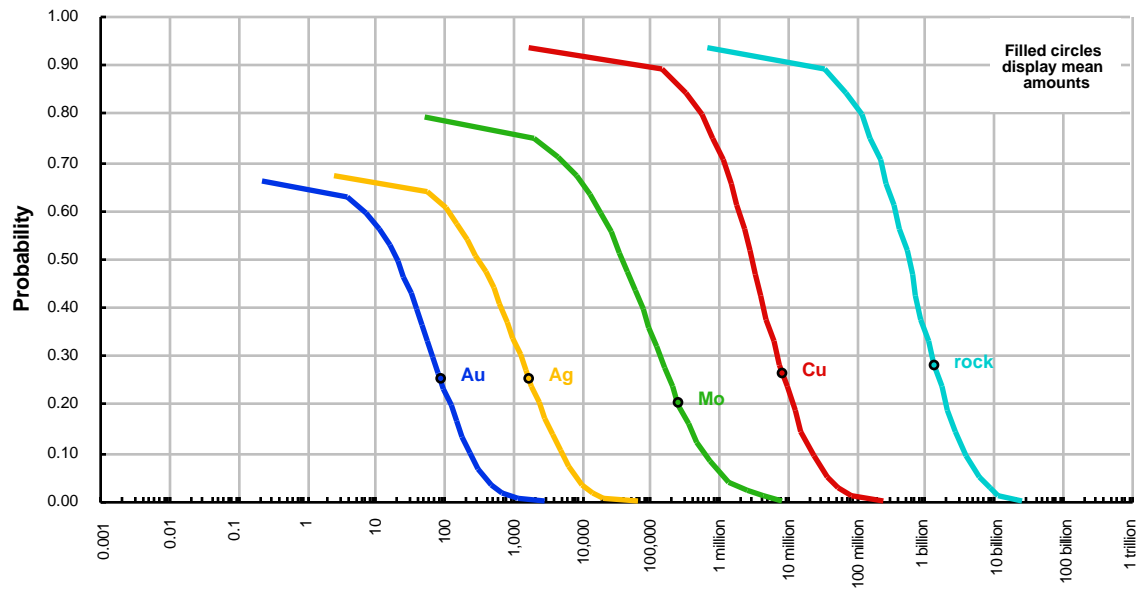
There is a 1% or greater chance of 10 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

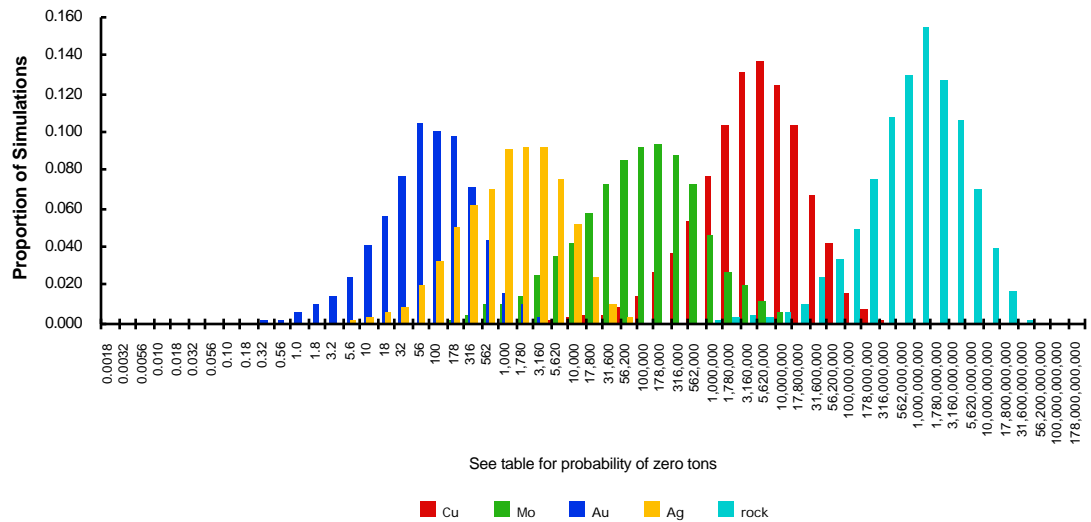
quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	120,000	0	0	0	28,000,000
0.50	3,100,000	40,000	20	310	580,000,000
0.10	22,000,000	580,000	236	4,900	3,800,000,000
0.05	36,000,000	1,100,000	380	7,900	5,900,000,000
mean	8,800,000	260,000	90	1,700	1,400,000,000
Probability of mean	0.26	0.20	0.25	0.25	0.28
Probability of zero	0.06	0.21	0.34	0.33	0.06

The tract ID is SB10

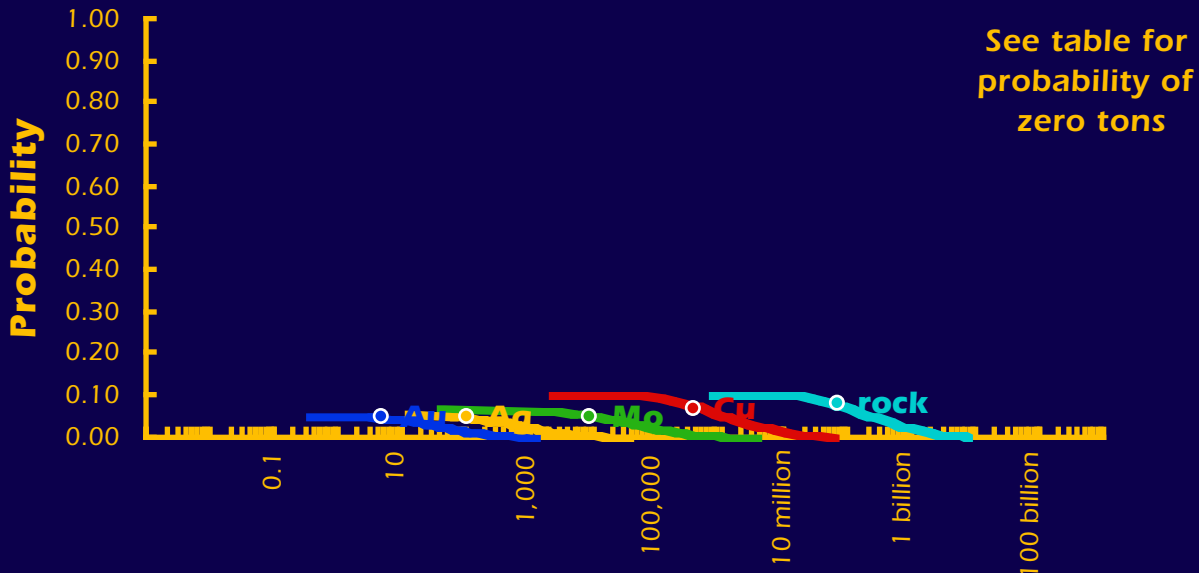
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

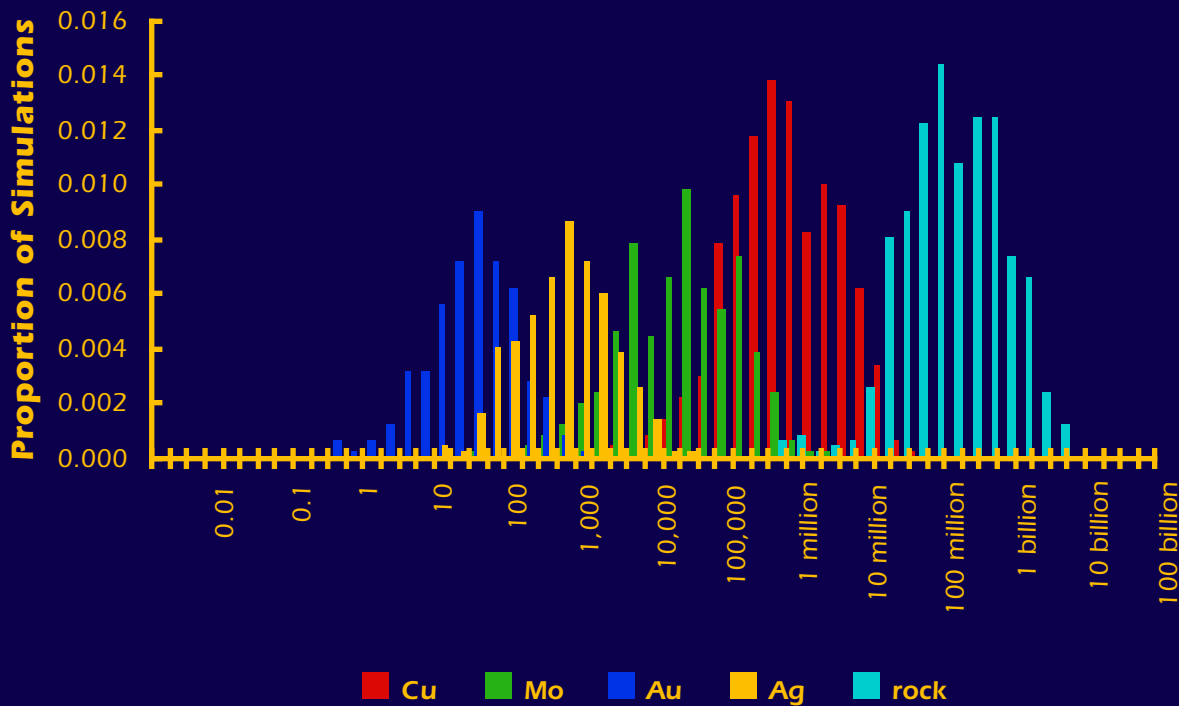


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB11

The Mark3 Index is 4:

Porphry Cu

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	27,000	0	0	0	6,200,000
0.05	1,000,000	8,300	0	58	210,000,000
mean	370,000	8,800	5	100	65,000,000
Probability of mean	0.07	0.05	0.05	0.05	0.08
Probability of zero	0.90	0.93	0.95	0.95	0.90

The tract ID is SB11The Mark3 Index is 4: **Porphyry Cu**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

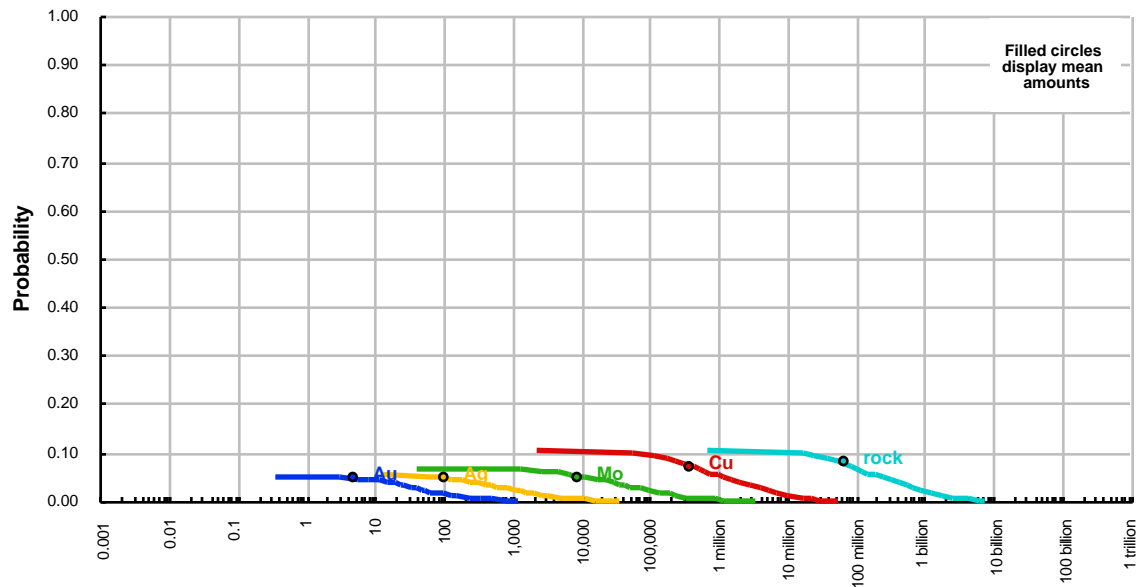
There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

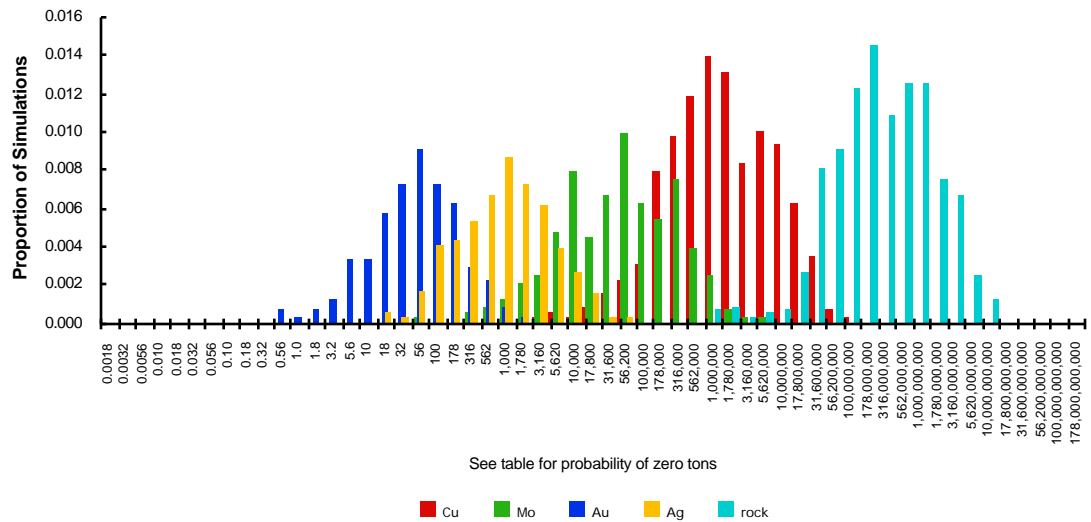
quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	27,000	0	0	0	6,200,000
0.05	1,000,000	8,300	0	58	210,000,000
mean	370,000	8,800	5	100	65,000,000
Probability of mean	0.07	0.05	0.05	0.05	0.08
Probability of zero	0.90	0.93	0.95	0.95	0.90

The tract ID is SB11

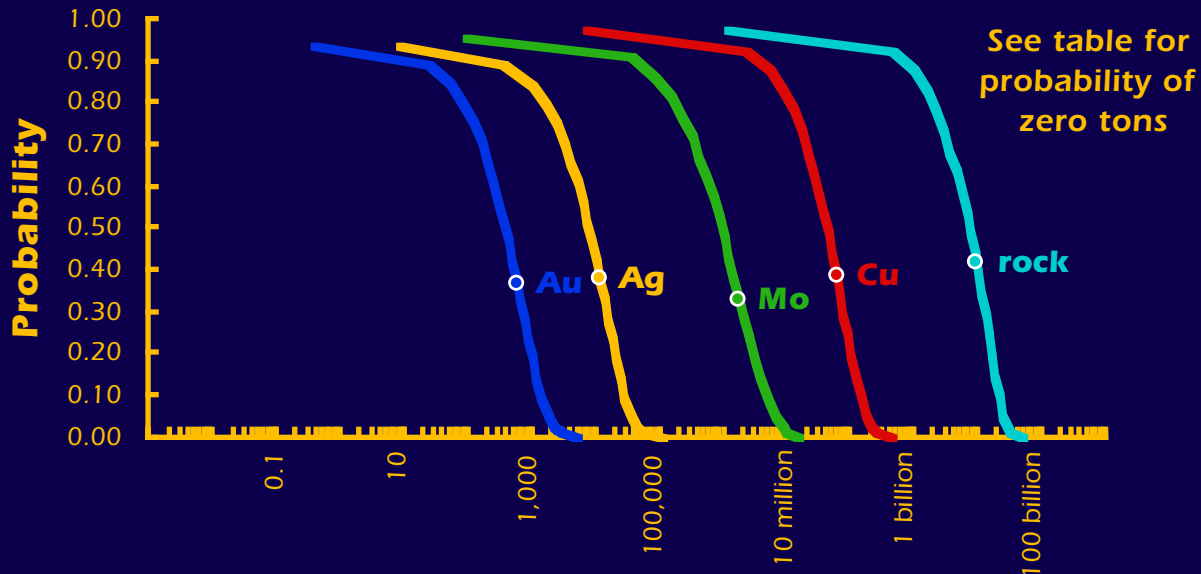
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

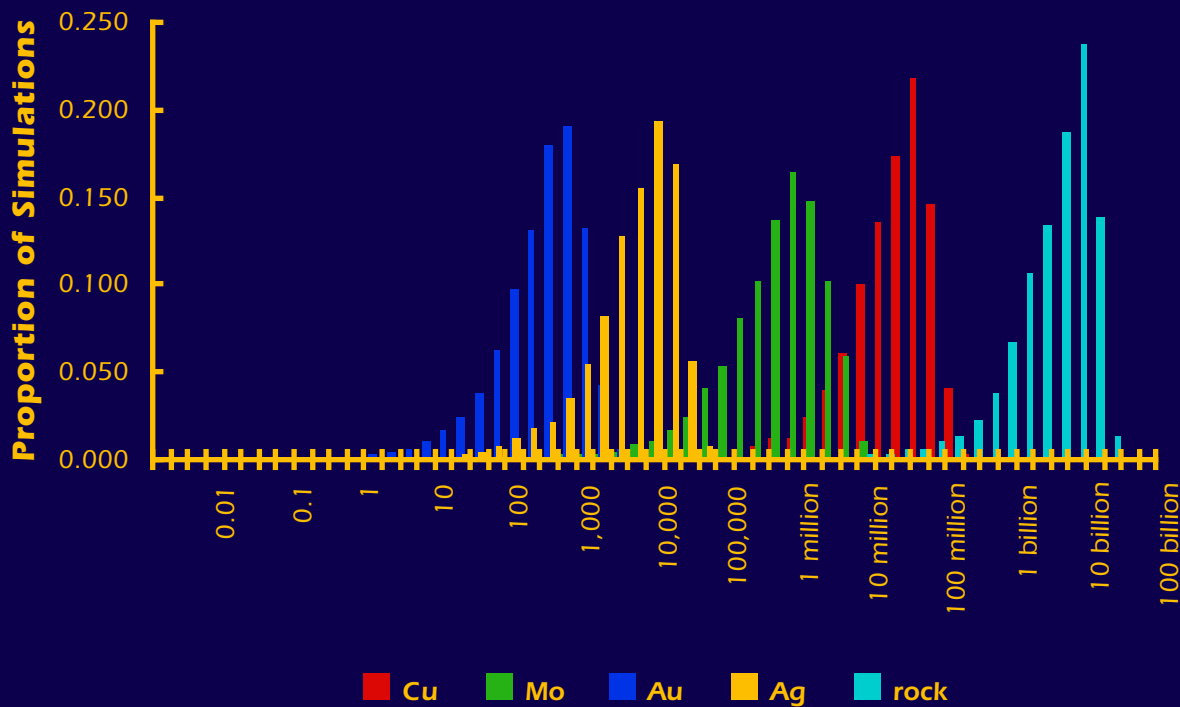


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB13

The Mark3 Index is 4:

Porphyry Cu

There is a 90% or greater chance of 3 or more deposits.

There is a 50% or greater chance of 15 or more deposits.

There is a 10% or greater chance of 40 or more deposits.

There is a 5% or greater chance of 40 or more deposits.

There is a 1% or greater chance of 40 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	910,000	2,900	0	0	190,000,000
0.90	4,000,000	44,000	18	290	760,000,000
0.50	42,000,000	930,000	380	7,700	7,100,000,000
0.10	140,000,000	4,600,000	1,320	27,000	21,000,000,000
0.05	170,000,000	6,400,000	1,800	34,000	24,000,000,000
mean	58,000,000	1,700,000	560	11,000	9,200,000,000
Probability of mean	0.39	0.33	0.37	0.38	0.42
Probability of zero	0.02	0.04	0.06	0.06	0.02

The tract ID is SB13The Mark3 Index is 4: **Porphyry Cu**

There is a 90% or greater chance of 3 or more deposits.

There is a 50% or greater chance of 15 or more deposits.

There is a 10% or greater chance of 40 or more deposits.

There is a 5% or greater chance of 40 or more deposits.

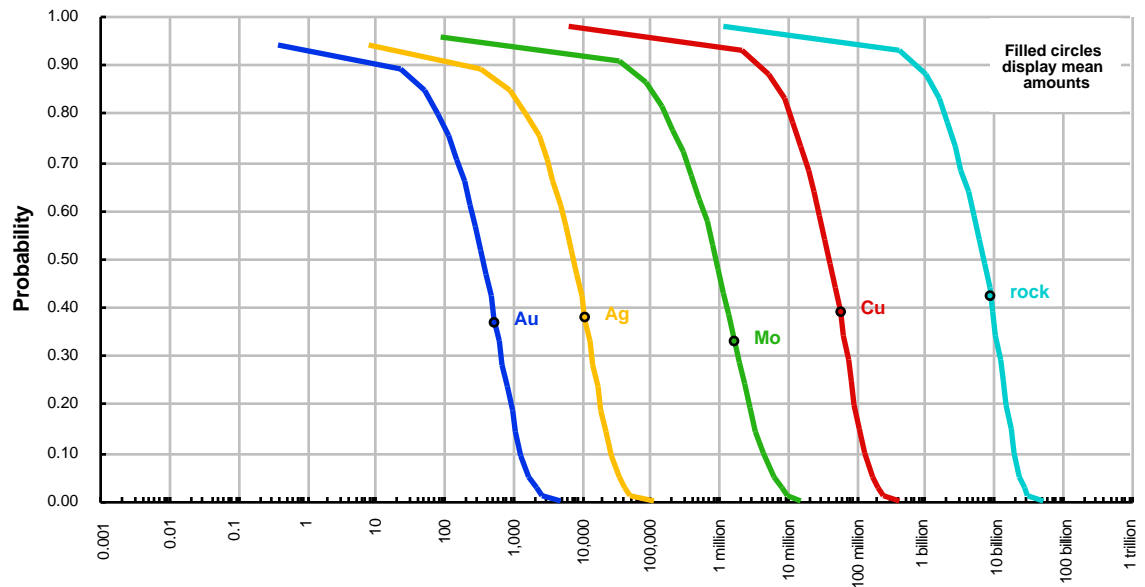
There is a 1% or greater chance of 40 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

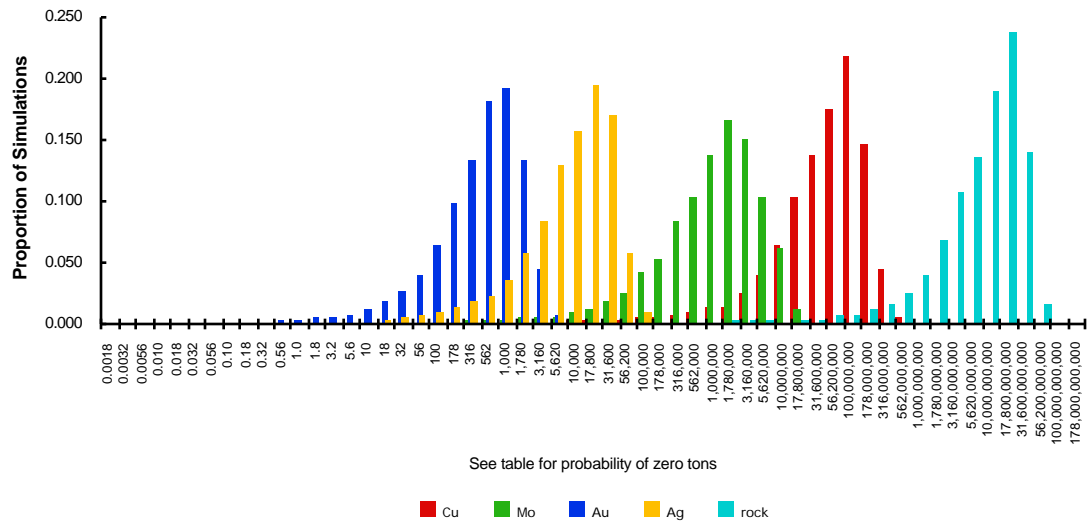
quantile	Cu	Mo	Au	Ag	rock
0.95	910,000	2,900	0	0	190,000,000
0.90	4,000,000	44,000	18	290	760,000,000
0.50	42,000,000	930,000	380	7,700	7,100,000,000
0.10	140,000,000	4,600,000	1,320	27,000	21,000,000,000
0.05	170,000,000	6,400,000	1,800	34,000	24,000,000,000
mean	58,000,000	1,700,000	560	11,000	9,200,000,000
Probability of mean	0.39	0.33	0.37	0.38	0.42
Probability of zero	0.02	0.04	0.06	0.06	0.02

The tract ID is SB13

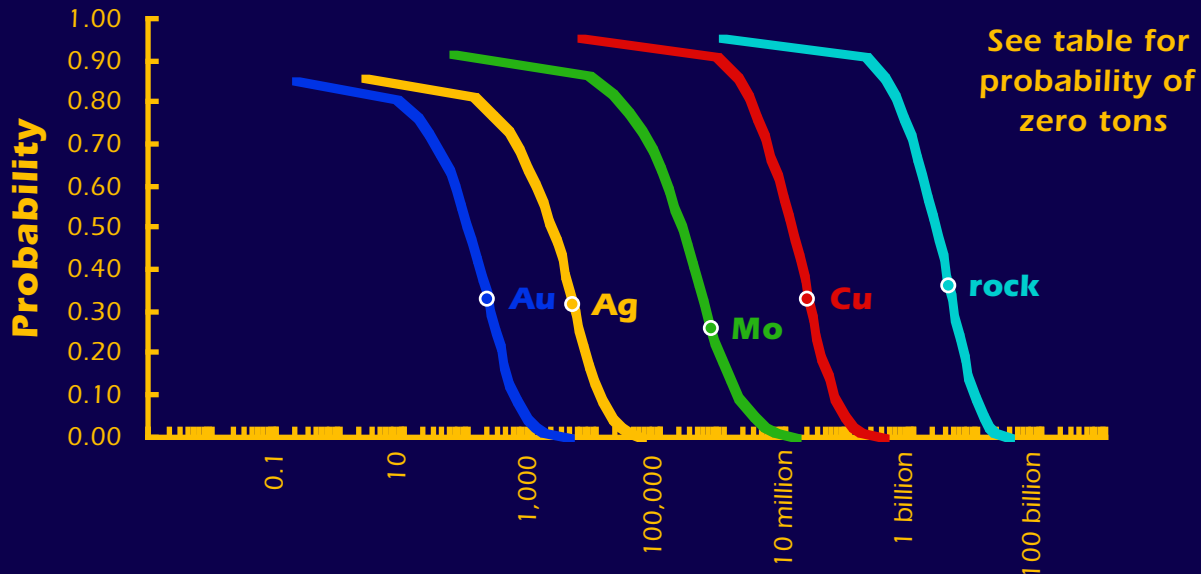
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

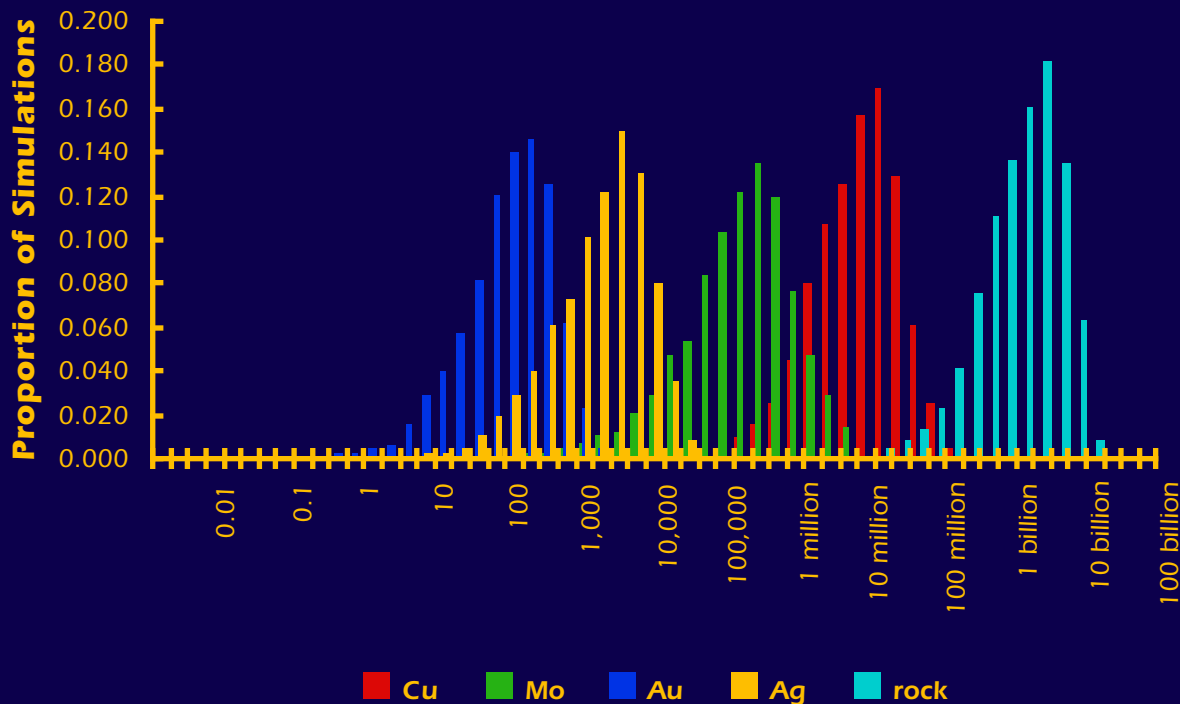


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB14

The Mark3 Index is 4:

Porphry Cu

There is a 90% or greater chance of 2 or more deposits.
 There is a 50% or greater chance of 5 or more deposits.
 There is a 10% or greater chance of 15 or more deposits.
 There is a 5% or greater chance of 15 or more deposits.
 There is a 1% or greater chance of 15 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	160,000	0	0	0	35,000,000
0.90	990,000	1,800	0	0	210,000,000
0.50	12,000,000	220,000	100	2,000	2,100,000,000
0.10	52,000,000	1,600,000	526	11,000	8,500,000,000
0.05	76,000,000	2,900,000	750	16,000	12,000,000,000
mean	22,000,000	640,000	210	4,300	3,400,000,000
Probability of mean	0.33	0.26	0.33	0.32	0.36
Probability of zero	0.04	0.08	0.15	0.14	0.04

The tract ID is SB14The Mark3 Index is 4: **Porphyry Cu**

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 5 or more deposits.

There is a 10% or greater chance of 15 or more deposits.

There is a 5% or greater chance of 15 or more deposits.

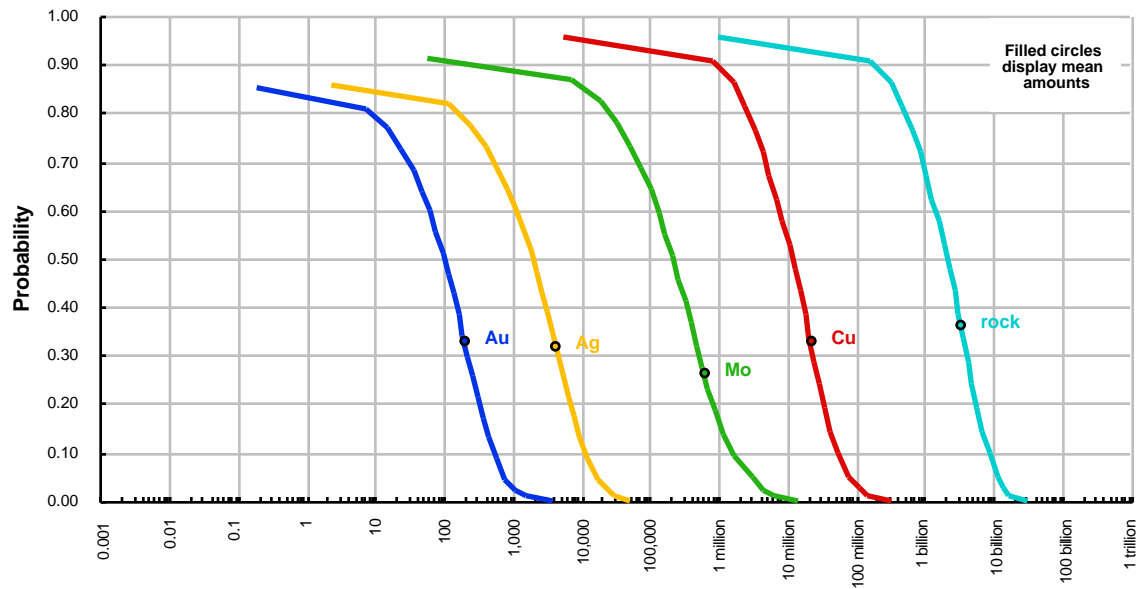
There is a 1% or greater chance of 15 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

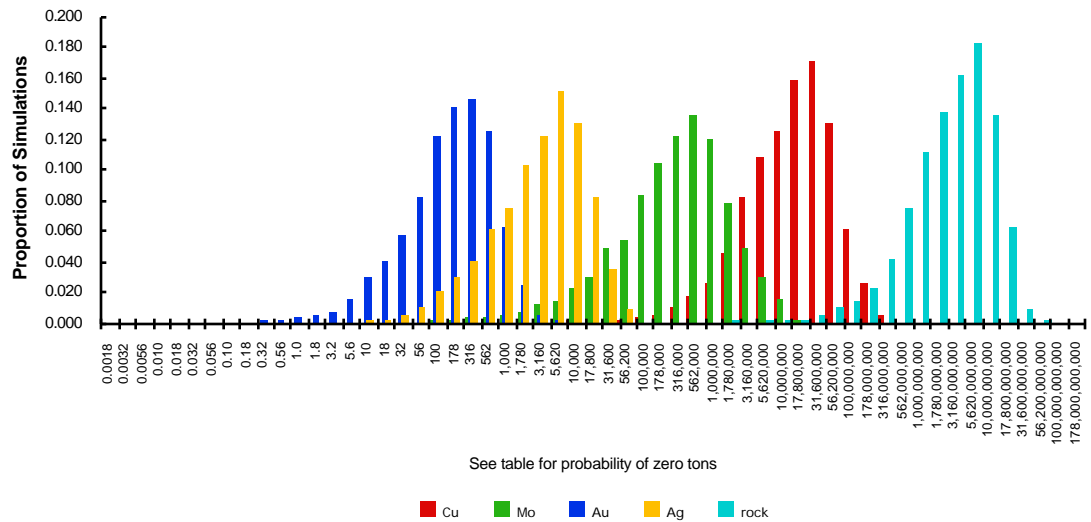
quantile	Cu	Mo	Au	Ag	rock
0.95	160,000	0	0	0	35,000,000
0.90	990,000	1,800	0	0	210,000,000
0.50	12,000,000	220,000	100	2,000	2,100,000,000
0.10	52,000,000	1,600,000	526	11,000	8,500,000,000
0.05	76,000,000	2,900,000	750	16,000	12,000,000,000
mean	22,000,000	640,000	210	4,300	3,400,000,000
Probability of mean	0.33	0.26	0.33	0.32	0.36
Probability of zero	0.04	0.08	0.15	0.14	0.04

The tract ID is SB14

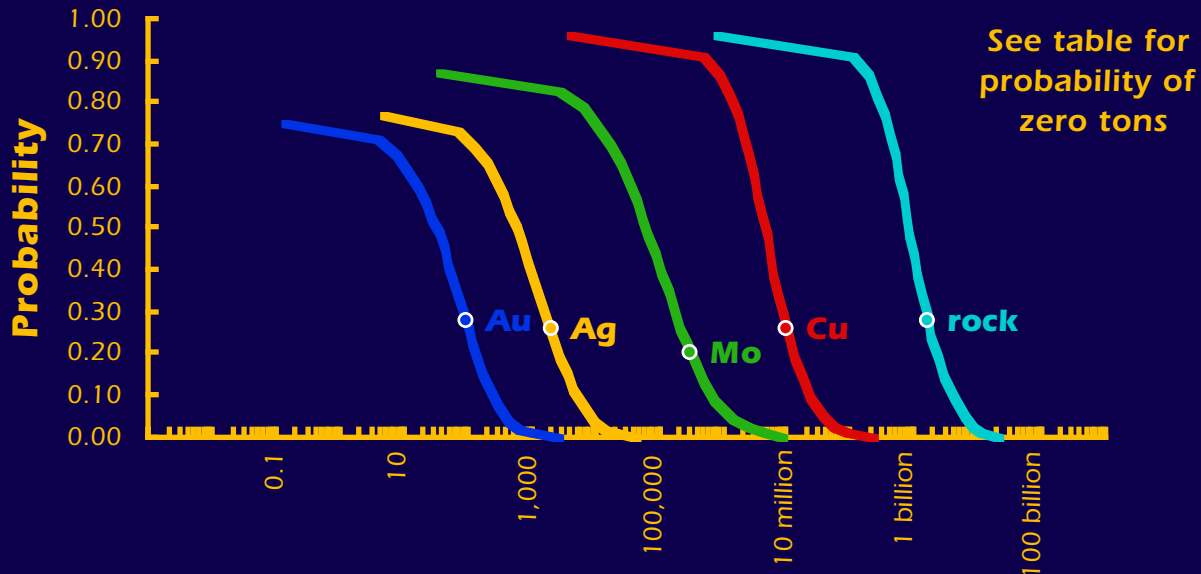
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

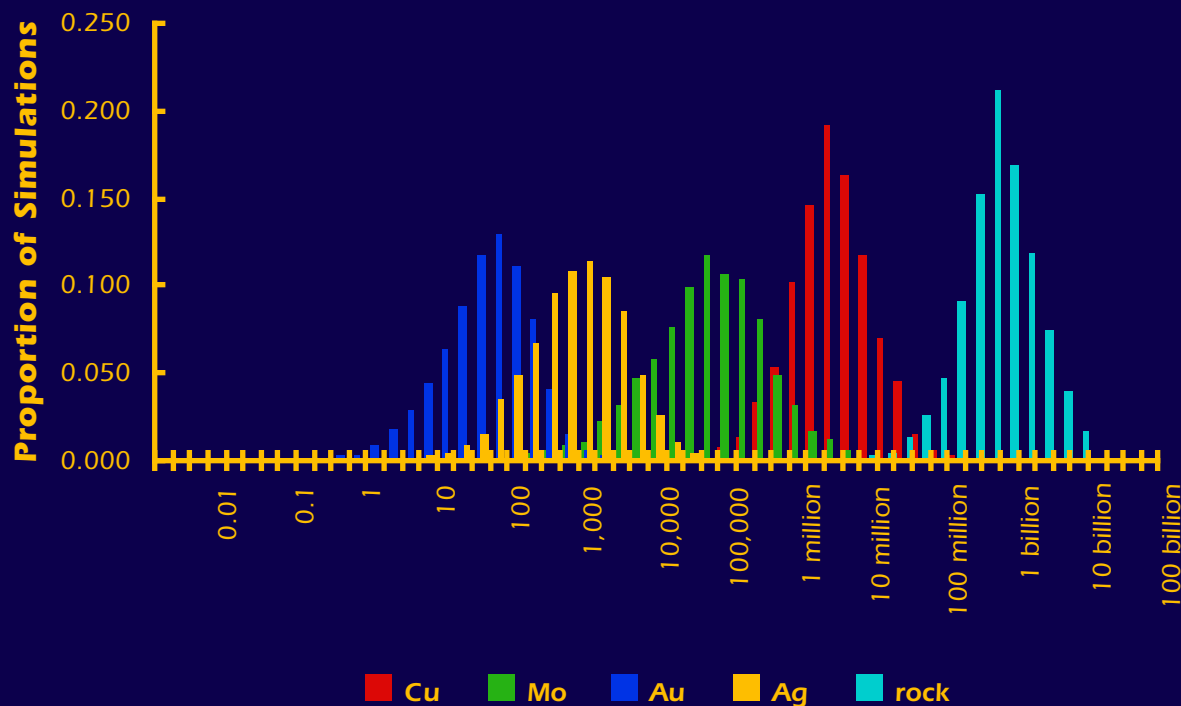


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB15

The Mark3 Index is 4:

Porphyry Cu

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

There is a 1% or greater chance of 9 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	150,000	0	0	0	37,000,000
0.90	590,000	0	0	0	130,000,000
0.50	4,400,000	61,000	32	550	780,000,000
0.10	23,000,000	620,000	231	4,900	3,900,000,000
0.05	38,000,000	1,200,000	360	8,300	5,900,000,000
mean	9,600,000	280,000	90	1,900	1,500,000,000
Probability of mean	0.26	0.20	0.28	0.26	0.28
Probability of zero	0.04	0.13	0.25	0.23	0.04

The tract ID is SB15The Mark3 Index is 4: **Porphyry Cu**

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

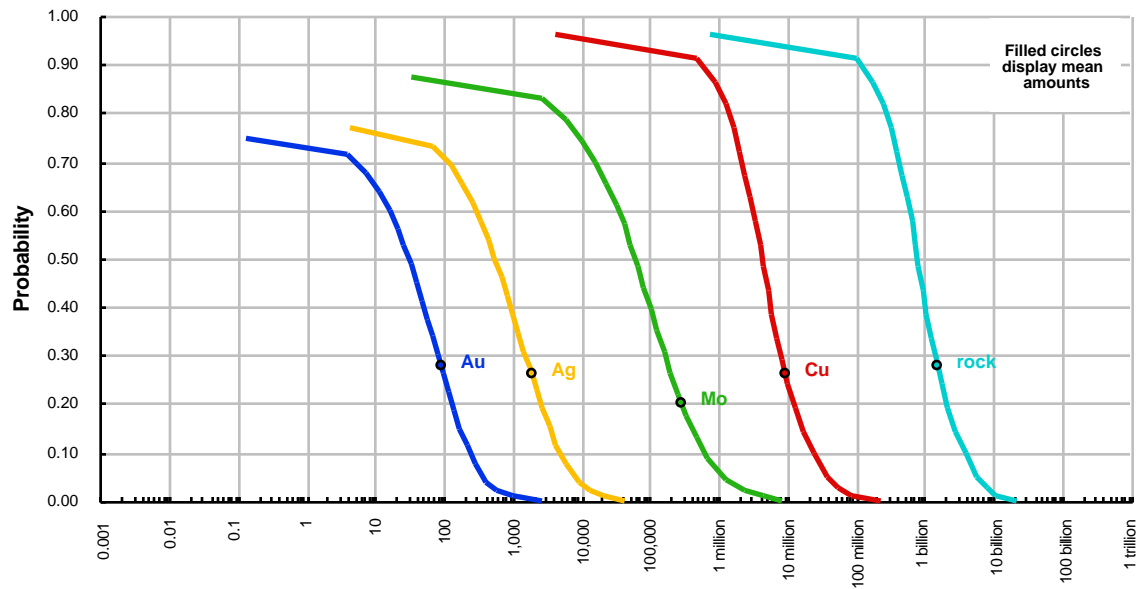
There is a 1% or greater chance of 9 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

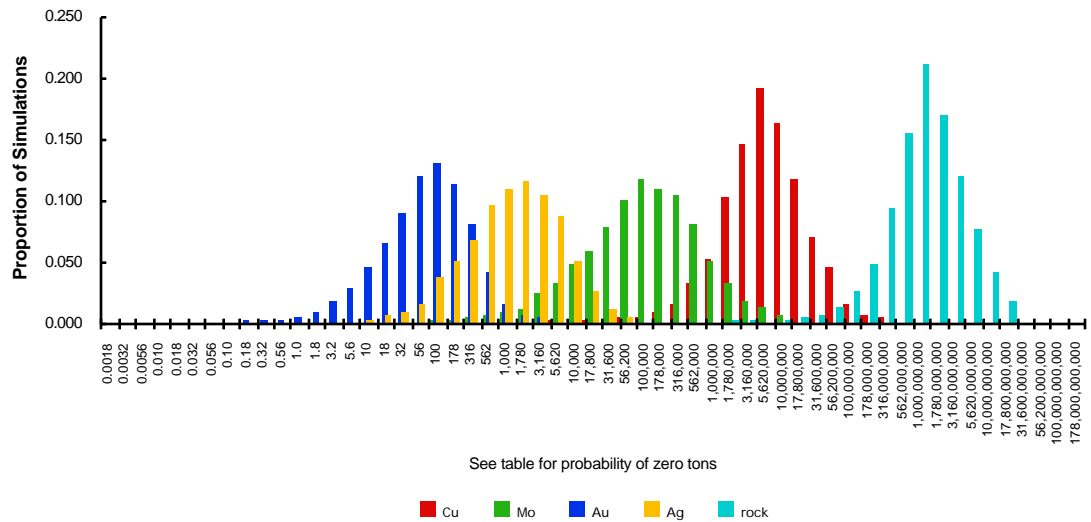
quantile	Cu	Mo	Au	Ag	rock
0.95	150,000	0	0	0	37,000,000
0.90	590,000	0	0	0	130,000,000
0.50	4,400,000	61,000	32	550	780,000,000
0.10	23,000,000	620,000	231	4,900	3,900,000,000
0.05	38,000,000	1,200,000	360	8,300	5,900,000,000
mean	9,600,000	280,000	90	1,900	1,500,000,000
Probability of mean	0.26	0.20	0.28	0.26	0.28
Probability of zero	0.04	0.13	0.25	0.23	0.04

The tract ID is SB15

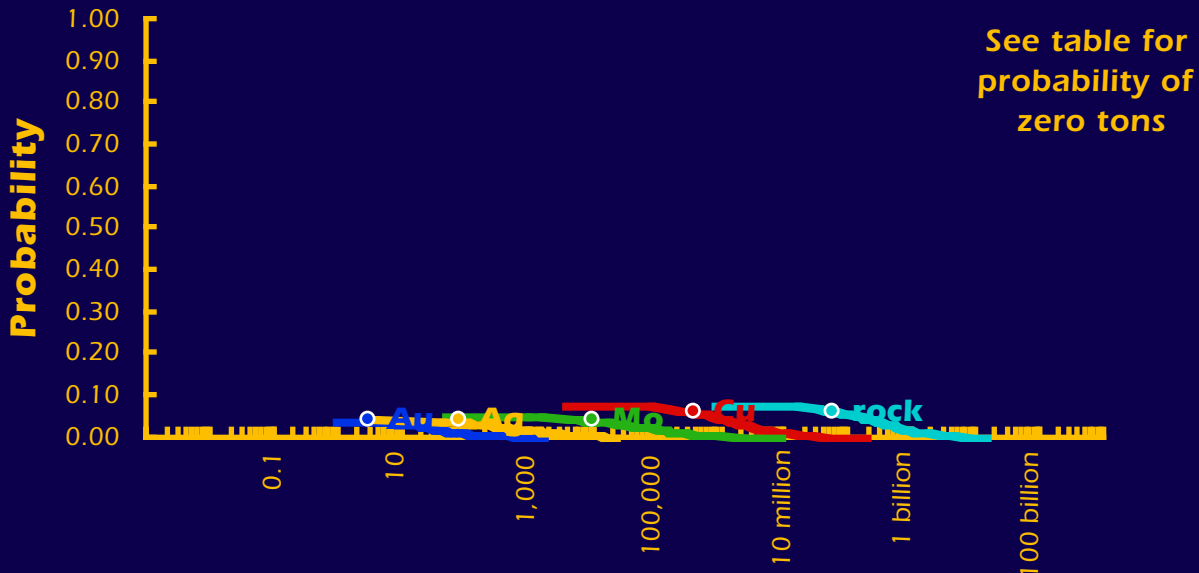
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

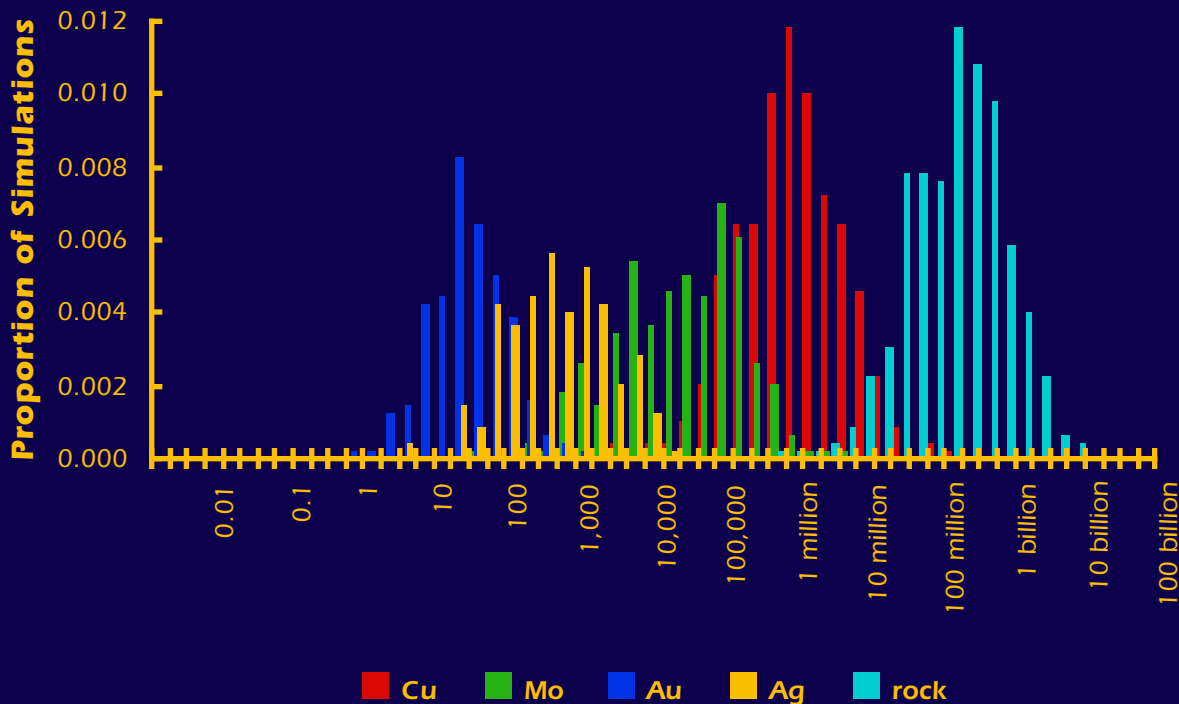


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB16

The Mark3 Index is 4:

Porphry Cu

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	650,000	870	0	0	150,000,000
mean	360,000	9,500	3	75	52,000,000
Probability of mean	0.06	0.04	0.04	0.04	0.06
Probability of zero	0.92	0.95	0.96	0.96	0.92

The tract ID is SB16The Mark3 Index is 4: **Porphyry Cu**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

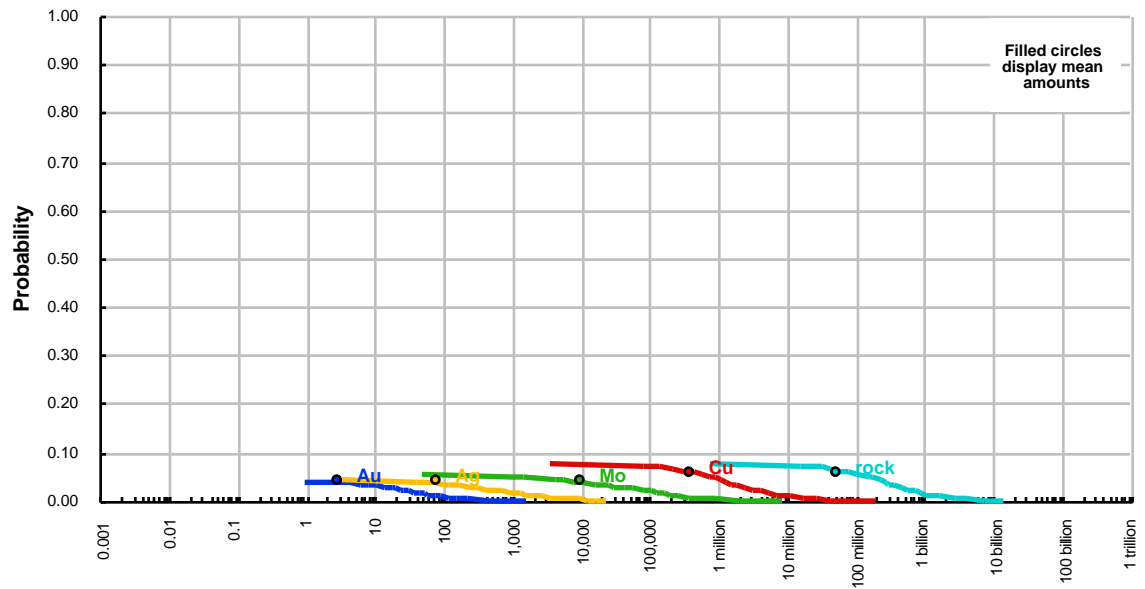
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

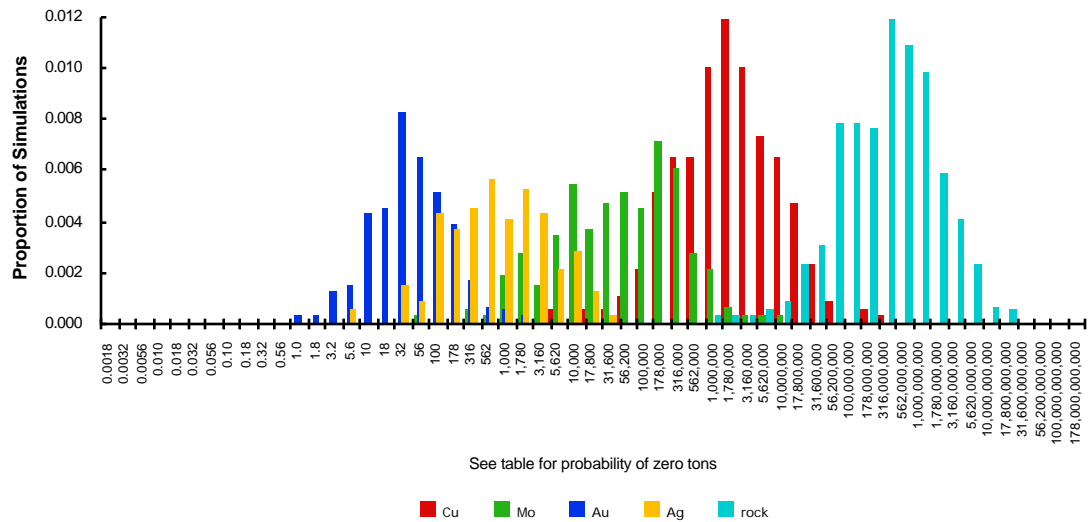
quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	0	0	0	0	0
0.10	0	0	0	0	0
0.05	650,000	870	0	0	150,000,000
mean	360,000	9,500	3	75	52,000,000
Probability of mean	0.06	0.04	0.04	0.04	0.06
Probability of zero	0.92	0.95	0.96	0.96	0.92

The tract ID is SB16

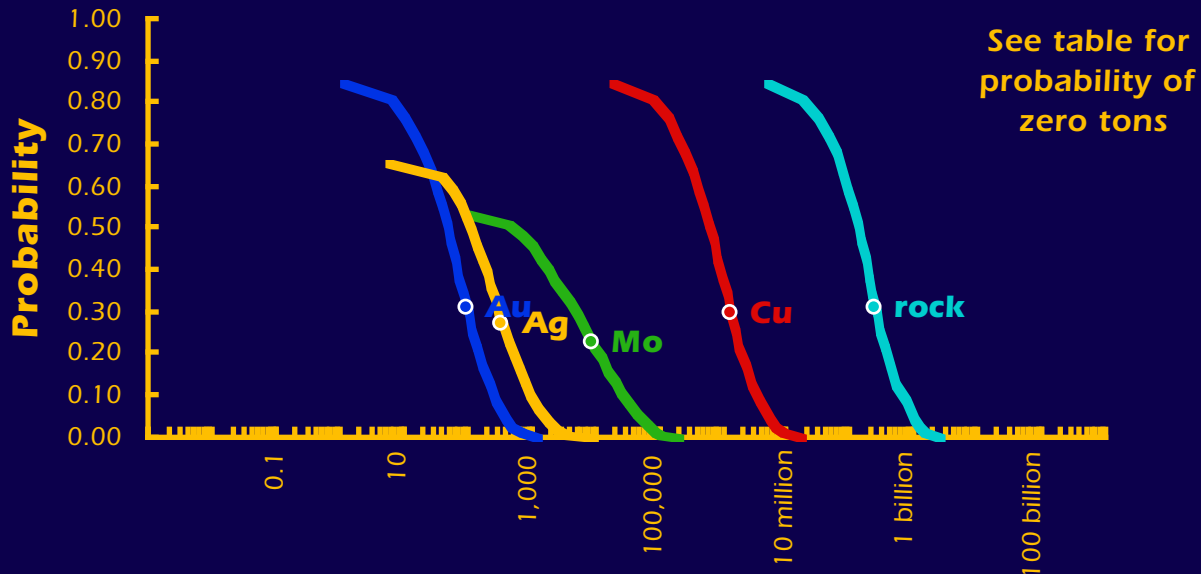
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

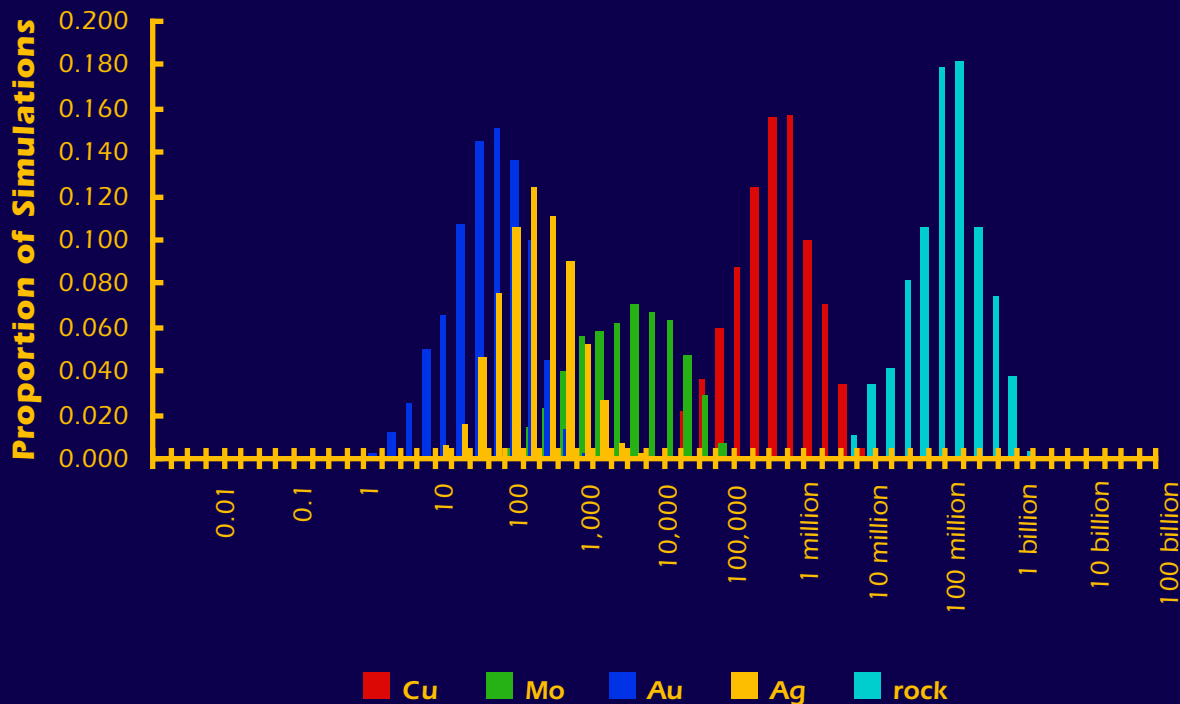


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB17

The Mark3 Index is 34:

Porphyry Cu-Au

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	610,000	520	46	110	130,000,000
0.10	3,400,000	27,000	247	900	630,000,000
0.05	5,100,000	46,000	340	1,400	890,000,000
mean	1,200,000	8,300	93	330	230,000,000
Probability of mean	0.30	0.23	0.31	0.27	0.31
Probability of zero	0.15	0.46	0.15	0.34	0.15

The tract ID is SB17The Mark3 Index is 34: **Porphyry Cu-Au**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

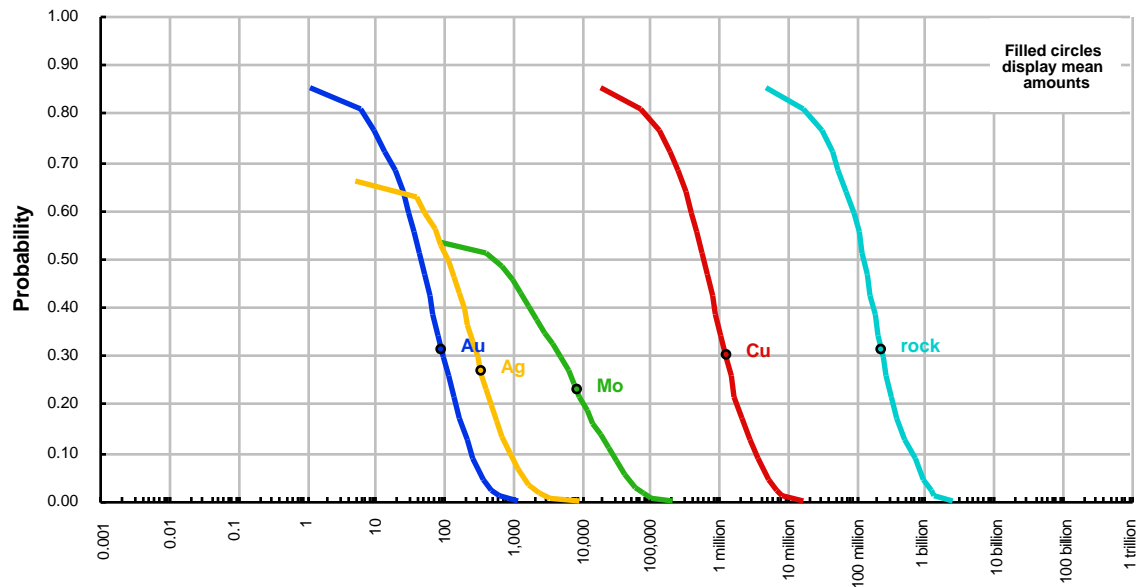
There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

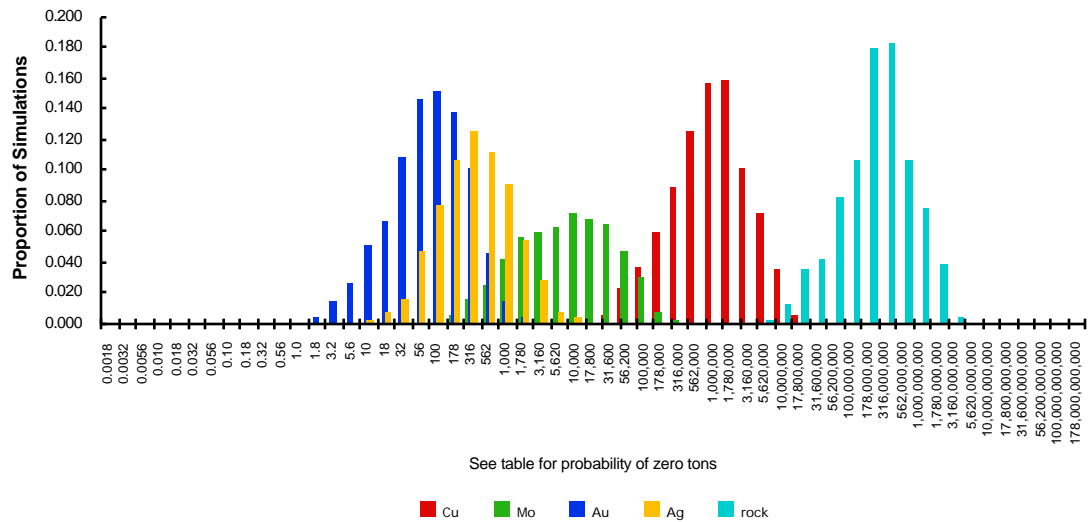
quantile	Cu	Mo	Au	Ag	rock
0.95	0	0	0	0	0
0.90	0	0	0	0	0
0.50	610,000	520	46	110	130,000,000
0.10	3,400,000	27,000	247	900	630,000,000
0.05	5,100,000	46,000	340	1,400	890,000,000
mean	1,200,000	8,300	93	330	230,000,000
Probability of mean	0.30	0.23	0.31	0.27	0.31
Probability of zero	0.15	0.46	0.15	0.34	0.15

The tract ID is SB17

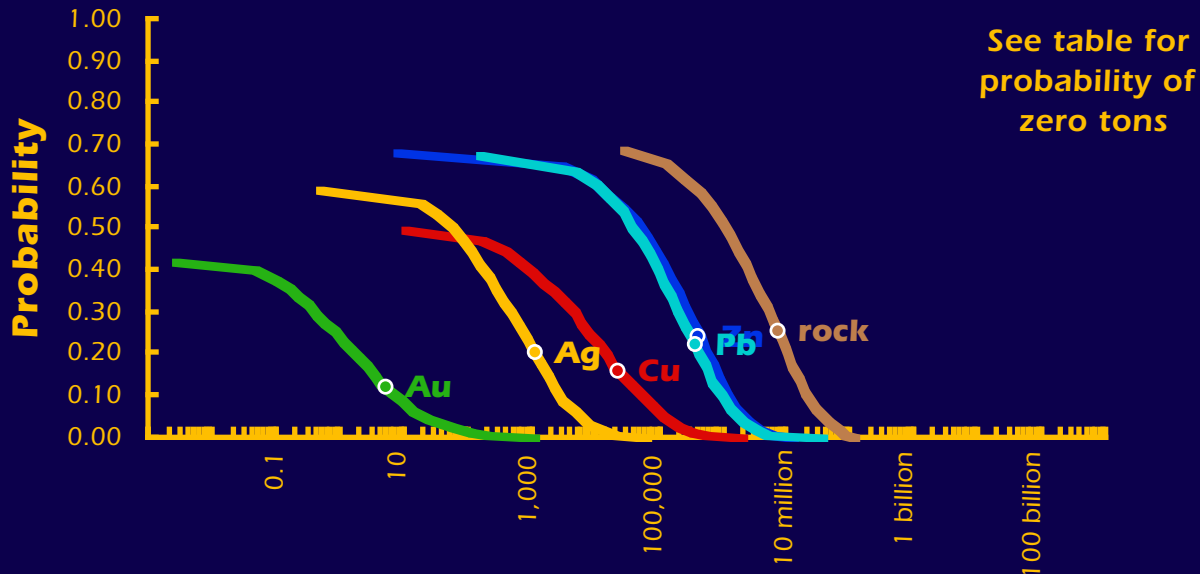
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

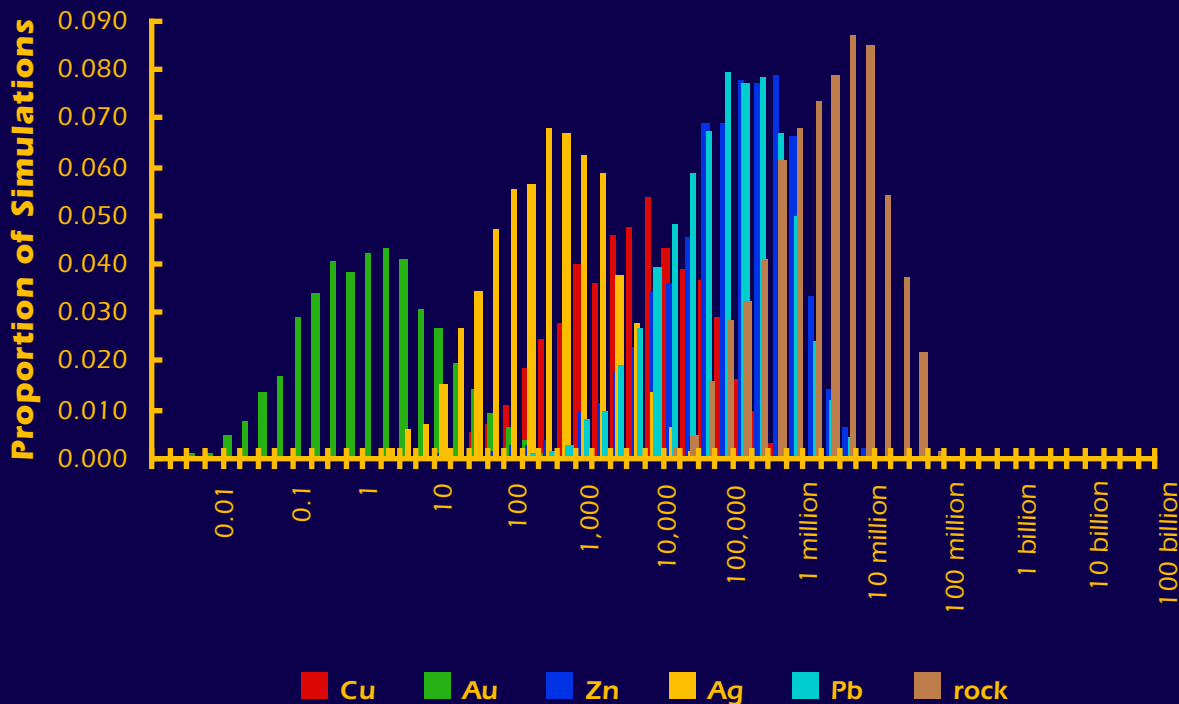


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB18

The Mark3 Index is 92:

Polymetallic Replacement + skarn Zn-Pb

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

There is a 1% or greater chance of 7 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	51,000	56	38,000	1,100,000
0.10	51,000	7	1,170,000	2,700	930,000	21,000,000
0.05	110,000	20	1,900,000	5,500	1,600,000	36,000,000
mean	22,000	5	420,000	1,100	350,000	7,000,000
Probability of mean	0.16	0.12	0.24	0.20	0.22	0.25
Probability of zero	0.50	0.58	0.32	0.41	0.33	0.31

The tract ID is SB18The Mark3 Index is 92: **Polymetallic Replacement + skarn Zn-Pb**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

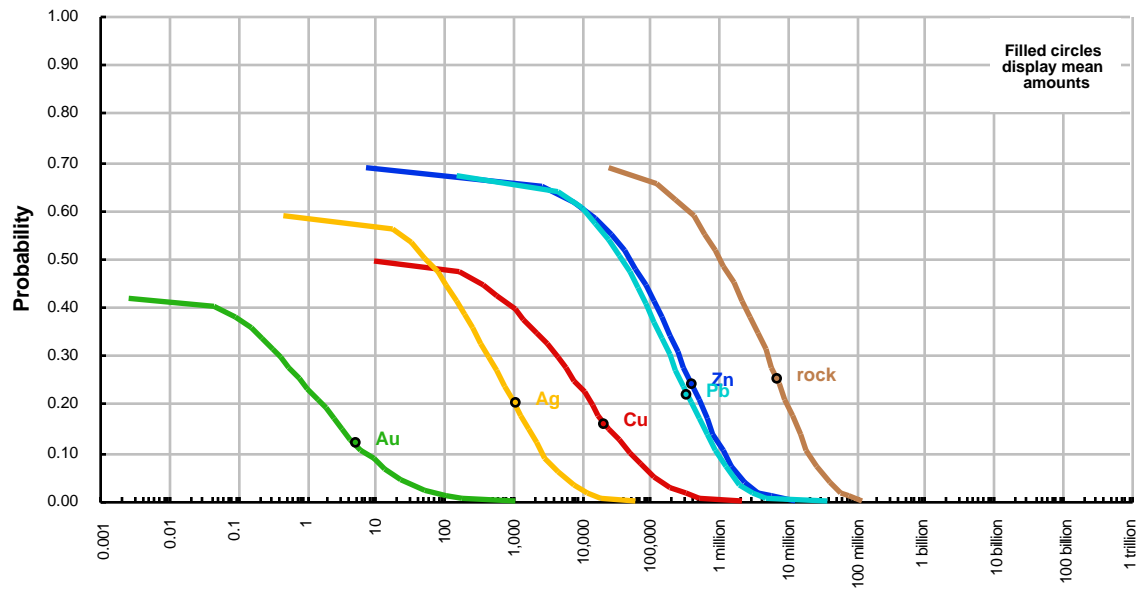
There is a 1% or greater chance of 7 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

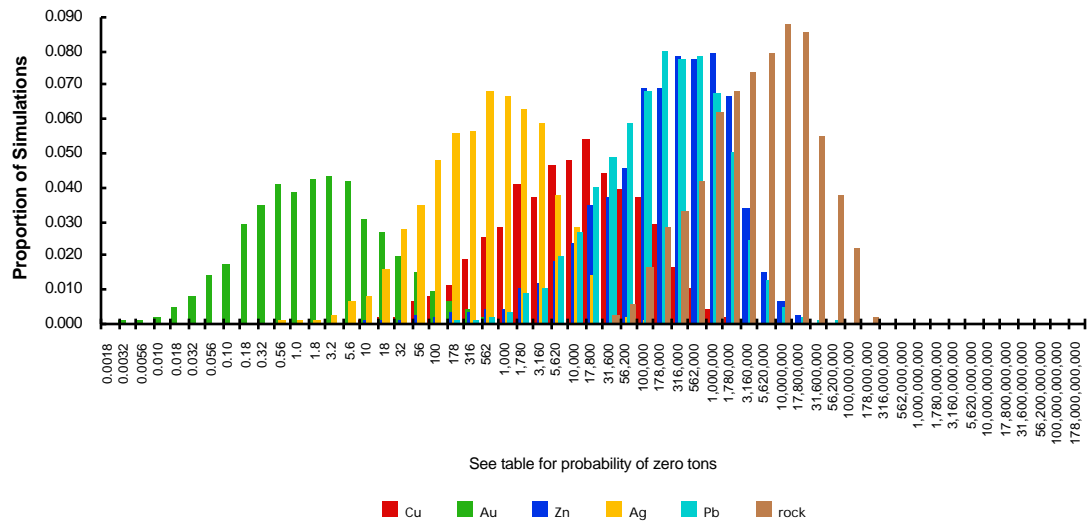
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	51,000	56	38,000	1,100,000
0.10	51,000	7	1,170,000	2,700	930,000	21,000,000
0.05	110,000	20	1,900,000	5,500	1,600,000	36,000,000
mean	22,000	5	420,000	1,100	350,000	7,000,000
Probability of mean	0.16	0.12	0.24	0.20	0.22	0.25
Probability of zero	0.50	0.58	0.32	0.41	0.33	0.31

The tract ID is SB18

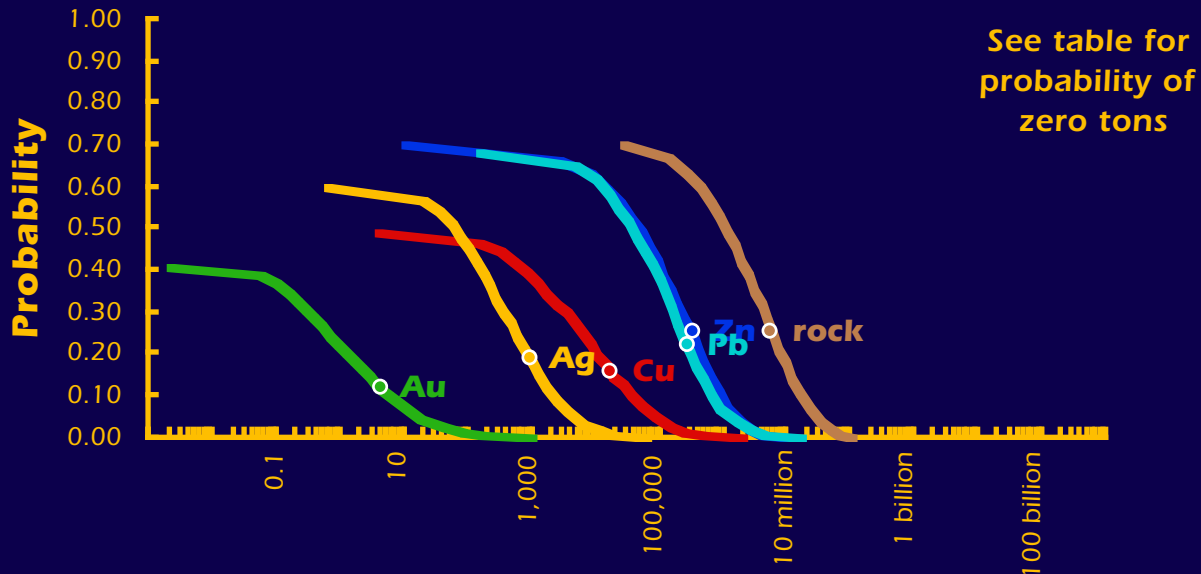
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

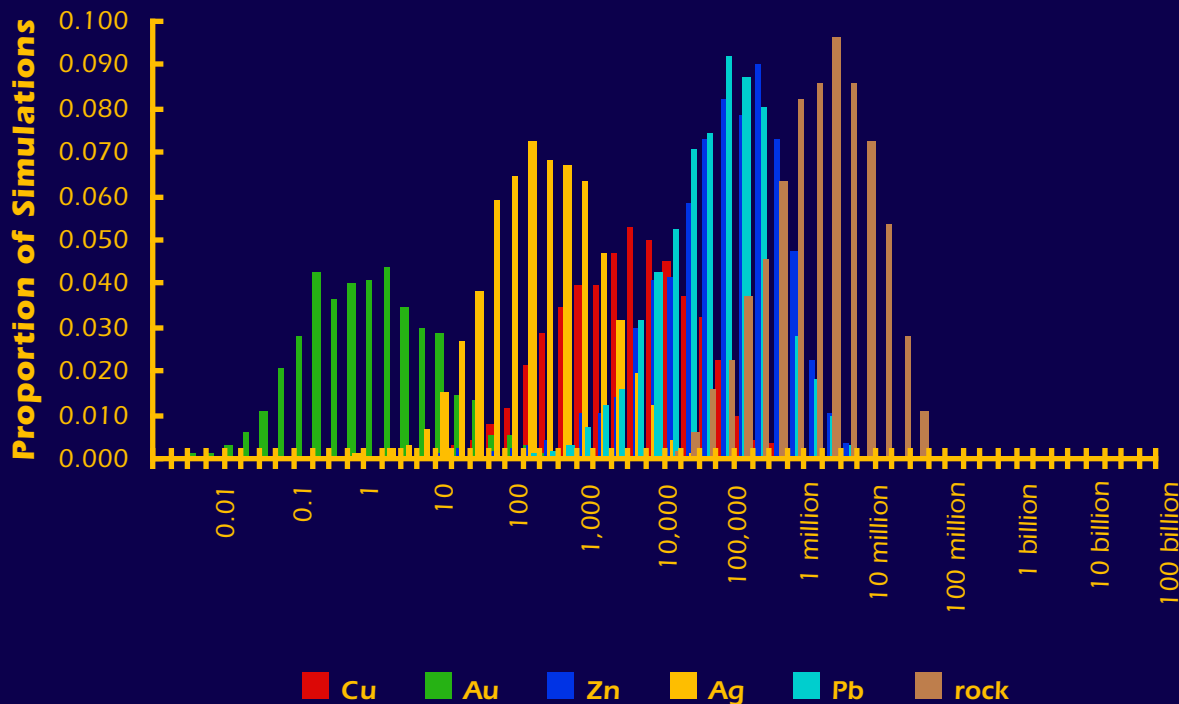


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB19

The Mark3 Index is 92:

Polymetallic Replacement + skarn Zn-Pb

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	47,000	61	38,000	1,100,000
0.10	36,000	6	857,000	2,100	650,000	17,000,000
0.05	84,000	15	1,500,000	4,300	1,200,000	26,000,000
mean	17,000	4	310,000	880	270,000	5,600,000
Probability of mean	0.16	0.12	0.25	0.19	0.22	0.25
Probability of zero	0.51	0.59	0.30	0.40	0.32	0.30

The tract ID is SB19The Mark3 Index is 92: **Polymetallic Replacement + skarn Zn-Pb**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

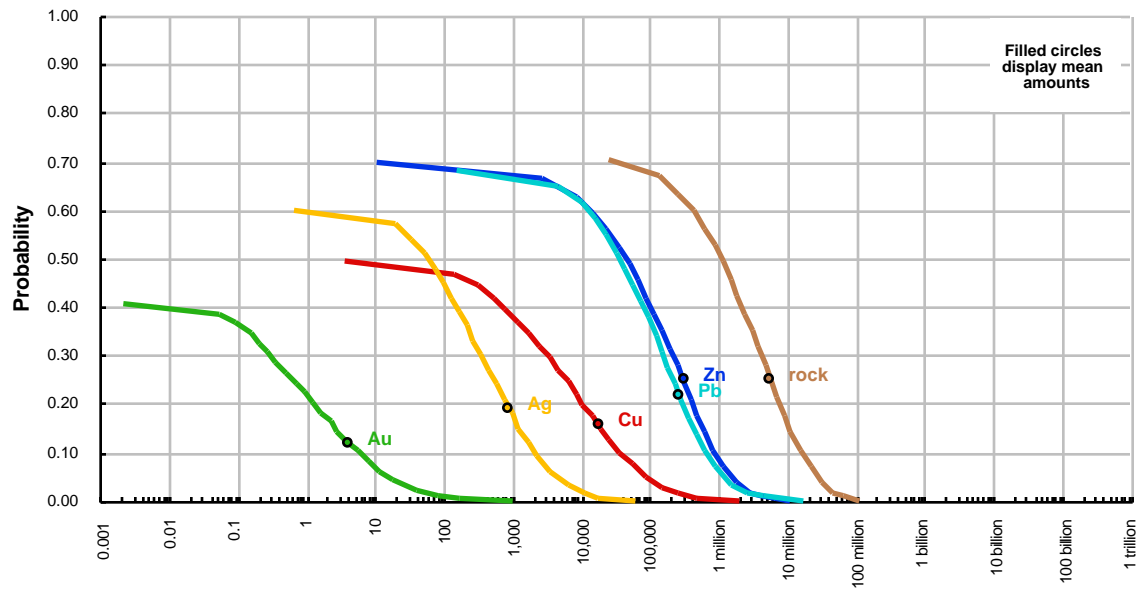
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

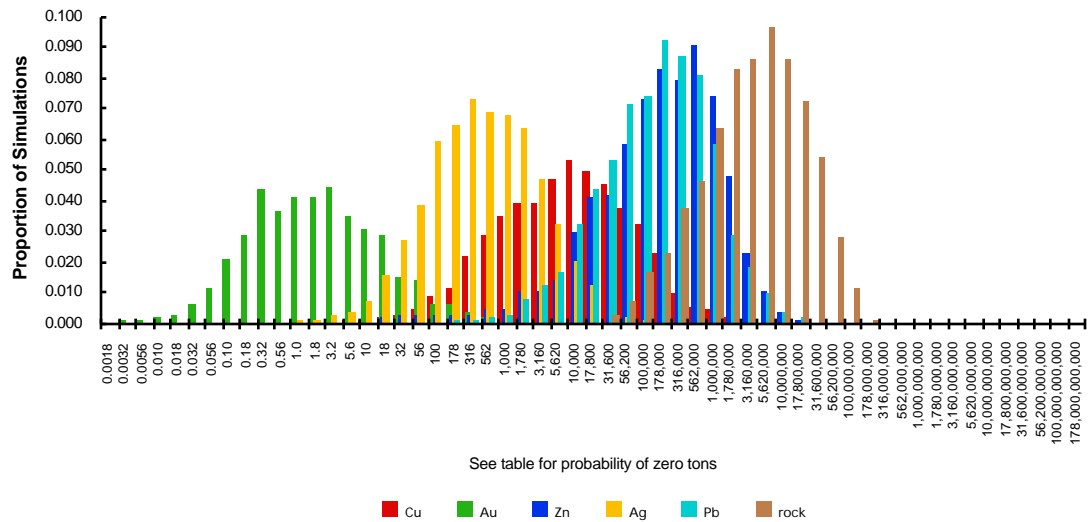
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	47,000	61	38,000	1,100,000
0.10	36,000	6	857,000	2,100	650,000	17,000,000
0.05	84,000	15	1,500,000	4,300	1,200,000	26,000,000
mean	17,000	4	310,000	880	270,000	5,600,000
Probability of mean	0.16	0.12	0.25	0.19	0.22	0.25
Probability of zero	0.51	0.59	0.30	0.40	0.32	0.30

The tract ID is SB19

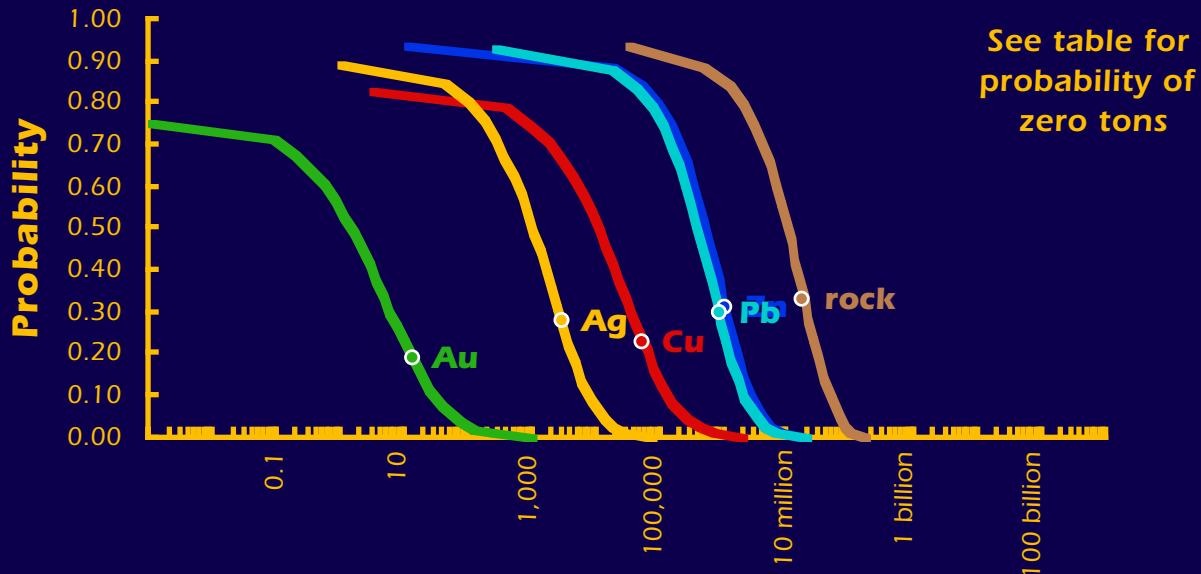
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

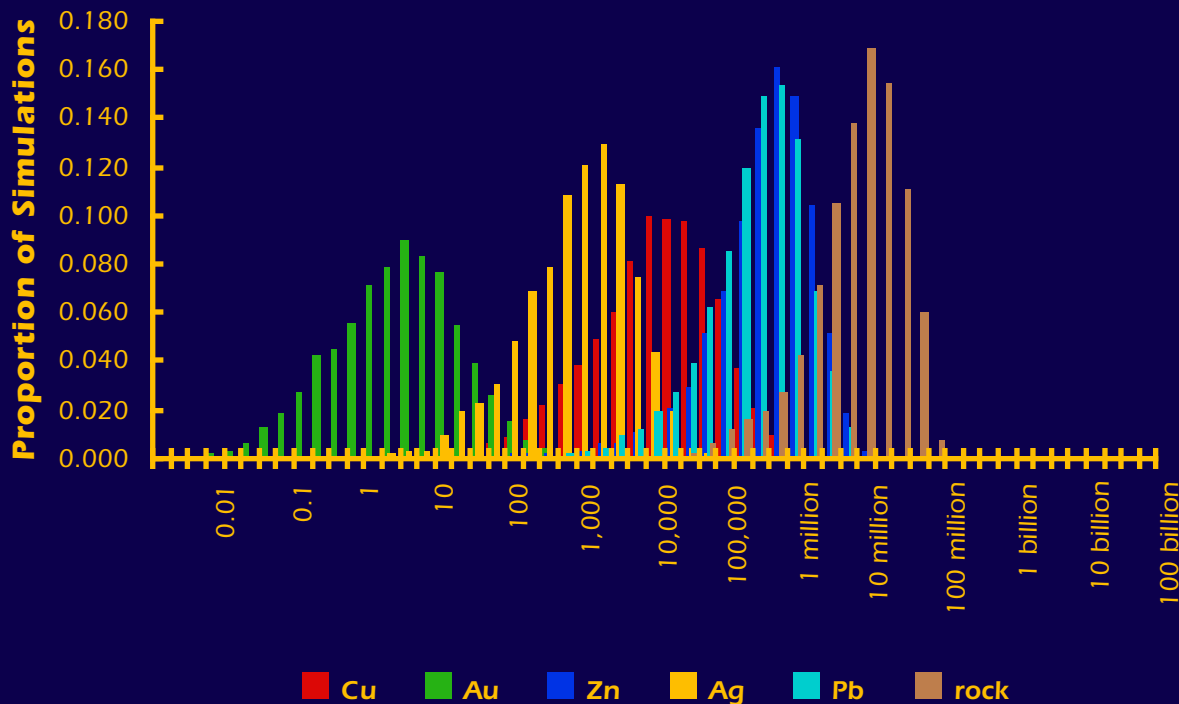


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB20

The Mark3 Index is 92:

Polymetallic Replacement + skarn Zn-Pb

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 7 or more deposits.

There is a 1% or greater chance of 10 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	11,000	0	11,000	330,000
0.50	11,000	1	530,000	1,000	390,000	10,000,000
0.10	130,000	29	2,650,000	7,500	2,000,000	46,000,000
0.05	240,000	58	3,800,000	13,000	3,100,000	65,000,000
mean	53,000	13	1,000,000	2,900	820,000	18,000,000
Probability of mean	0.23	0.19	0.31	0.28	0.30	0.33
Probability of zero	0.17	0.25	0.07	0.11	0.07	0.06

The tract ID is SB20The Mark3 Index is 92: **Polymetallic Replacement + skarn Zn-Pb**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 7 or more deposits.

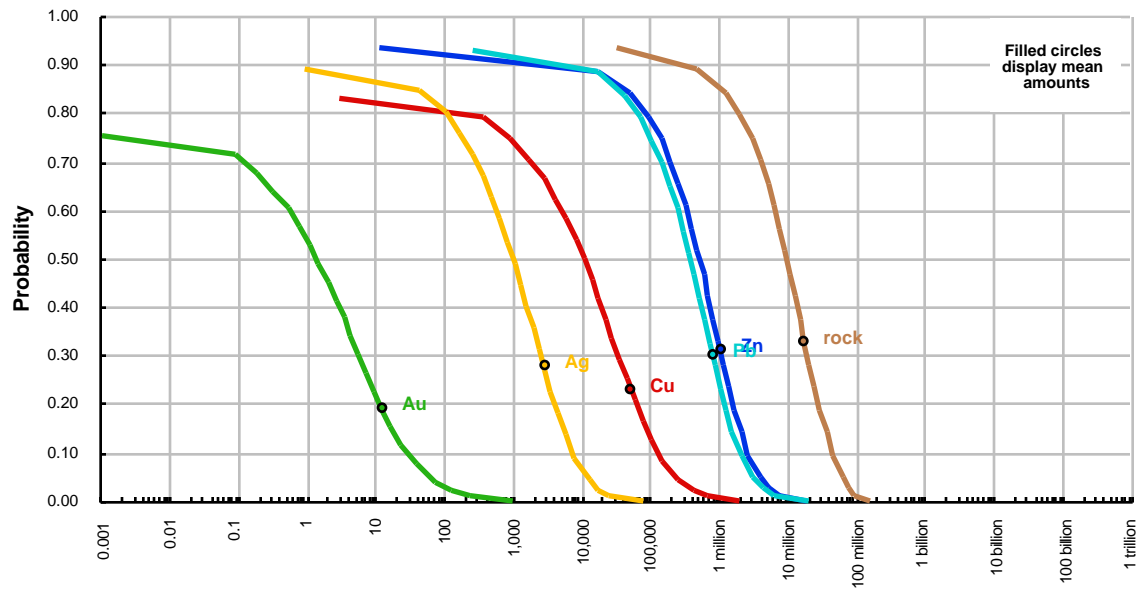
There is a 1% or greater chance of 10 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

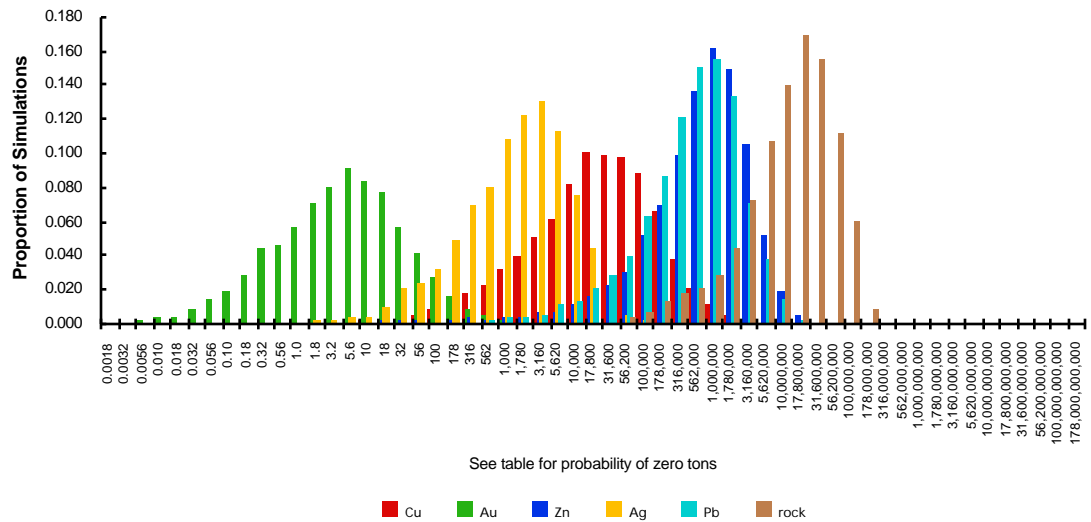
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	11,000	0	11,000	330,000
0.50	11,000	1	530,000	1,000	390,000	10,000,000
0.10	130,000	29	2,650,000	7,500	2,000,000	46,000,000
0.05	240,000	58	3,800,000	13,000	3,100,000	65,000,000
mean	53,000	13	1,000,000	2,900	820,000	18,000,000
Probability of mean	0.23	0.19	0.31	0.28	0.30	0.33
Probability of zero	0.17	0.25	0.07	0.11	0.07	0.06

The tract ID is SB20

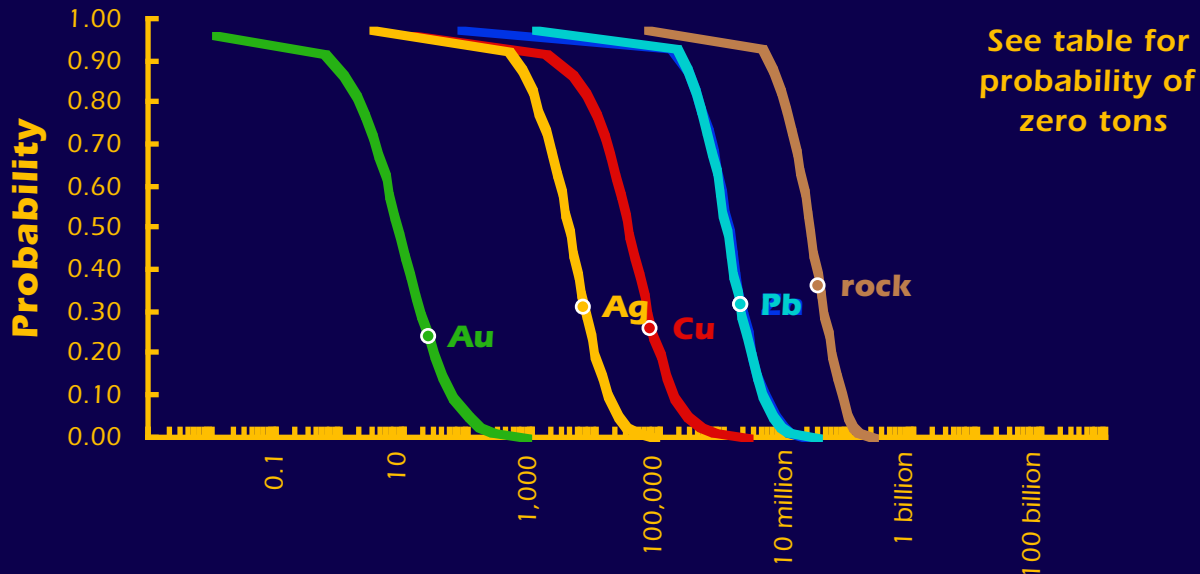
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

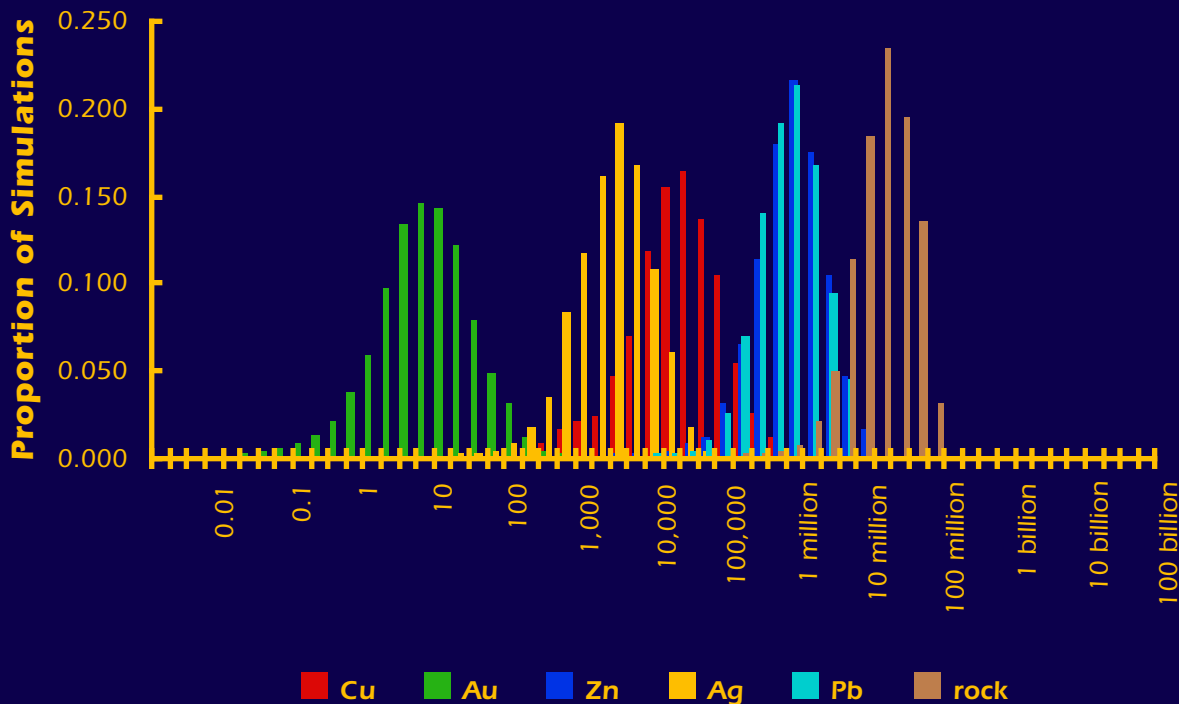


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB21

The Mark3 Index is 47:

Polymetallic replacement

There is a 90% or greater chance of 4 or more deposits.

There is a 50% or greater chance of 5 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 8 or more deposits.

There is a 1% or greater chance of 10 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	470	0	85,000	240	120,000	2,500,000
0.90	2,300	1	210,000	610	240,000	5,200,000
0.50	32,000	8	1,200,000	3,600	1,100,000	22,000,000
0.10	170,000	55	4,460,000	16,000	4,100,000	74,000,000
0.05	270,000	97	6,300,000	22,000	6,100,000	90,000,000
mean	73,000	23	1,900,000	6,400	1,800,000	31,000,000
Probability of mean	0.26	0.24	0.32	0.31	0.32	0.36
Probability of zero	0.04	0.04	0.02	0.03	0.02	0.02

The tract ID is SB21The Mark3 Index is 47: **Polymetallic replacement**

There is a 90% or greater chance of 4 or more deposits.

There is a 50% or greater chance of 5 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 8 or more deposits.

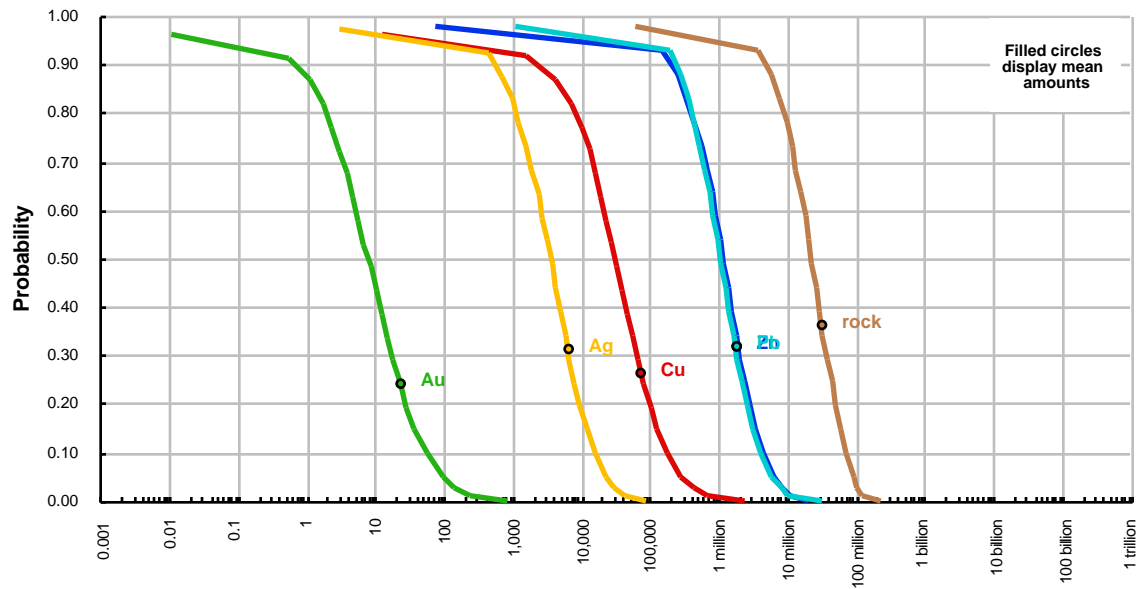
There is a 1% or greater chance of 10 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

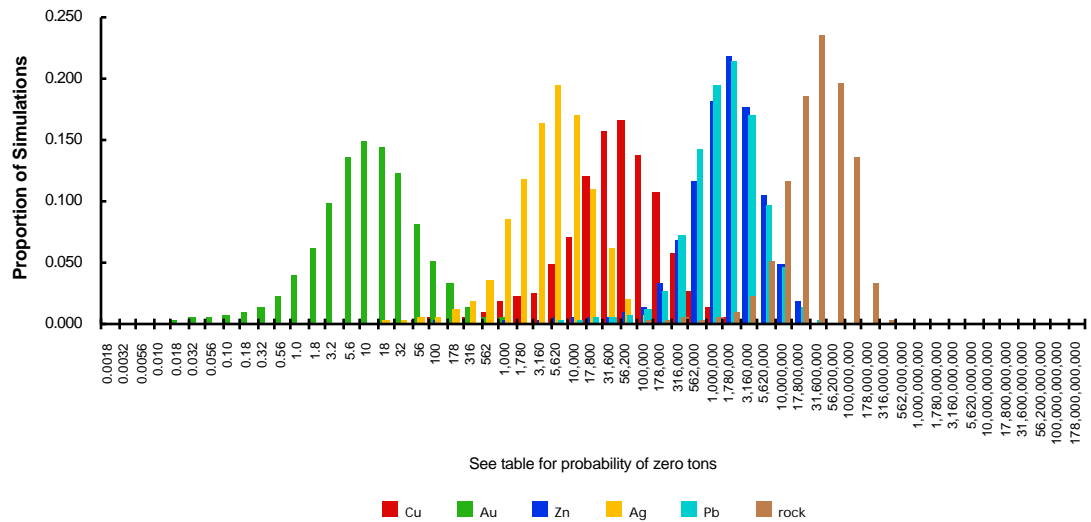
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	470	0	85,000	240	120,000	2,500,000
0.90	2,300	1	210,000	610	240,000	5,200,000
0.50	32,000	8	1,200,000	3,600	1,100,000	22,000,000
0.10	170,000	55	4,460,000	16,000	4,100,000	74,000,000
0.05	270,000	97	6,300,000	22,000	6,100,000	90,000,000
mean	73,000	23	1,900,000	6,400	1,800,000	31,000,000
Probability of mean	0.26	0.24	0.32	0.31	0.32	0.36
Probability of zero	0.04	0.04	0.02	0.03	0.02	0.02

The tract ID is SB21

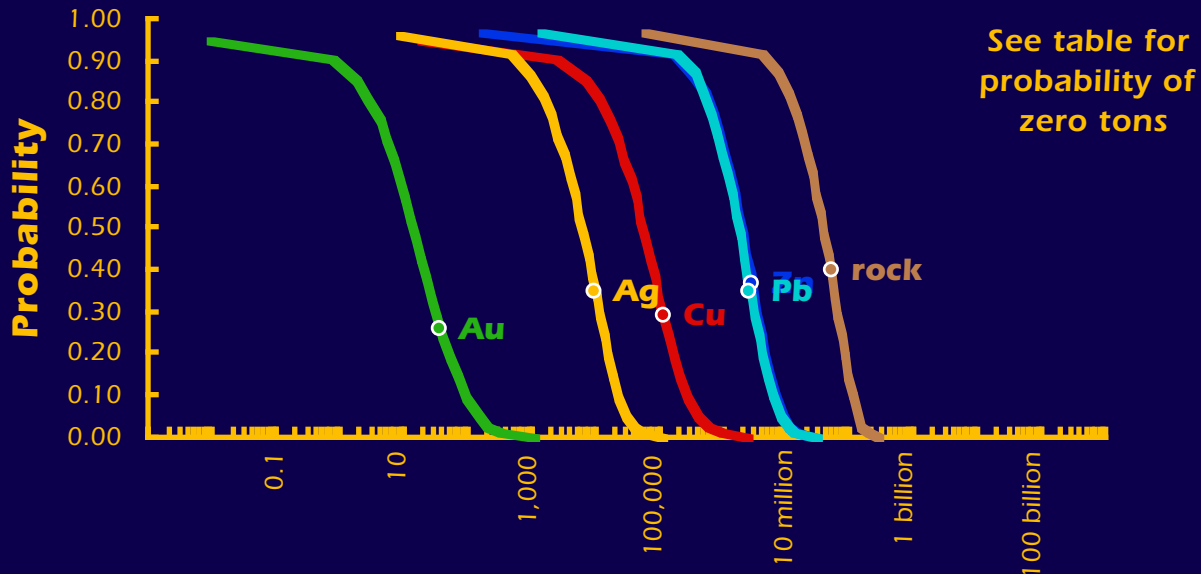
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

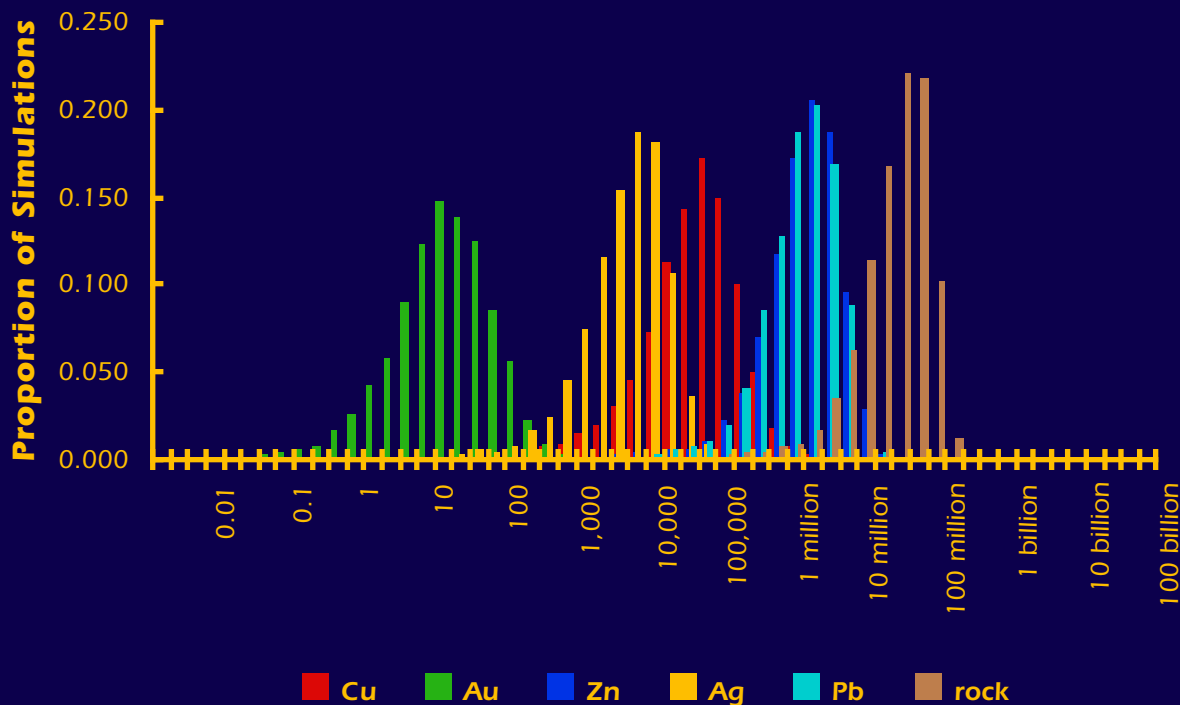


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB22

The Mark3 Index is 47:

Polymetallic replacement

There is a 90% or greater chance of 3 or more deposits.
There is a 50% or greater chance of 7 or more deposits.
There is a 10% or greater chance of 12 or more deposits.
There is a 5% or greater chance of 14 or more deposits.
There is a 1% or greater chance of 18 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	28,000	130	62,000	1,100,000
0.90	2,800	1	230,000	620	250,000	5,300,000
0.50	55,000	14	1,900,000	6,000	1,700,000	36,000,000
0.10	260,000	92	6,330,000	23,000	6,000,000	100,000,000
0.05	400,000	140	8,400,000	30,000	8,000,000	130,000,000
mean	110,000	35	2,800,000	9,500	2,600,000	47,000,000
Probability of mean	0.29	0.26	0.37	0.35	0.35	0.40
Probability of zero	0.05	0.05	0.03	0.04	0.03	0.03

The tract ID is SB22The Mark3 Index is 47: **Polymetallic replacement**

There is a 90% or greater chance of 3 or more deposits.

There is a 50% or greater chance of 7 or more deposits.

There is a 10% or greater chance of 12 or more deposits.

There is a 5% or greater chance of 14 or more deposits.

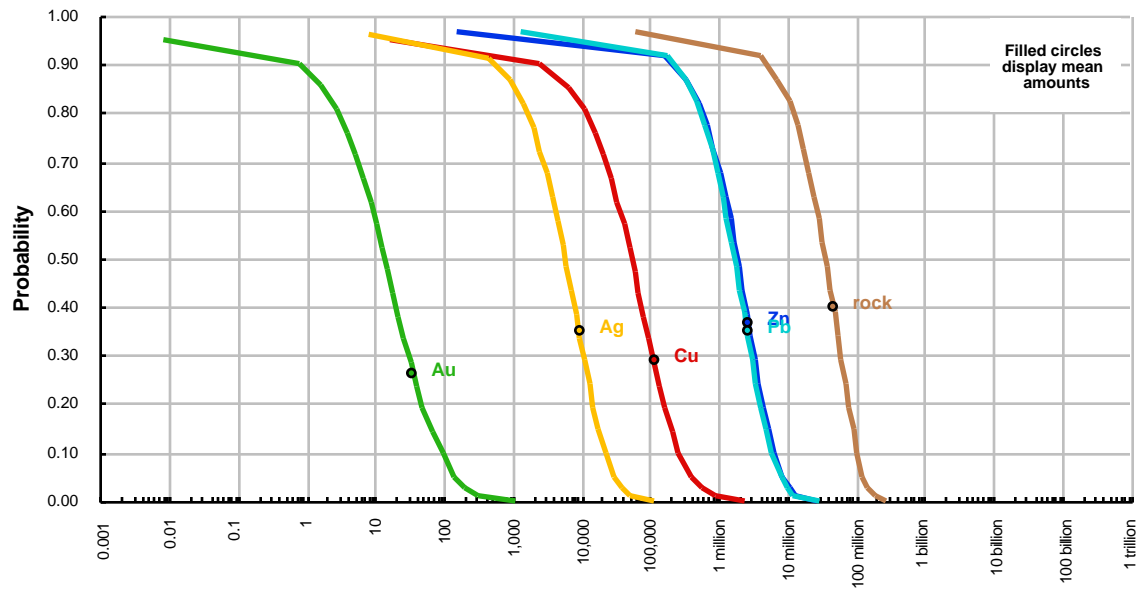
There is a 1% or greater chance of 18 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

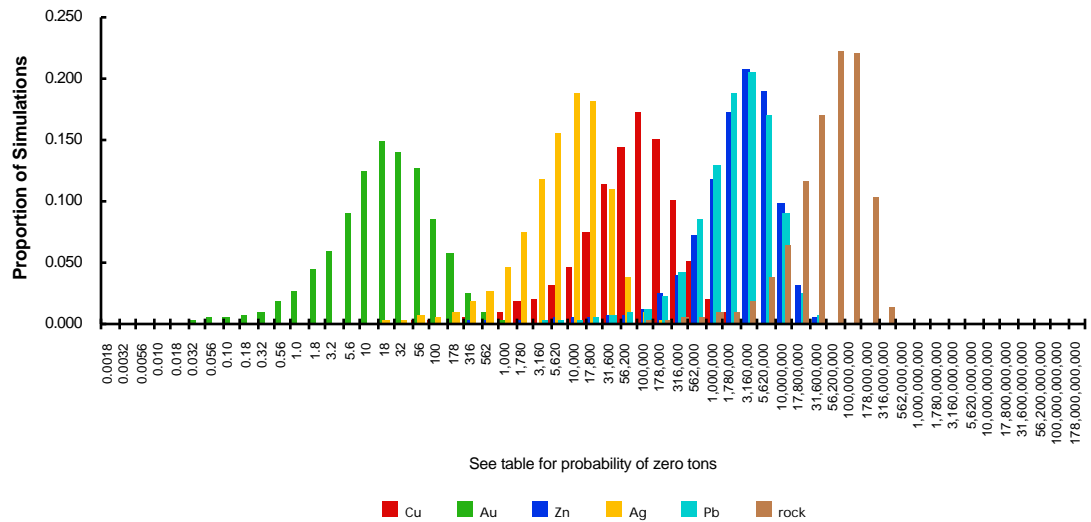
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	28,000	130	62,000	1,100,000
0.90	2,800	1	230,000	620	250,000	5,300,000
0.50	55,000	14	1,900,000	6,000	1,700,000	36,000,000
0.10	260,000	92	6,330,000	23,000	6,000,000	100,000,000
0.05	400,000	140	8,400,000	30,000	8,000,000	130,000,000
mean	110,000	35	2,800,000	9,500	2,600,000	47,000,000
Probability of mean	0.29	0.26	0.37	0.35	0.35	0.40
Probability of zero	0.05	0.05	0.03	0.04	0.03	0.03

The tract ID is SB22

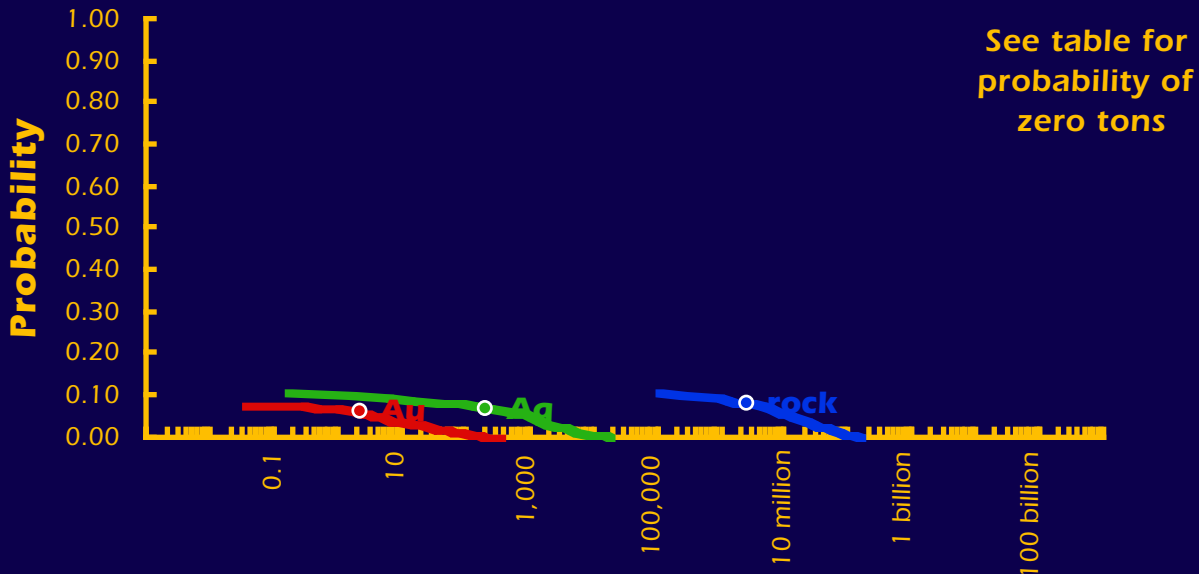
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

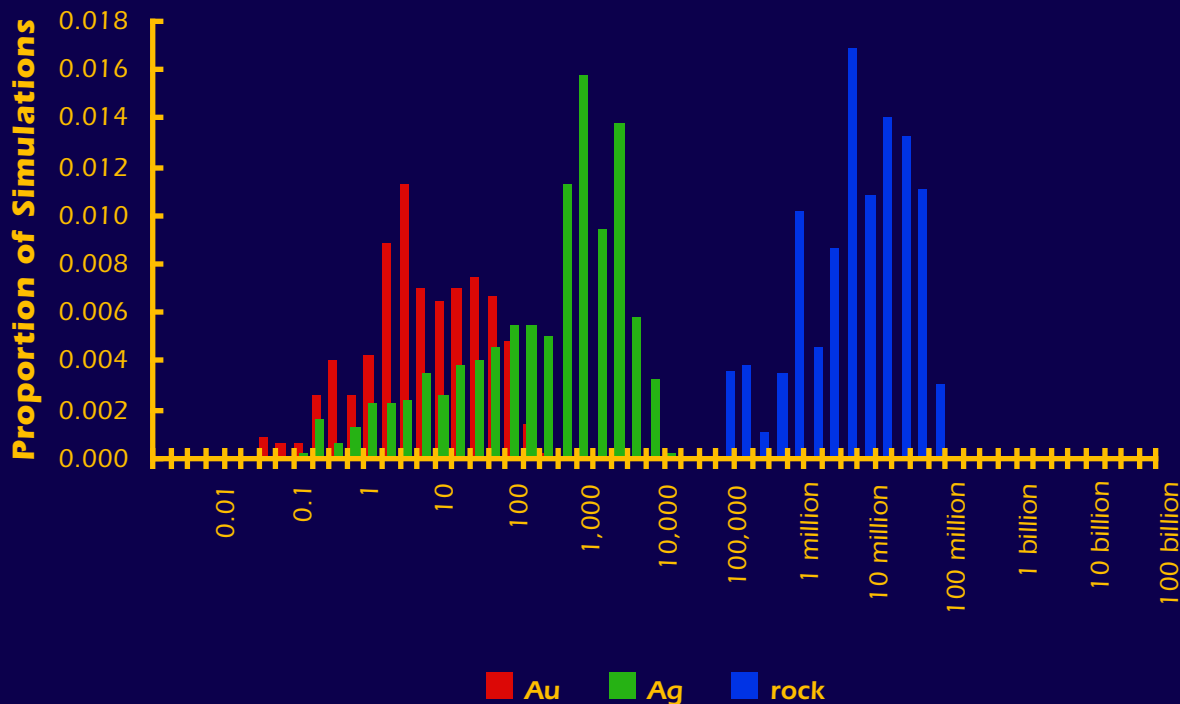


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB23

The Mark3 Index is 18:

Distal disseminated Ag-Au

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	1	199,000
0.05	3	920	12,000,000
mean	2	200	2,500,000
Probability of mean	0.06	0.07	0.08
Probability of zero	0.92	0.90	0.90

The tract ID is SB23The Mark3 Index is 18: **Distal disseminated Ag-Au**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

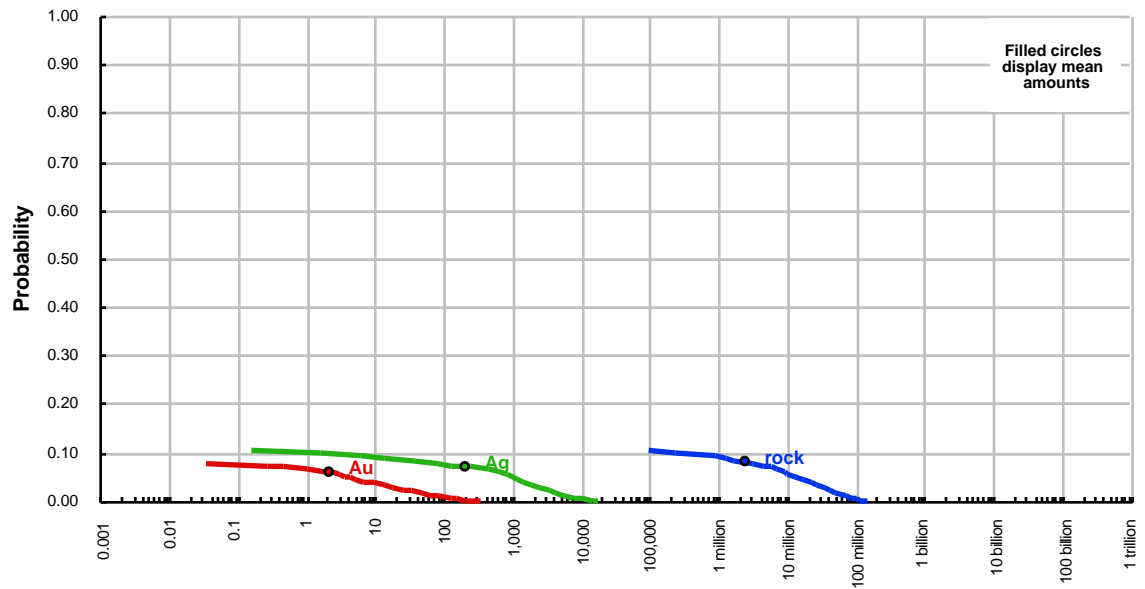
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

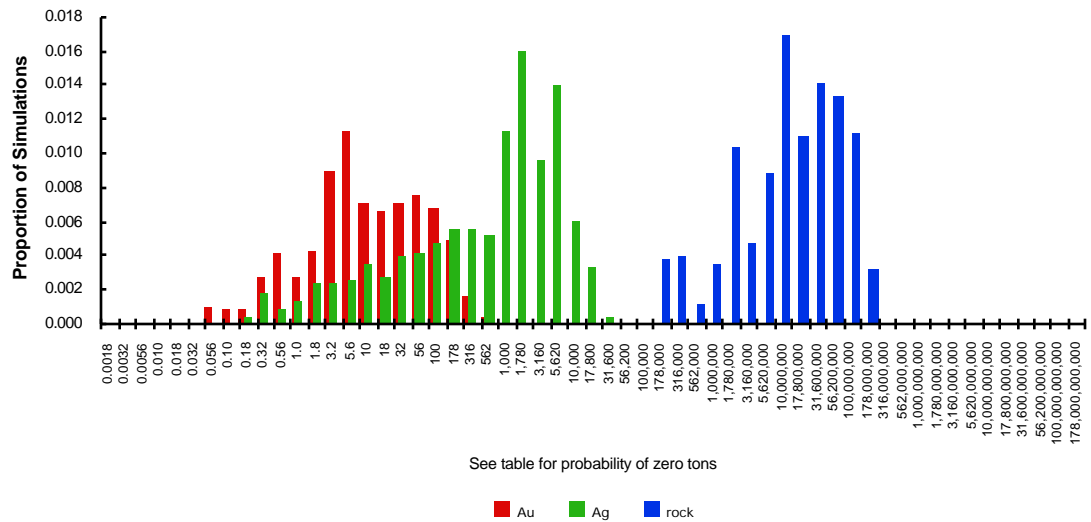
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	1	199,000
0.05	3	920	12,000,000
mean	2	200	2,500,000
Probability of mean	0.06	0.07	0.08
Probability of zero	0.92	0.90	0.90

The tract ID is SB23

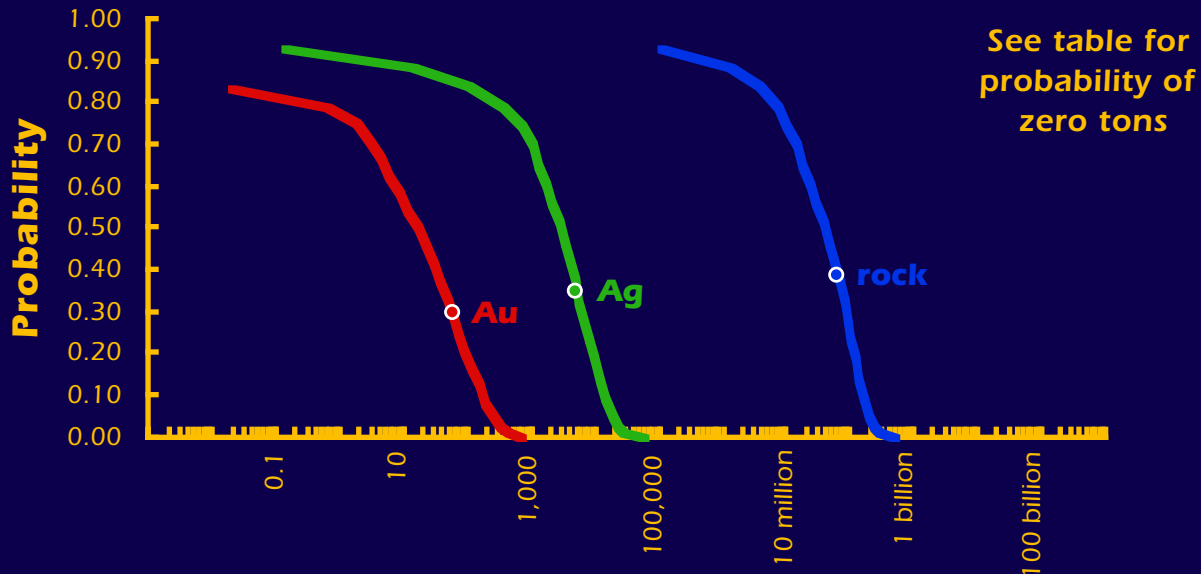
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

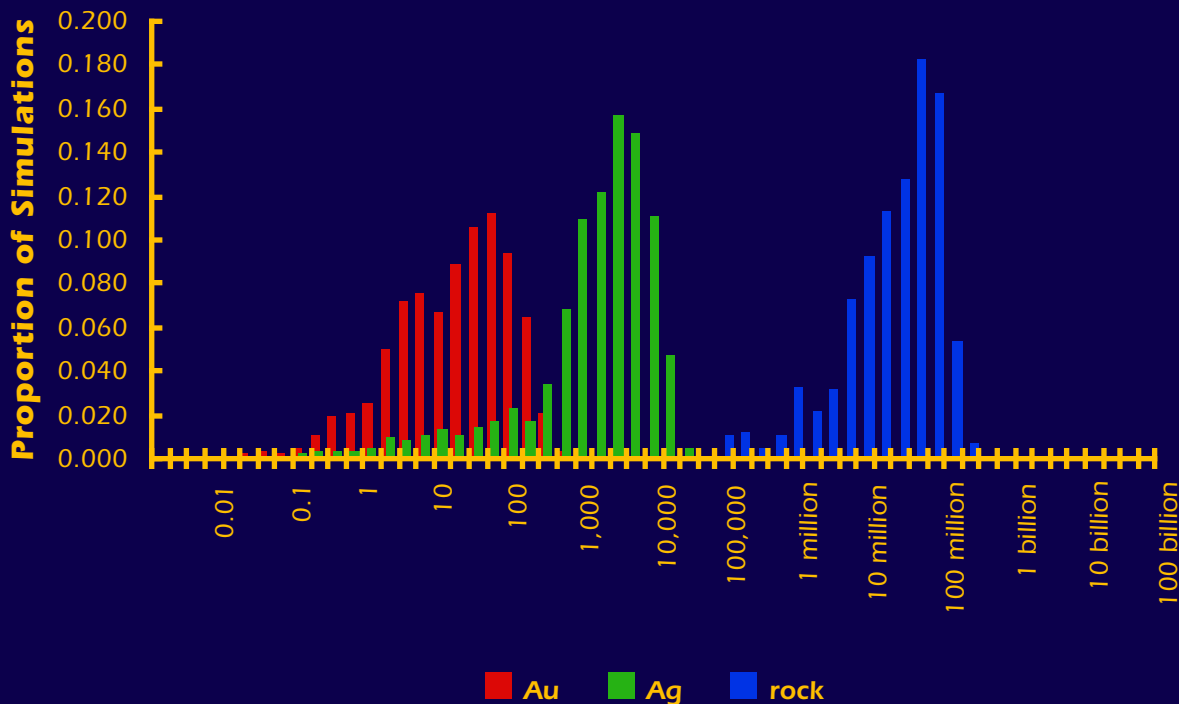


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB24

The Mark3 Index is 18:

Distal disseminated Ag-Au

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 7 or more deposits.

There is a 1% or greater chance of 10 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	6	900,000
0.50	16	2,700	37,000,000
0.10	170	13,000	148,000,000
0.05	240	18,000	190,000,000
mean	55	5,000	61,000,000
Probability of mean	0.30	0.35	0.39
Probability of zero	0.17	0.07	0.07

The tract ID is SB24The Mark3 Index is 18: **Distal disseminated Ag-Au**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 7 or more deposits.

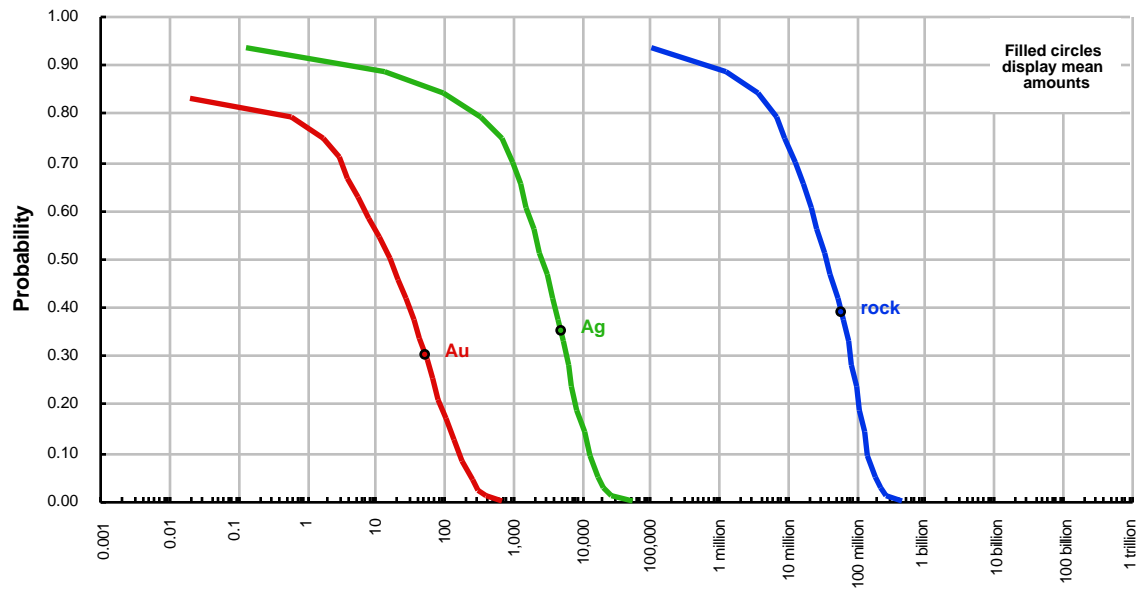
There is a 1% or greater chance of 10 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

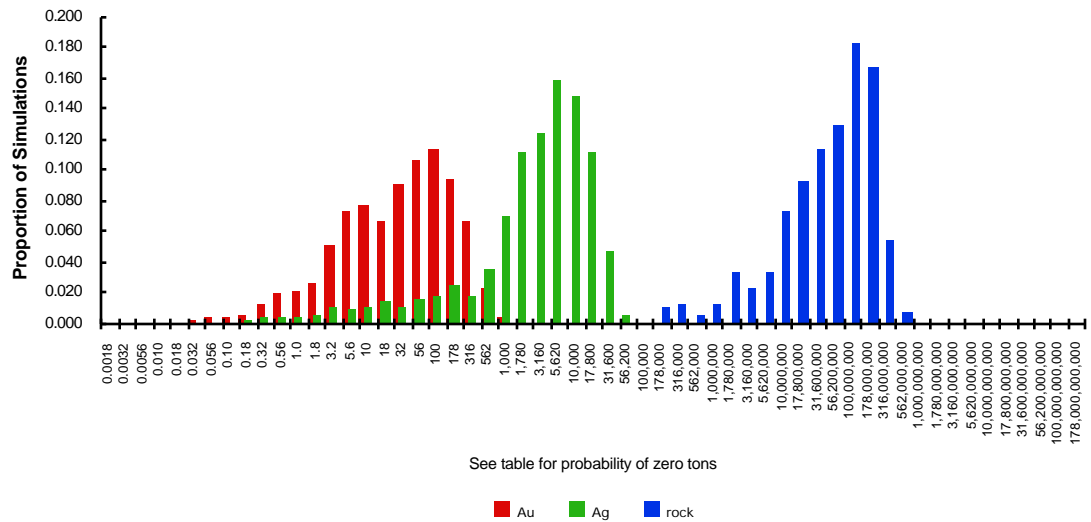
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	6	900,000
0.50	16	2,700	37,000,000
0.10	170	13,000	148,000,000
0.05	240	18,000	190,000,000
mean	55	5,000	61,000,000
Probability of mean	0.30	0.35	0.39
Probability of zero	0.17	0.07	0.07

The tract ID is SB24

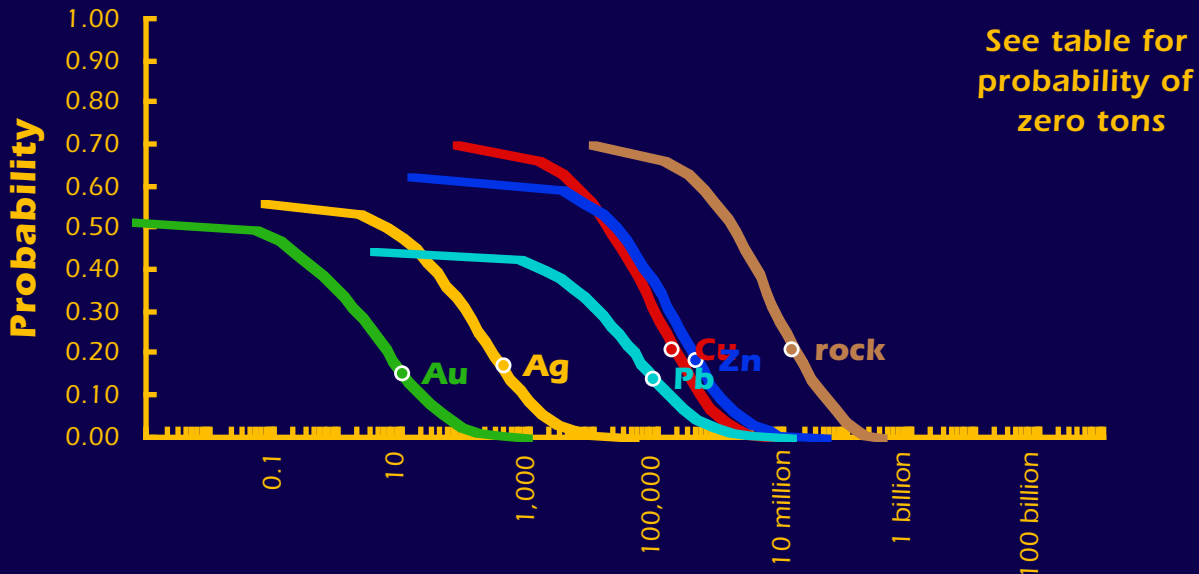
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

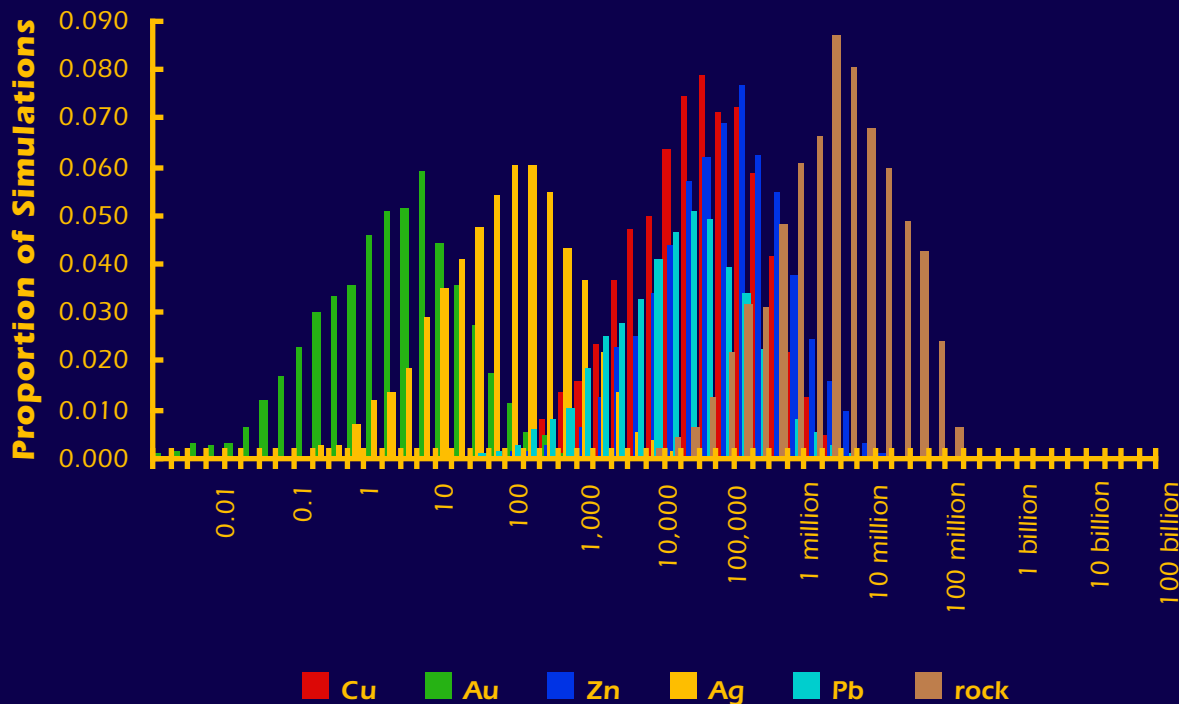


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB25

The Mark3 Index is 93:

Massive sulfide, kuroko

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 7 or more deposits.

There is a 1% or greater chance of 7 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	18,000	0	22,000	7	0	1,500,000
0.10	460,000	18	891,000	770	150,000	40,000,000
0.05	830,000	43	1,900,000	1,700	350,000	72,000,000
mean	180,000	10	410,000	370	83,000	13,000,000
Probability of mean	0.21	0.15	0.18	0.17	0.14	0.21
Probability of zero	0.30	0.48	0.37	0.44	0.55	0.30

The tract ID is SB25The Mark3 Index is 93: **Massive sulfide, kuroko**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 3 or more deposits.

There is a 5% or greater chance of 7 or more deposits.

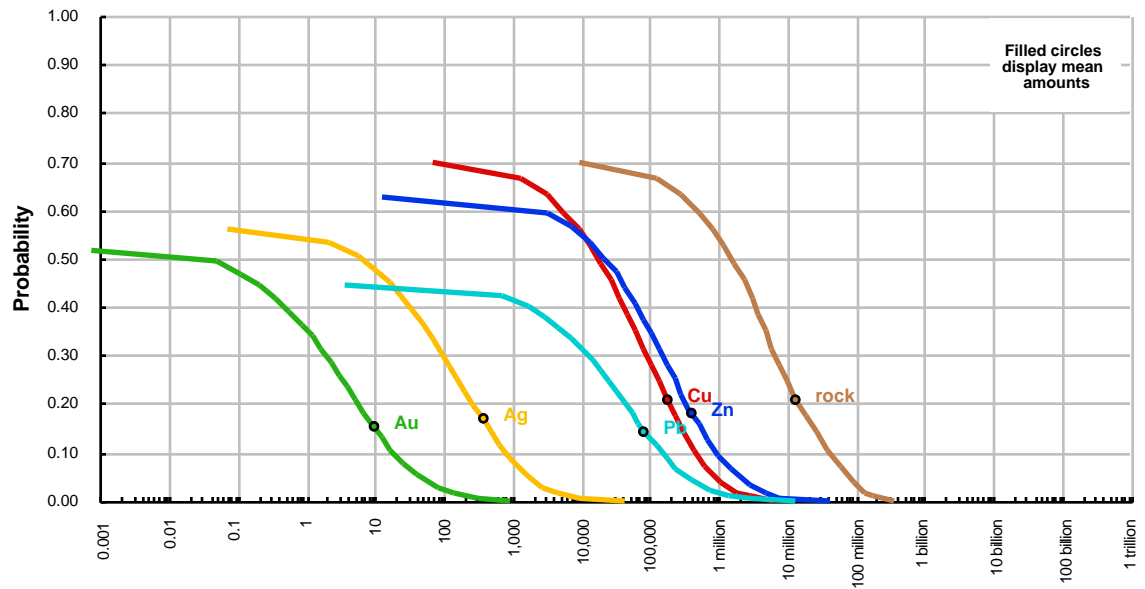
There is a 1% or greater chance of 7 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

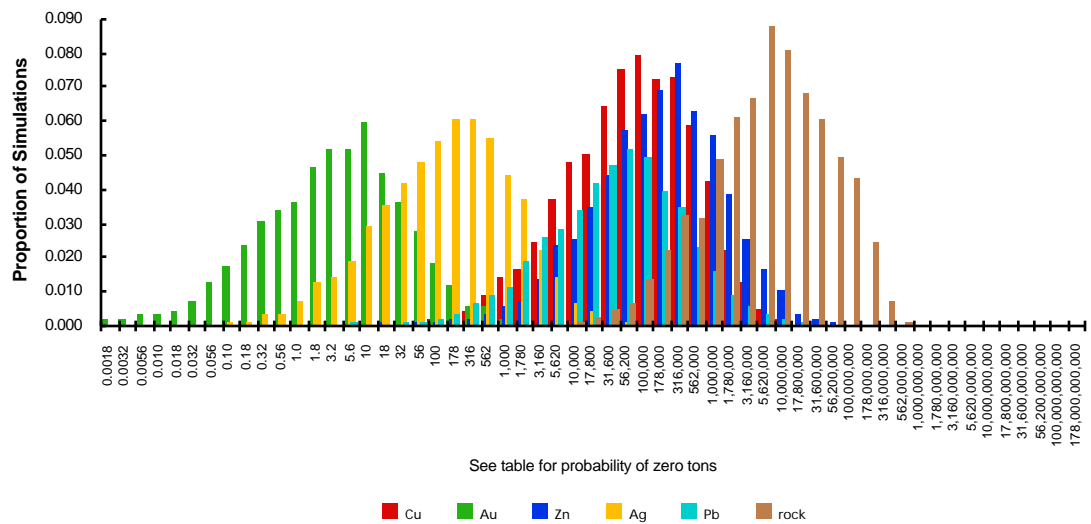
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	18,000	0	22,000	7	0	1,500,000
0.10	460,000	18	891,000	770	150,000	40,000,000
0.05	830,000	43	1,900,000	1,700	350,000	72,000,000
mean	180,000	10	410,000	370	83,000	13,000,000
Probability of mean	0.21	0.15	0.18	0.17	0.14	0.21
Probability of zero	0.30	0.48	0.37	0.44	0.55	0.30

The tract ID is SB25

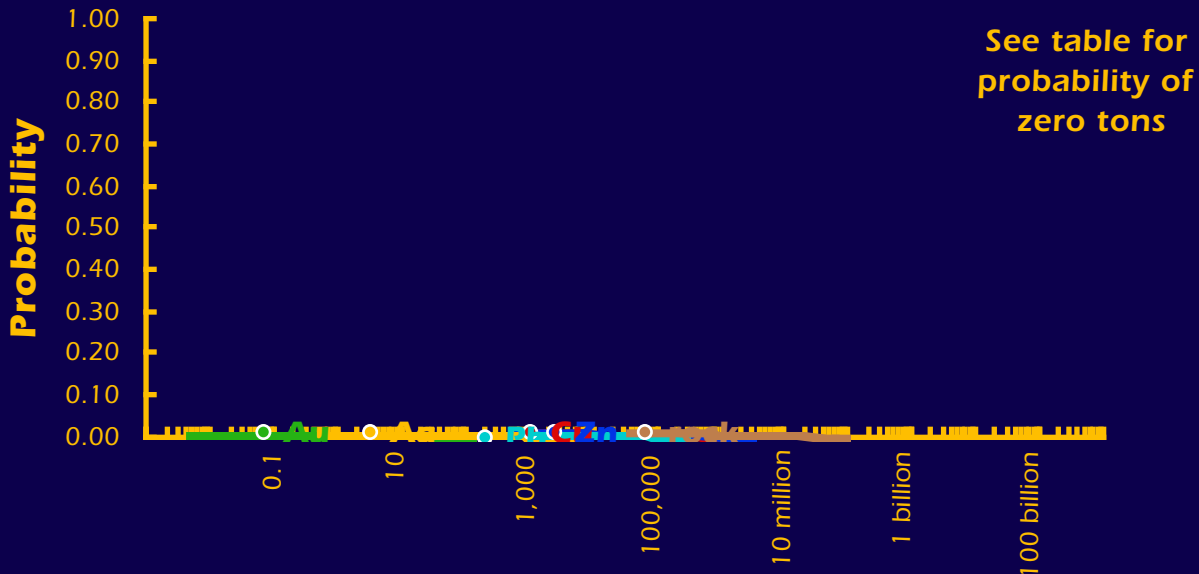
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

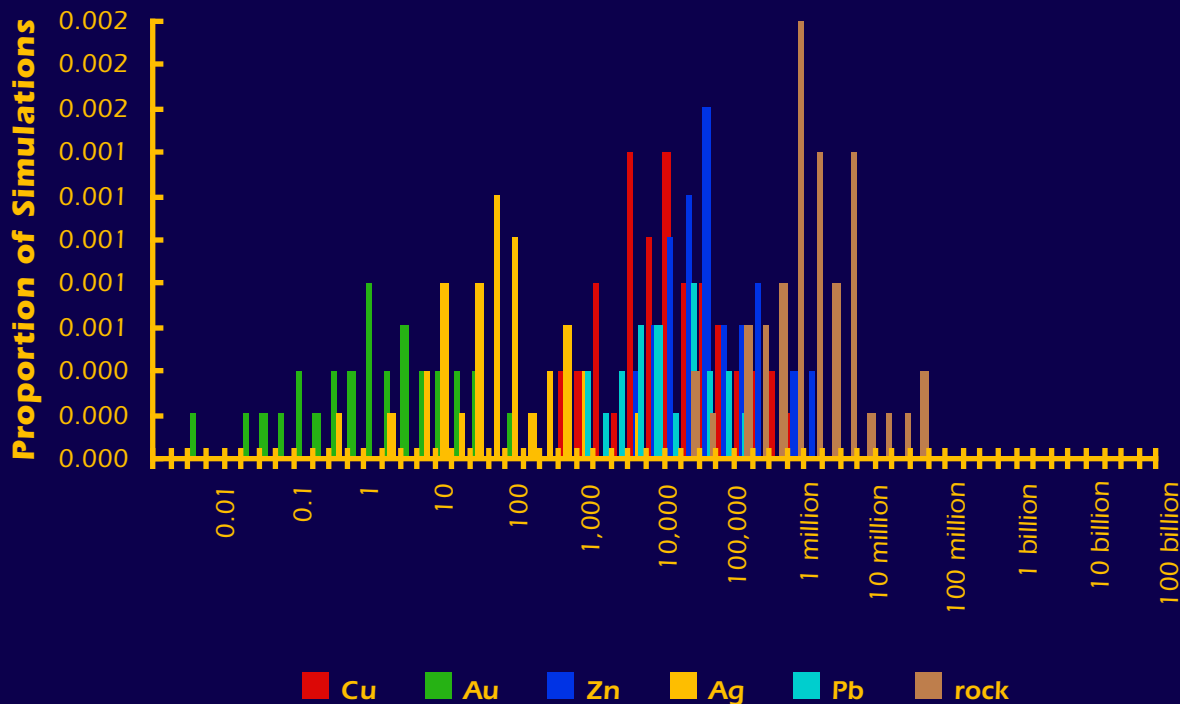


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB26

The Mark3 Index is 93:

Massive sulfide, kuroko

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	1,000	0	2,400	3	200	66,000
Probability of mean	0.01	0.01	0.01	0.01	0.00	0.01
Probability of zero	0.99	0.99	0.99	0.99	1.00	0.99

The tract ID is SB26The Mark3 Index is 93: **Massive sulfide, kuroko**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

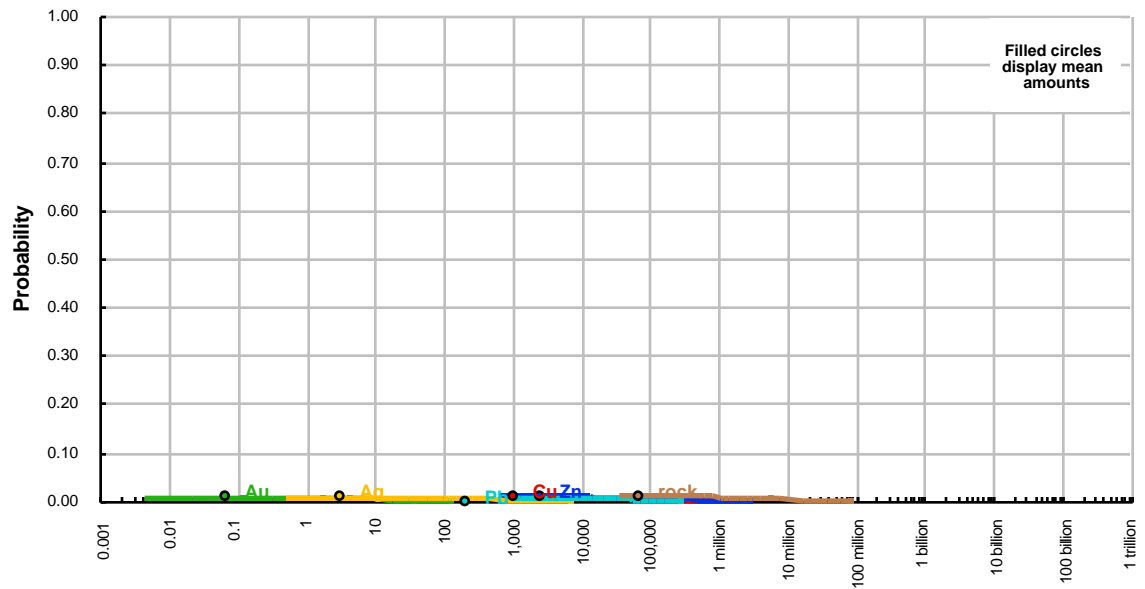
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

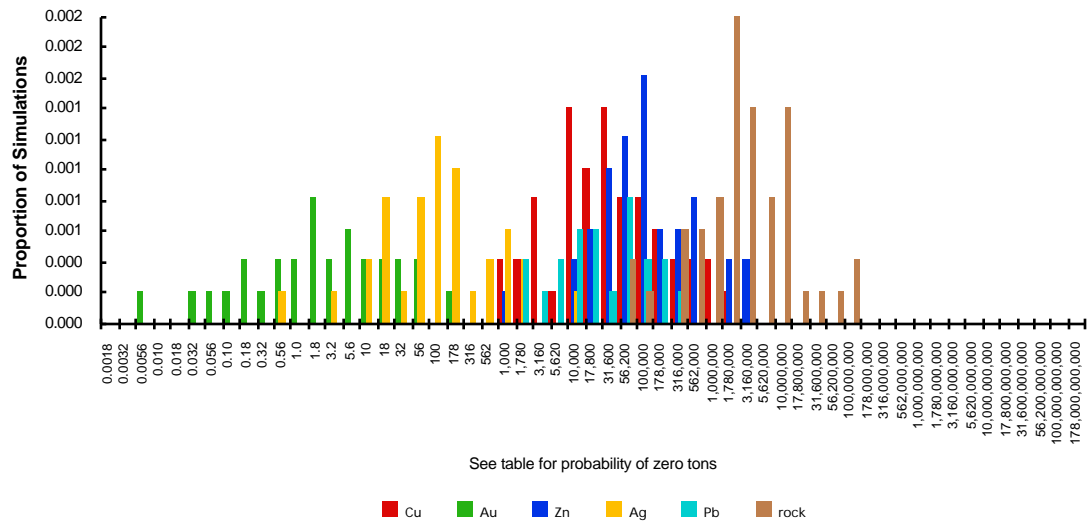
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	0	0	0	0	0
mean	1,000	0	2,400	3	200	66,000
Probability of mean	0.01	0.01	0.01	0.01	0.00	0.01
Probability of zero	0.99	0.99	0.99	0.99	1.00	0.99

The tract ID is SB26

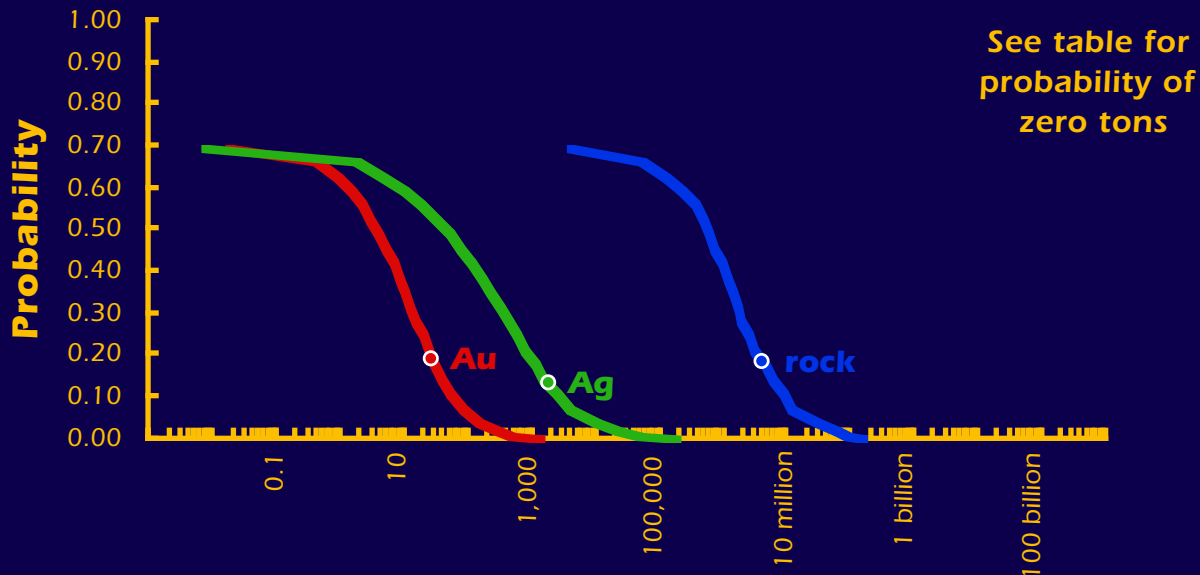
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

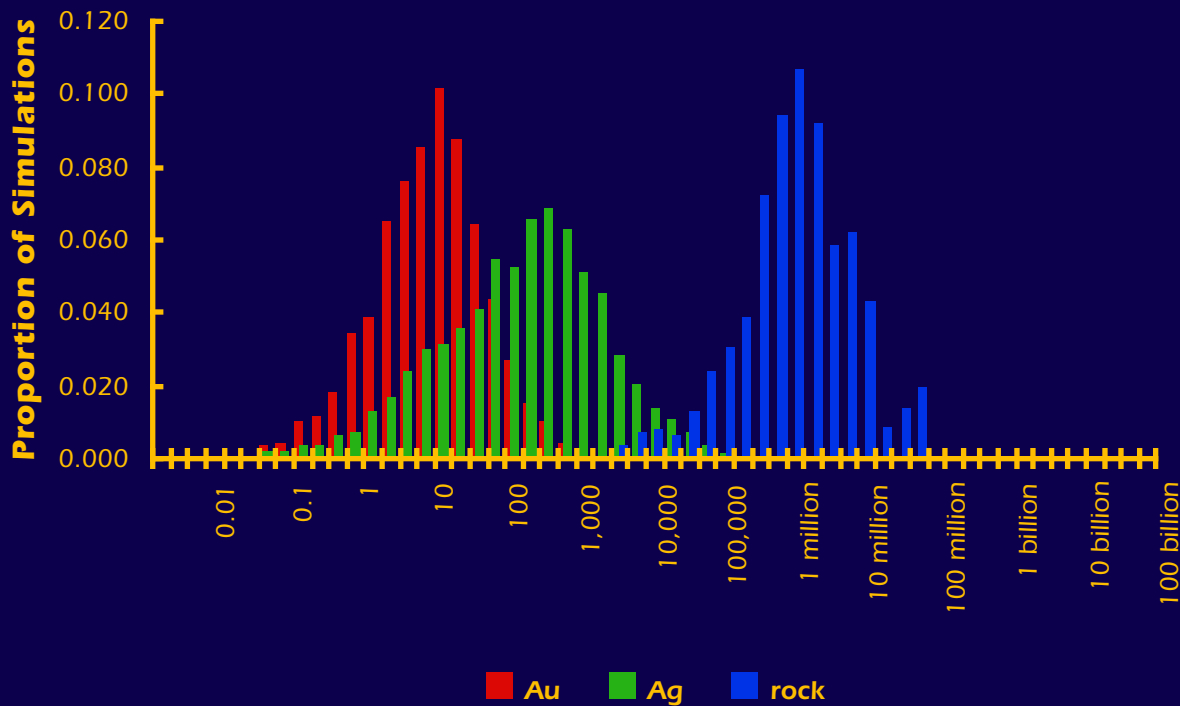


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB27

The Mark3 Index is 16:

Epithermal vein, Comstock

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	4	44	550,000
0.10	56	2,600	9,030,000
0.05	110	6,600	15,000,000
mean	26	1,700	4,200,000
Probability of mean	0.19	0.13	0.18
Probability of zero	0.30	0.30	0.30

The tract ID is SB27

The Mark3 Index is 16: **Epithermal vein, Comstock**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

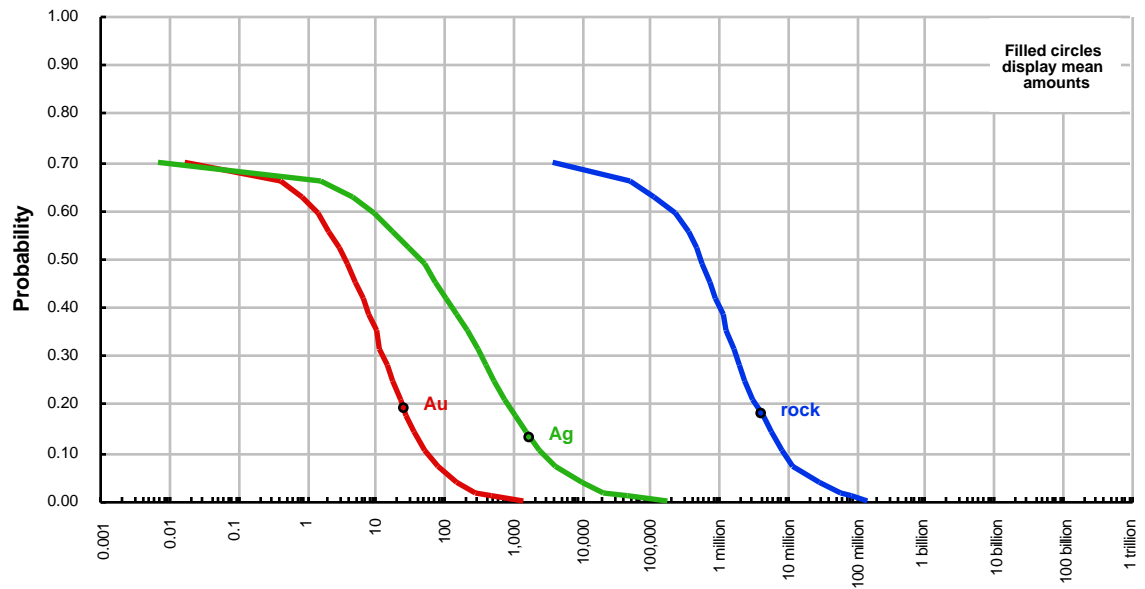
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

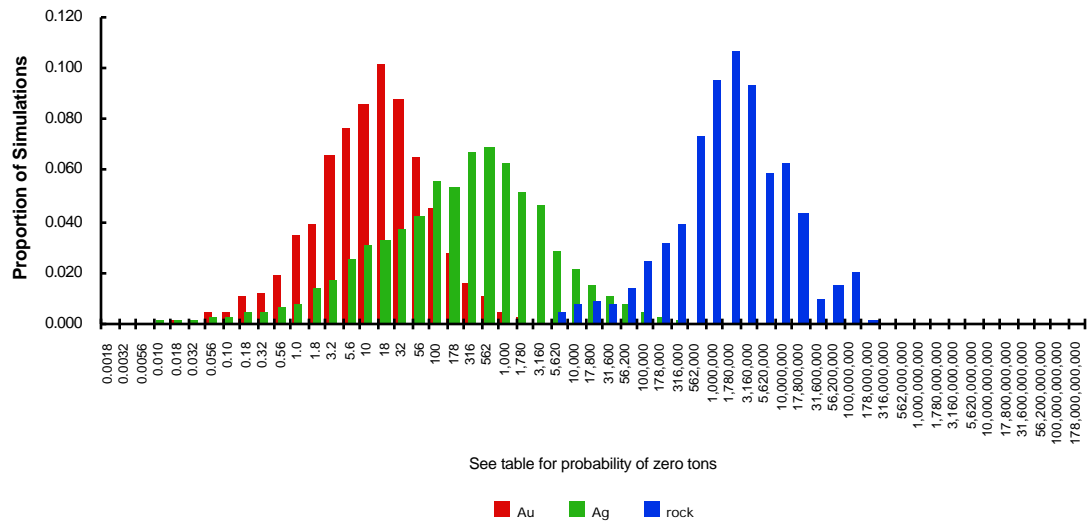
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	4	44	550,000
0.10	56	2,600	9,030,000
0.05	110	6,600	15,000,000
mean	26	1,700	4,200,000
Probability of mean	0.19	0.13	0.18
Probability of zero	0.30	0.30	0.30

The tract ID is SB27

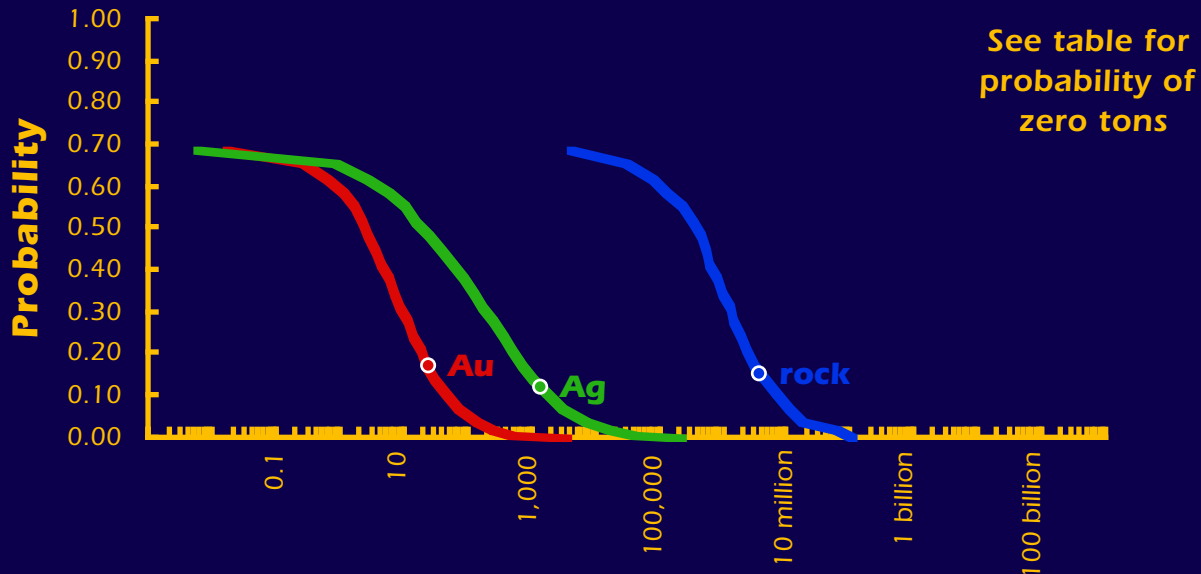
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

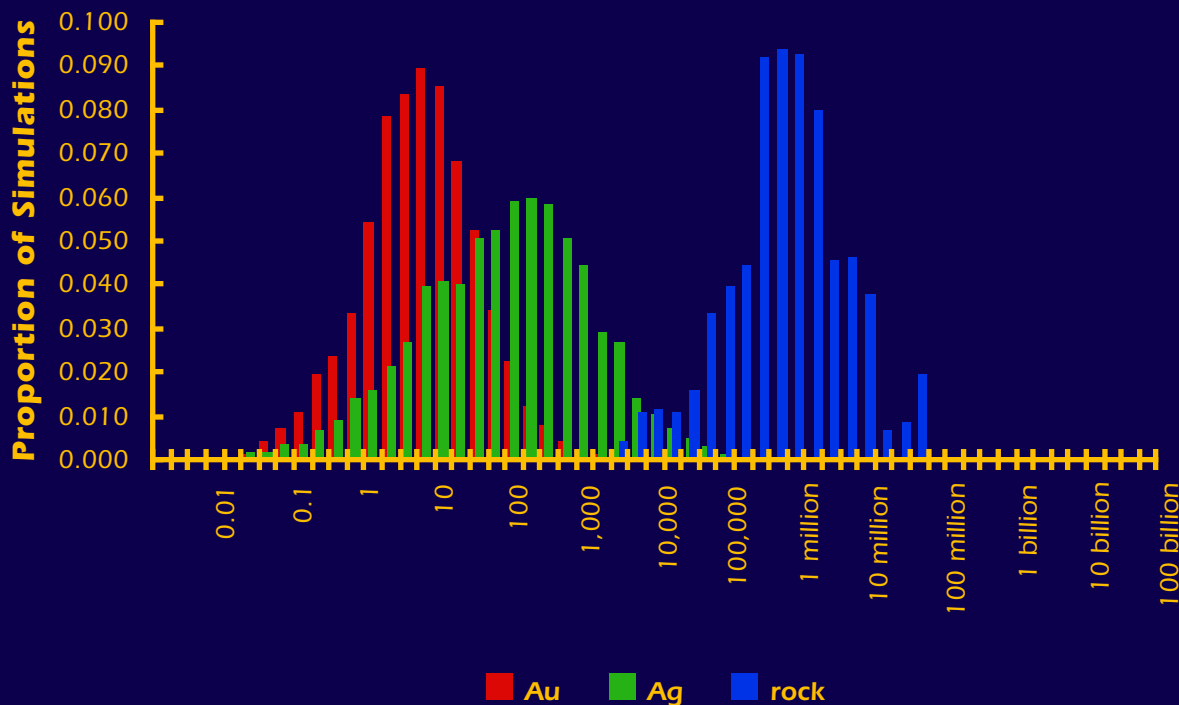


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB28

The Mark3 Index is 16:

Epithermal vein, Comstock

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	2	20	380,000
0.10	44	1,600	7,130,000
0.05	93	4,300	14,000,000
mean	23	1,300	3,500,000
Probability of mean	0.17	0.12	0.15
Probability of zero	0.31	0.31	0.31

The tract ID is SB28The Mark3 Index is 16: **Epithermal vein, Comstock**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

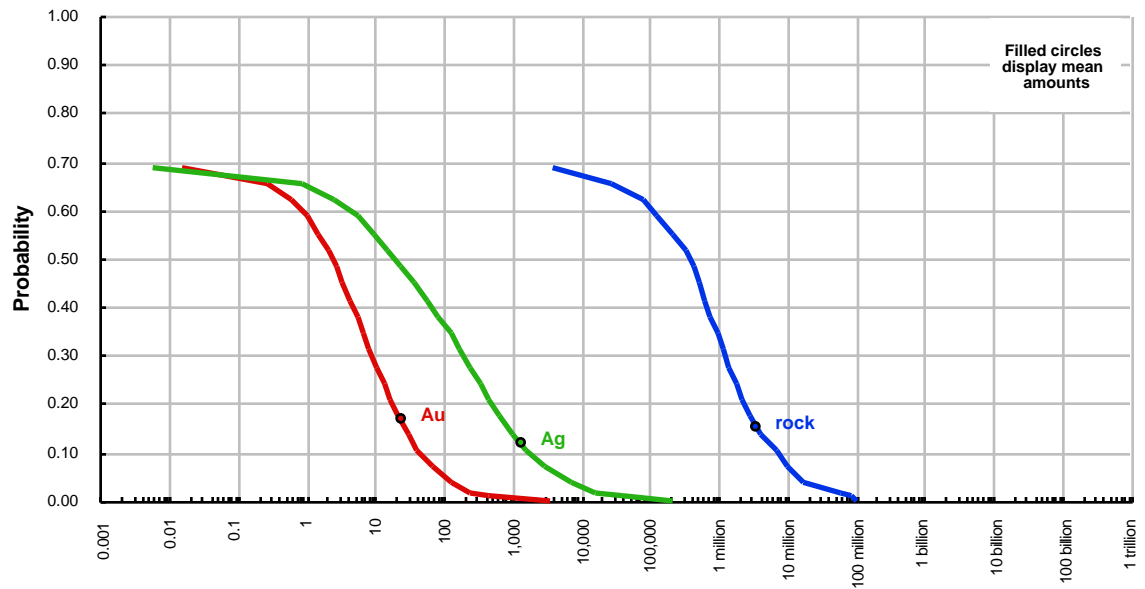
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

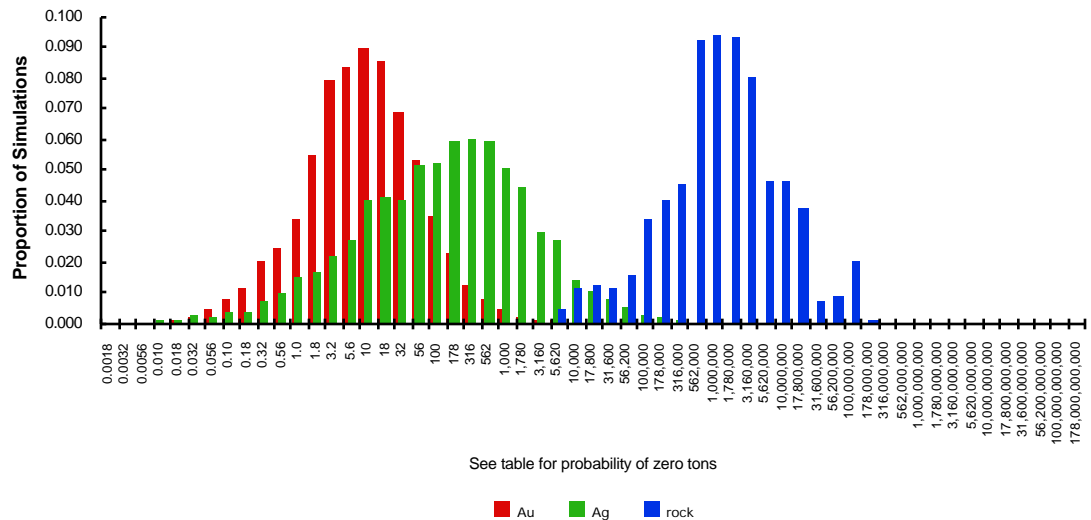
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	2	20	380,000
0.10	44	1,600	7,130,000
0.05	93	4,300	14,000,000
mean	23	1,300	3,500,000
Probability of mean	0.17	0.12	0.15
Probability of zero	0.31	0.31	0.31

The tract ID is SB28

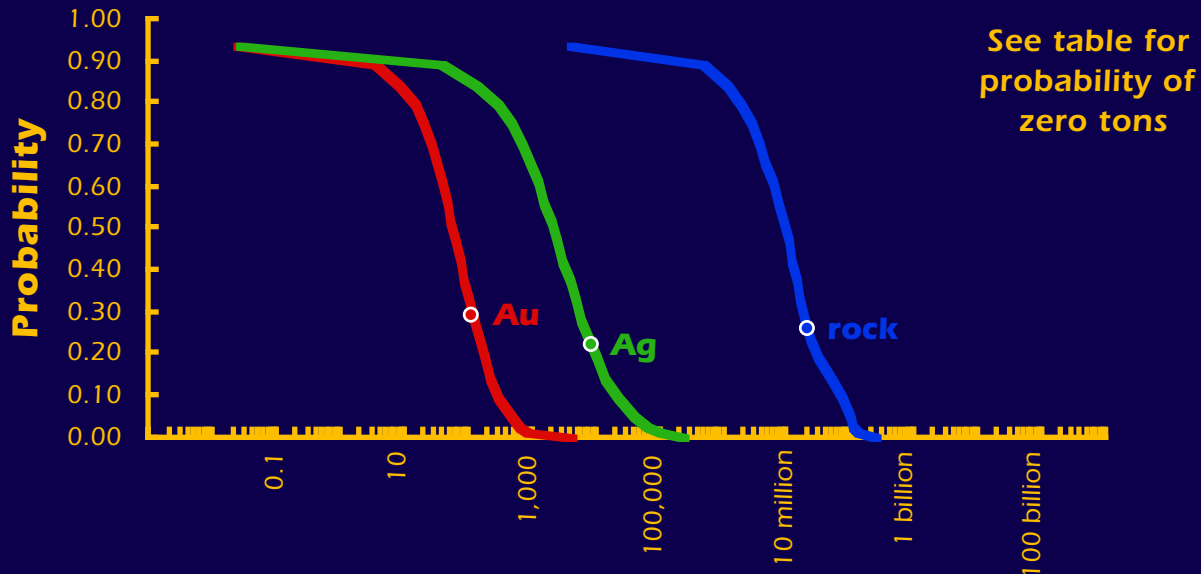
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

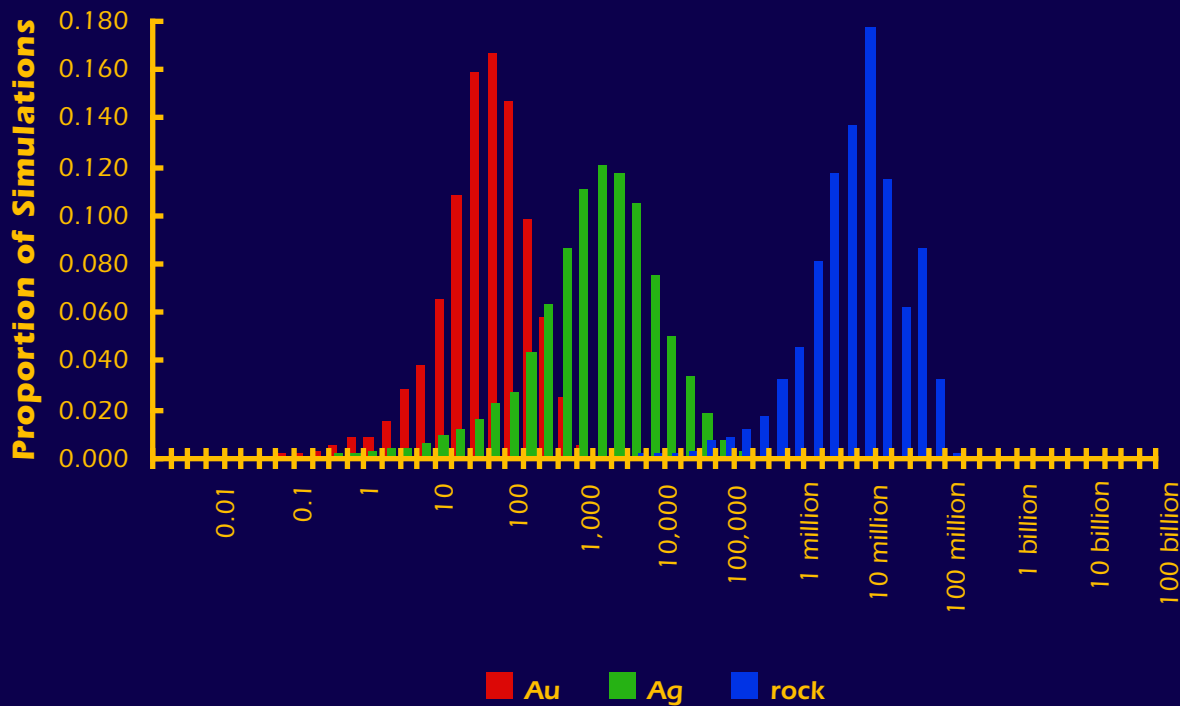


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB29

The Mark3 Index is 16:

Epithermal vein, Comstock

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 5 or more deposits.

There is a 10% or greater chance of 7 or more deposits.

There is a 5% or greater chance of 10 or more deposits.

There is a 1% or greater chance of 15 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	3	25	360,000
0.50	56	2,100	9,100,000
0.10	290	20,000	67,200,000
0.05	440	37,000	93,000,000
mean	120	8,100	21,000,000
Probability of mean	0.29	0.22	0.26
Probability of zero	0.06	0.06	0.06

The tract ID is SB29The Mark3 Index is 16: **Epithermal vein, Comstock**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 5 or more deposits.

There is a 10% or greater chance of 7 or more deposits.

There is a 5% or greater chance of 10 or more deposits.

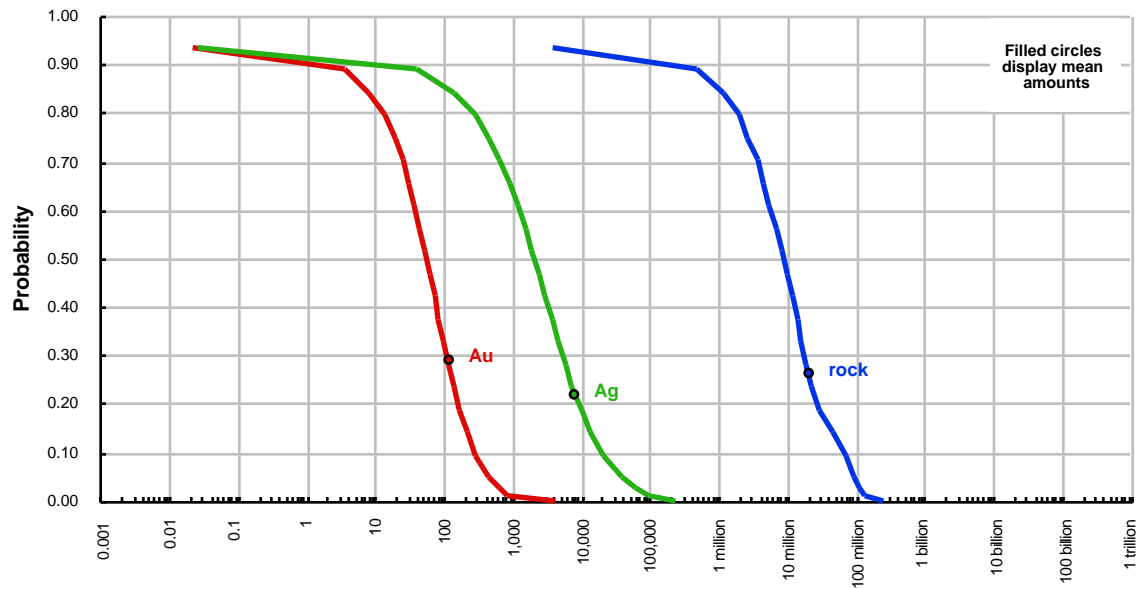
There is a 1% or greater chance of 15 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

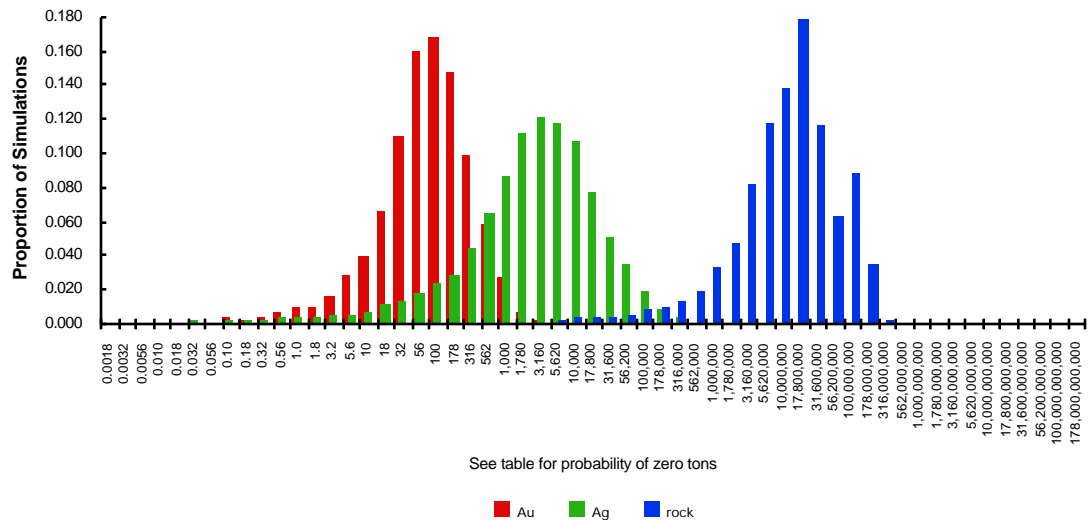
quantile	Au	Ag	rock
0.95	0	0	0
0.90	3	25	360,000
0.50	56	2,100	9,100,000
0.10	290	20,000	67,200,000
0.05	440	37,000	93,000,000
mean	120	8,100	21,000,000
Probability of mean	0.29	0.22	0.26
Probability of zero	0.06	0.06	0.06

The tract ID is SB29

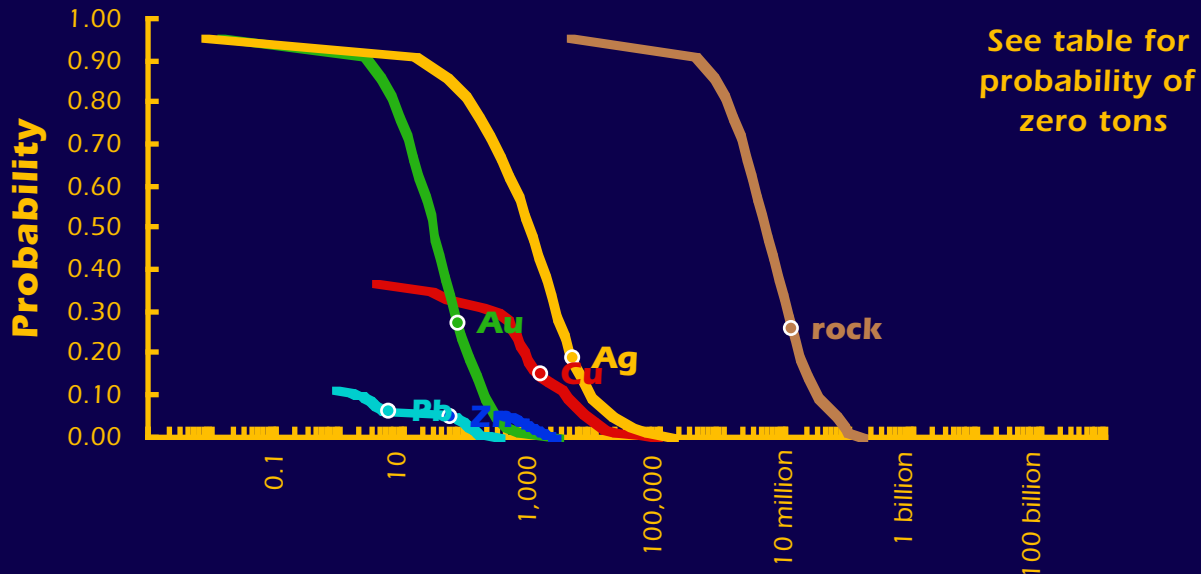
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

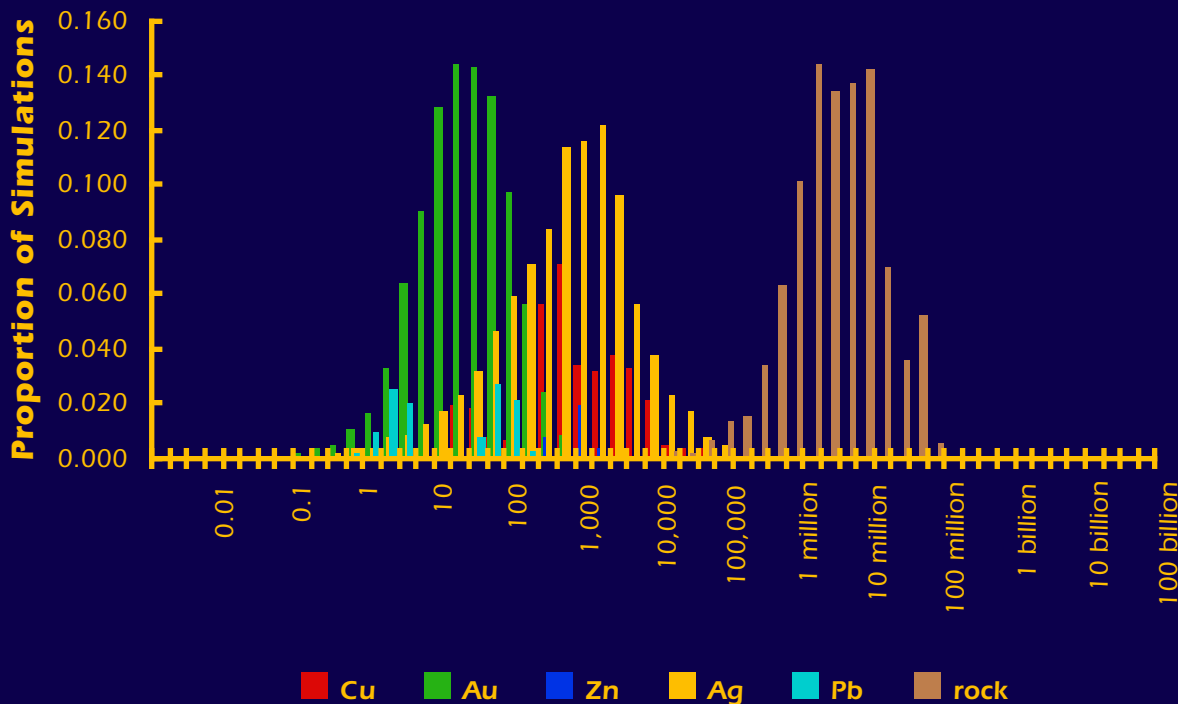


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB30

The Mark3 Index is 25:

Epithermal vein, quartz-adularia

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 7 or more deposits.

There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	1	0	77,000
0.90	0	3	0	19	0	470,000
0.50	0	28	0	890	0	4,400,000
0.10	3,300	170	0	8,400	2	29,000,000
0.05	7,000	260	390	18,000	56	61,000,000
mean	1,400	69	52	4,200	6	12,000,000
Probability of mean	0.15	0.27	0.05	0.19	0.06	0.26
Probability of zero	0.63	0.04	0.95	0.04	0.89	0.04

The tract ID is SB30The Mark3 Index is 25: **Epithermal vein, quartz-adularia**

There is a 90% or greater chance of 2 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 6 or more deposits.

There is a 5% or greater chance of 7 or more deposits.

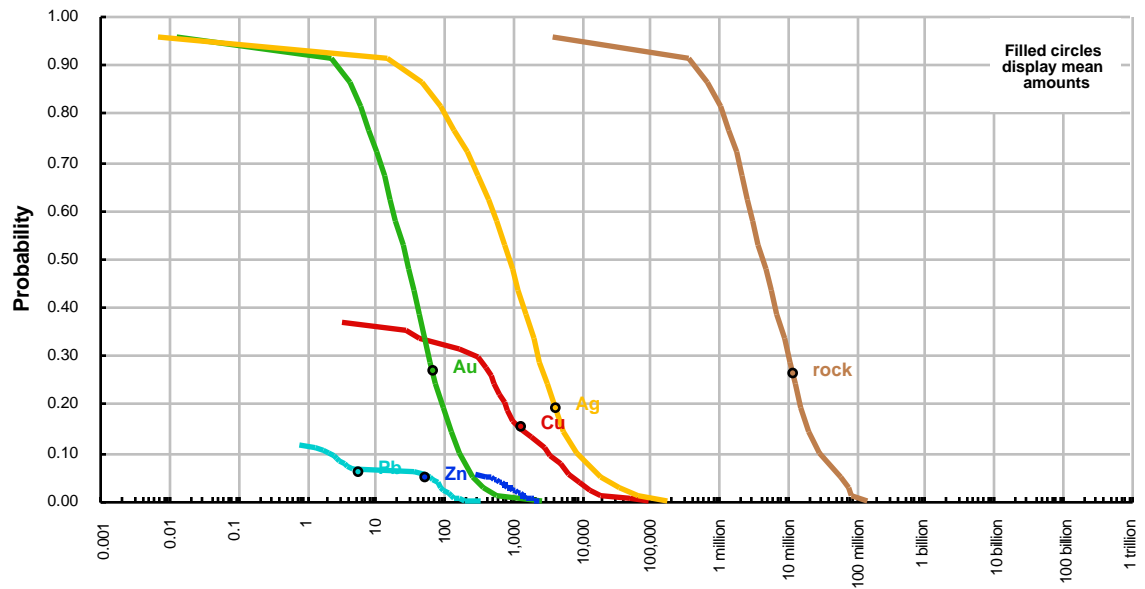
There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

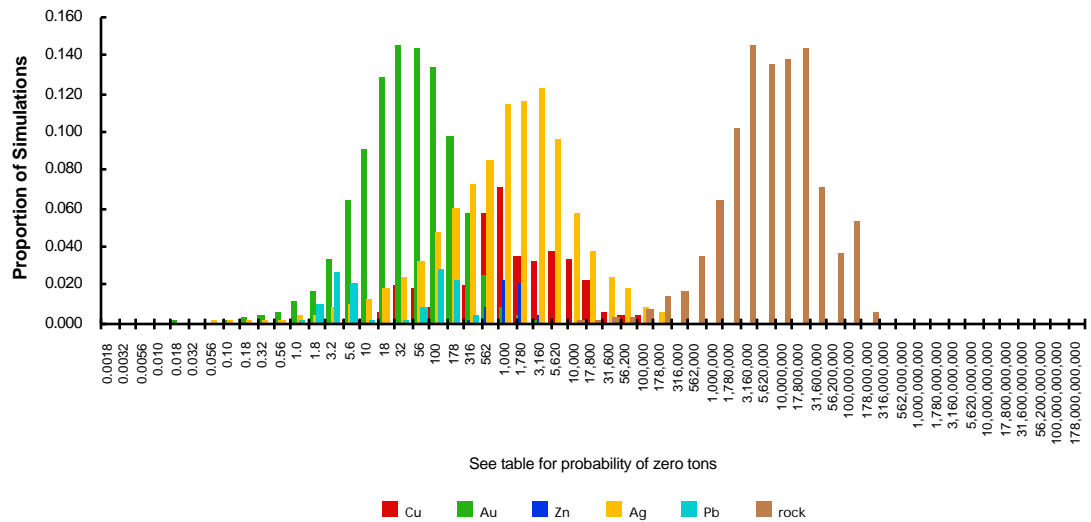
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	1	0	77,000
0.90	0	3	0	19	0	470,000
0.50	0	28	0	890	0	4,400,000
0.10	3,300	170	0	8,400	2	29,000,000
0.05	7,000	260	390	18,000	56	61,000,000
mean	1,400	69	52	4,200	6	12,000,000
Probability of mean	0.15	0.27	0.05	0.19	0.06	0.26
Probability of zero	0.63	0.04	0.95	0.04	0.89	0.04

The tract ID is SB30

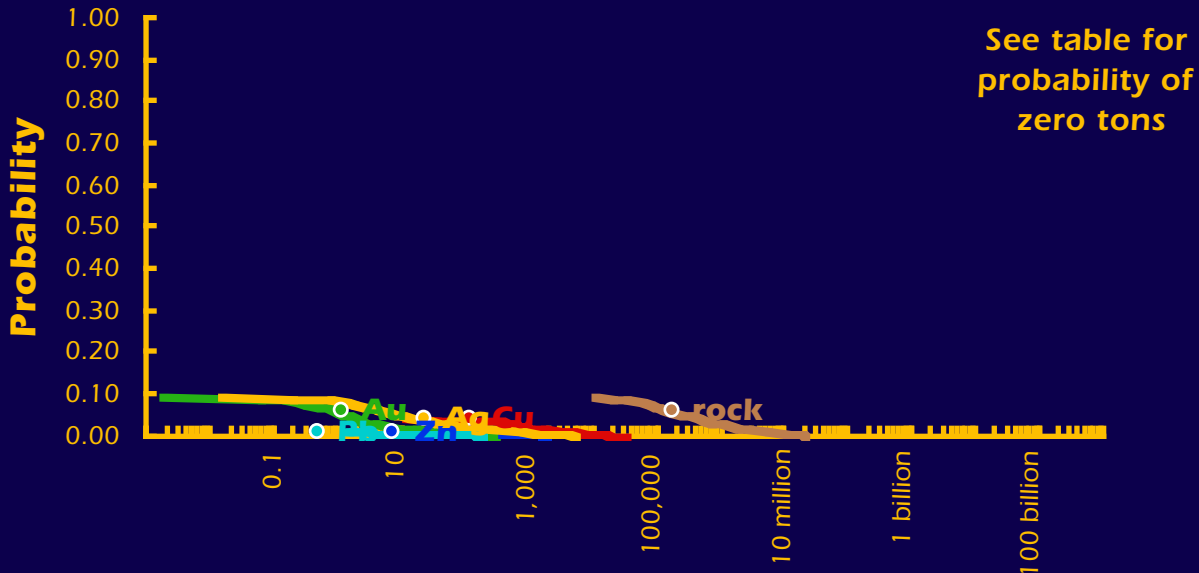
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

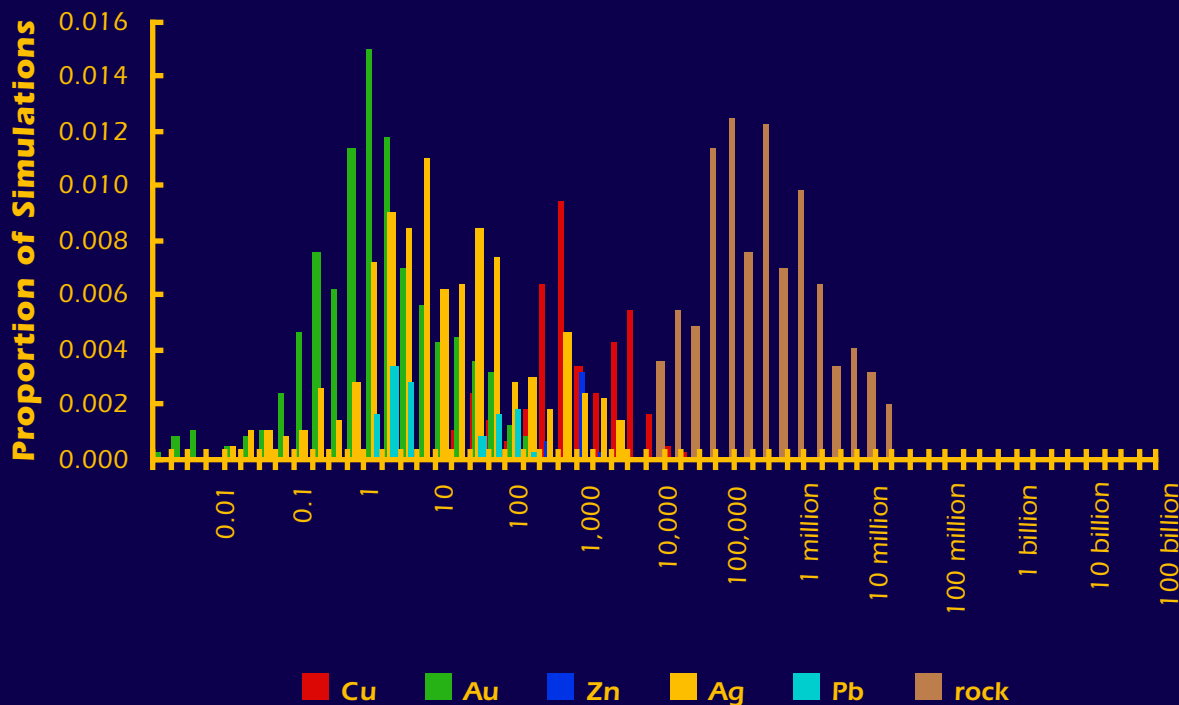


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB31

The Mark3 Index is 28:

Epithermal vein, Sado

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	1	0	9	0	280,000
mean	120	1	7	21	1	170,000
Probability of mean	0.04	0.06	0.01	0.04	0.01	0.06
Probability of zero	0.96	0.91	0.99	0.91	0.99	0.91

The tract ID is SB31The Mark3 Index is 28: **Epithermal vein, Sado**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

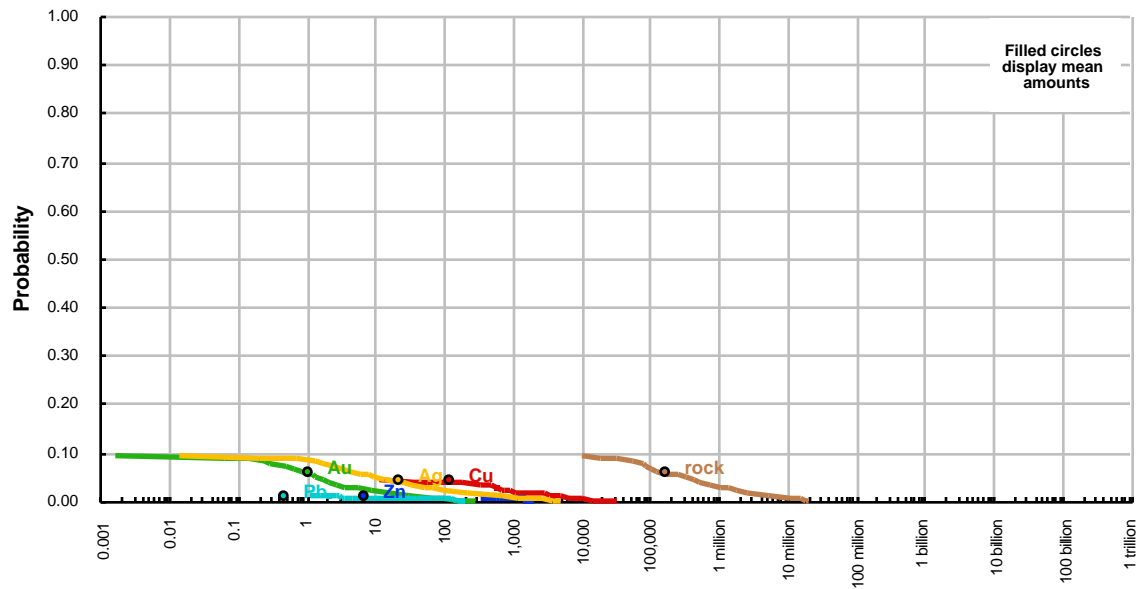
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

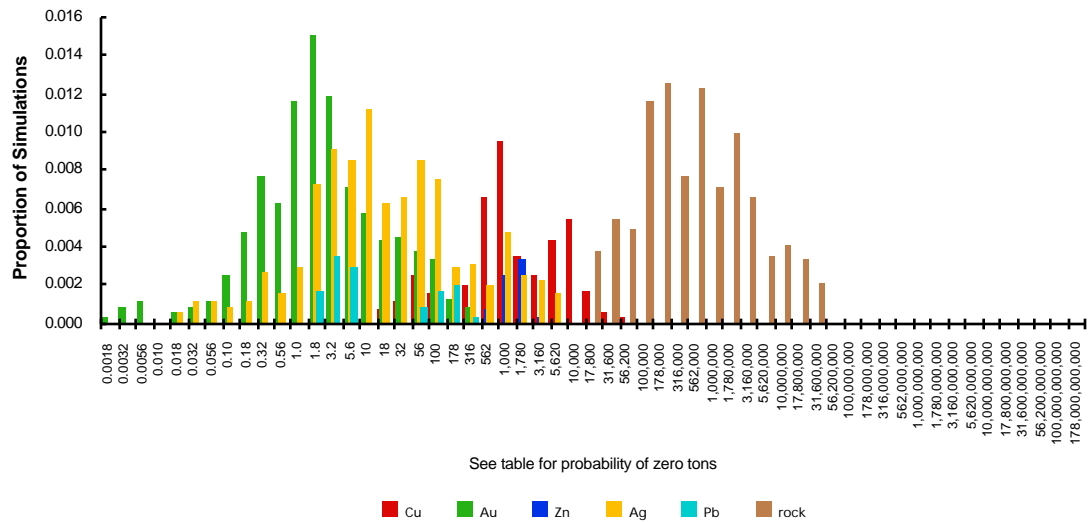
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	0
0.90	0	0	0	0	0	0
0.50	0	0	0	0	0	0
0.10	0	0	0	0	0	0
0.05	0	1	0	9	0	280,000
mean	120	1	7	21	1	170,000
Probability of mean	0.04	0.06	0.01	0.04	0.01	0.06
Probability of zero	0.96	0.91	0.99	0.91	0.99	0.91

The tract ID is SB31

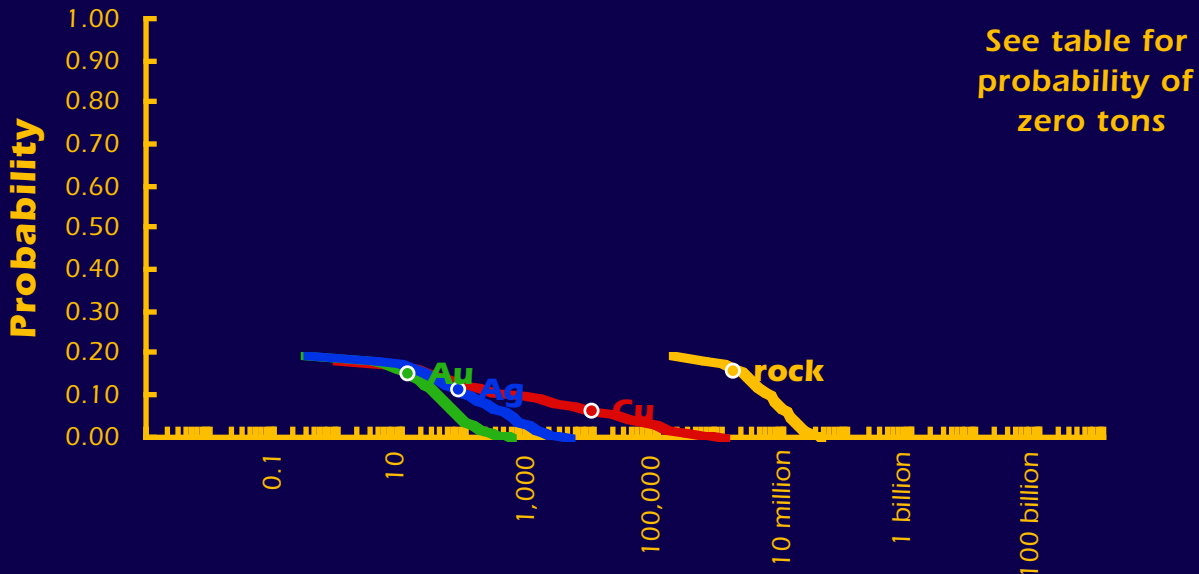
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

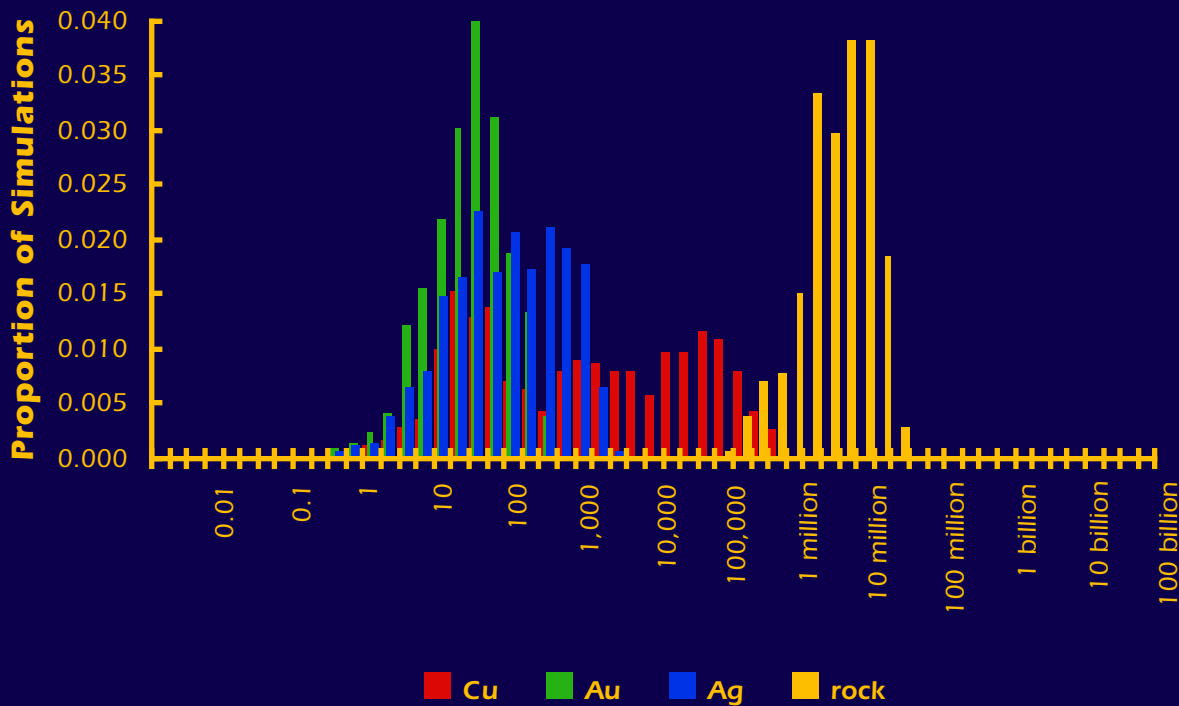


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB32

The Mark3 Index is 38:

Epithermal vein, quartz-alunite

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	750	35	108	5,400,000
0.05	27,000	74	490	12,000,000
mean	9,000	12	73	1,600,000
Probability of mean	0.06	0.15	0.11	0.16
Probability of zero	0.82	0.81	0.81	0.81

The tract ID is SB32The Mark3 Index is 38: **Epithermal vein, quartz-alunite**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 3 or more deposits.

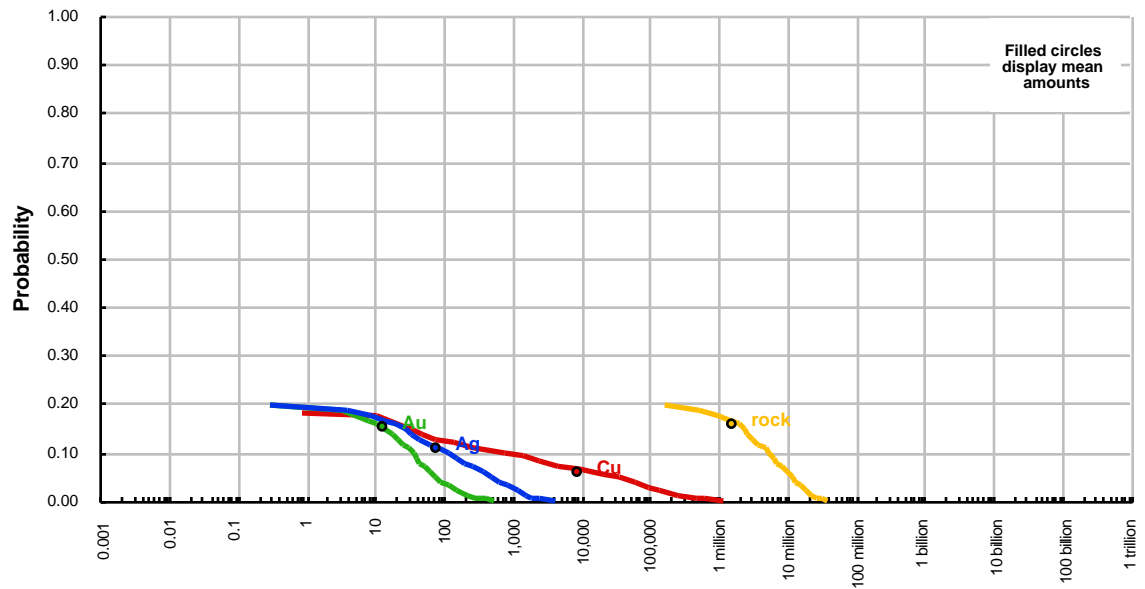
There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

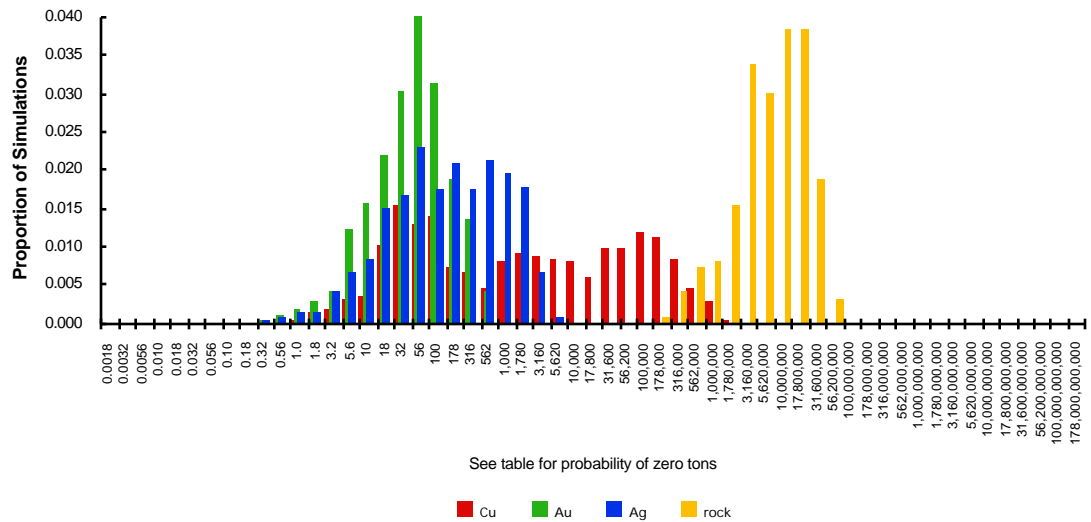
quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	750	35	108	5,400,000
0.05	27,000	74	490	12,000,000
mean	9,000	12	73	1,600,000
Probability of mean	0.06	0.15	0.11	0.16
Probability of zero	0.82	0.81	0.81	0.81

The tract ID is SB32

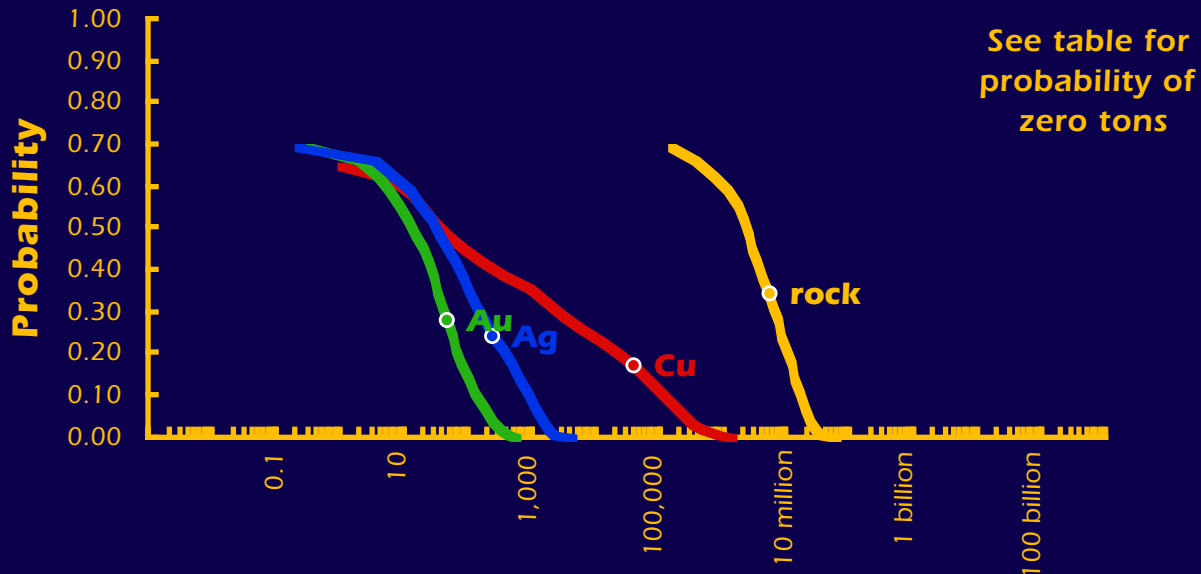
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

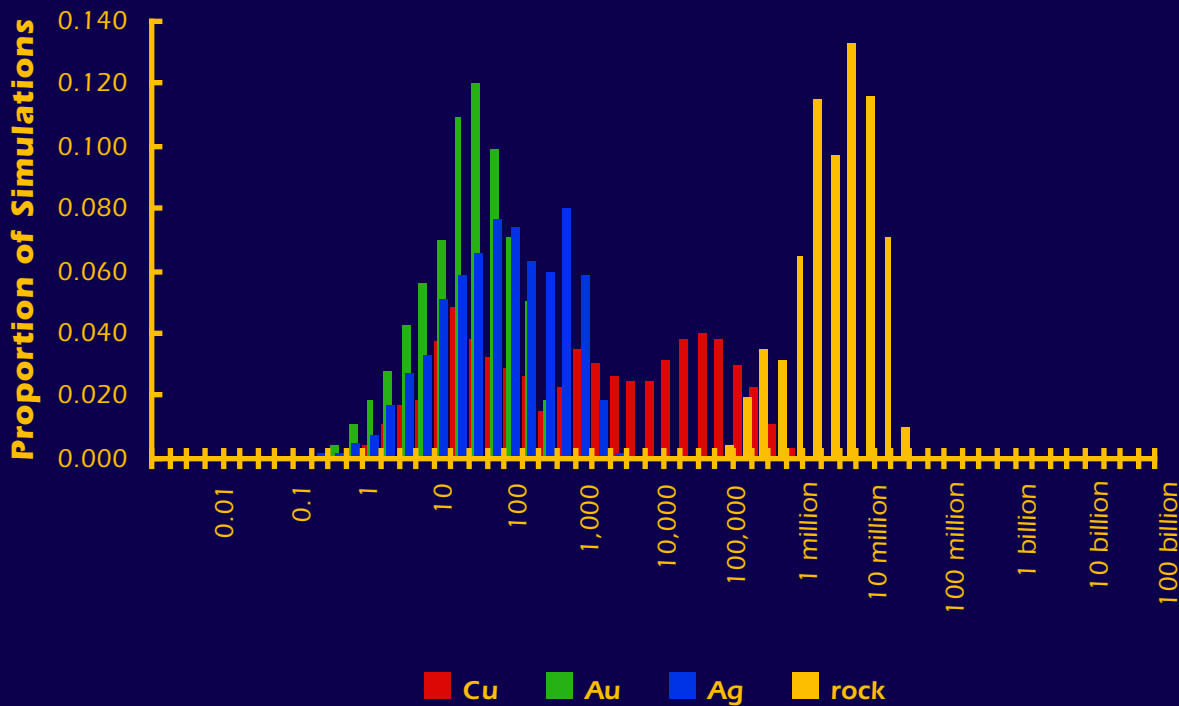


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB33

The Mark3 Index is 38:

Epithermal vein, quartz-alunite

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	38	14	31	2,300,000
0.10	110,000	130	835	16,000,000
0.05	240,000	210	1,300	21,000,000
mean	39,000	45	240	5,400,000
Probability of mean	0.17	0.28	0.24	0.34
Probability of zero	0.35	0.31	0.31	0.31

The tract ID is SB33The Mark3 Index is 38: **Epithermal vein, quartz-alunite**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 2 or more deposits.

There is a 5% or greater chance of 4 or more deposits.

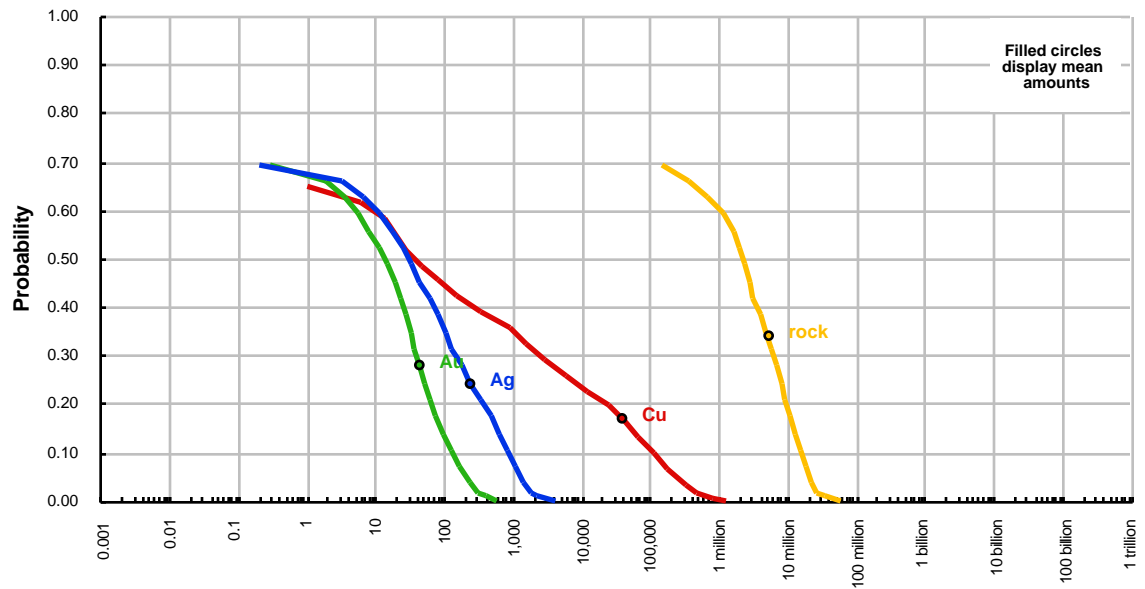
There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

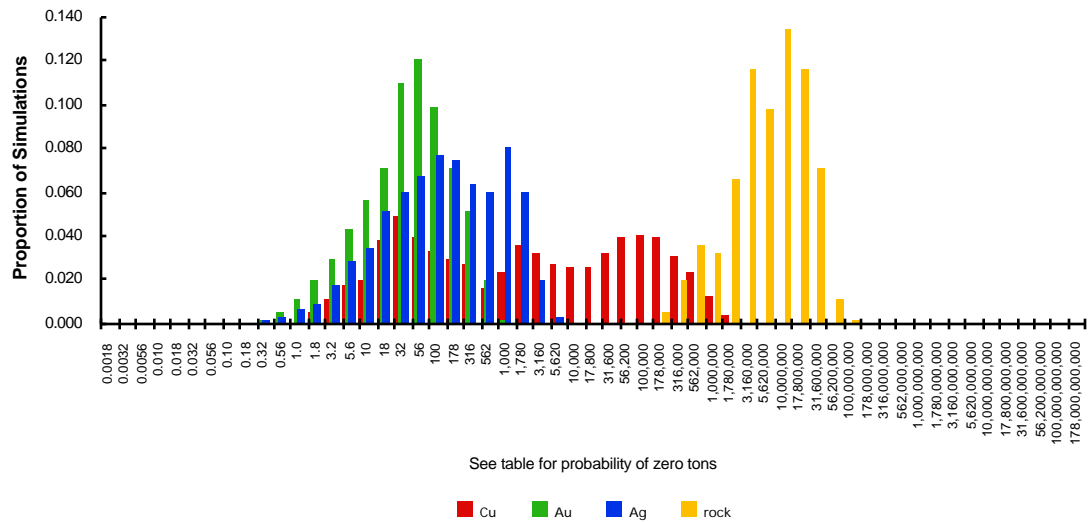
quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	38	14	31	2,300,000
0.10	110,000	130	835	16,000,000
0.05	240,000	210	1,300	21,000,000
mean	39,000	45	240	5,400,000
Probability of mean	0.17	0.28	0.24	0.34
Probability of zero	0.35	0.31	0.31	0.31

The tract ID is SB33

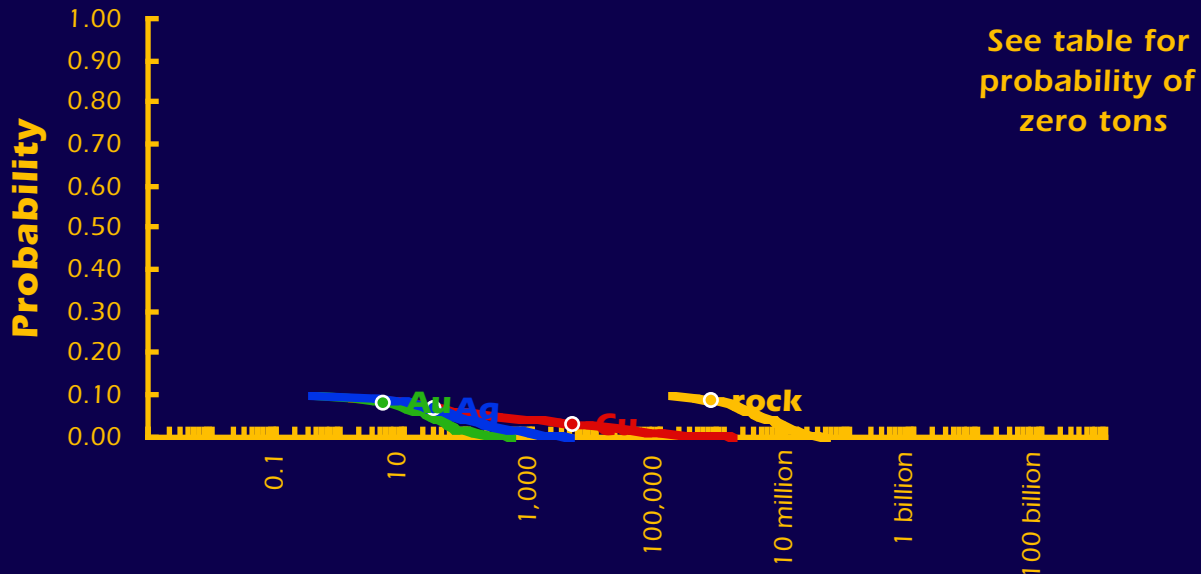
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

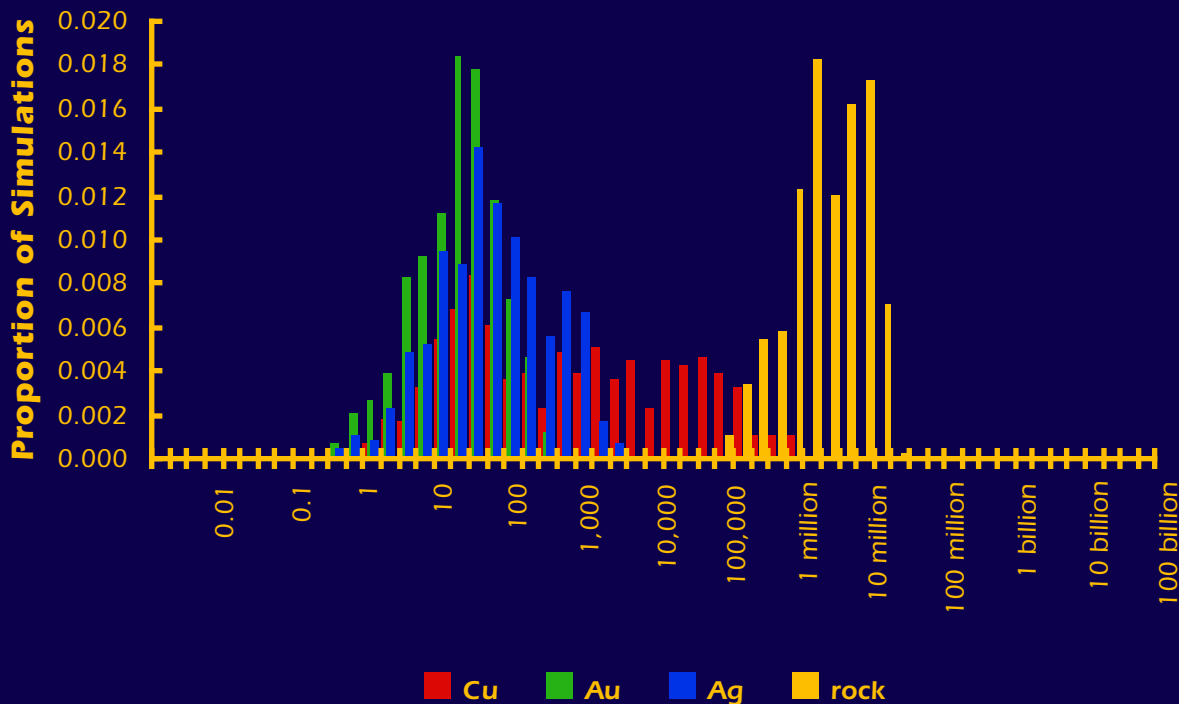


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB35

The Mark3 Index is 38:

Epithermal vein, quartz-alunite

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	270	25	61	3,400,000
mean	4,400	5	28	640,000
Probability of mean	0.03	0.08	0.07	0.09
Probability of zero	0.91	0.90	0.90	0.90

The tract ID is SB35The Mark3 Index is 38: **Epithermal vein, quartz-alunite**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 2 or more deposits.

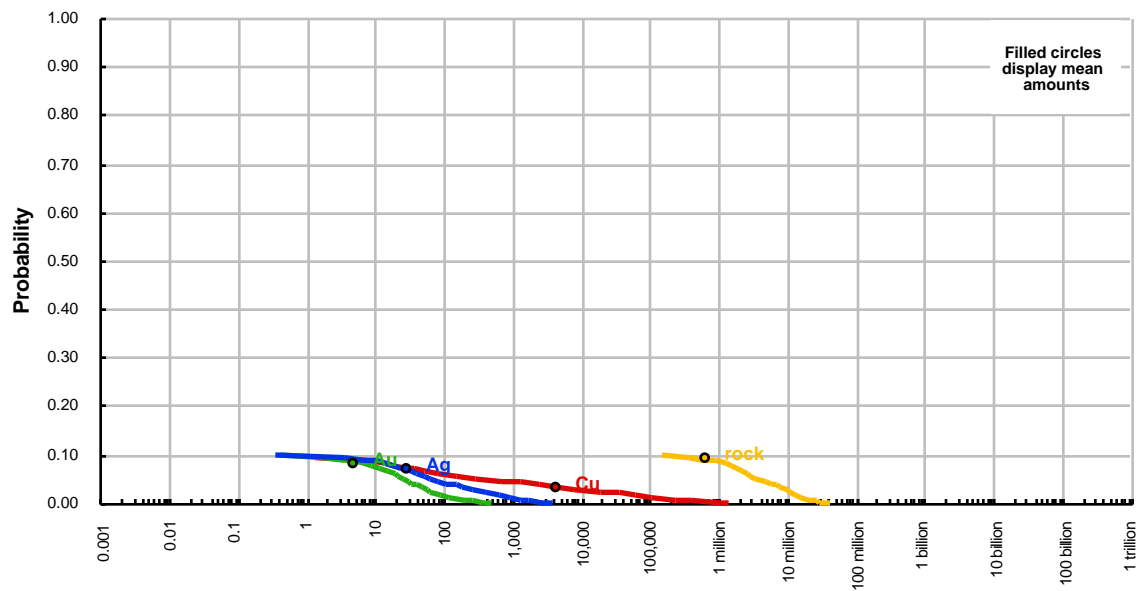
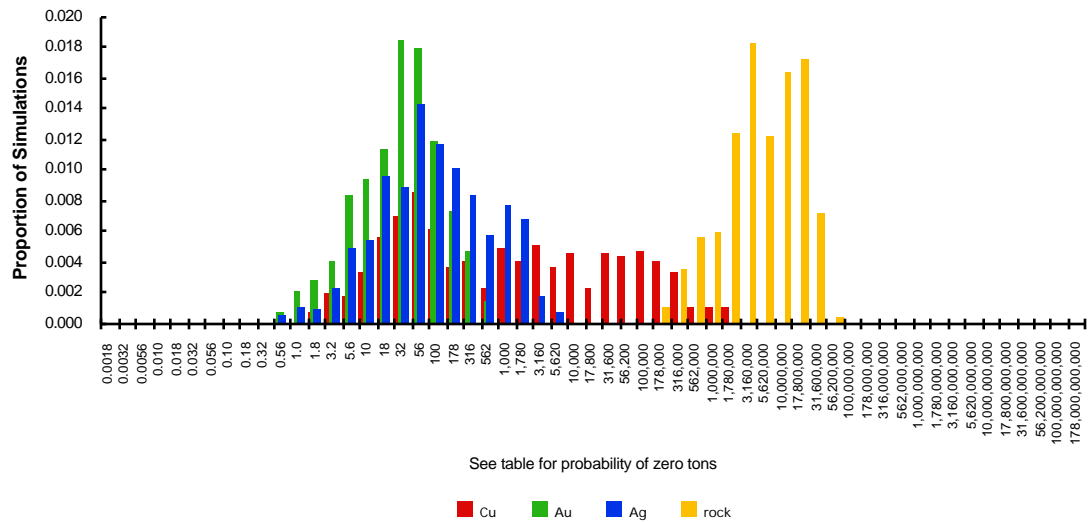
There is a 1% or greater chance of 4 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

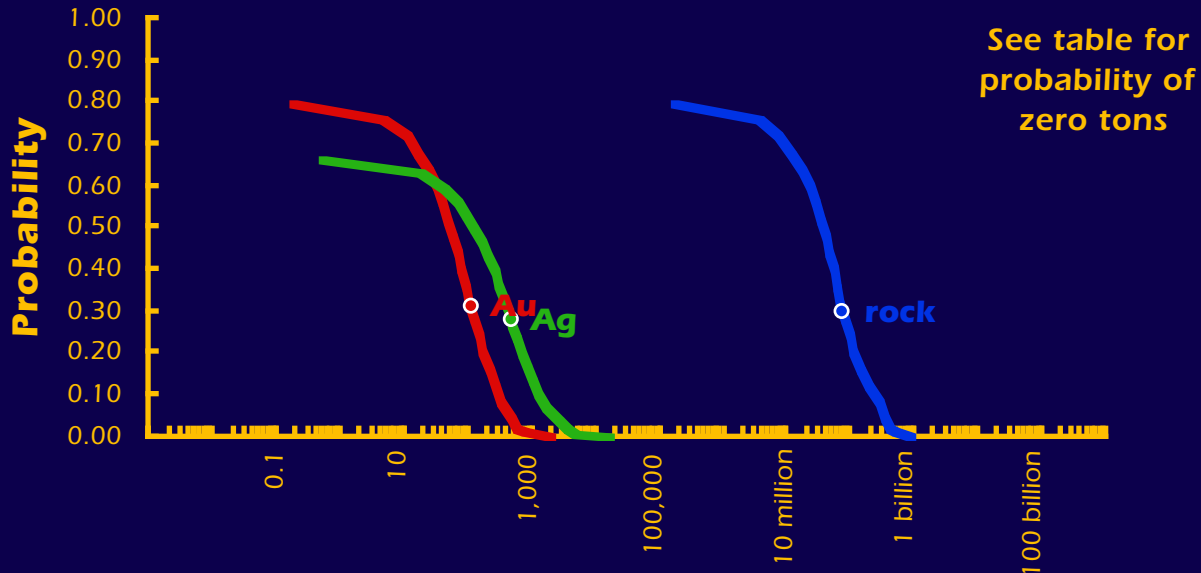
quantile	Cu	Au	Ag	rock
0.95	0	0	0	0
0.90	0	0	0	0
0.50	0	0	0	0
0.10	0	0	0	0
0.05	270	25	61	3,400,000
mean	4,400	5	28	640,000
Probability of mean	0.03	0.08	0.07	0.09
Probability of zero	0.91	0.90	0.90	0.90

The tract ID is SB35

Cumulative Distributions of Contained Metal and Mineralized Rock

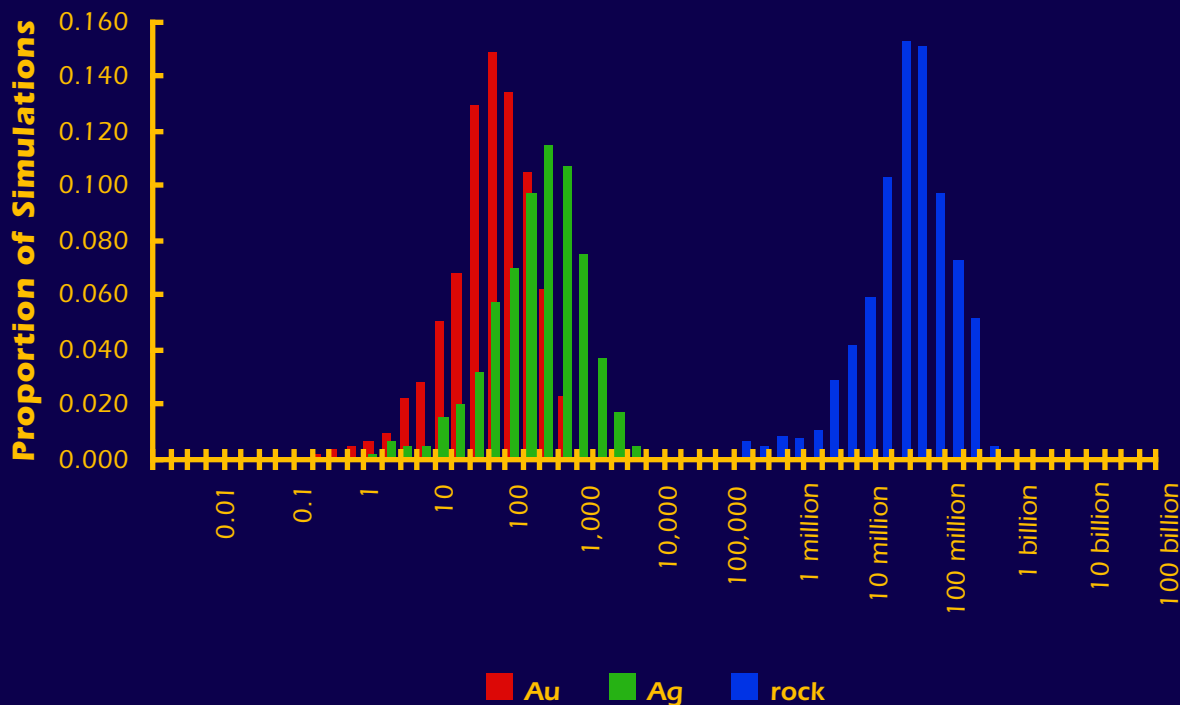
Histograms of Contained Metal and Mineralized Rock
(metric tons)

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB36

The Mark3 Index is 45:

Hot spring Au-Ag

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	51	120	36,000,000
0.10	290	1,200	230,000,000
0.05	420	2,000	330,000,000
mean	110	460	74,000,000
Probability of mean	0.31	0.28	0.30
Probability of zero	0.20	0.34	0.20

The tract ID is SB36The Mark3 Index is 45: **Hot spring Au-Ag**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 2 or more deposits.

There is a 10% or greater chance of 4 or more deposits.

There is a 5% or greater chance of 6 or more deposits.

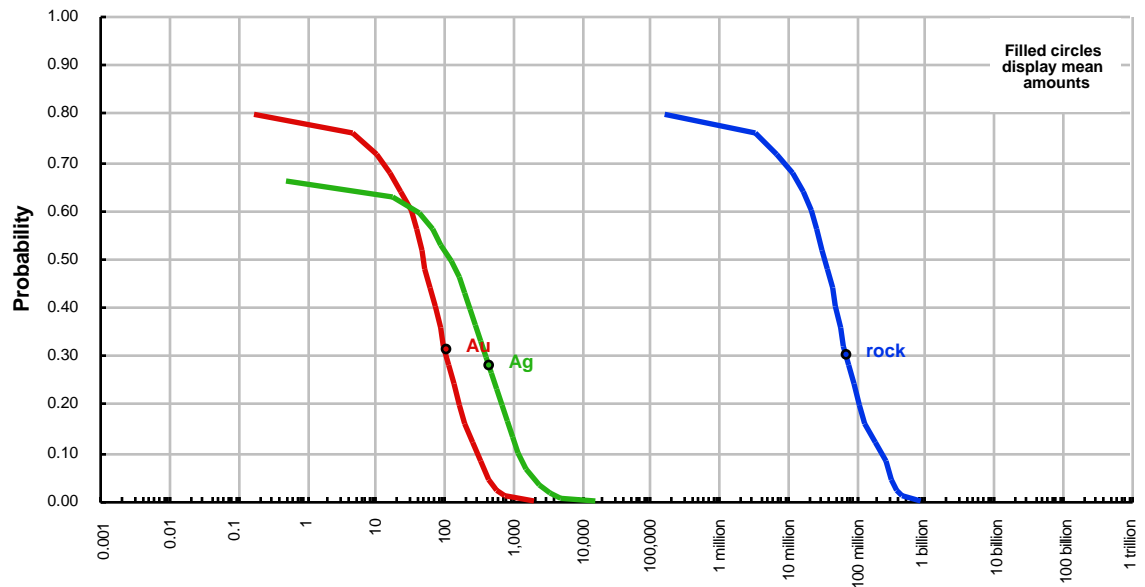
There is a 1% or greater chance of 8 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

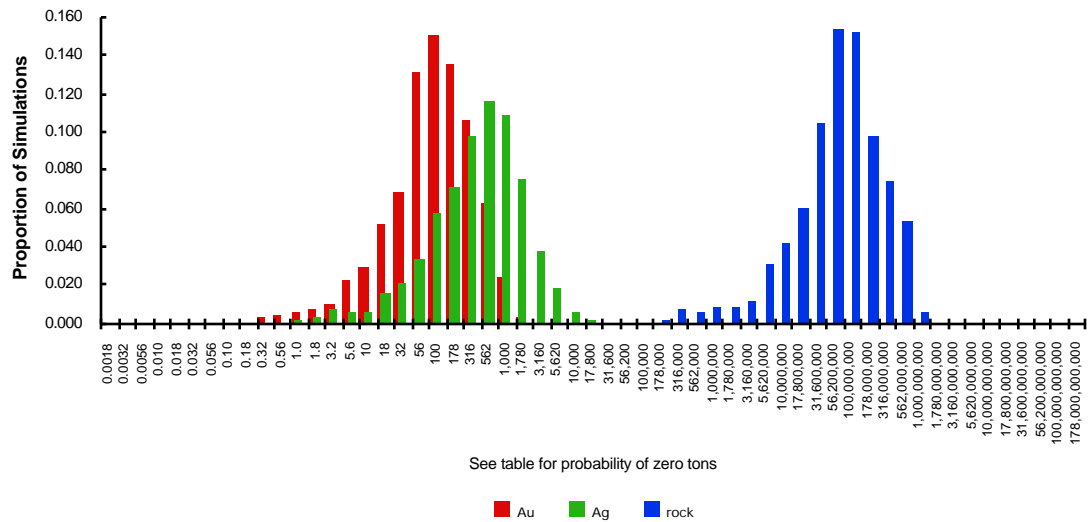
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	51	120	36,000,000
0.10	290	1,200	230,000,000
0.05	420	2,000	330,000,000
mean	110	460	74,000,000
Probability of mean	0.31	0.28	0.30
Probability of zero	0.20	0.34	0.20

The tract ID is SB36

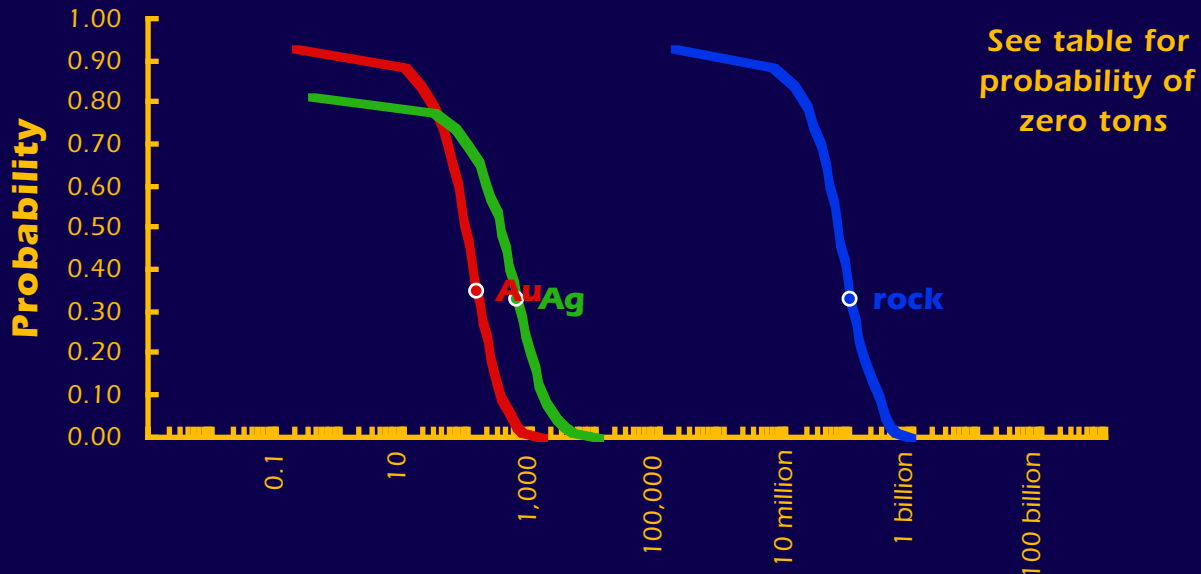
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

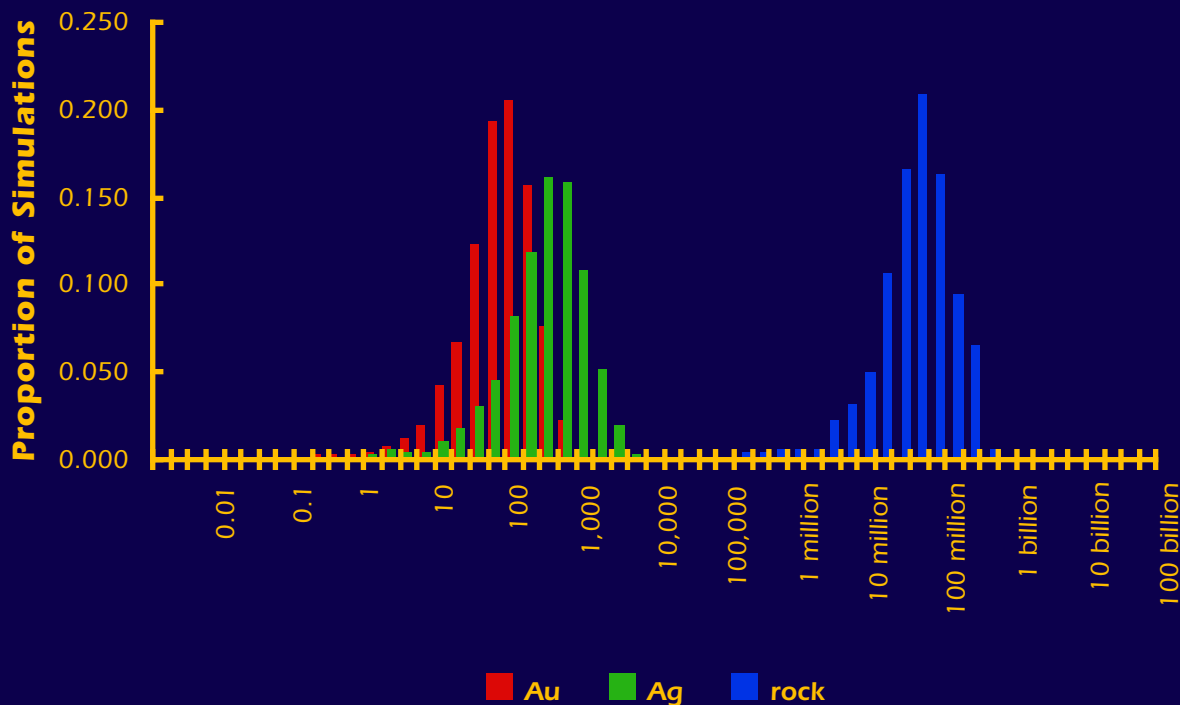


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB37

The Mark3 Index is 45:

Hot spring Au-Ag

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	6	0	4,200,000
0.50	89	310	63,000,000
0.10	320	1,500	273,000,000
0.05	450	2,200	350,000,000
mean	140	590	99,000,000
Probability of mean	0.35	0.33	0.33
Probability of zero	0.07	0.18	0.07

The tract ID is SB37The Mark3 Index is 45: **Hot spring Au-Ag**

There is a 90% or greater chance of 1 or more deposits.

There is a 50% or greater chance of 3 or more deposits.

There is a 10% or greater chance of 5 or more deposits.

There is a 5% or greater chance of 5 or more deposits.

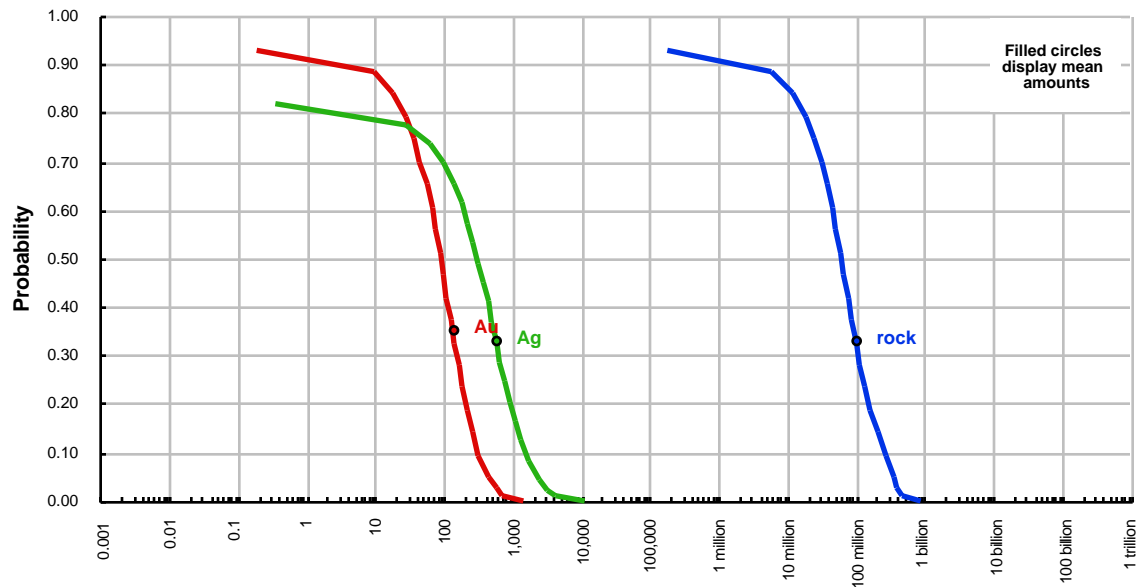
There is a 1% or greater chance of 5 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

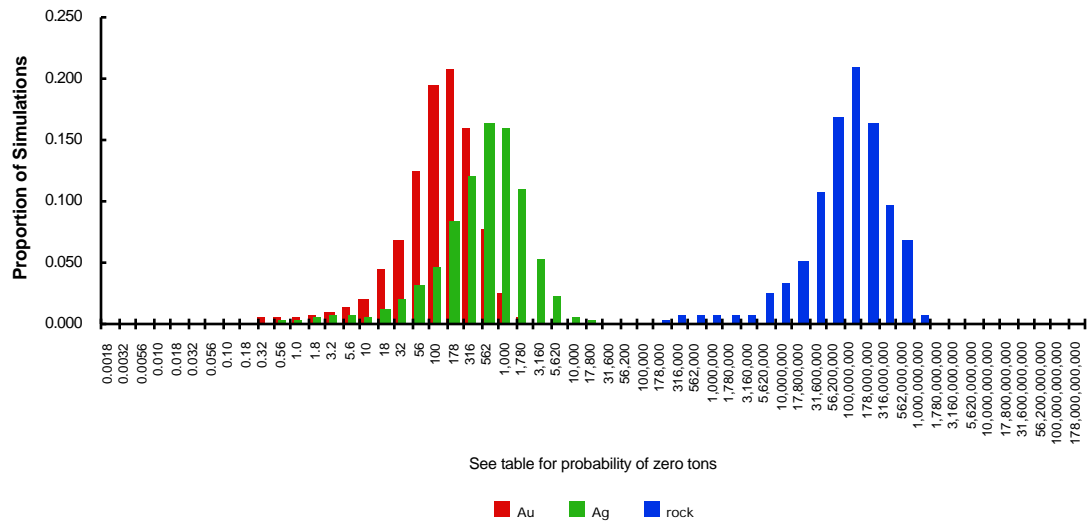
quantile	Au	Ag	rock
0.95	0	0	0
0.90	6	0	4,200,000
0.50	89	310	63,000,000
0.10	320	1,500	273,000,000
0.05	450	2,200	350,000,000
mean	140	590	99,000,000
Probability of mean	0.35	0.33	0.33
Probability of zero	0.07	0.18	0.07

The tract ID is SB37

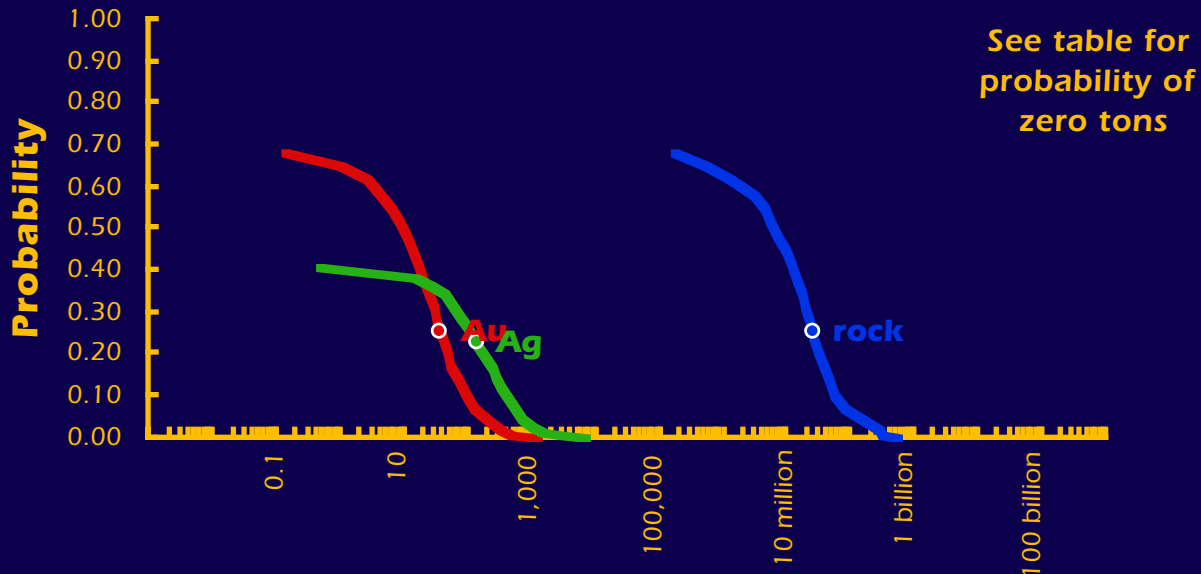
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

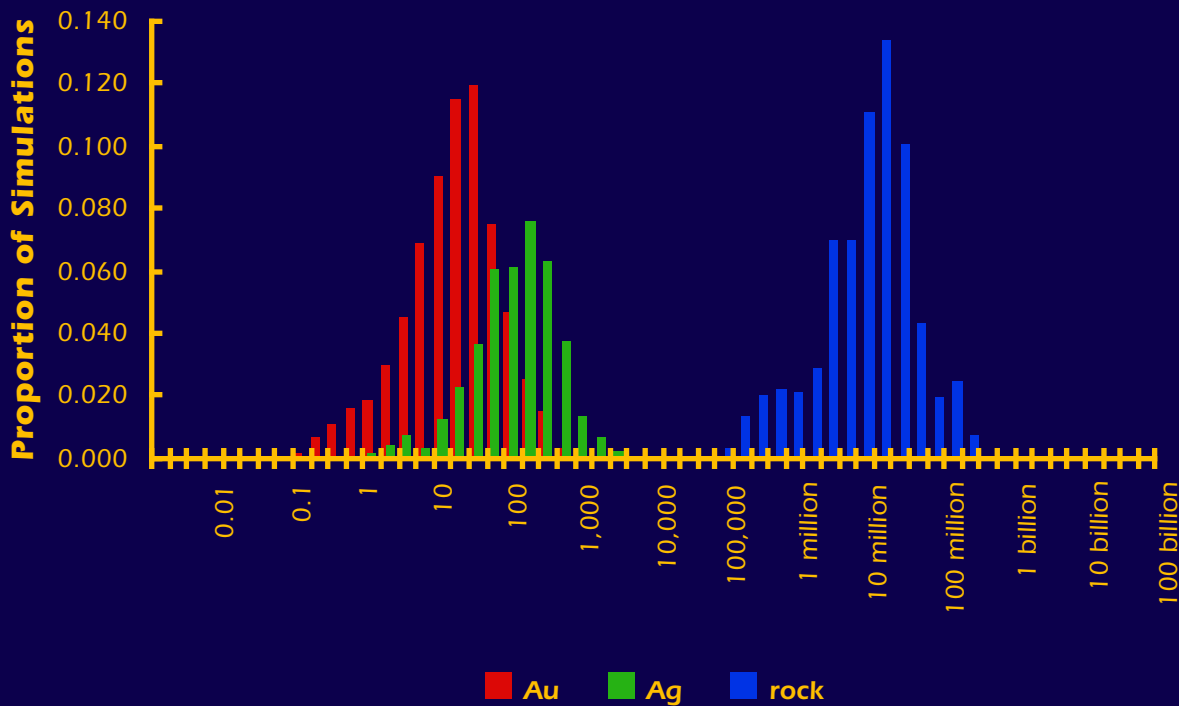


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



The tract ID is SB38

The Mark3 Index is 45:

Hot spring Au-Ag

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	9	0	5,900,000
0.10	92	380	53,200,000
0.05	160	640	100,000,000
mean	36	130	24,000,000
Probability of mean	0.25	0.23	0.25
Probability of zero	0.32	0.60	0.32

The tract ID is SB38The Mark3 Index is 45: **Hot spring Au-Ag**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 1 or more deposits.

There is a 10% or greater chance of 1 or more deposits.

There is a 5% or greater chance of 1 or more deposits.

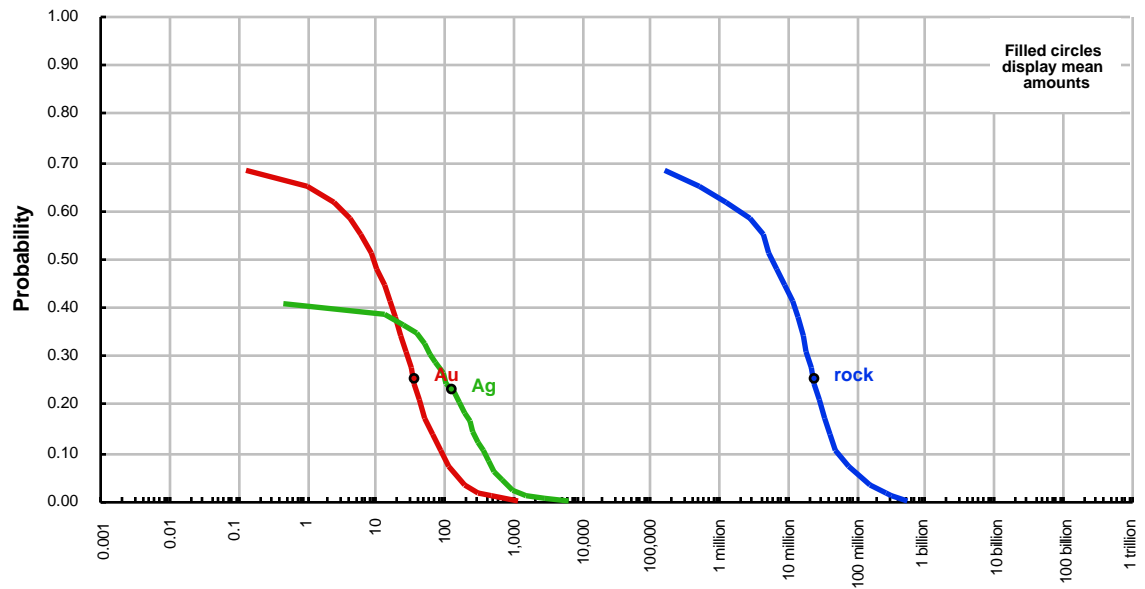
There is a 1% or greater chance of 2 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

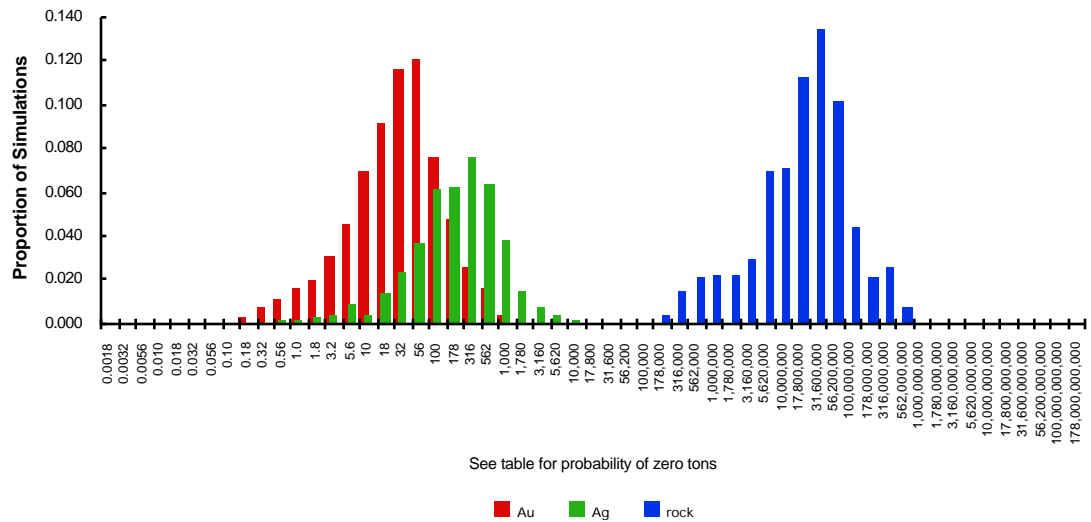
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	9	0	5,900,000
0.10	92	380	53,200,000
0.05	160	640	100,000,000
mean	36	130	24,000,000
Probability of mean	0.25	0.23	0.25
Probability of zero	0.32	0.60	0.32

The tract ID is SB38

Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)



Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)

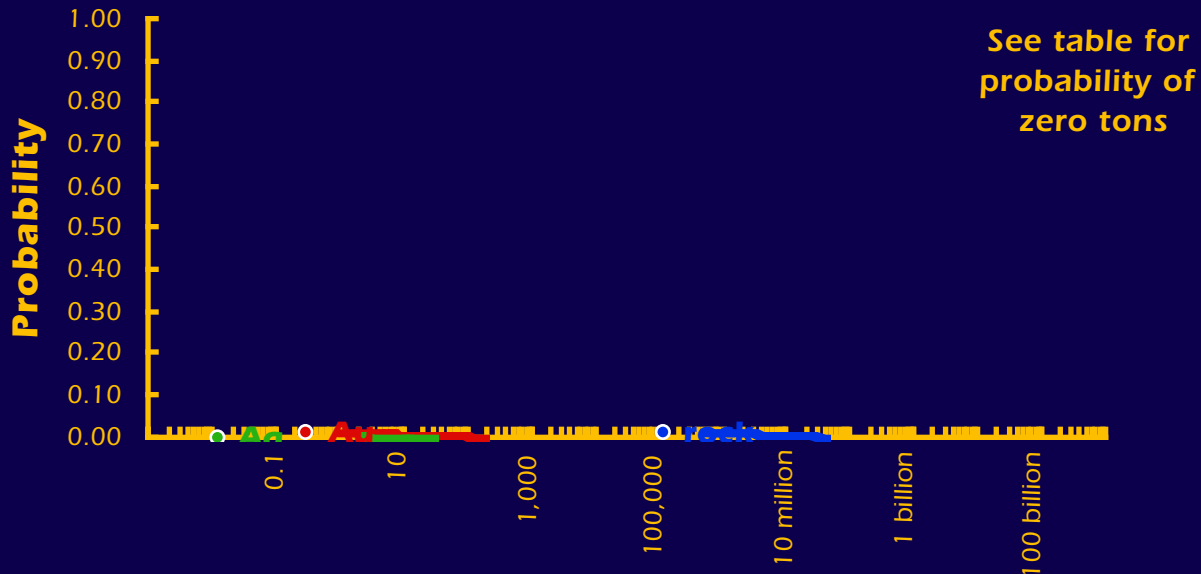


Figure 1 is a histogram showing the proportion of simulations for three materials: Au (red), Ag (green), and rock (blue). The x-axis represents the proportion of simulations on a logarithmic scale, ranging from 0.01 to 100 billion. The y-axis represents the proportion of simulations, ranging from 0.000 to 0.003. The distribution for Au is centered around 10, Ag is centered around 10, and rock is centered around 10 million.

Material	Proportion of Simulations (X-axis)	Proportion of Simulations (Y-axis)
Au	1	0.0001
	2	0.0002
	5	0.0004
	10	0.0008
	20	0.0004
	50	0.0002
	100	0.0001
	200	0.0001
	500	0.0001
	1000	0.0001
Ag	1	0.0001
	2	0.0002
	5	0.0004
	10	0.0008
	20	0.0004
rock	100,000	0.0001
	200,000	0.0002
	500,000	0.0004
	1,000,000	0.0008
	2,000,000	0.0004
	5,000,000	0.0008
	10,000,000	0.0008
	20,000,000	0.0004
	50,000,000	0.0008
	100,000,000	0.0004

The tract ID is SB40

The Mark3 Index is 17:
Sediment-hosted Au

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	0	0
0.05	0	0	0
mean	0	0	110,000
Probability of mean	0.01	0.00	0.01
Probability of zero	0.99	1.00	0.99

The tract ID is SB40The Mark3 Index is 17: **Sediment-hosted Au**

There is a 90% or greater chance of 0 or more deposits.

There is a 50% or greater chance of 0 or more deposits.

There is a 10% or greater chance of 0 or more deposits.

There is a 5% or greater chance of 0 or more deposits.

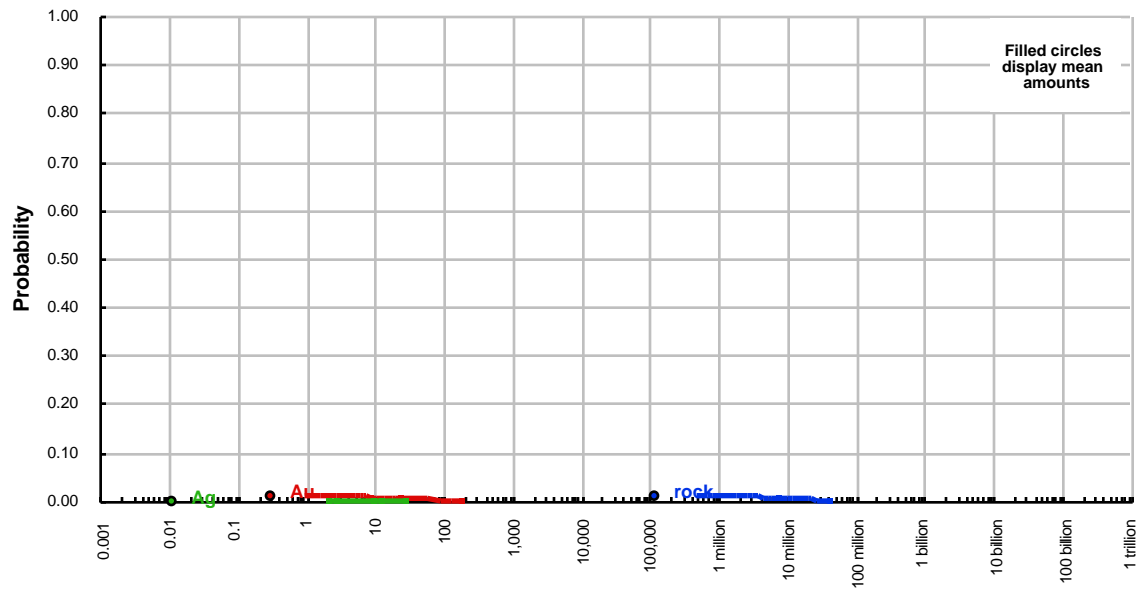
There is a 1% or greater chance of 1 or more deposits.

Estimated amounts of contained metal and mineralized rock (metric tons)

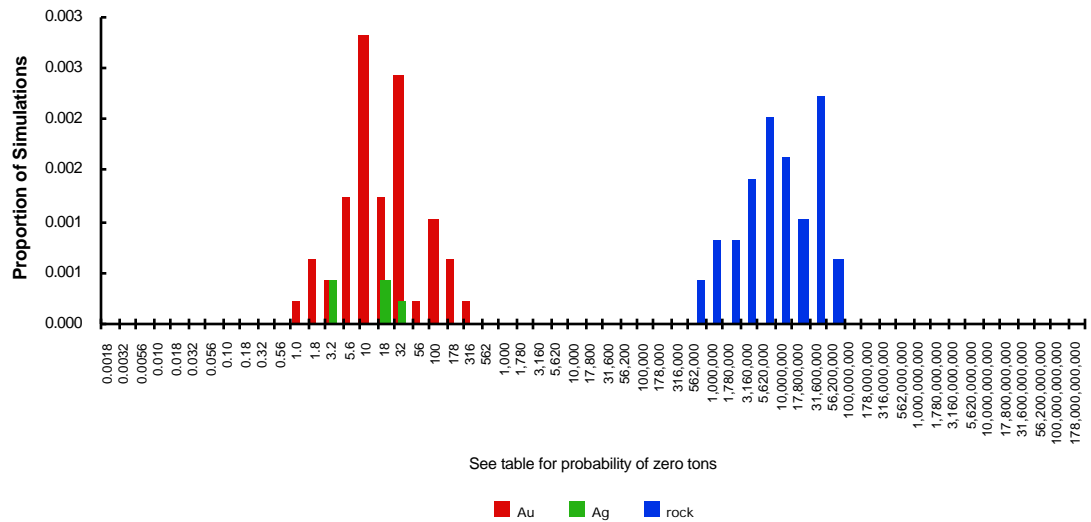
quantile	Au	Ag	rock
0.95	0	0	0
0.90	0	0	0
0.50	0	0	0
0.10	0	0	0
0.05	0	0	0
mean	0	0	110,000
Probability of mean	0.01	0.00	0.01
Probability of zero	0.99	1.00	0.99

The tract ID is SB40

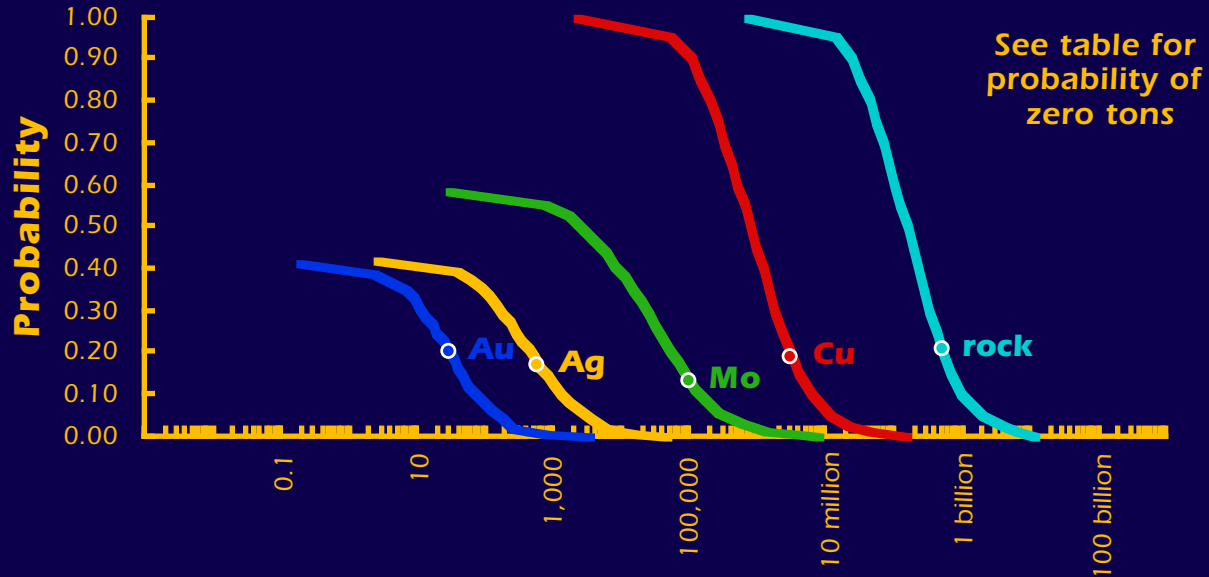
Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

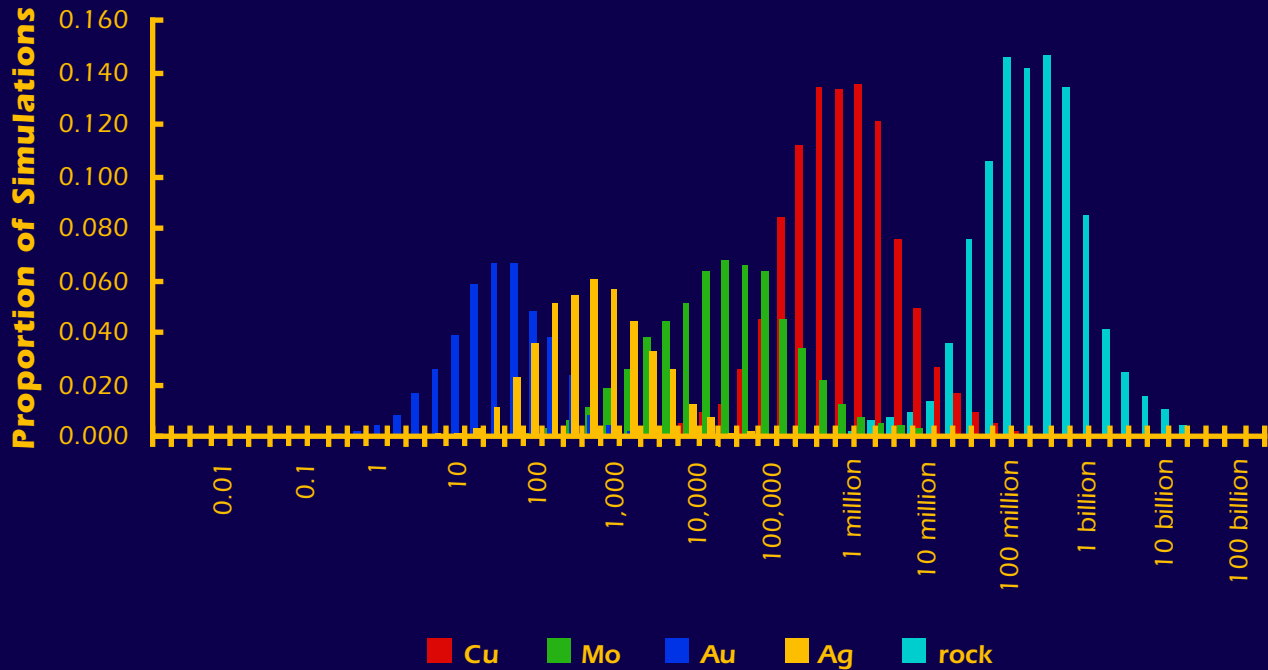


Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 4: **Porphyry Cu**

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	52,000	0	0	0	13,000,000
0.90	100,000	0	0	0	23,000,000
0.50	770,000	2,600	0	0	150,000,000
0.10	6,000,000	150,000	71	1,300	950,000,000
0.05	12,000,000	330,000	140	3,000	1,900,000,000
mean	3,100,000	97,000	29	590	490,000,000
Probability of mean	0.19	0.13	0.20	0.17	0.21
Probability of zero	0.00	0.42	0.59	0.58	0.00

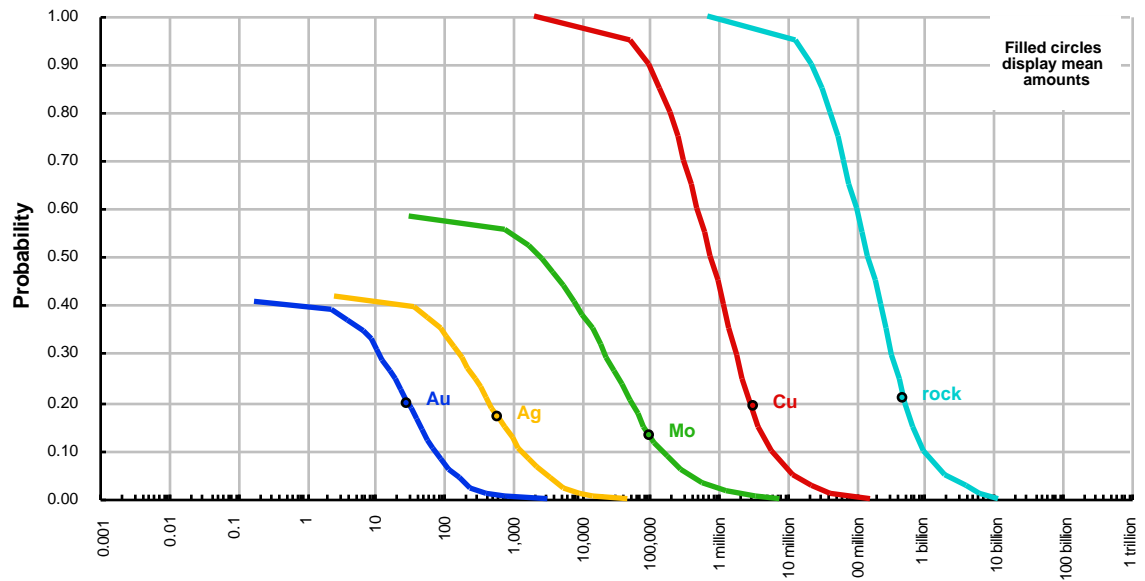
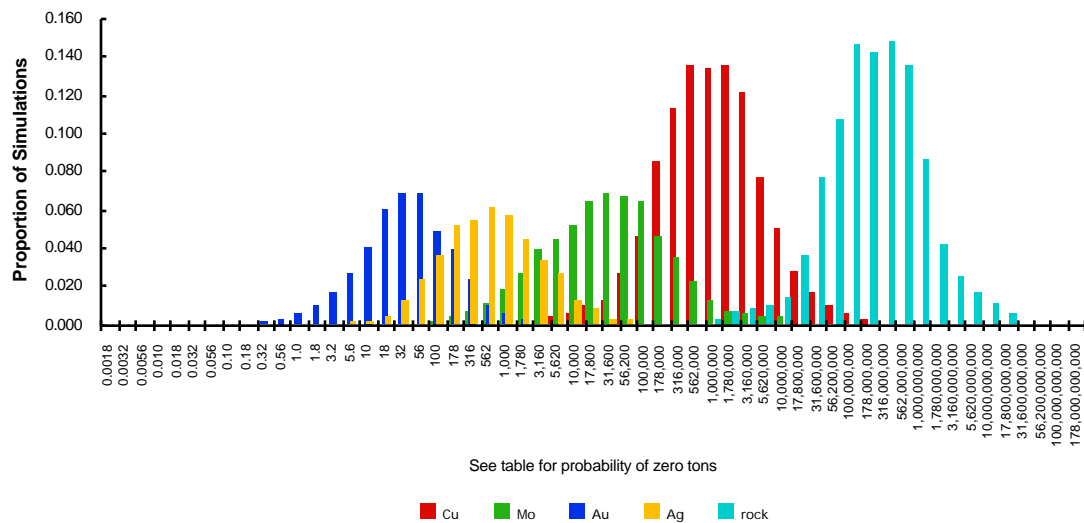
Simulated amounts of metal in a single deposit

Mark3 Index 4: **Porphyry Cu**

Estimated amounts of contained metal and mineralized rock (metric tons)

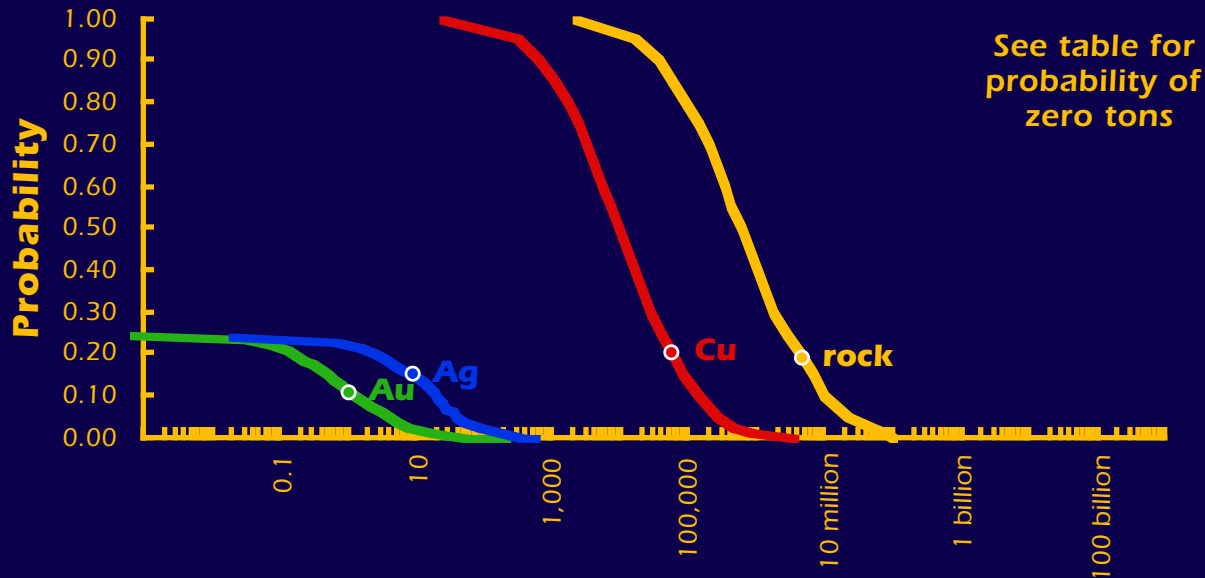
quantile	Cu	Mo	Au	Ag	rock
0.95	52,000	0	0	0	13,000,000
0.90	100,000	0	0	0	23,000,000
0.50	770,000	2,600	0	0	150,000,000
0.10	6,000,000	150,000	71	1,300	950,000,000
0.05	12,000,000	330,000	140	3,000	1,900,000,000
mean	3,100,000	97,000	29	590	490,000,000
Probability of mean	0.19	0.13	0.20	0.17	0.21
Probability of zero	0.00	0.42	0.59	0.58	0.00

Simulated amounts of metal in a single deposit

Mark3 Index 4: **Porphyry Cu****Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

Mark3 Index 8: Skarn Cu

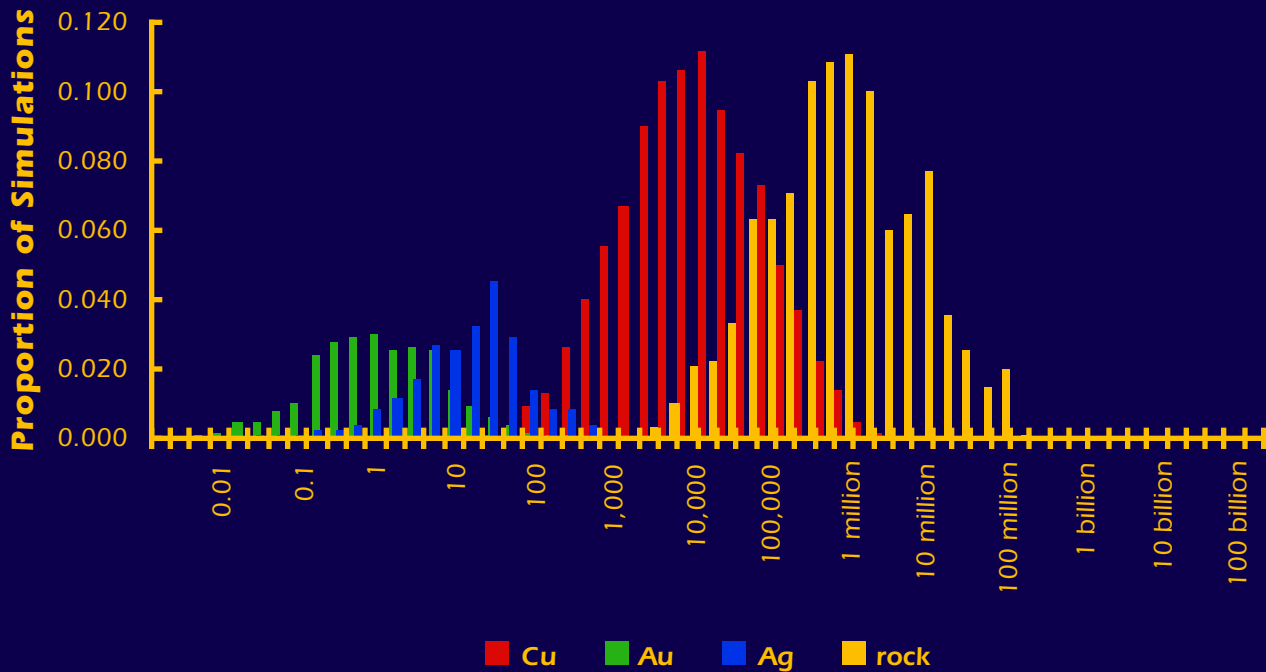
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 8: Skarn Cu

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 8: Skarn Cu

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Ag	rock
0.95	310	0	0	16,000
0.90	620	0	0	35,000
0.50	9,300	0	0	580,000
0.10	140,000	1	20	9,700,000
0.05	270,000	4	38	22,000,000
mean	58,000	1	9	4,600,000
Probability of mean	0.20	0.11	0.15	0.19
Probability of zero	0.00	0.75	0.76	0.00

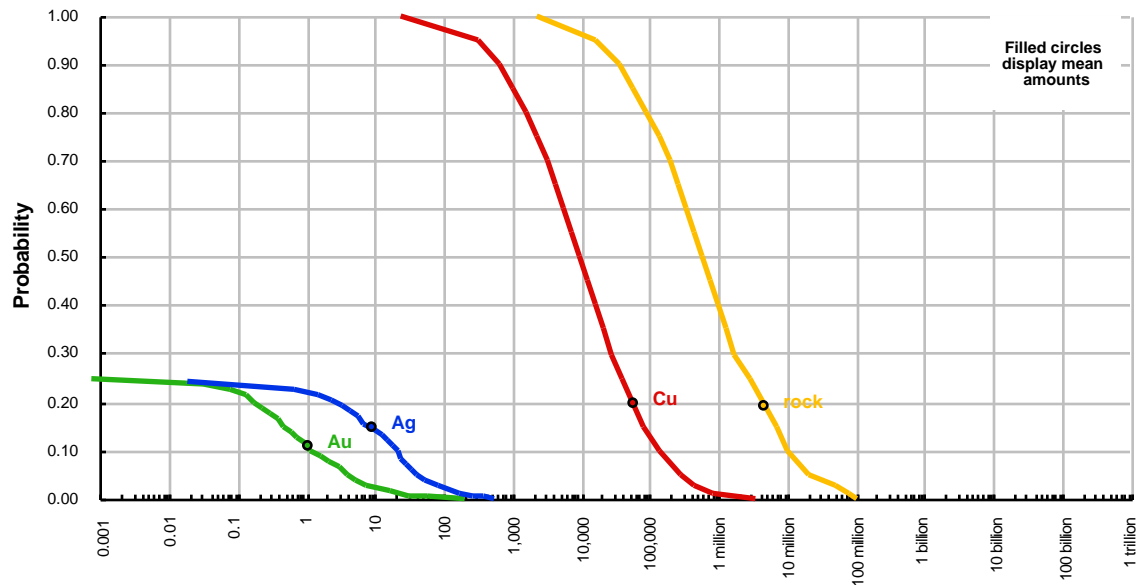
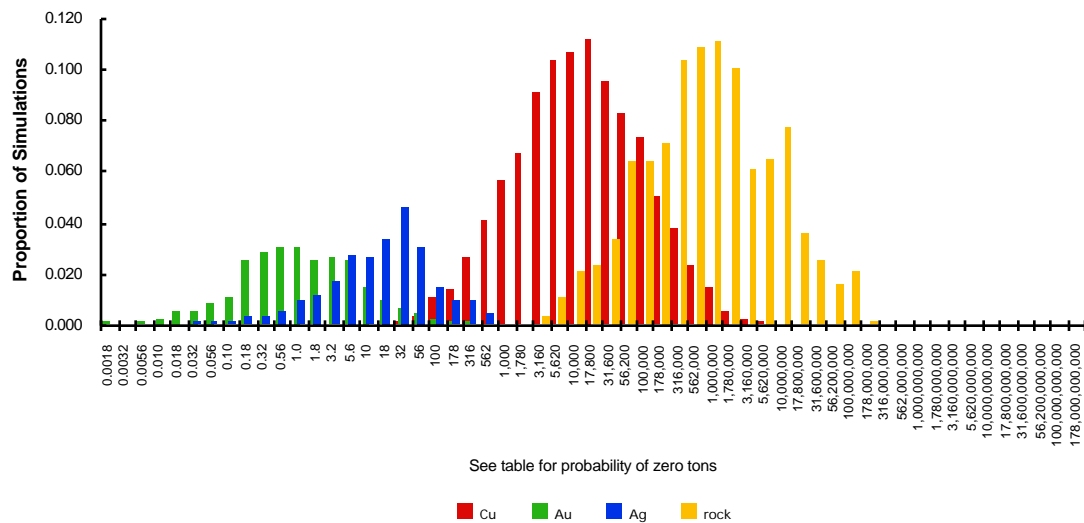
Simulated amounts of metal in a single deposit

Mark3 Index 8: **Skarn Cu**

Estimated amounts of contained metal and mineralized rock (metric tons)

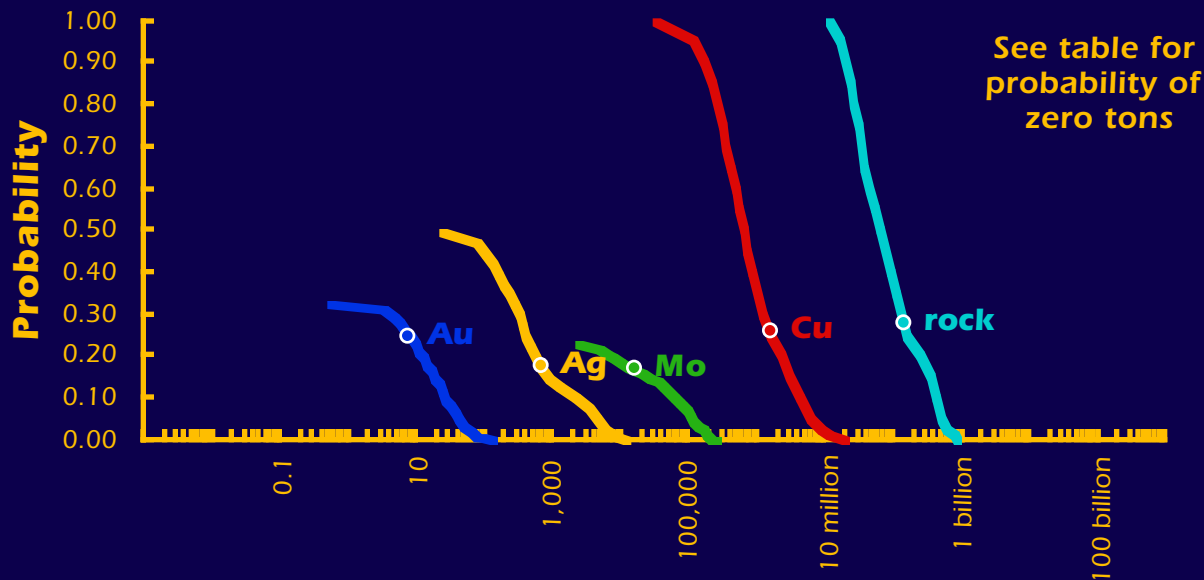
quantile	Cu	Au	Ag	rock
0.95	310	0	0	16,000
0.90	620	0	0	35,000
0.50	9,300	0	0	580,000
0.10	140,000	1	20	9,700,000
0.05	270,000	4	38	22,000,000
mean	58,000	1	9	4,600,000
Probability of mean	0.20	0.11	0.15	0.19
Probability of zero	0.00	0.75	0.76	0.00

Simulated amounts of metal in a single deposit

Mark3 Index 8: **Skarn Cu****Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

Mark3 Index 9: Porphyry Cu, skarn related

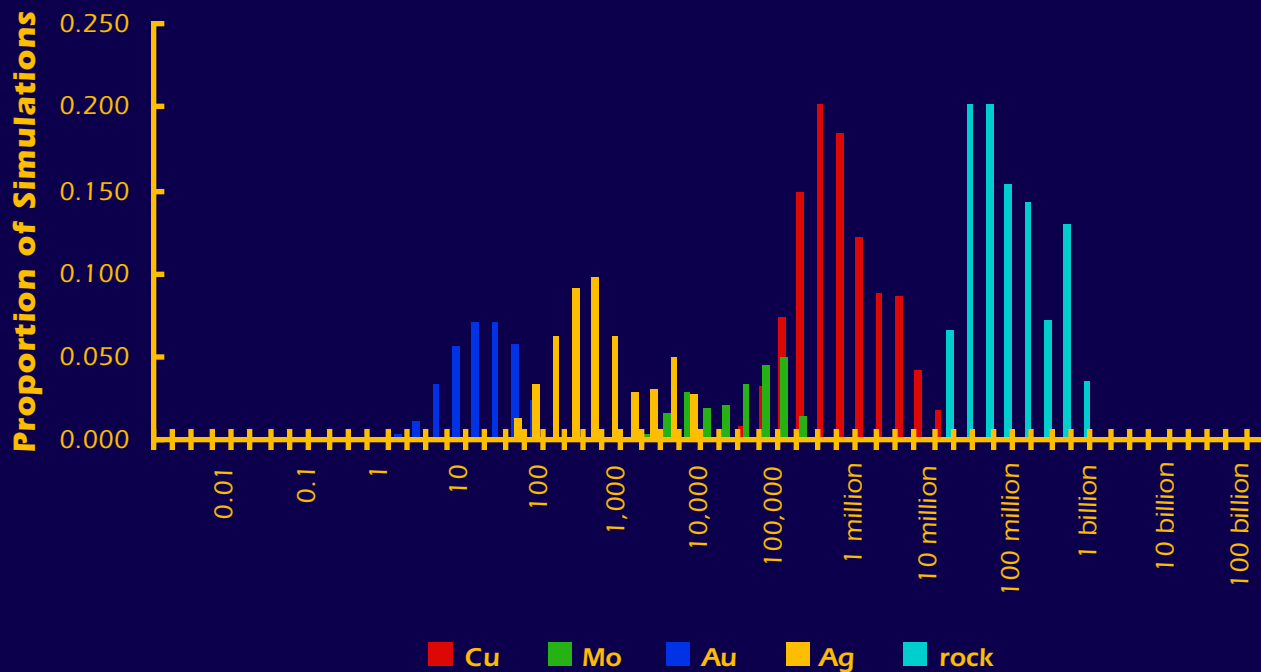
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 9: Porphyry Cu, skarn related

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 9: **Porphyry Cu, skarn related**

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	110,000	0	0	0	17,000,000
0.90	170,000	0	0	0	21,000,000
0.50	620,000	0	0	0	63,000,000
0.10	4,400,000	63,000	27	2,100	440,000,000
0.05	6,100,000	120,000	43	4,500	530,000,000
mean	1,500,000	16,000	8	660	140,000,000
Probability of mean	0.26	0.17	0.25	0.18	0.28
Probability of zero	0.00	0.77	0.67	0.51	0.00

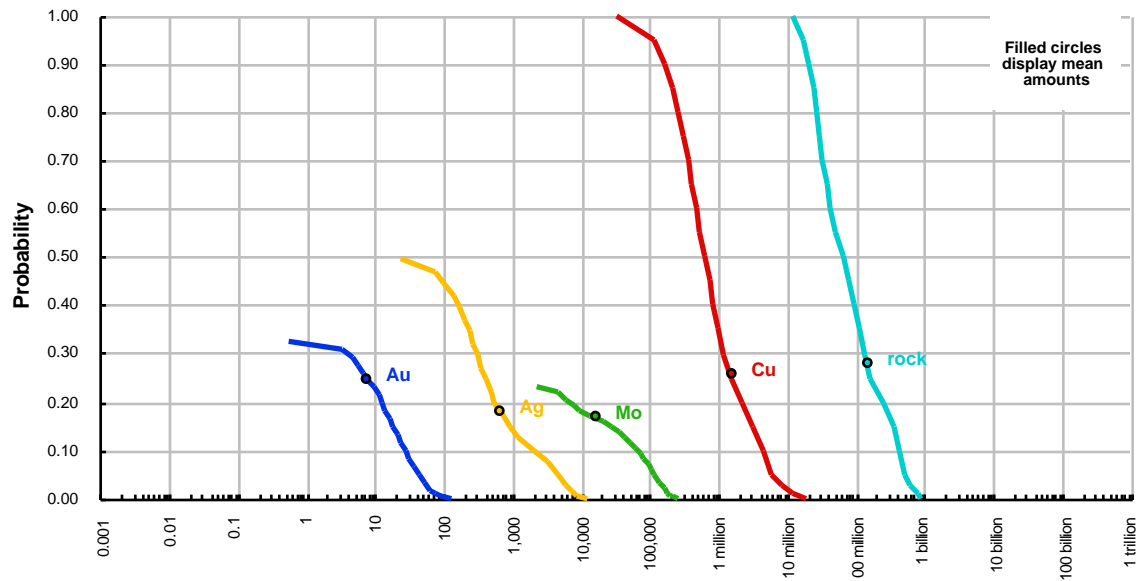
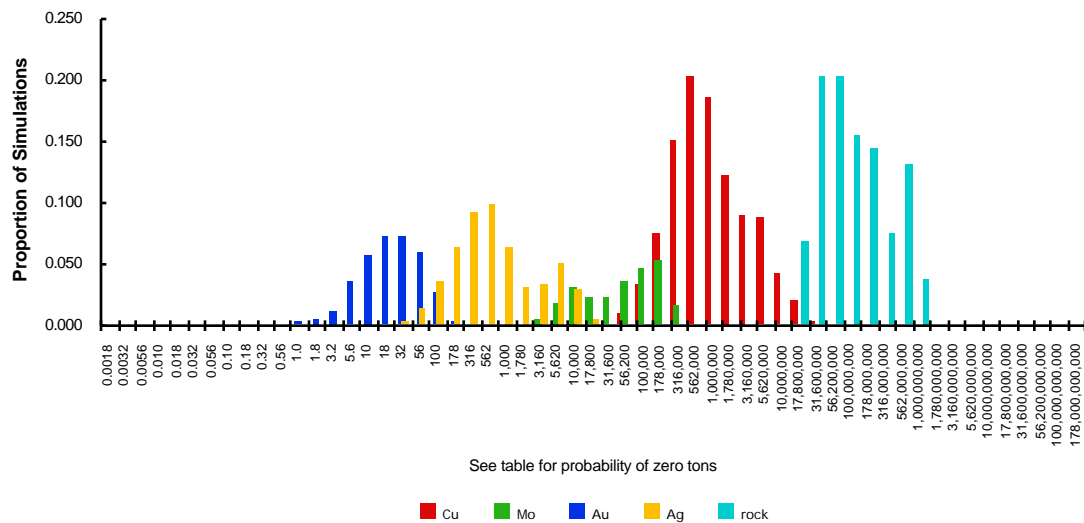
Simulated amounts of metal in a single deposit

Mark3 Index 9: **Porphyry Cu, skarn related**

Estimated amounts of contained metal and mineralized rock (metric tons)

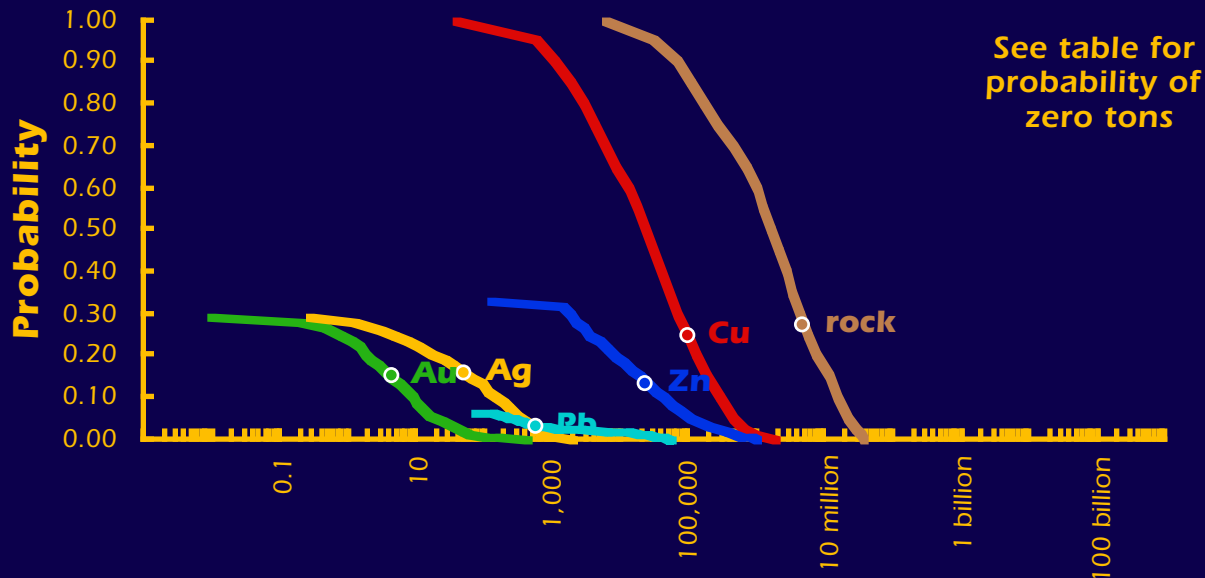
quantile	Cu	Mo	Au	Ag	rock
0.95	110,000	0	0	0	17,000,000
0.90	170,000	0	0	0	21,000,000
0.50	620,000	0	0	0	63,000,000
0.10	4,400,000	63,000	27	2,100	440,000,000
0.05	6,100,000	120,000	43	4,500	530,000,000
mean	1,500,000	16,000	8	660	140,000,000
Probability of mean	0.26	0.17	0.25	0.18	0.28
Probability of zero	0.00	0.77	0.67	0.51	0.00

Simulated amounts of metal in a single deposit

Mark3 Index 9: **Porphyry Cu, skarn related****Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

Mark3 Index 11: Massive sulfide, Cyprus

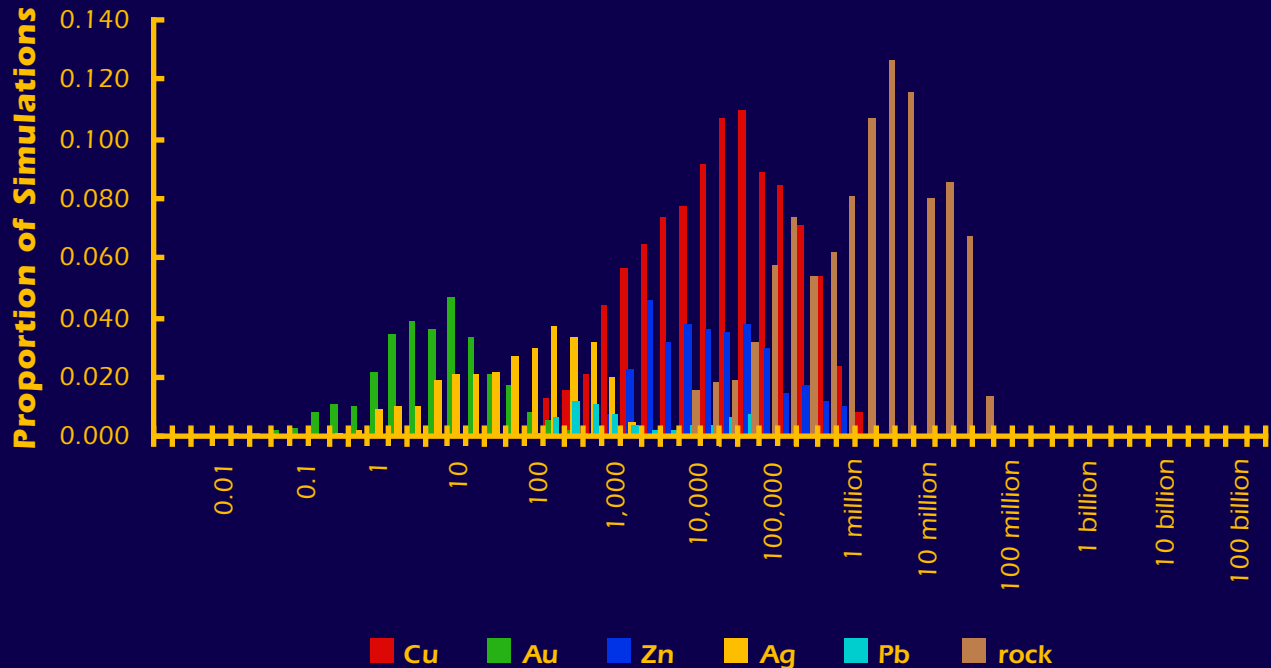
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 11: Massive sulfide, Cyprus

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 11: Massive sulfide, Cyprus

Estimated amounts of contained metal and mineralized rock (metric tons)

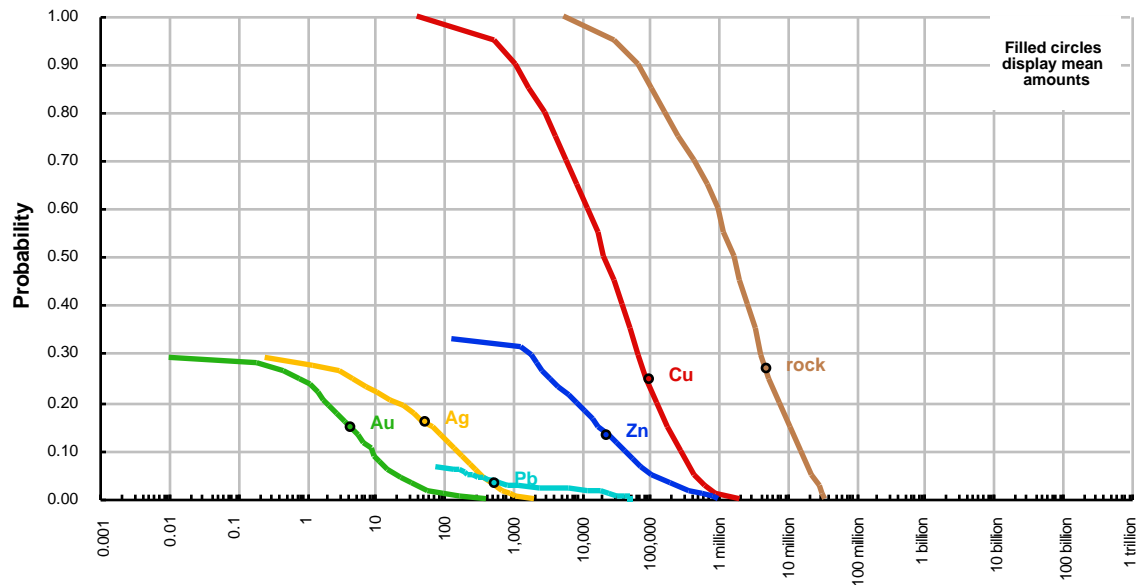
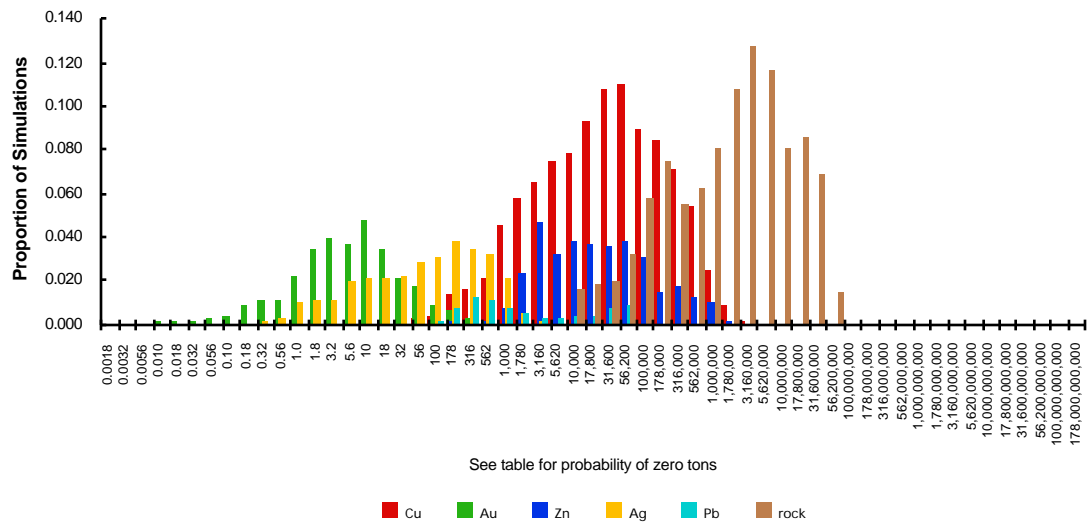
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	540	0	0	0	0	31,000
0.90	1,100	0	0	0	0	66,000
0.50	22,000	0	0	0	0	1,600,000
0.10	270,000	9	42,100	150	0	16,000,000
0.05	440,000	19	100,000	350	240	22,000,000
mean	93,000	4	24,000	51	560	4,900,000
Probability of mean	0.25	0.15	0.13	0.16	0.03	0.27
Probability of zero	0.00	0.71	0.67	0.71	0.94	0.00

Simulated amounts of metal in a single deposit

Mark3 Index 11: **Massive sulfide, Cyprus**

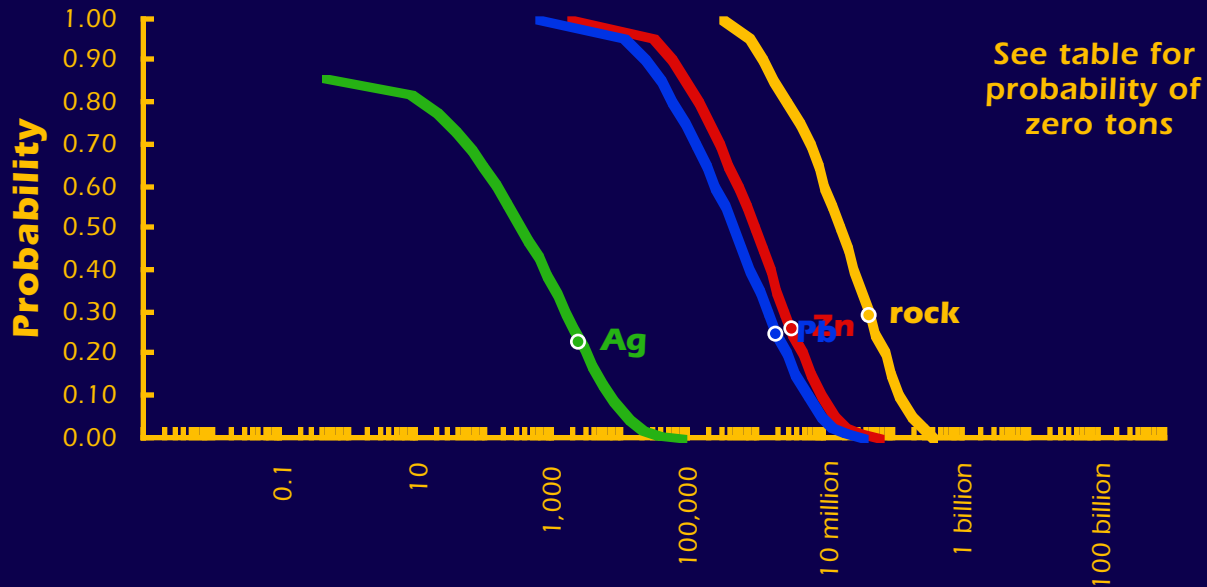
Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	540	0	0	0	0	31,000
0.90	1,100	0	0	0	0	66,000
0.50	22,000	0	0	0	0	1,600,000
0.10	270,000	9	42,100	150	0	16,000,000
0.05	440,000	19	100,000	350	240	22,000,000
mean	93,000	4	24,000	51	560	4,900,000
Probability of mean	0.25	0.15	0.13	0.16	0.03	0.27
Probability of zero	0.00	0.71	0.67	0.71	0.94	0.00

Simulated amounts of metal in a single deposit Mark3 Index 11: **Massive sulfide, Cyprus****Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

Mark3 Index 13: Sedimentary exhalative Zn-Pb

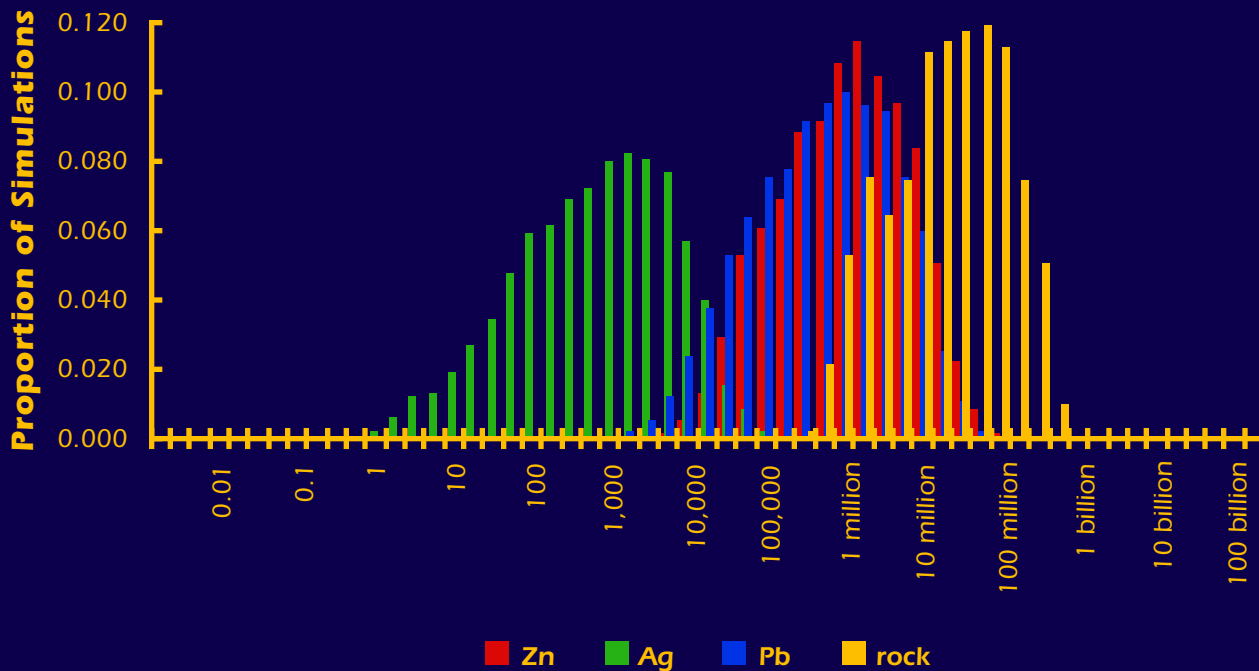
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 13: Sedimentary exhalative Zn-Pb

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 13: Sedimentary exhalative Zn-Pb

Estimated amounts of contained metal and mineralized rock (metric tons)

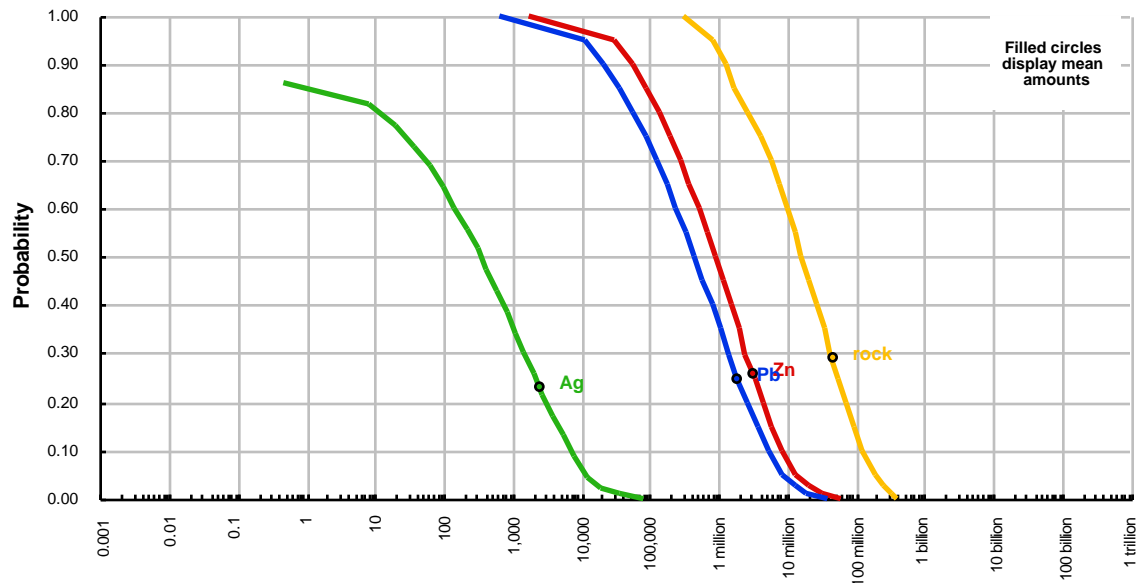
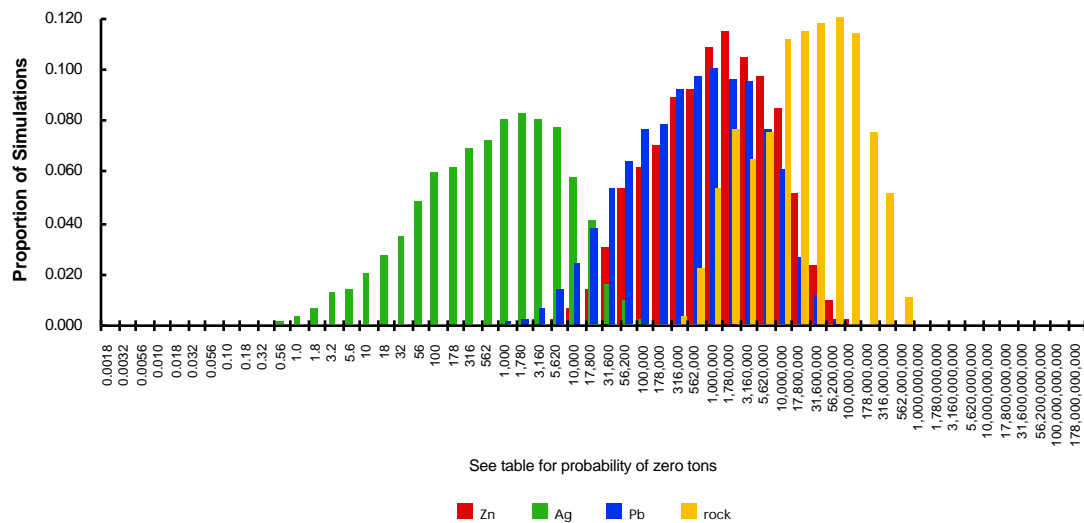
quantile	Zn	Ag	Pb	rock
0.95	31,000	0	11,000	800,000
0.90	55,000	0	22,000	1,200,000
0.50	910,000	350	450,000	16,000,000
0.10	8,800,000	6,900	5,430,000	120,000,000
0.05	14,000,000	12,000	8,800,000	200,000,000
mean	3,200,000	2,500	1,900,000	45,000,000
Probability of mean	0.26	0.23	0.25	0.29
Probability of zero	0.00	0.14	0.00	0.00

Simulated amounts of metal in a single deposit

Mark3 Index 13: **Sedimentary exhalative Zn-Pb**

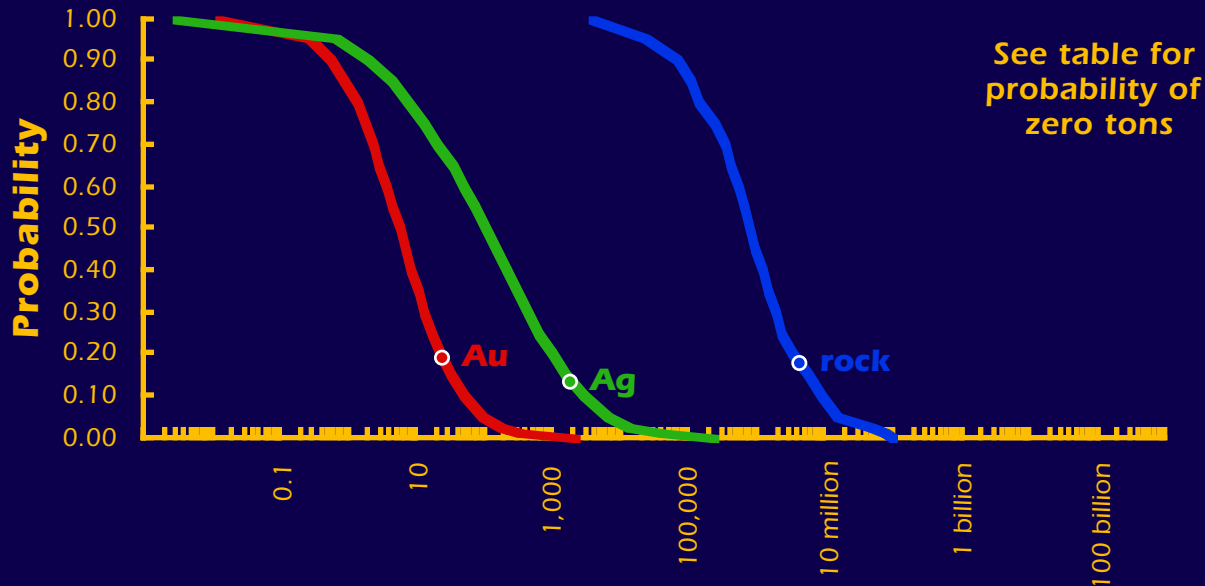
Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Zn	Ag	Pb	rock
0.95	31,000	0	11,000	800,000
0.90	55,000	0	22,000	1,200,000
0.50	910,000	350	450,000	16,000,000
0.10	8,800,000	6,900	5,430,000	120,000,000
0.05	14,000,000	12,000	8,800,000	200,000,000
mean	3,200,000	2,500	1,900,000	45,000,000
Probability of mean	0.26	0.23	0.25	0.29
Probability of zero	0.00	0.14	0.00	0.00

Simulated amounts of metal in a single deposit Mark3 Index 13: **Sedimentary exhalative Zn-Pb****Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

Mark3 Index 16: Epithermal vein, Comstock

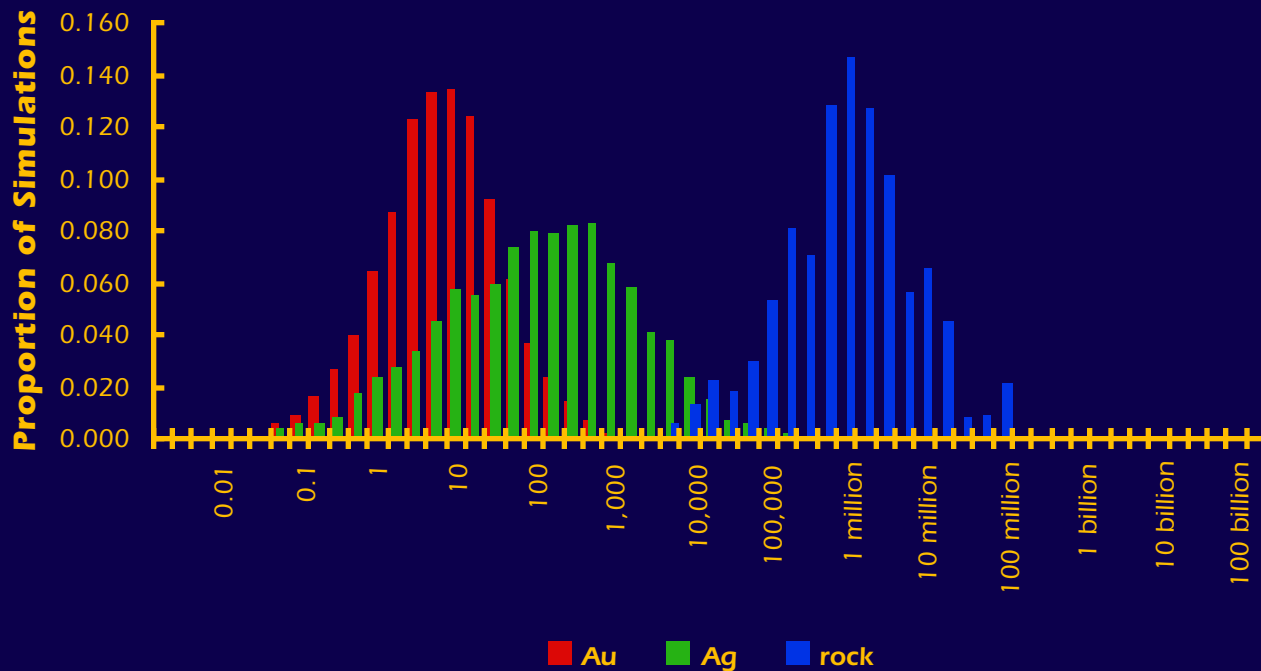
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 16: Epithermal vein, Comstock

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 16: Epithermal vein, Comstock

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	1	22,000
0.90	1	2	65,000
0.50	5	100	770,000
0.10	47	2,900	8,870,000
0.05	93	6,400	14,000,000
mean	23	1,800	4,100,000
Probability of mean	0.19	0.13	0.18
Probability of zero	0.00	0.00	0.00

Simulated amounts of metal in a single deposit

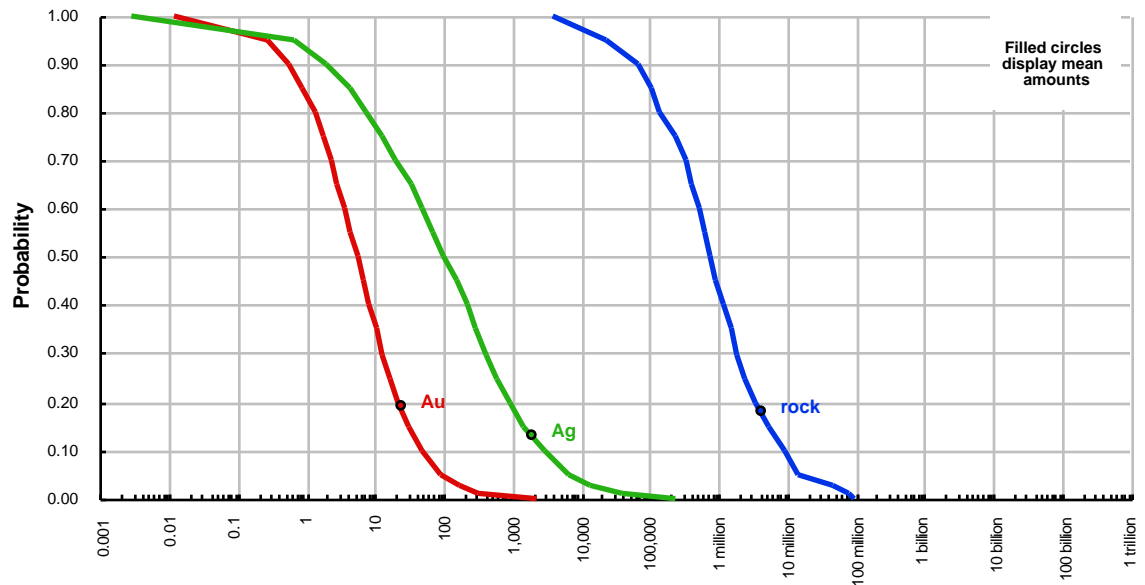
Mark3 Index 16: **Epithermal vein, Comstock**

Estimated amounts of contained metal and mineralized rock (metric tons)

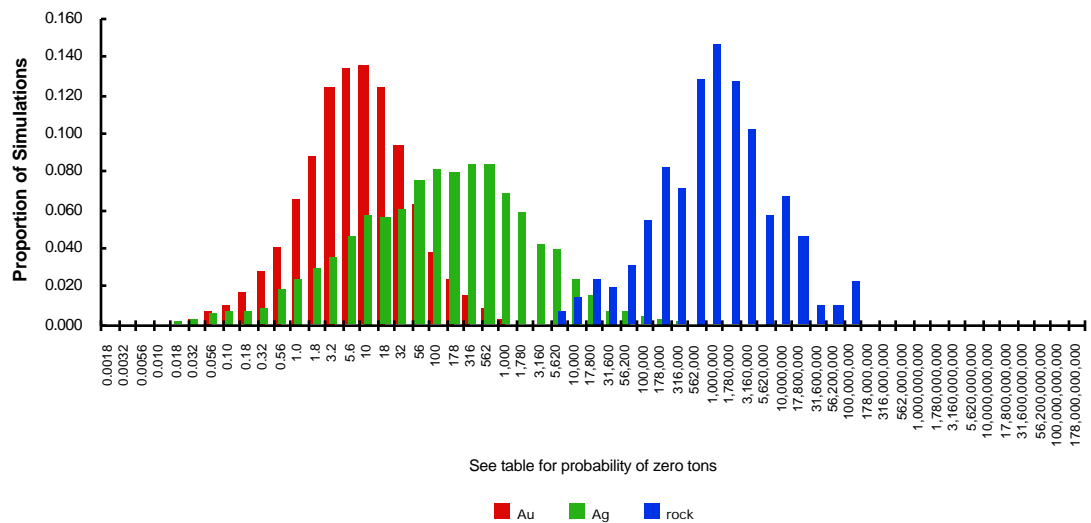
quantile	Au	Ag	rock
0.95	0	1	22,000
0.90	1	2	65,000
0.50	5	100	770,000
0.10	47	2,900	8,870,000
0.05	93	6,400	14,000,000
mean	23	1,800	4,100,000
Probability of mean	0.19	0.13	0.18
Probability of zero	0.00	0.00	0.00

Simulated amounts of metal in a single deposit Mark3 Index 16: Epithermal vein, Comstock

Cumulative Distributions of Contained Metal and Mineralized Rock

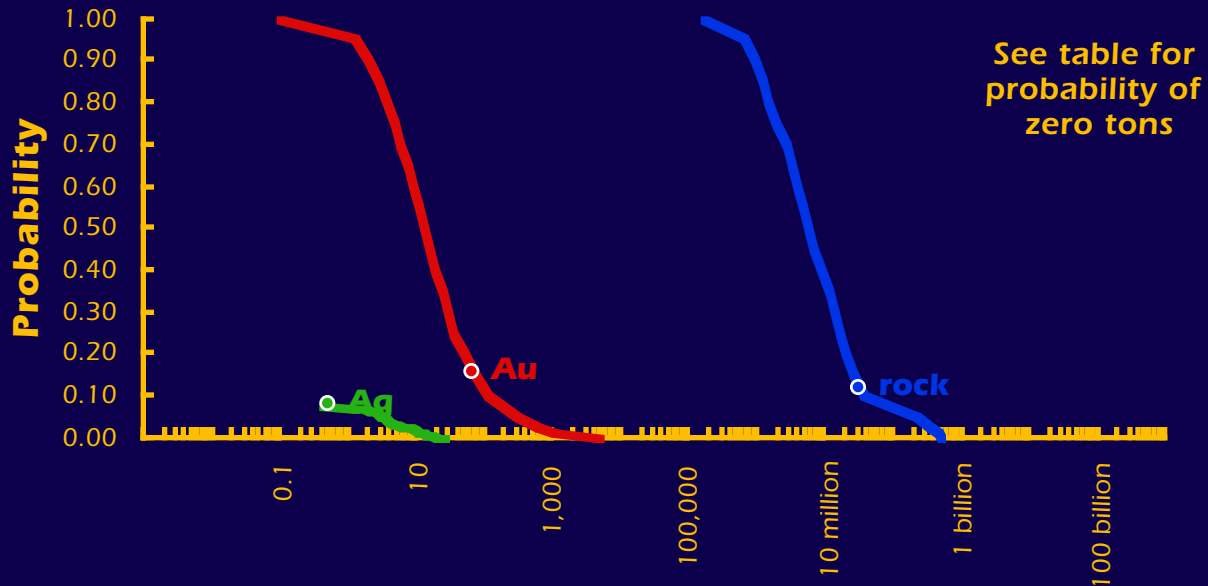


Histograms of Contained Metal and Mineralized Rock (metric tons)



Mark3 Index 17: Sediment-hosted Au

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)

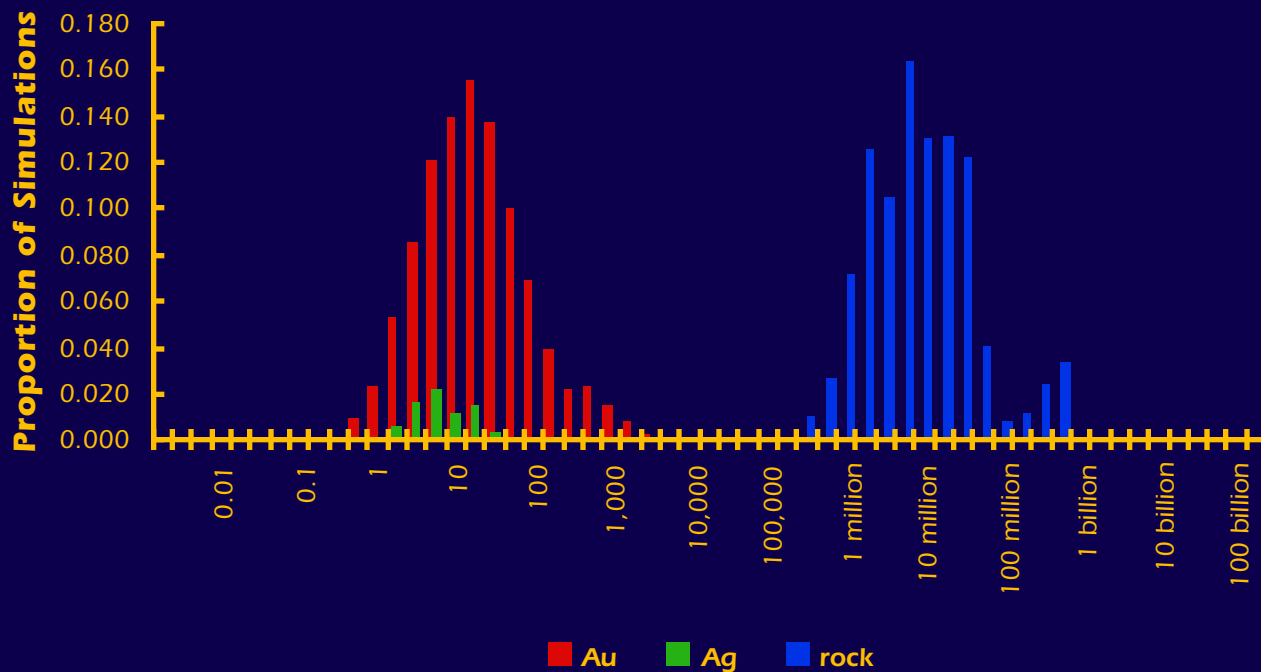


See table for
probability of
zero tons

Filled circles display mean amounts

Mark3 Index 17: Sediment-hosted Au

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 17: Sediment-hosted Au

Estimated amounts of contained metal and mineralized rock (metric tons)

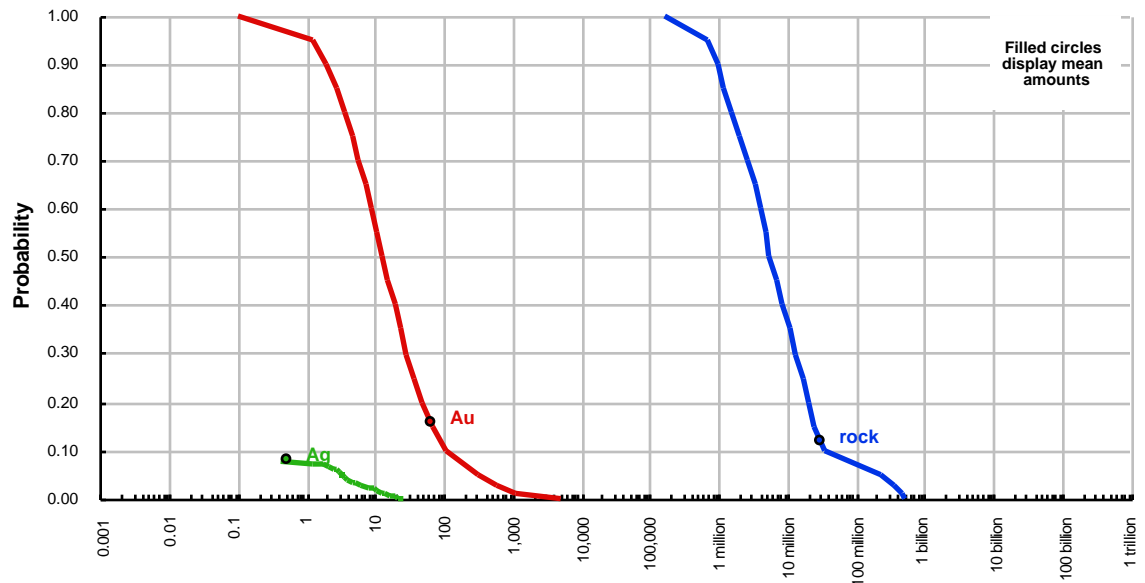
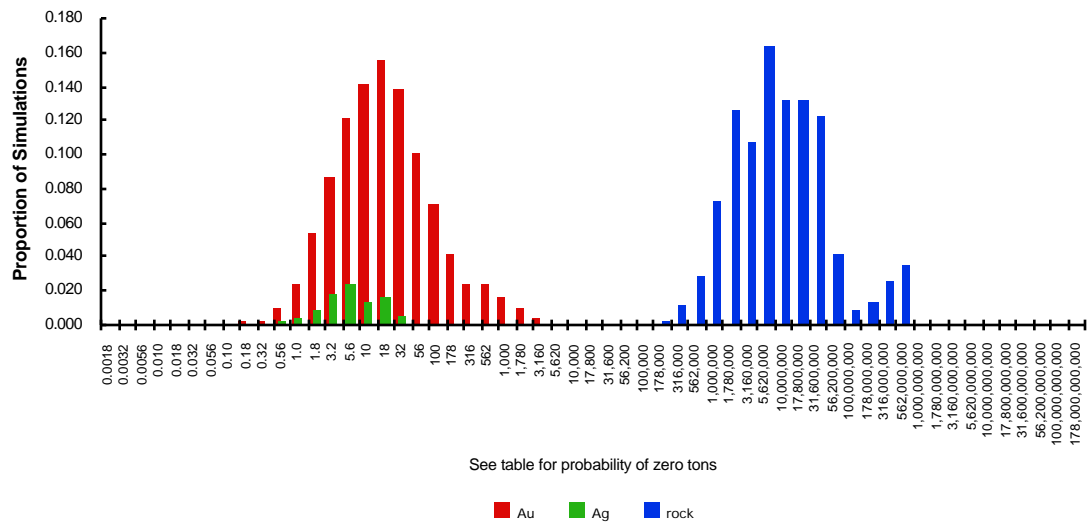
quantile	Au	Ag	rock
0.95	1	0	670,000
0.90	2	0	960,000
0.50	13	0	5,600,000
0.10	110	0	36,300,000
0.05	310	3	230,000,000
mean	65	1	30,000,000
Probability of mean	0.16	0.08	0.12
Probability of zero	0.00	0.92	0.00

Simulated amounts of metal in a single deposit

Mark3 Index 17: **Sediment-hosted Au**

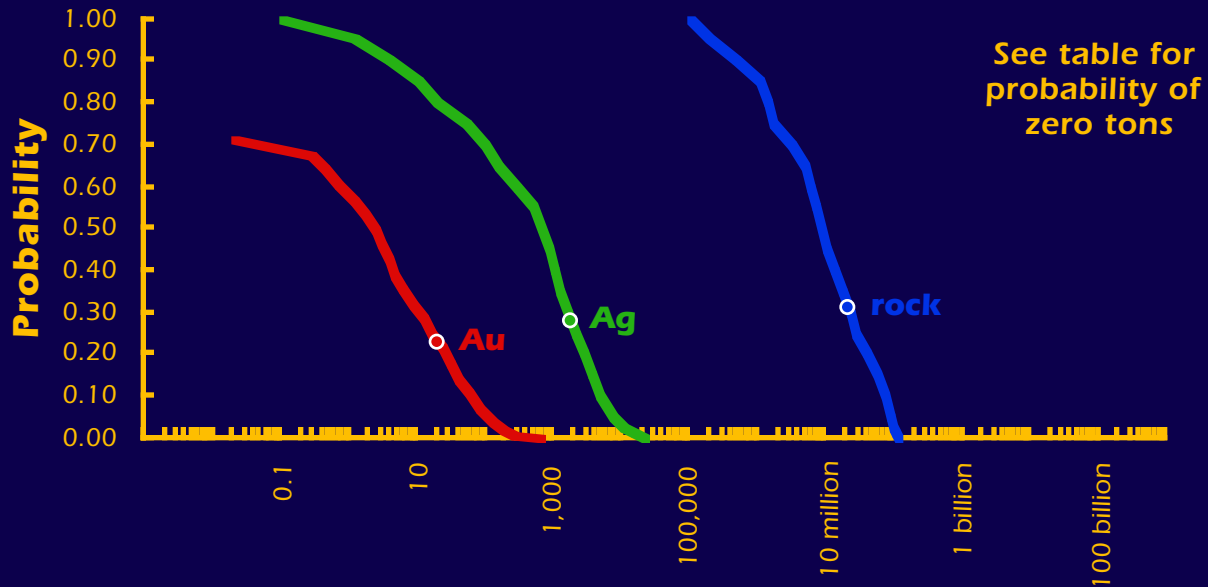
Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	1	0	670,000
0.90	2	0	960,000
0.50	13	0	5,600,000
0.10	110	0	36,300,000
0.05	310	3	230,000,000
mean	65	1	30,000,000
Probability of mean	0.16	0.08	0.12
Probability of zero	0.00	0.92	0.00

Simulated amounts of metal in a single deposit Mark3 Index 17: **Sediment-hosted Au****Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

Mark3 Index 18: **Distal disseminated Ag-Au**

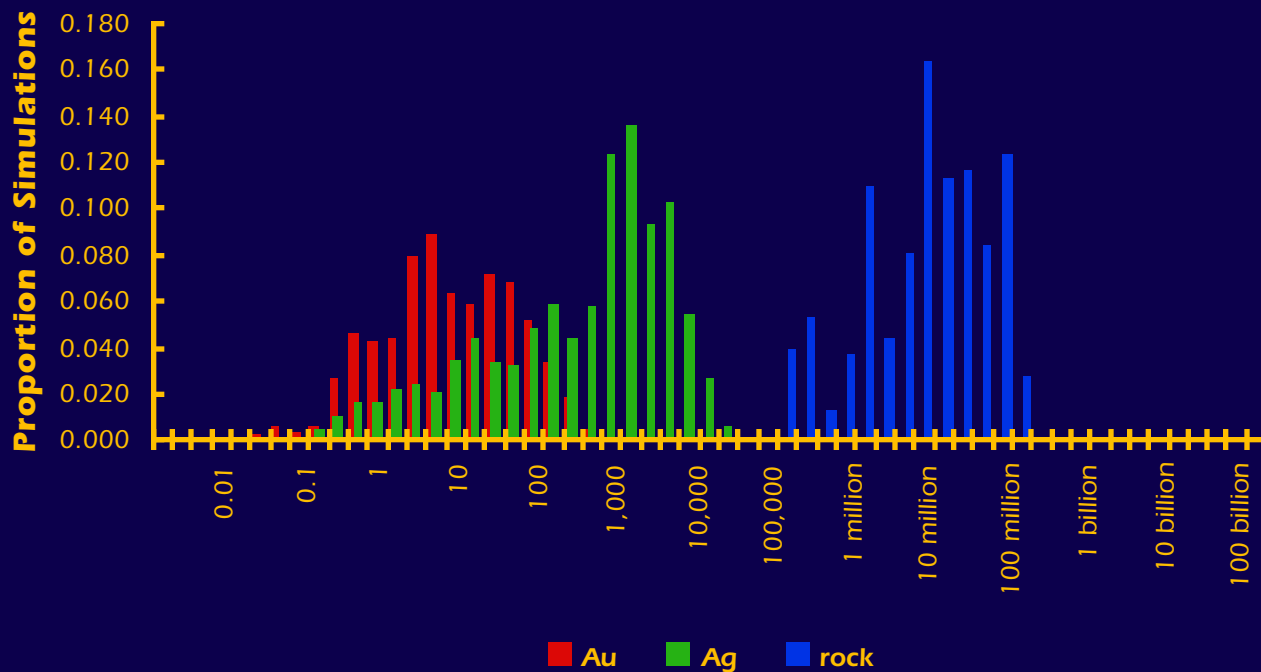
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 18: Distal disseminated Ag-Au

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 18: Distal disseminated Ag-Au

Estimated amounts of contained metal and mineralized rock (metric tons)

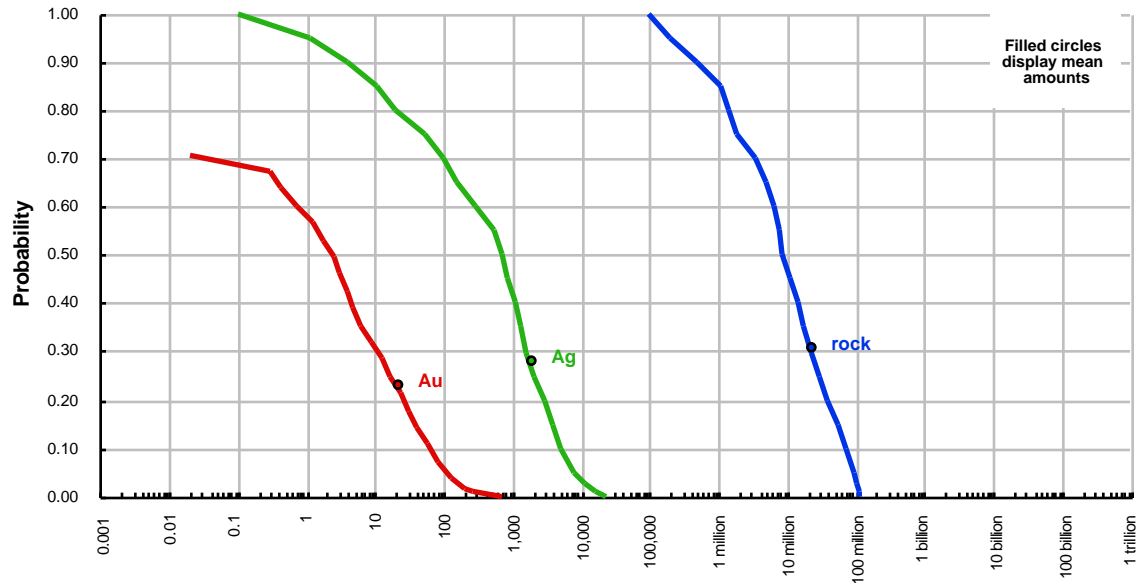
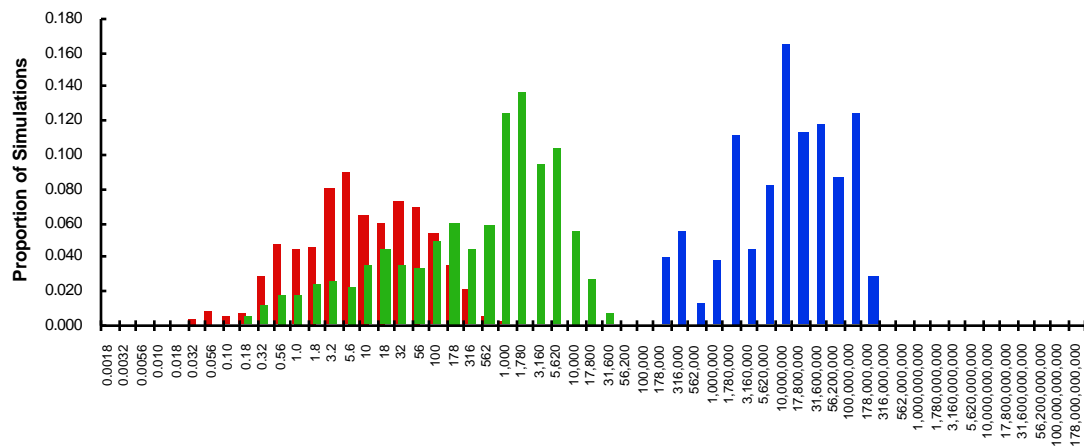
quantile	Au	Ag	rock
0.95	0	1	200,000
0.90	0	4	480,000
0.50	2	690	8,800,000
0.10	62	5,100	75,300,000
0.05	110	7,900	91,000,000
mean	21	1,800	22,000,000
Probability of mean	0.23	0.28	0.31
Probability of zero	0.29	0.00	0.00

Simulated amounts of metal in a single deposit

Mark3 Index 18: **Distal disseminated Ag-Au**

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	1	200,000
0.90	0	4	480,000
0.50	2	690	8,800,000
0.10	62	5,100	75,300,000
0.05	110	7,900	91,000,000
mean	21	1,800	22,000,000
Probability of mean	0.23	0.28	0.31
Probability of zero	0.29	0.00	0.00

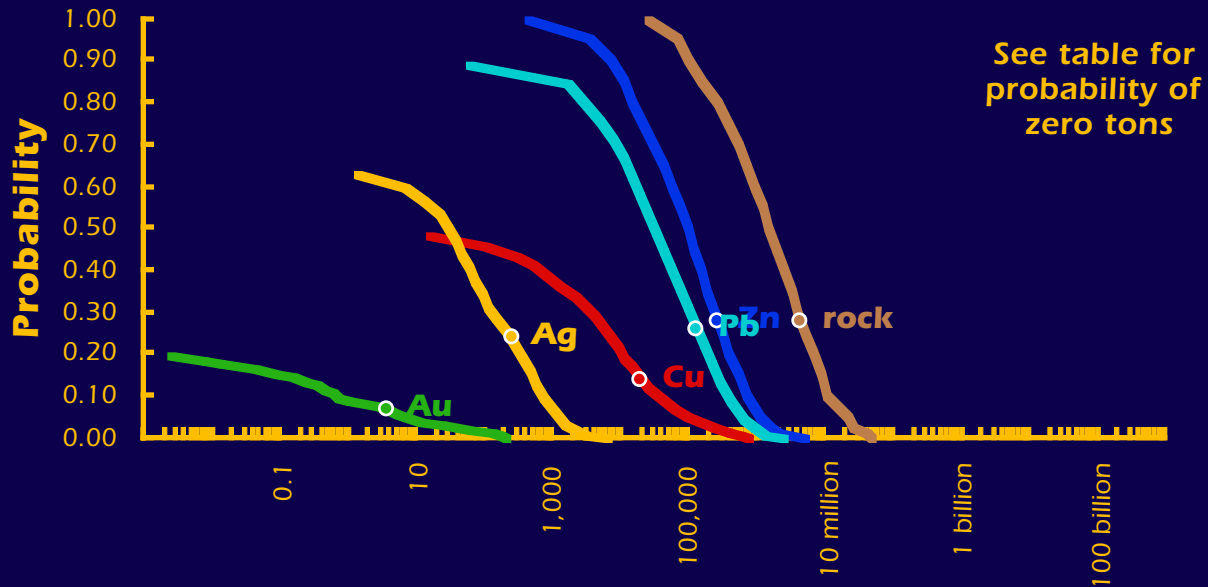
Simulated amounts of metal in a single deposit Mark3 Index 18: **Distal disseminated Ag-Au****Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

See table for probability of zero tons

■ Au ■ Ag ■ rock

Mark3 Index 22: Skarn Zn-Pb

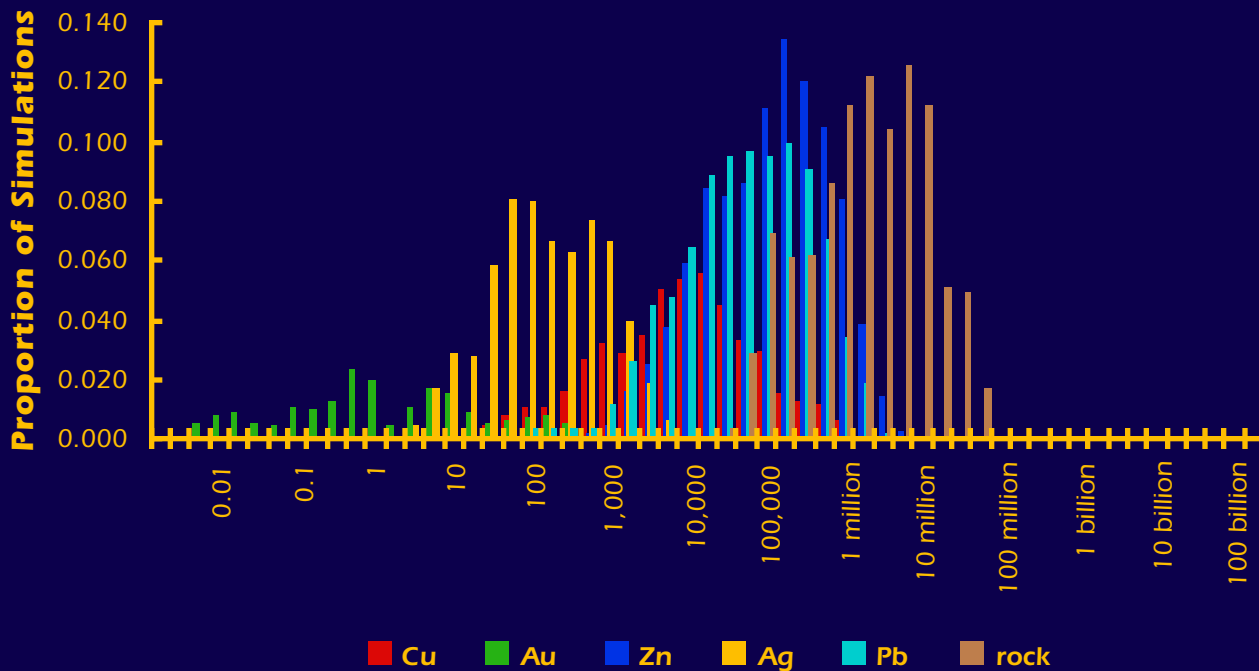
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 22: Skarn Zn-Pb

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 22: Skorn Zn-Pb

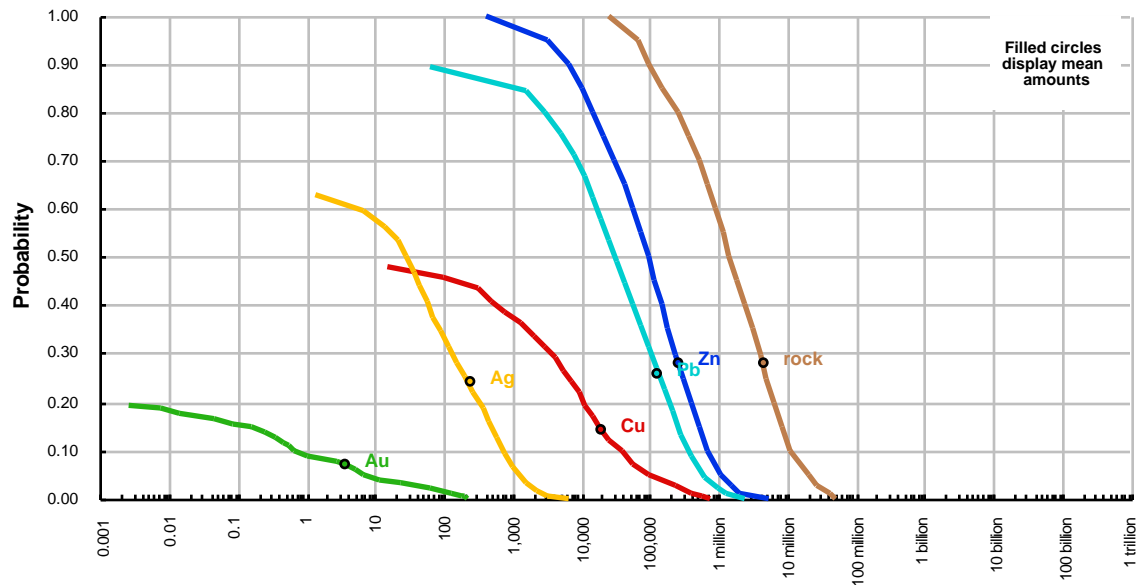
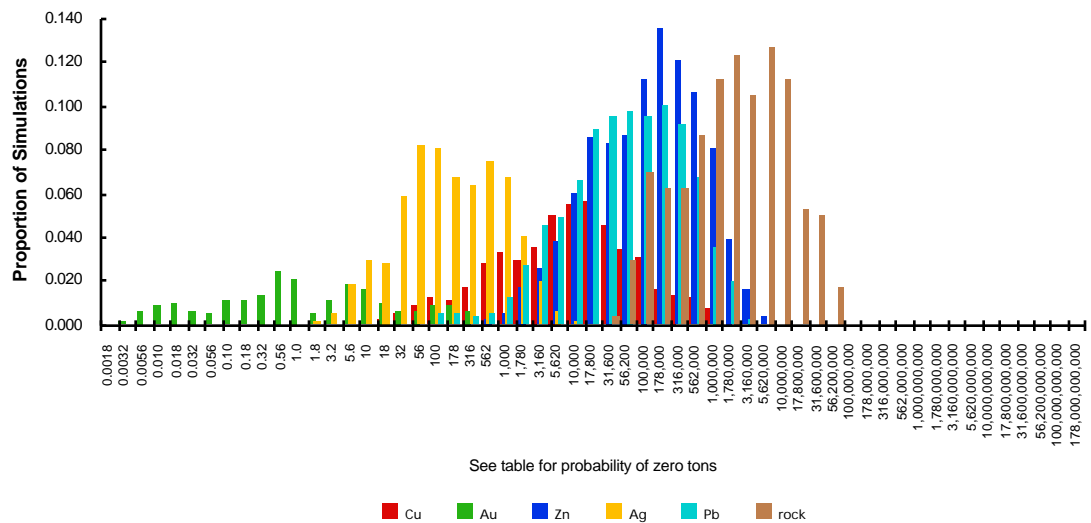
Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	3,300	0	0	69,000
0.90	0	0	6,900	0	0	100,000
0.50	0	0	96,000	30	32,000	1,400,000
0.10	35,000	1	708,000	730	370,000	11,000,000
0.05	93,000	6	1,100,000	1,200	600,000	21,000,000
mean	20,000	3	260,000	240	130,000	4,400,000
Probability of mean	0.14	0.07	0.28	0.24	0.26	0.28
Probability of zero	0.52	0.81	0.00	0.37	0.11	0.00

Simulated amounts of metal in a single deposit

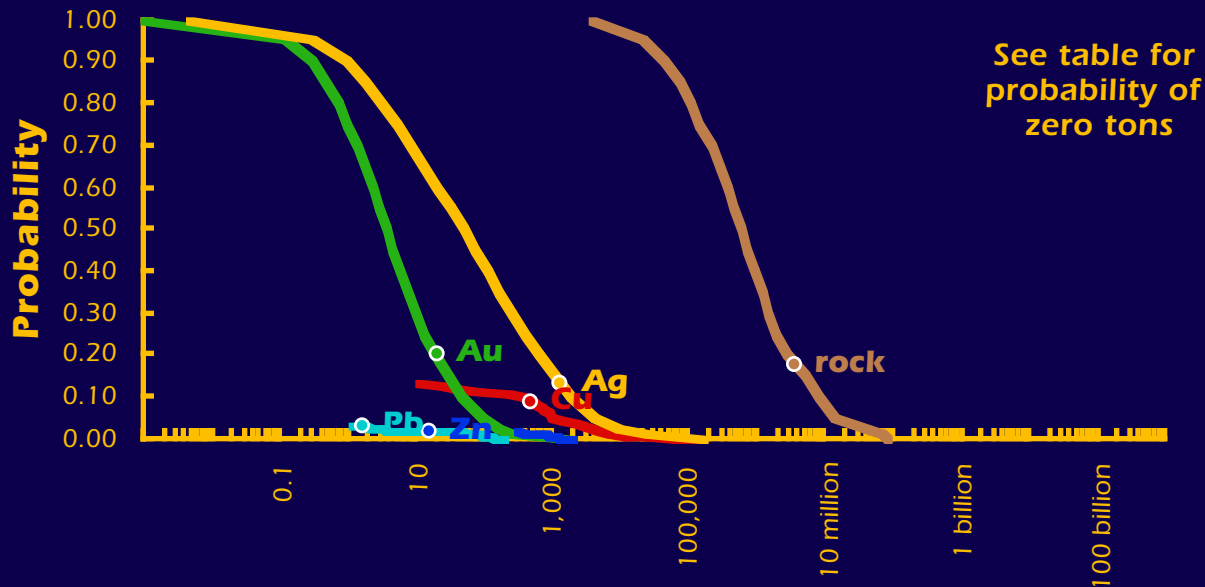
Mark3 Index 22: **Skarn Zn-Pb***Estimated amounts of contained metal and mineralized rock (metric tons)*

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	3,300	0	0	69,000
0.90	0	0	6,900	0	0	100,000
0.50	0	0	96,000	30	32,000	1,400,000
0.10	35,000	1	708,000	730	370,000	11,000,000
0.05	93,000	6	1,100,000	1,200	600,000	21,000,000
mean	20,000	3	260,000	240	130,000	4,400,000
Probability of mean	0.14	0.07	0.28	0.24	0.26	0.28
Probability of zero	0.52	0.81	0.00	0.37	0.11	0.00

Simulated amounts of metal in a single deposit Mark3 Index 22: **Skarn Zn-Pb****Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

Mark3 Index 25: Epithermal vein, quartz-adularia

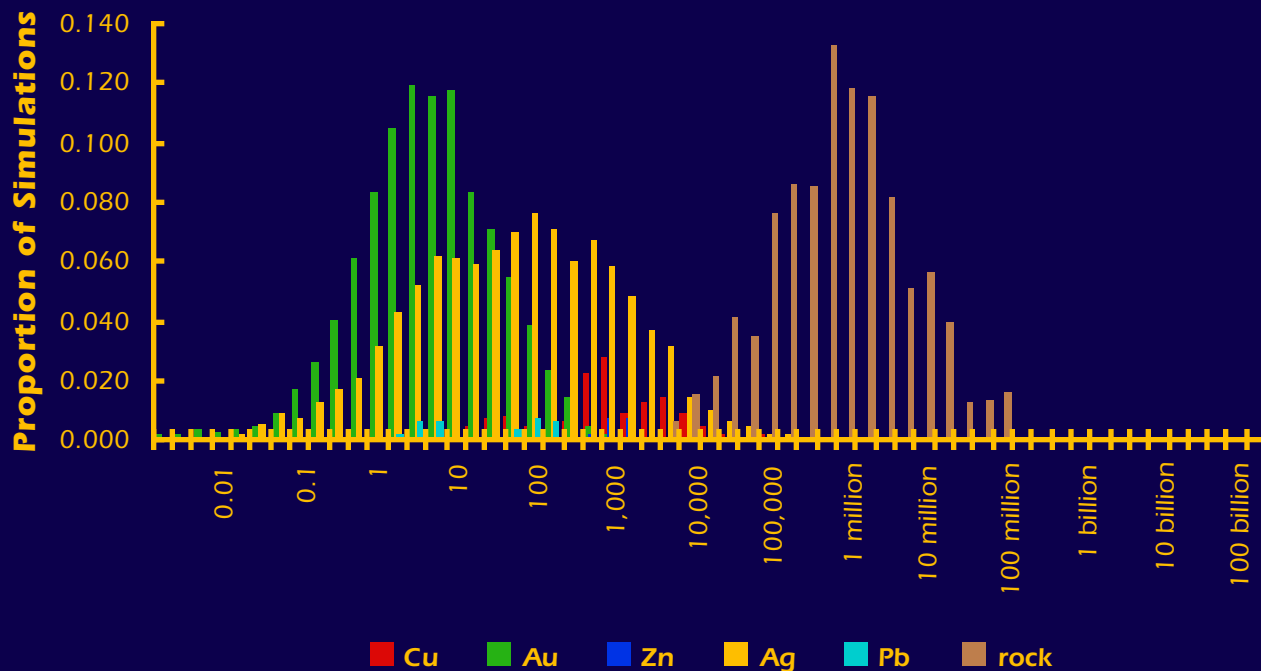
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 25: Epithermal vein, quartz-adularia

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 25: Epithermal vein, quartz-adularia

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	20,000
0.90	0	0	0	1	0	43,000
0.50	0	4	0	49	0	570,000
0.10	350	44	0	1,900	0	8,100,000
0.05	1,100	89	0	4,300	0	14,000,000
mean	460	19	15	1,300	2	3,600,000
Probability of mean	0.09	0.20	0.02	0.13	0.03	0.18
Probability of zero	0.87	0.00	0.98	0.00	0.97	0.00

Simulated amounts of metal in a single deposit

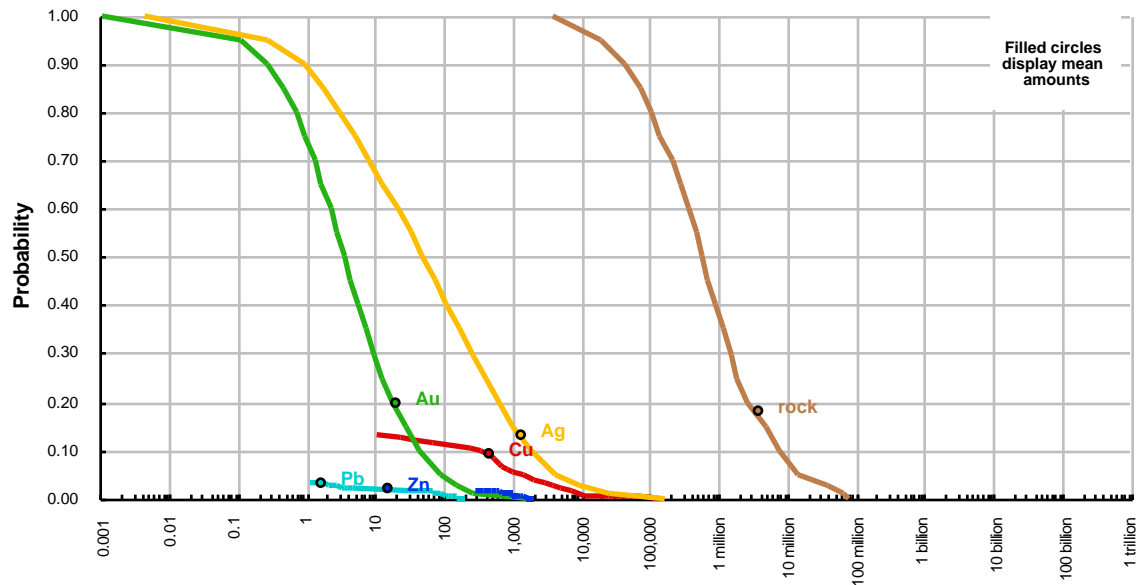
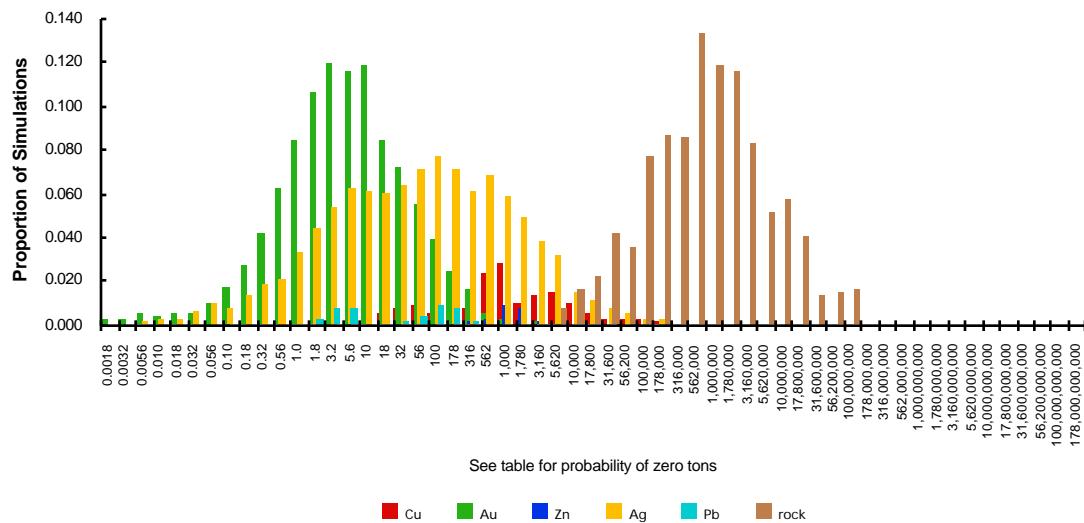
Mark3 Index 25: **Epithermal vein, quartz-adularia**

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	20,000
0.90	0	0	0	1	0	43,000
0.50	0	4	0	49	0	570,000
0.10	350	44	0	1,900	0	8,100,000
0.05	1,100	89	0	4,300	0	14,000,000
mean	460	19	15	1,300	2	3,600,000
Probability of mean	0.09	0.20	0.02	0.13	0.03	0.18
Probability of zero	0.87	0.00	0.98	0.00	0.97	0.00

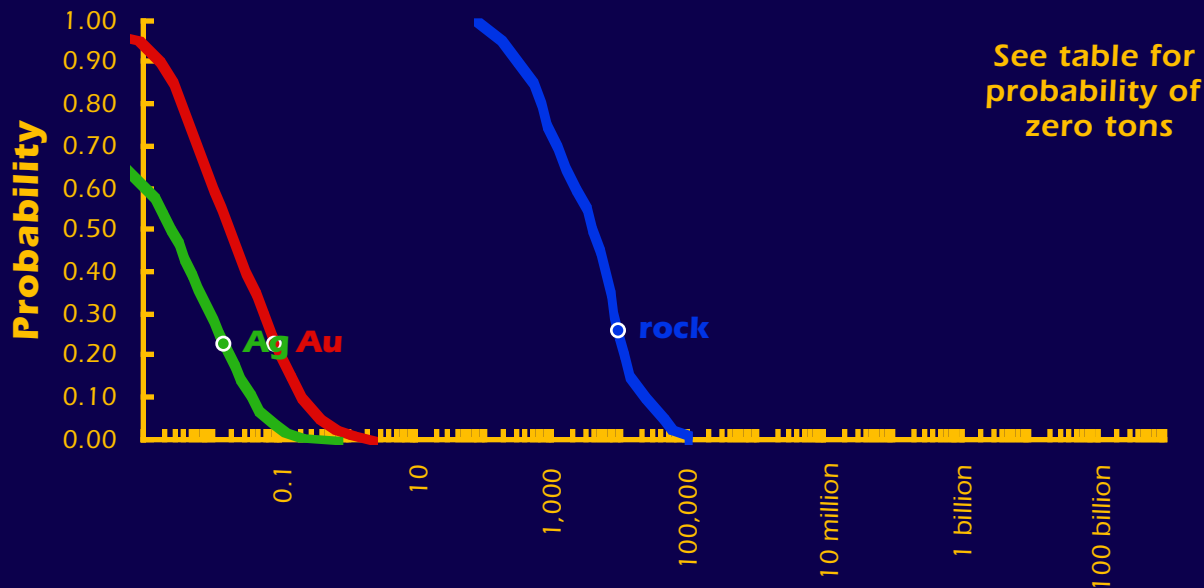
Simulated amounts of metal in a single deposit Mark3 Index 25: Epithermal vein, quartz-adularia

Cumulative Distributions of Contained Metal and Mineralized Rock

Histograms of Contained Metal and Mineralized Rock
(metric tons)

Mark3 Index 26: Low-sulfide Au-quartz vein, Chugach

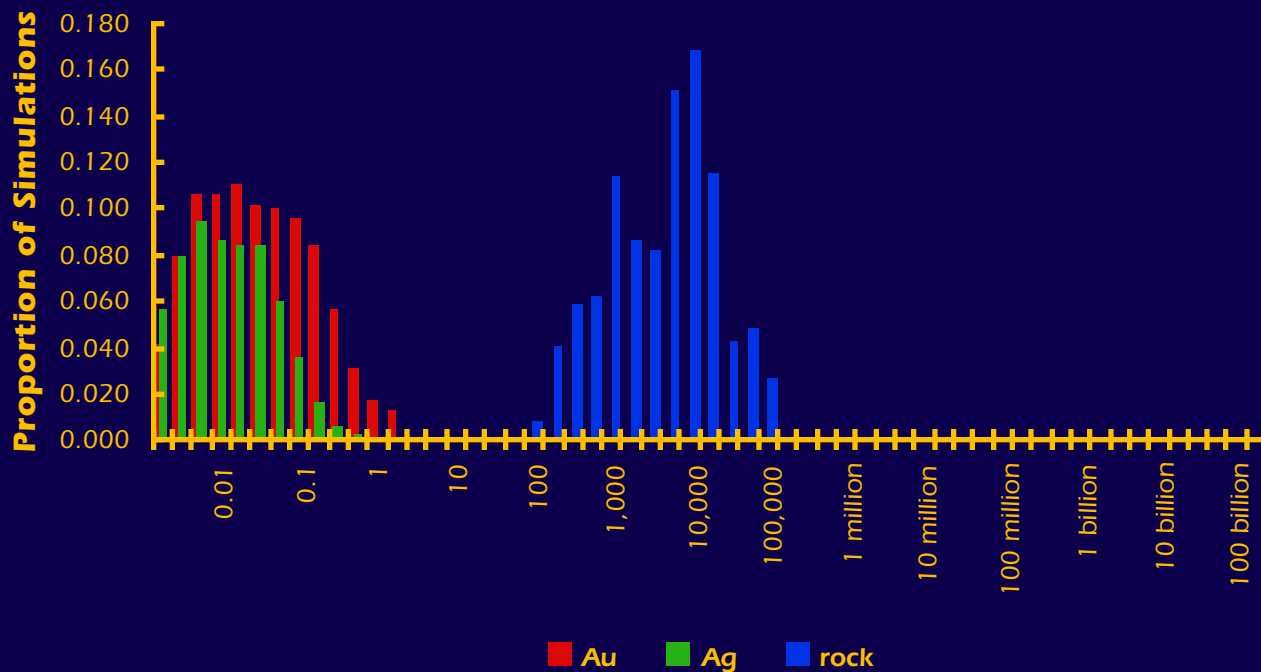
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 26: Low-sulfide Au-quartz vein, Chugach

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 26: Low-sulfide Au-quartz vein, Chugach

Estimated amounts of contained metal and mineralized rock (metric tons)

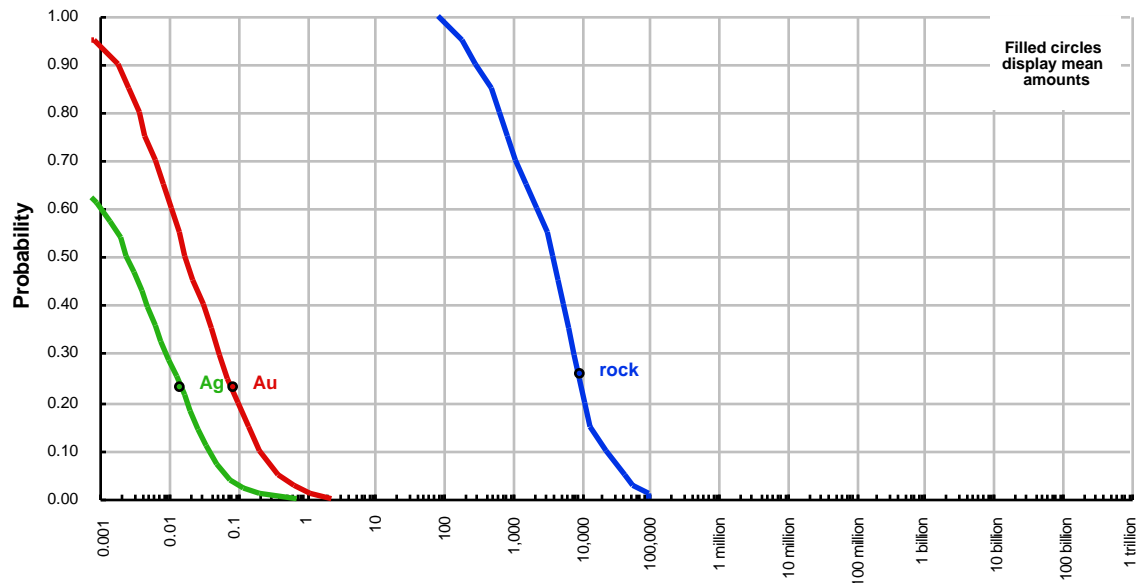
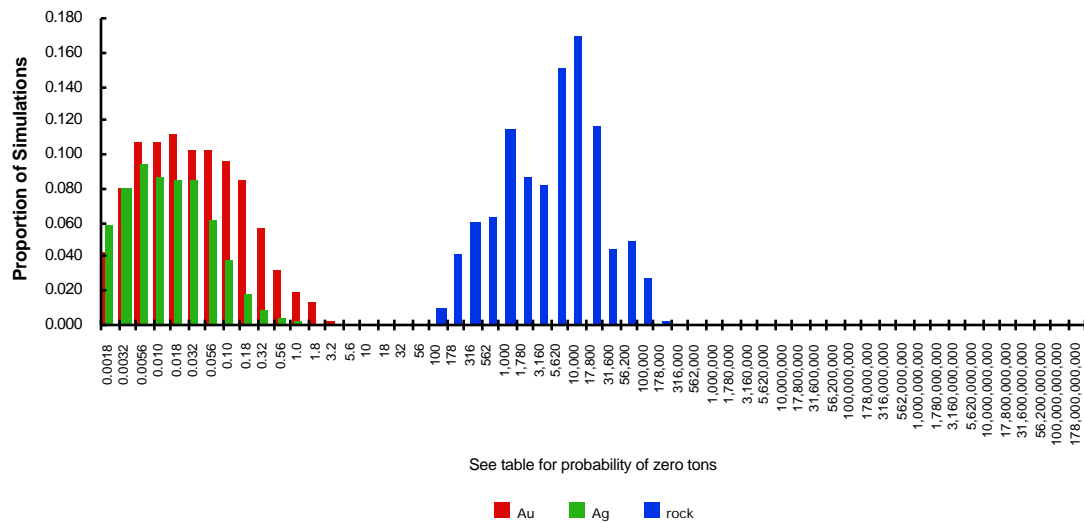
quantile	Au	Ag	rock
0.95	0	0	180
0.90	0	0	300
0.50	0	0	3,900
0.10	0	0	22,500
0.05	0	0	43,000
mean	0	0	9,200
Probability of mean	0.23	0.23	0.26
Probability of zero	0.00	0.28	0.00

Simulated amounts of metal in a single deposit

Mark3 Index 26: **Low-sulfide Au-quartz vein, Chugach**

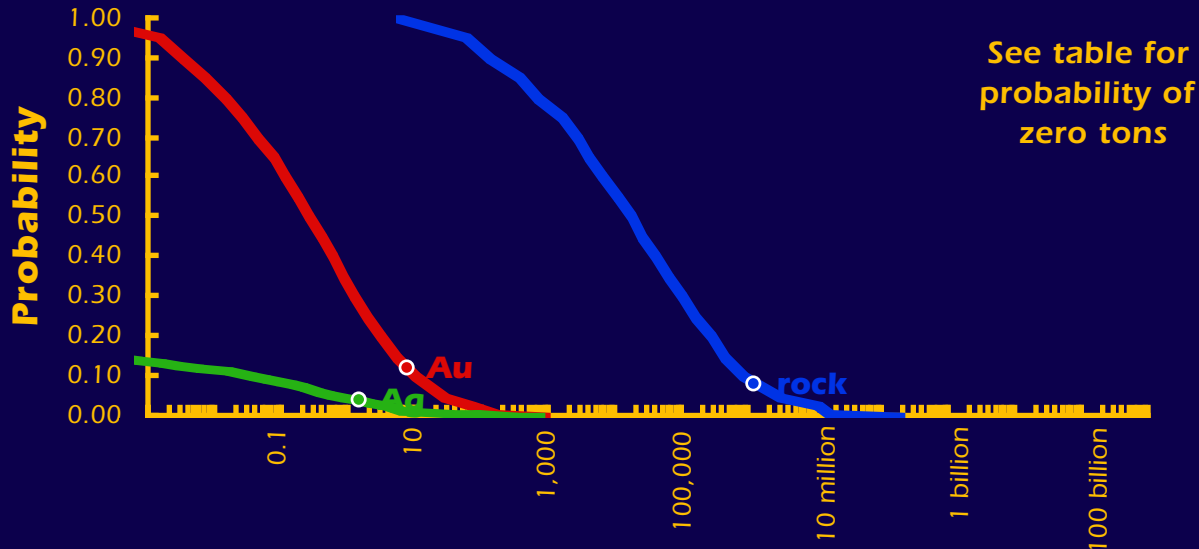
Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	180
0.90	0	0	300
0.50	0	0	3,900
0.10	0	0	22,500
0.05	0	0	43,000
mean	0	0	9,200
Probability of mean	0.23	0.23	0.26
Probability of zero	0.00	0.28	0.00

Simulated amounts of metal in a single deposit Mark3 Index 26: **Low-sulfide Au-quartz vein, Chugach****Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

Mark3 Index 27: Low-sulfide Au-quartz vein

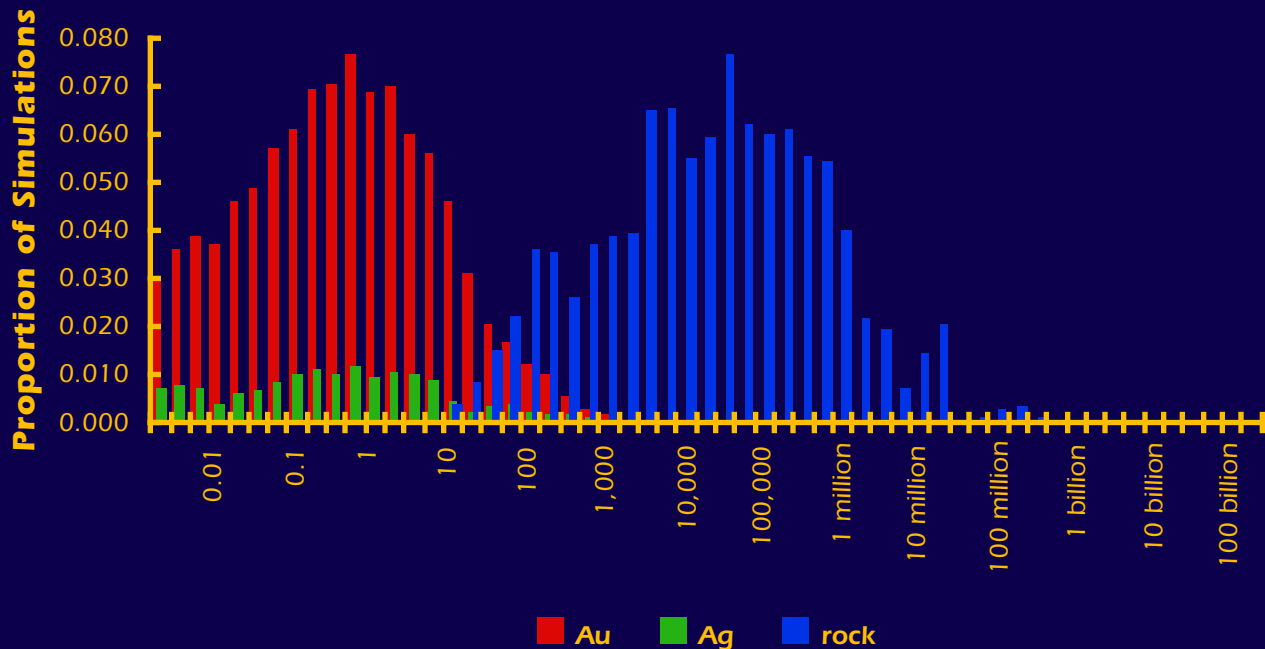
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 27: Low-sulfide Au-quartz vein

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 27: Low-sulfide Au-quartz vein

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	58
0.90	0	0	130
0.50	0	0	17,000
0.10	10	0	792,000
0.05	28	1	2,900,000
mean	8	1	1,200,000
Probability of mean	0.12	0.04	0.08
Probability of zero	0.00	0.84	0.00

Simulated amounts of metal in a single deposit

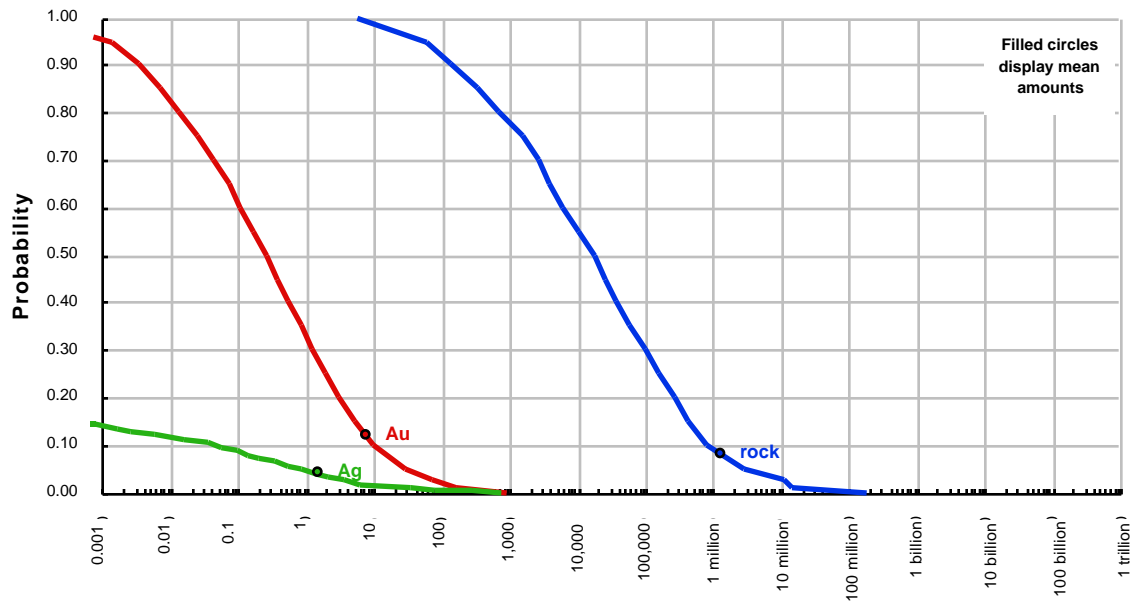
Mark3 Index 27: **Low-sulfide Au-quartz vein**

Estimated amounts of contained metal and mineralized rock (metric tons)

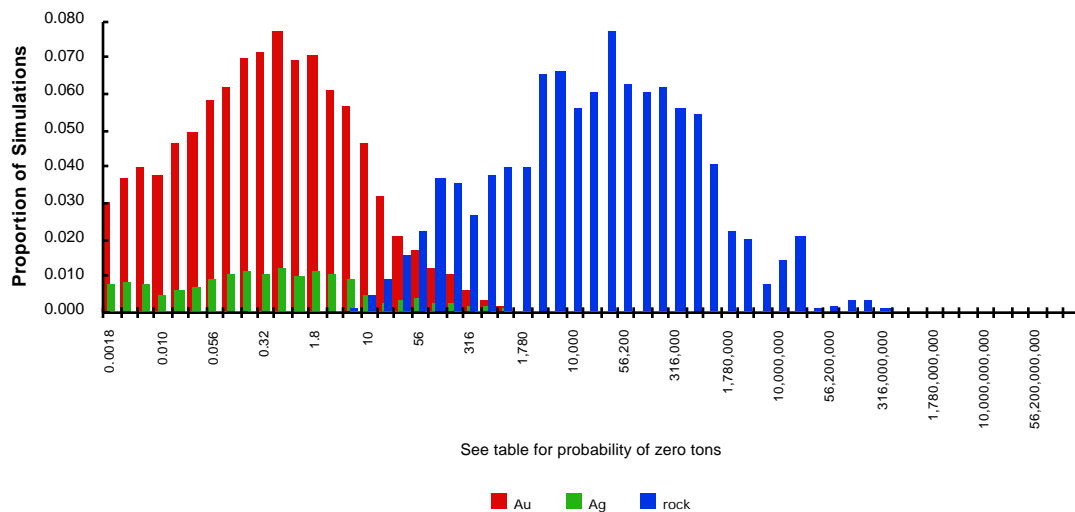
quantile	Au	Ag	rock
0.95	0	0	58
0.90	0	0	130
0.50	0	0	17,000
0.10	10	0	792,000
0.05	28	1	2,900,000
mean	8	1	1,200,000
Probability of mean	0.12	0.04	0.08
Probability of zero	0.00	0.84	0.00

Simulated amounts of metal in a single deposit Mark3 Index 27: **Low-sulfide Au-quartz vein**

Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

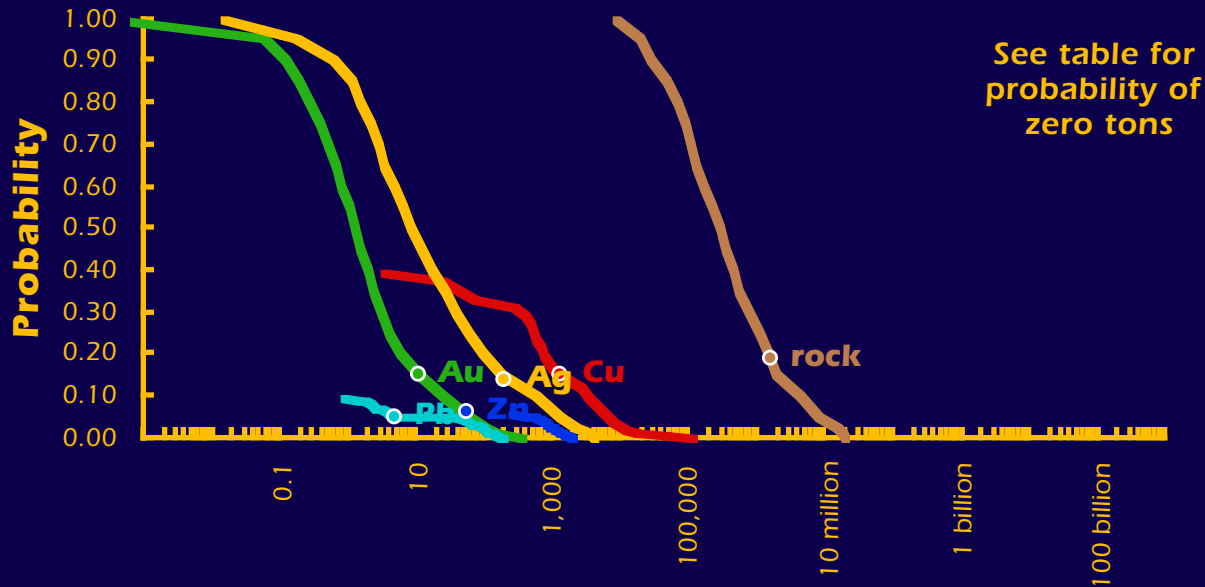


See table for probability of zero tons

Au Ag rock

Mark3 Index 28: Epithermal vein, Sado

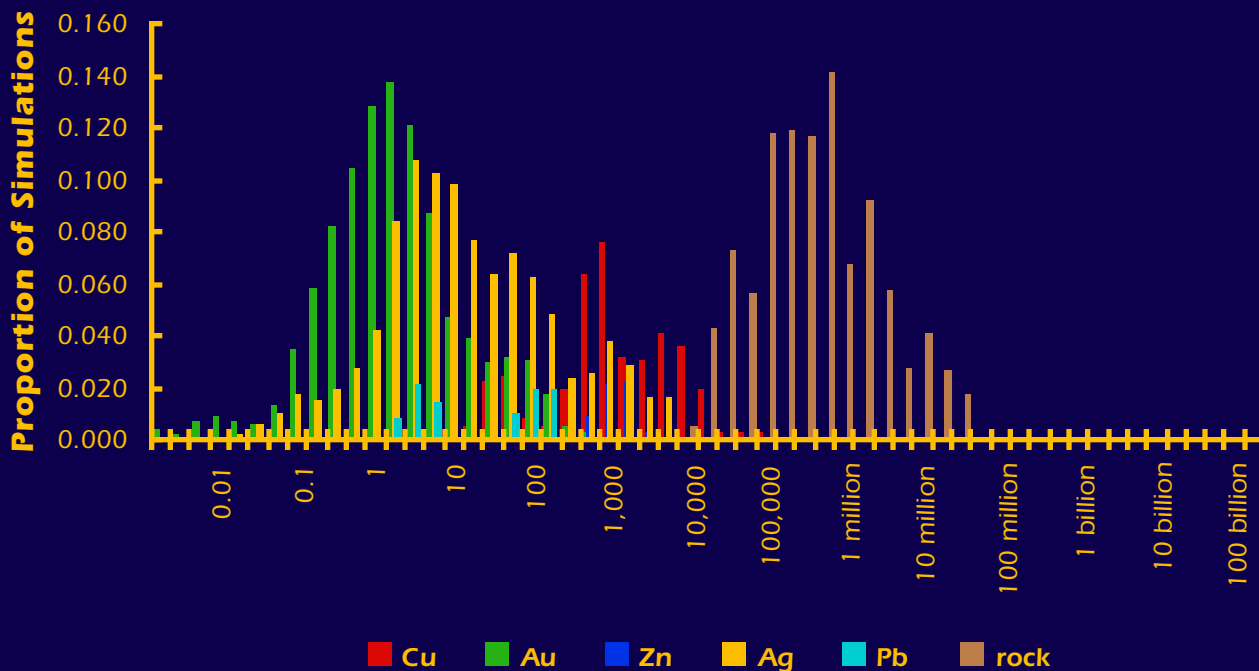
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 28: Epithermal vein, Sado

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 28: Epithermal vein, Sado

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	19,000
0.90	0	0	0	1	0	26,000
0.50	0	1	0	8	0	270,000
0.10	3,300	24	0	550	0	4,300,000
0.05	6,900	61	530	1,200	31	7,900,000
mean	1,300	10	55	200	5	1,500,000
Probability of mean	0.15	0.15	0.06	0.14	0.05	0.19
Probability of zero	0.61	0.00	0.94	0.00	0.90	0.00

Simulated amounts of metal in a single deposit

Mark3 Index 28: **Epithermal vein, Sado**

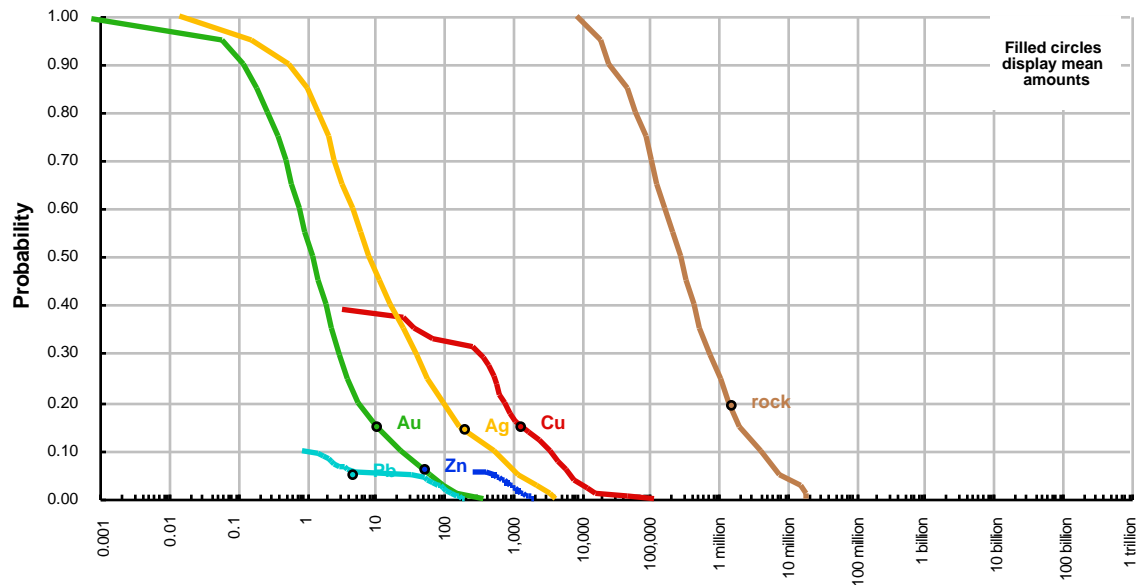
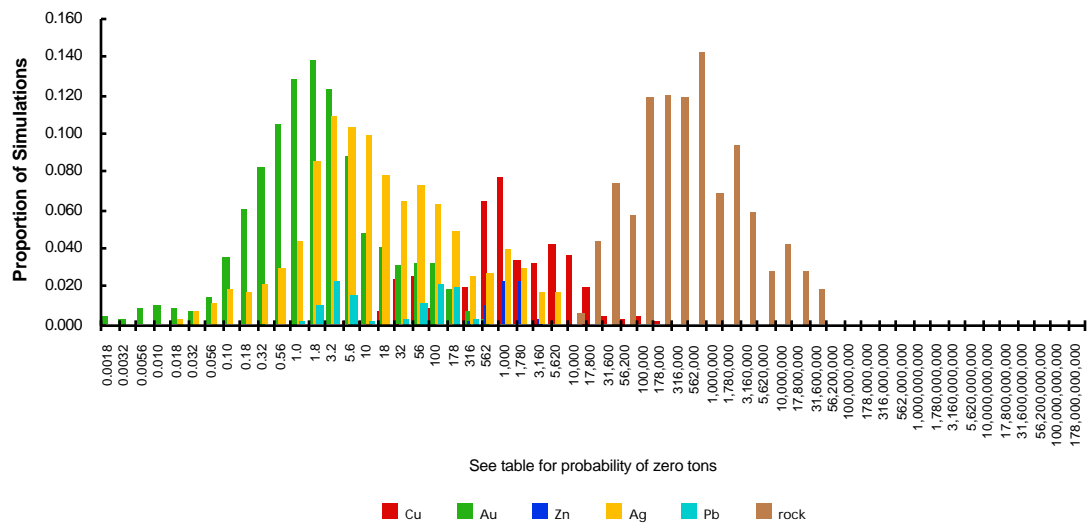
Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	19,000
0.90	0	0	0	1	0	26,000
0.50	0	1	0	8	0	270,000
0.10	3,300	24	0	550	0	4,300,000
0.05	6,900	61	530	1,200	31	7,900,000
mean	1,300	10	55	200	5	1,500,000
Probability of mean	0.15	0.15	0.06	0.14	0.05	0.19
Probability of zero	0.61	0.00	0.94	0.00	0.90	0.00

Simulated amounts of metal in a single deposit

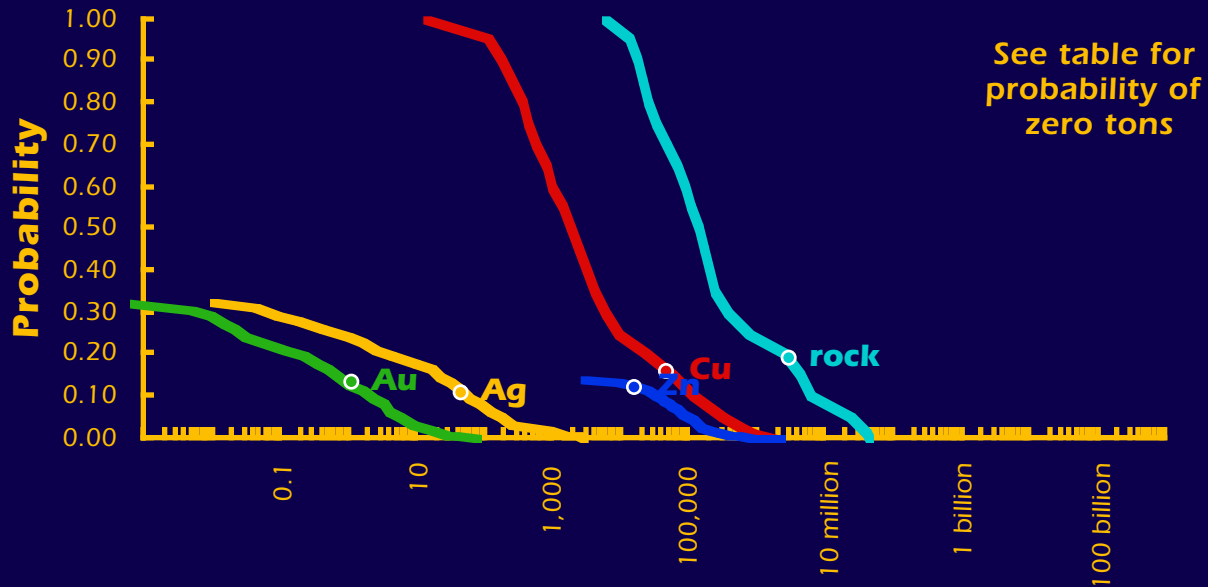
Mark3 Index 28: Epithermal vein, Sado

Cumulative Distributions of Contained Metal and Mineralized Rock

Histograms of Contained Metal and Mineralized Rock
(metric tons)

Mark3 Index 30: Massive sulfide, Besshi

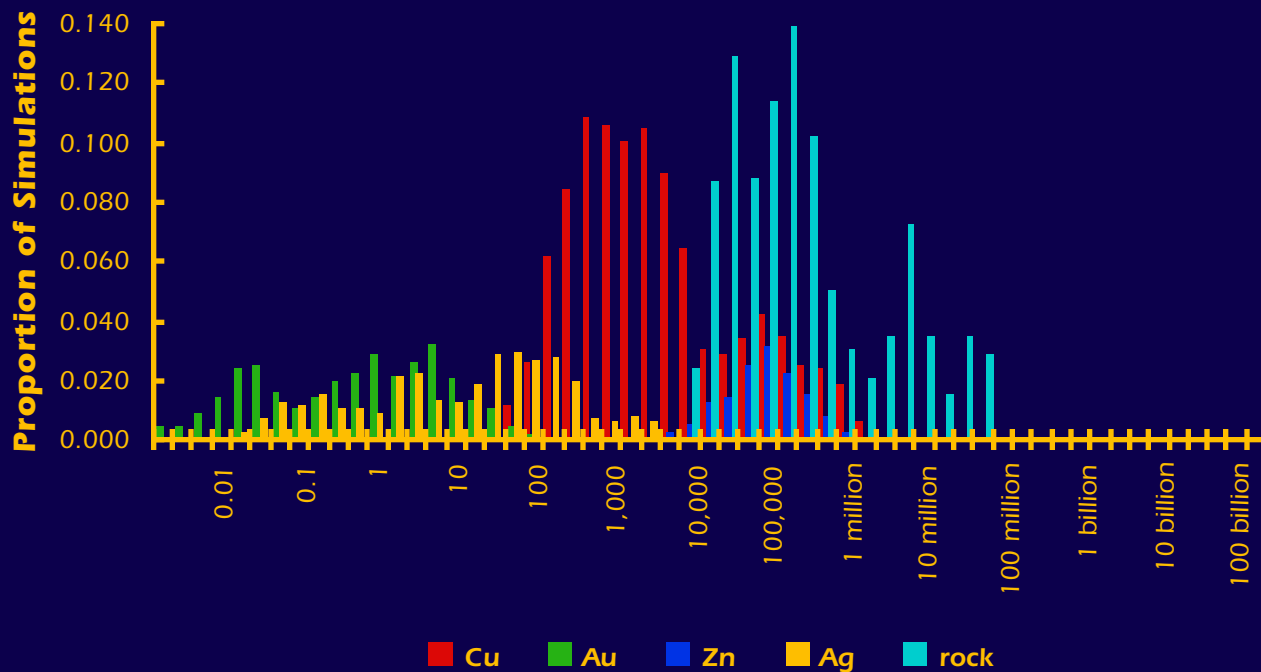
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 30: Massive sulfide, Besshi

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 30: Massive sulfide, Besshi

Estimated amounts of contained metal and mineralized rock (metric tons)

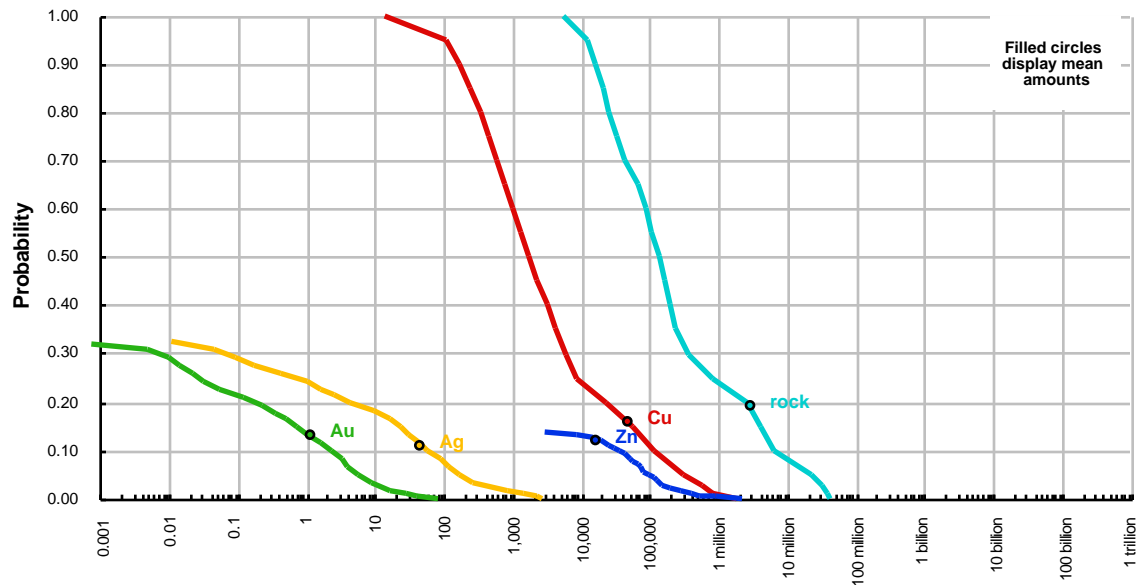
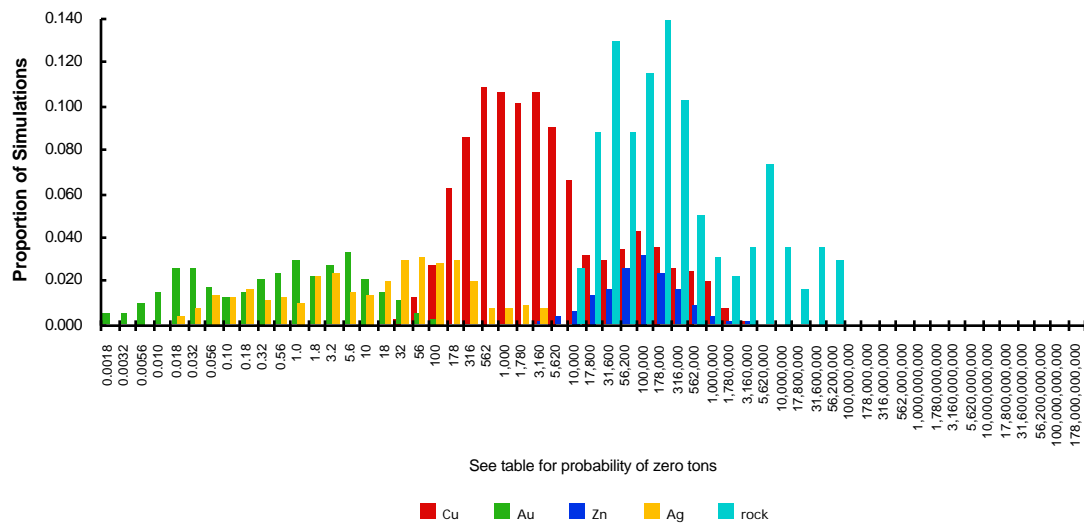
quantile	Cu	Au	Zn	Ag	rock
0.95	110	0	0	0	13,000
0.90	180	0	0	0	17,000
0.50	1,800	0	0	0	130,000
0.10	120,000	2	35,000	57	6,200,000
0.05	310,000	6	98,000	170	23,000,000
mean	49,000	1	17,000	45	2,900,000
Probability of mean	0.16	0.13	0.12	0.11	0.19
Probability of zero	0.00	0.68	0.86	0.67	0.00

Simulated amounts of metal in a single deposit

Mark3 Index 30: **Massive sulfide, Besshi**

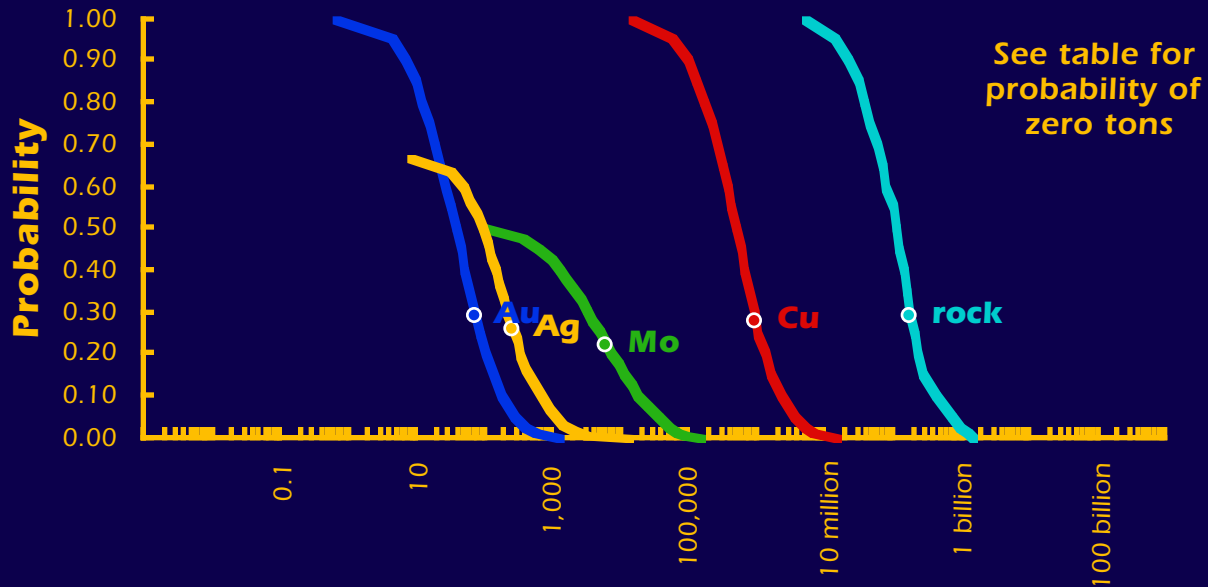
Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	rock
0.95	110	0	0	0	13,000
0.90	180	0	0	0	17,000
0.50	1,800	0	0	0	130,000
0.10	120,000	2	35,000	57	6,200,000
0.05	310,000	6	98,000	170	23,000,000
mean	49,000	1	17,000	45	2,900,000
Probability of mean	0.16	0.13	0.12	0.11	0.19
Probability of zero	0.00	0.68	0.86	0.67	0.00

Simulated amounts of metal in a single deposit Mark3 Index 30: **Massive sulfide, Besshi****Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

Mark3 Index 34: Porphyry Cu-Au

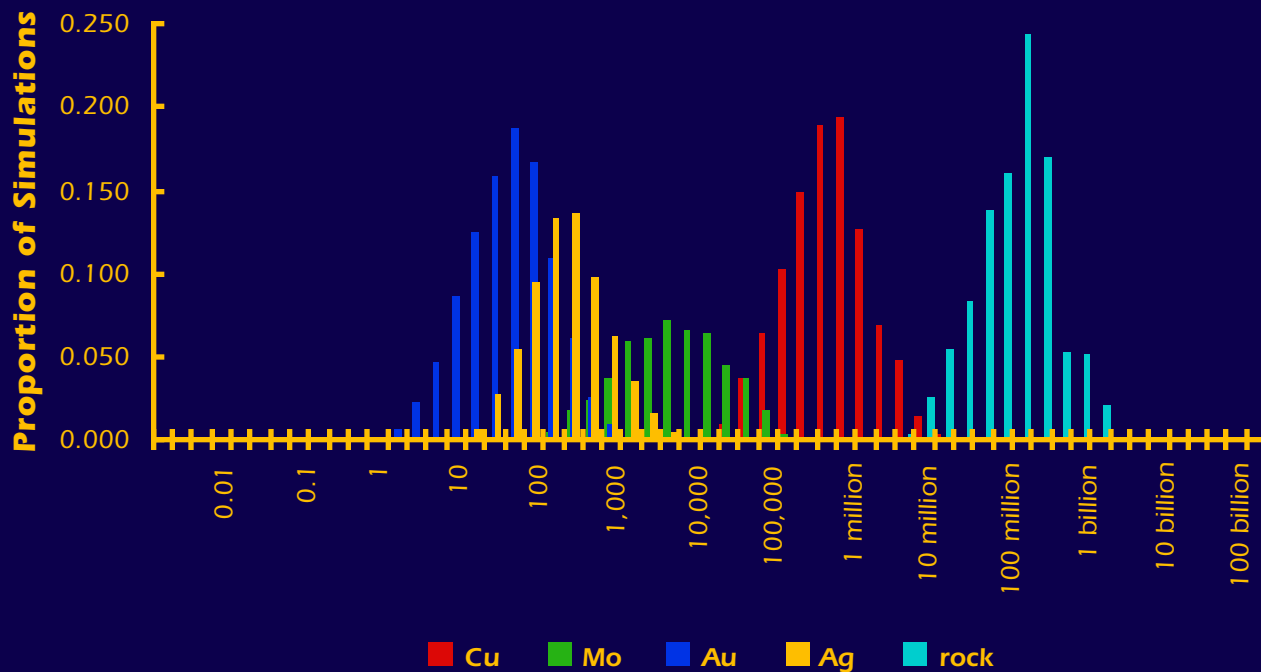
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 34: Porphyry Cu-Au

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 34: **Porphyrý Cu-Au**

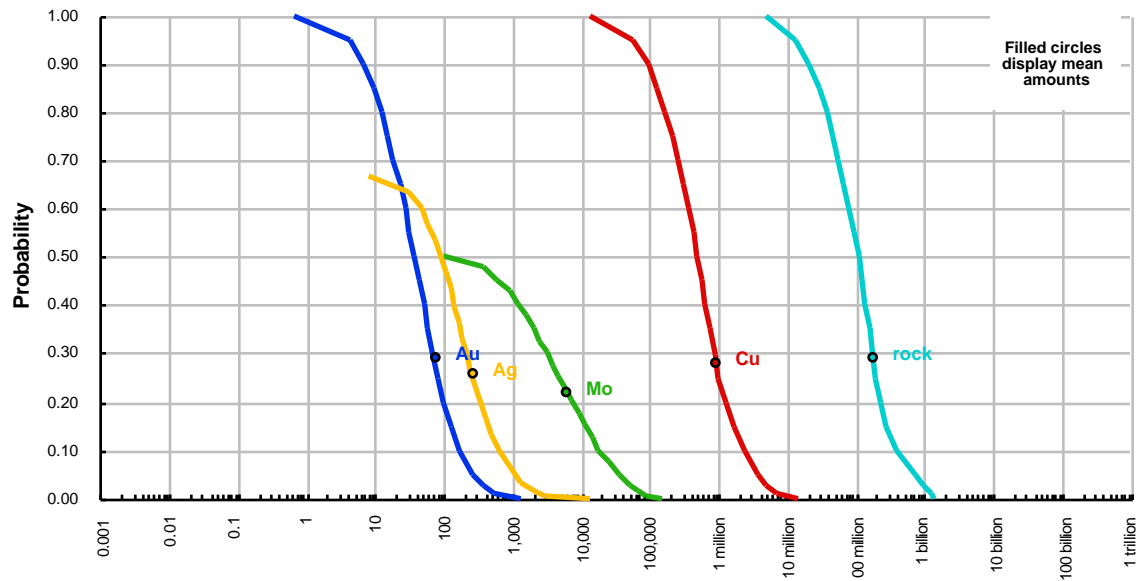
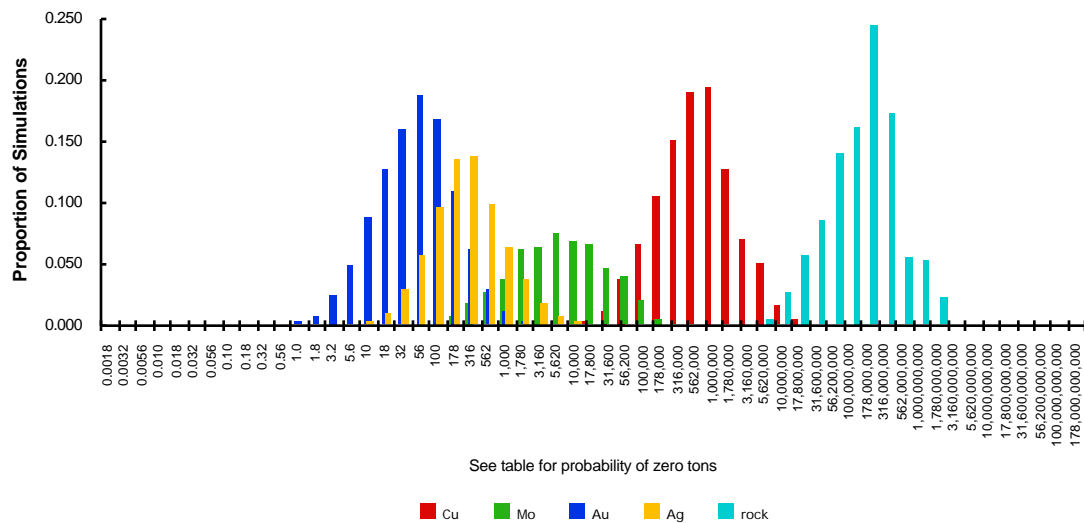
Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	58,000	0	4	0	14,000,000
0.90	93,000	0	7	0	21,000,000
0.50	490,000	180	38	92	110,000,000
0.10	2,300,000	18,000	172	650	410,000,000
0.05	3,700,000	37,000	270	1,100	730,000,000
mean	940,000	6,100	73	260	180,000,000
Probability of mean	0.28	0.22	0.29	0.26	0.29
Probability of zero	0.00	0.50	0.00	0.33	0.00

Simulated amounts of metal in a single deposit

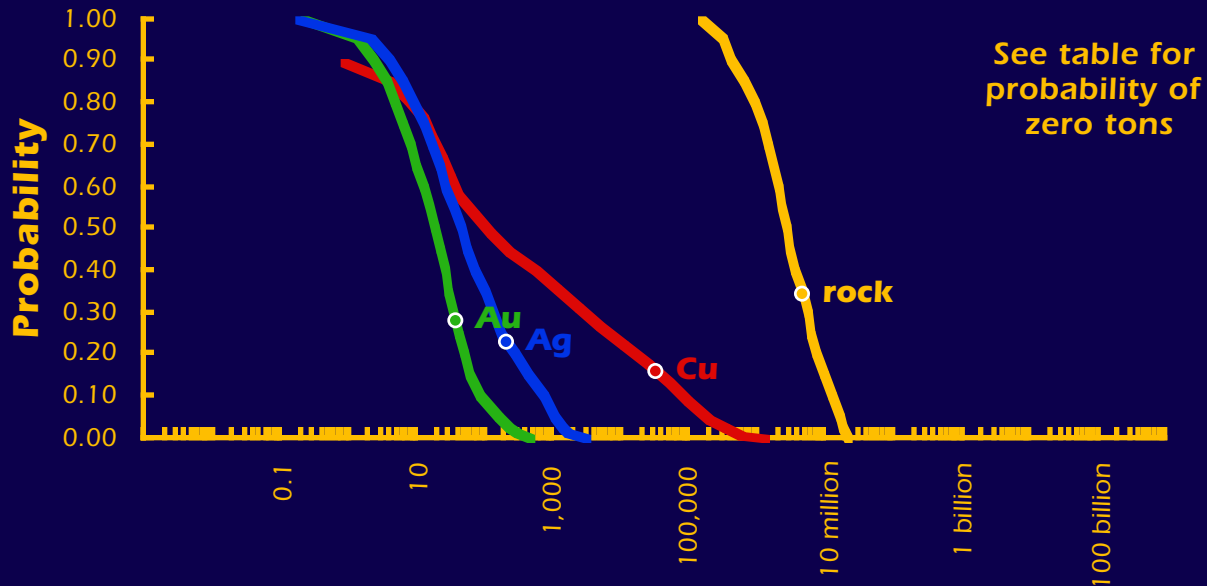
Mark3 Index 34: **Porphyry Cu-Au***Estimated amounts of contained metal and mineralized rock (metric tons)*

quantile	Cu	Mo	Au	Ag	rock
0.95	58,000	0	4	0	14,000,000
0.90	93,000	0	7	0	21,000,000
0.50	490,000	180	38	92	110,000,000
0.10	2,300,000	18,000	172	650	410,000,000
0.05	3,700,000	37,000	270	1,100	730,000,000
mean	940,000	6,100	73	260	180,000,000
Probability of mean	0.28	0.22	0.29	0.26	0.29
Probability of zero	0.00	0.50	0.00	0.33	0.00

Simulated amounts of metal in a single deposit Mark3 Index 34: **Porphyry Cu-Au****Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

Mark3 Index 38: Epithermal vein, quartz-alunite

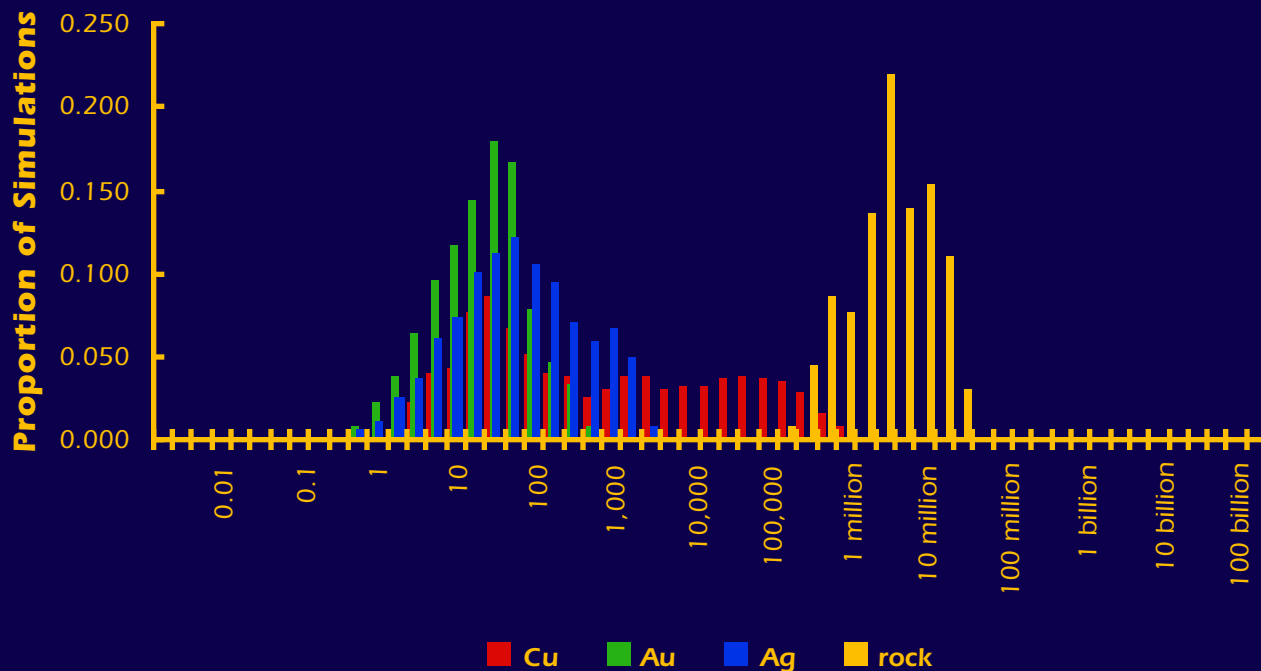
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 38: Epithermal vein, quartz-alunite

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 38: Epithermal vein, quartz-alunite

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Ag	rock
0.95	0	1	2	310,000
0.90	0	2	4	420,000
0.50	110	18	44	2,700,000
0.10	83,000	86	713	12,000,000
0.05	190,000	150	1,100	16,000,000
mean	32,000	37	200	4,600,000
Probability of mean	0.16	0.28	0.23	0.34
Probability of zero	0.11	0.00	0.00	0.00

Simulated amounts of metal in a single deposit

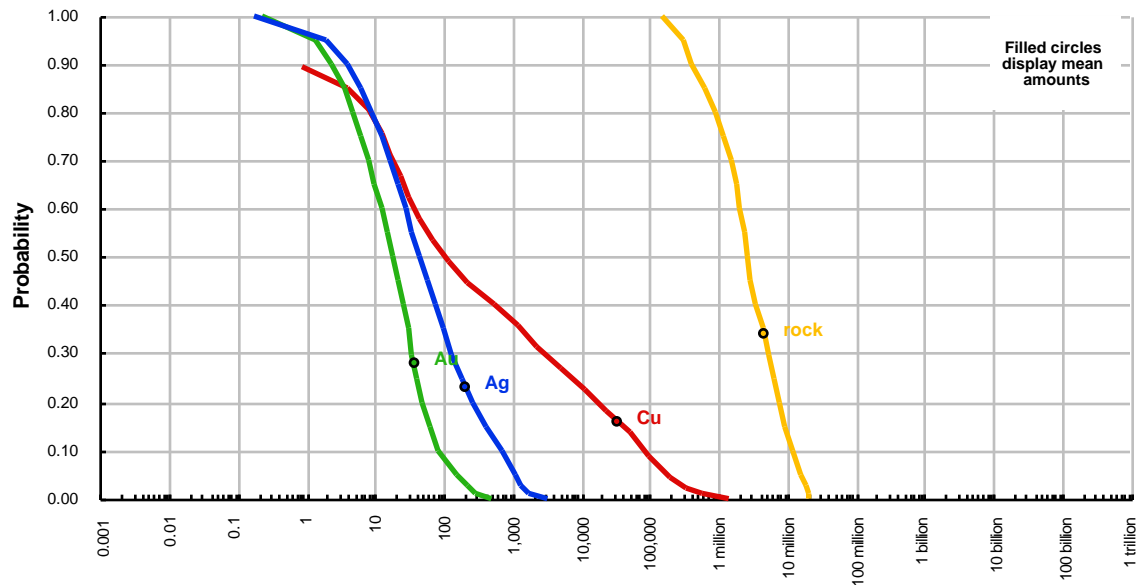
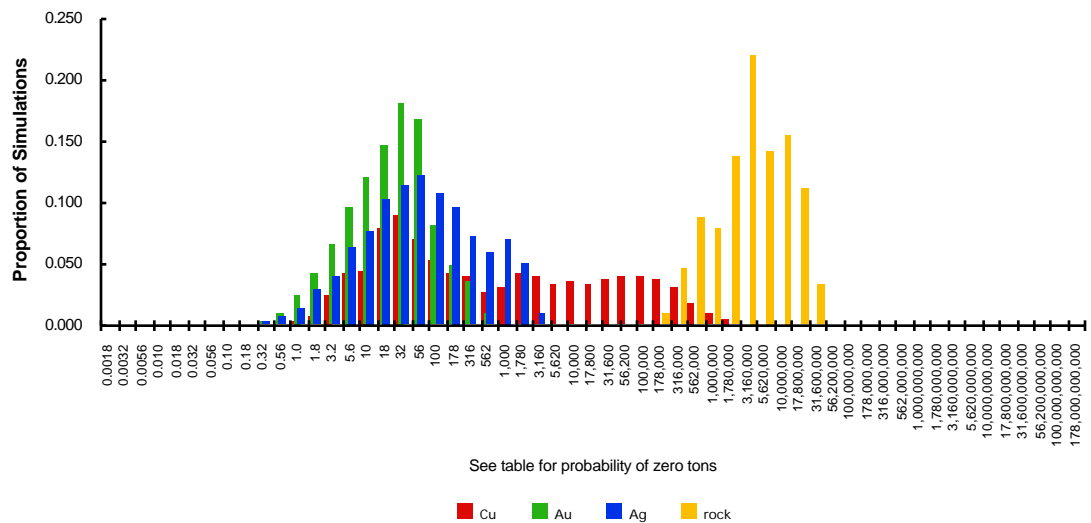
Mark3 Index 38: **Epithermal vein, quartz-alunite**

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Ag	rock
0.95	0	1	2	310,000
0.90	0	2	4	420,000
0.50	110	18	44	2,700,000
0.10	83,000	86	713	12,000,000
0.05	190,000	150	1,100	16,000,000
mean	32,000	37	200	4,600,000
Probability of mean	0.16	0.28	0.23	0.34
Probability of zero	0.11	0.00	0.00	0.00

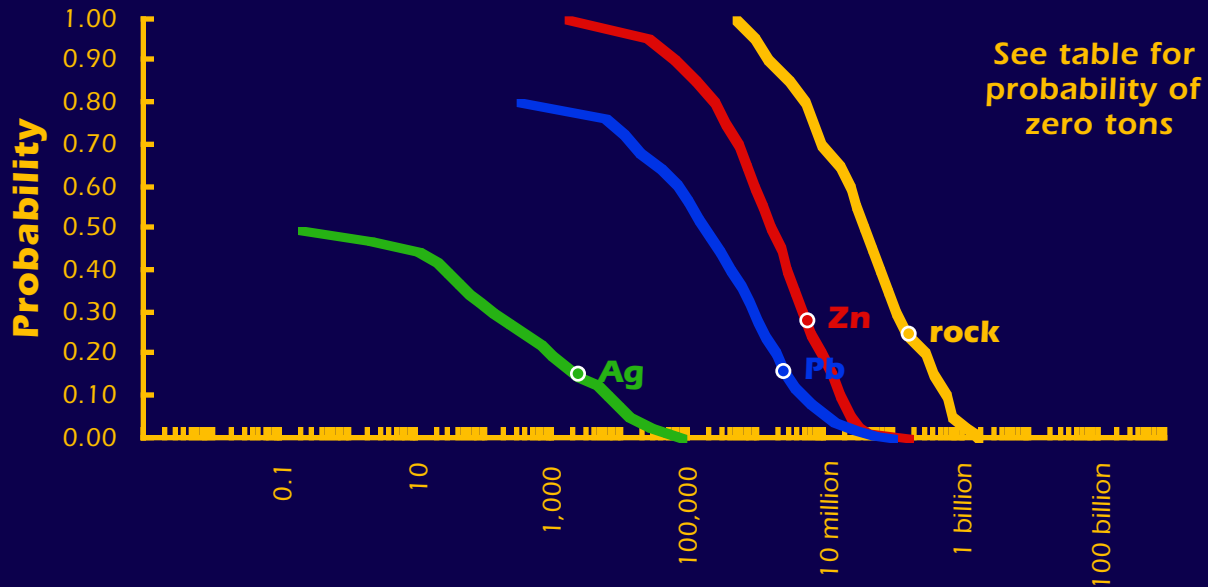
Simulated amounts of metal in a single deposit Mark3 Index 38: Epithermal vein, quartz-alunite

Cumulative Distributions of Contained Metal and Mineralized Rock

Histograms of Contained Metal and Mineralized Rock
(metric tons)

Mark3 Index 42: Mississippi Valley

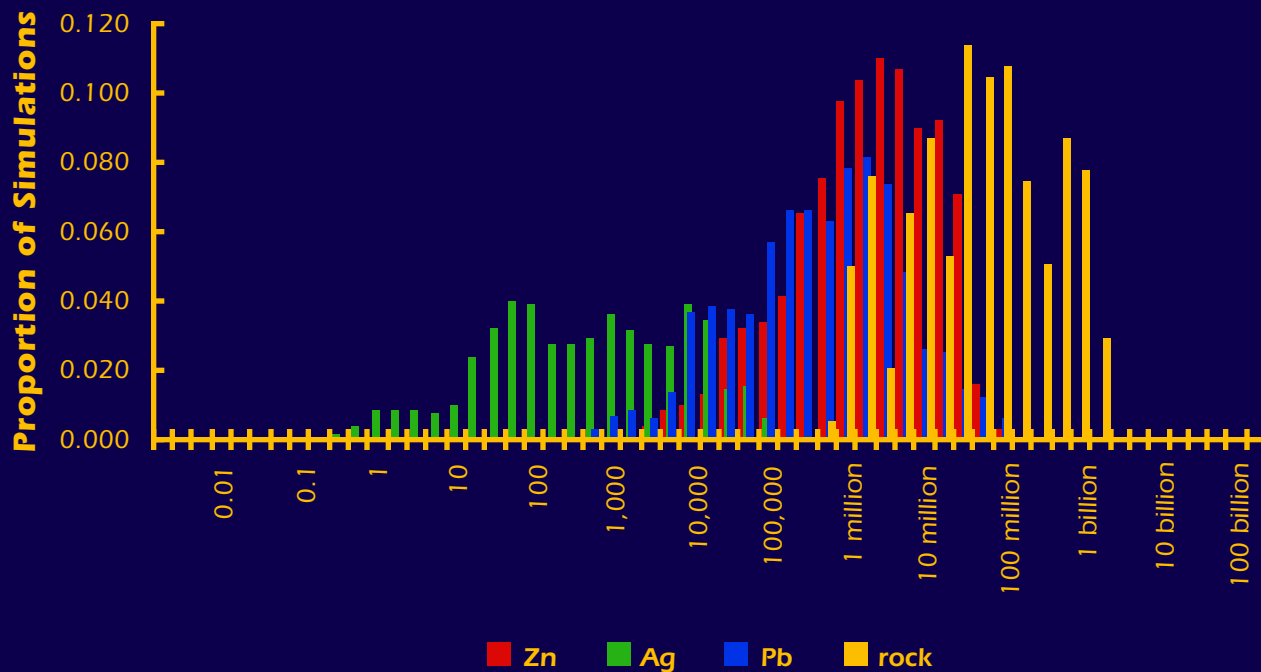
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 42: Mississippi Valley

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 42: **Mississippi Valley**

Estimated amounts of contained metal and mineralized rock (metric tons)

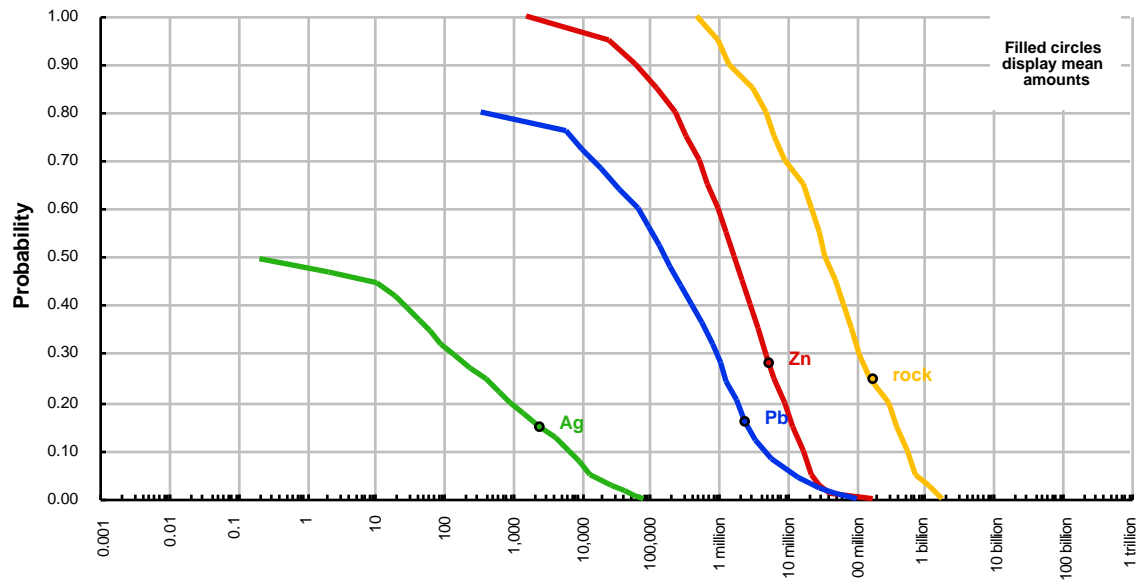
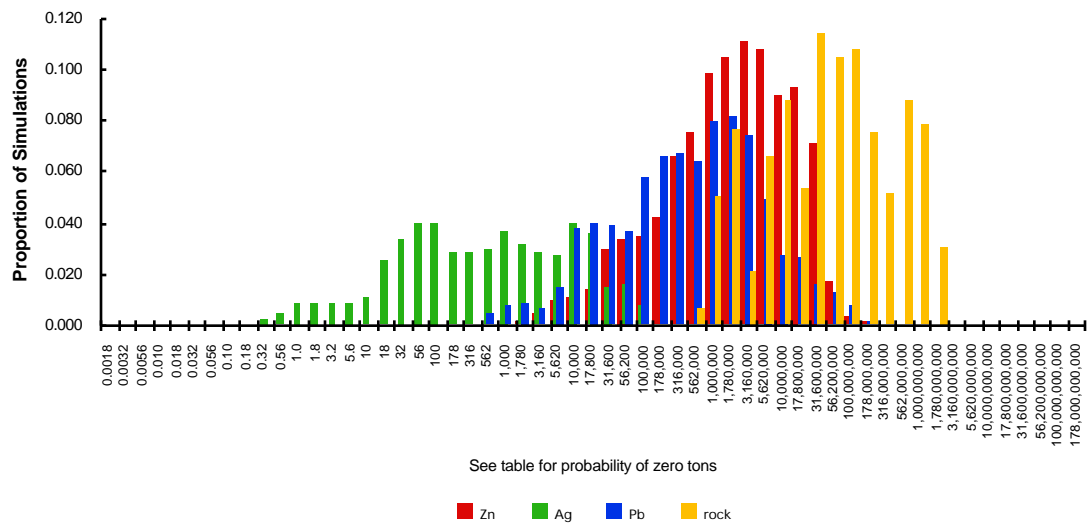
quantile	Zn	Ag	Pb	rock
0.95	25,000	0	0	950,000
0.90	61,000	0	0	1,400,000
0.50	1,600,000	0	170,000	36,000,000
0.10	17,000,000	6,400	4,360,000	590,000,000
0.05	23,000,000	13,000	12,000,000	730,000,000
mean	5,500,000	2,400	2,400,000	170,000,000
Probability of mean	0.28	0.15	0.16	0.25
Probability of zero	0.00	0.51	0.20	0.00

Simulated amounts of metal in a single deposit

Mark3 Index 42: **Mississippi Valley**

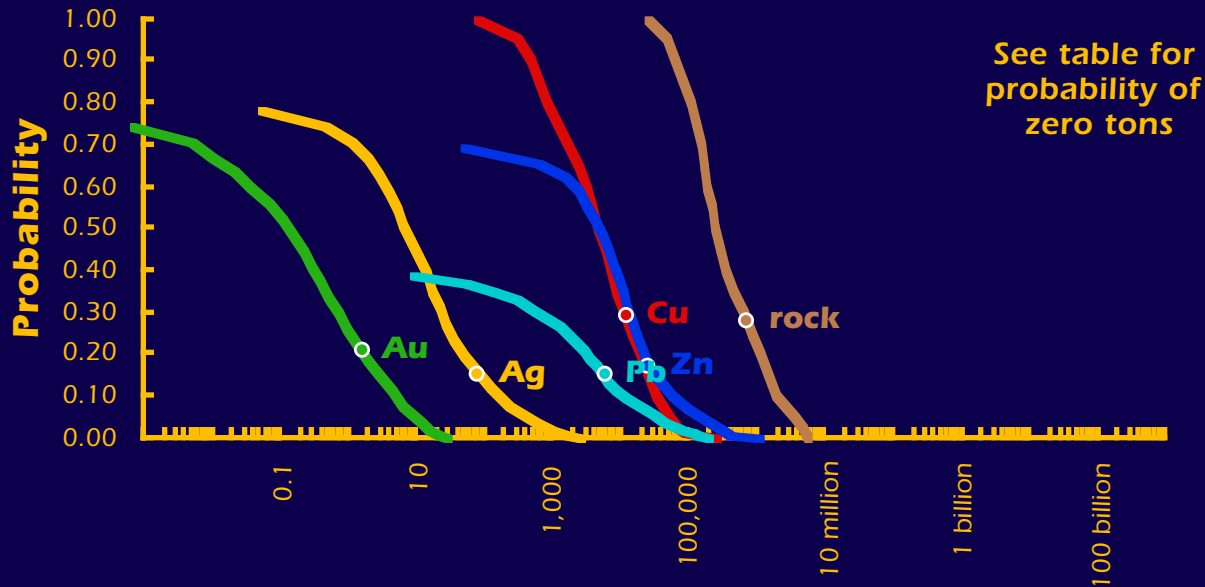
Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Zn	Ag	Pb	rock
0.95	25,000	0	0	950,000
0.90	61,000	0	0	1,400,000
0.50	1,600,000	0	170,000	36,000,000
0.10	17,000,000	6,400	4,360,000	590,000,000
0.05	23,000,000	13,000	12,000,000	730,000,000
mean	5,500,000	2,400	2,400,000	170,000,000
Probability of mean	0.28	0.15	0.16	0.25
Probability of zero	0.00	0.51	0.20	0.00

Simulated amounts of metal in a single deposit Mark3 Index 42: **Mississippi Valley****Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

Mark3 Index 44: Massive sulfide, Sierran kuroko

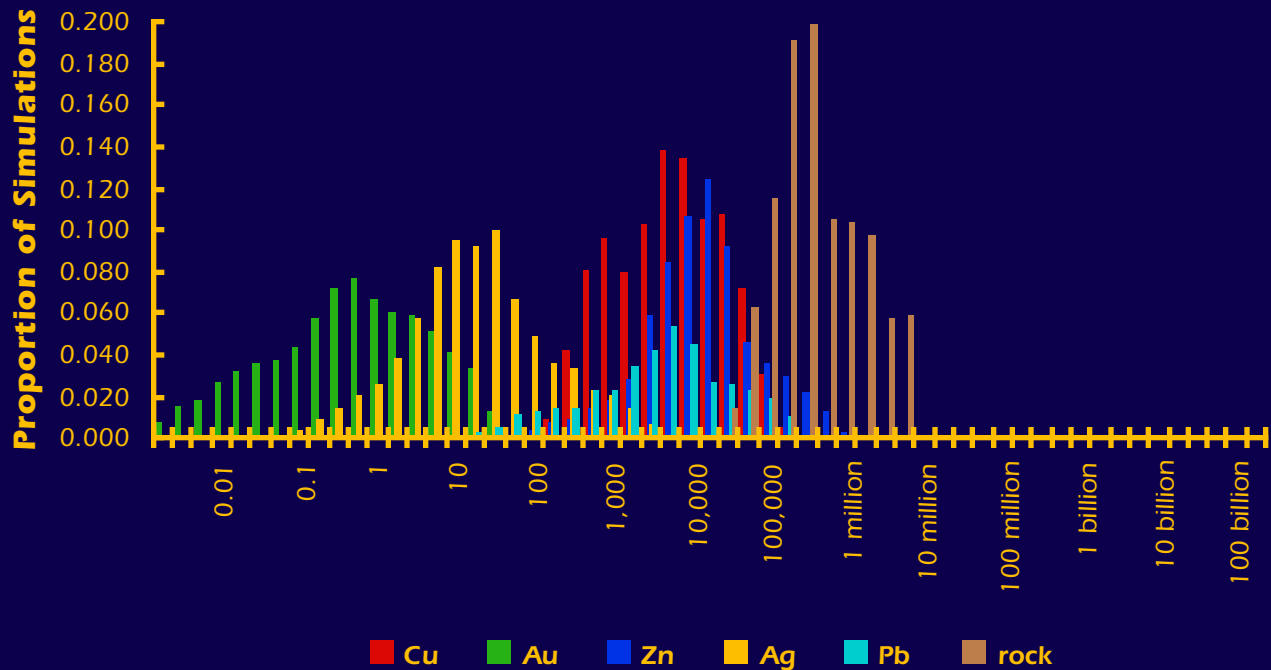
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 44: Massive sulfide, Sierran kuroko

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 44: Massive sulfide, Sierran kuroko

Estimated amounts of contained metal and mineralized rock (metric tons)

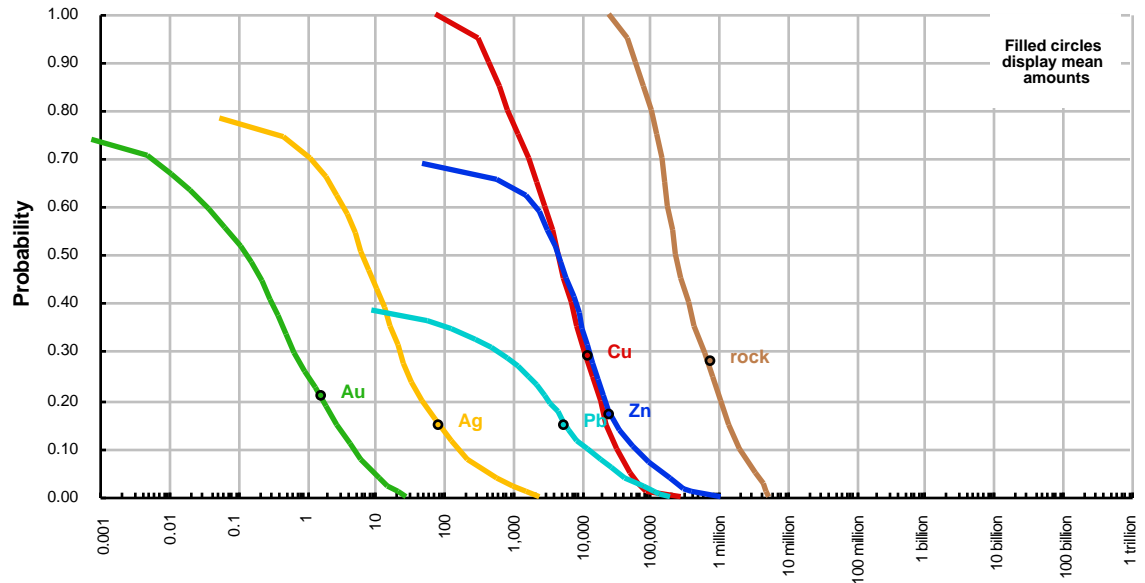
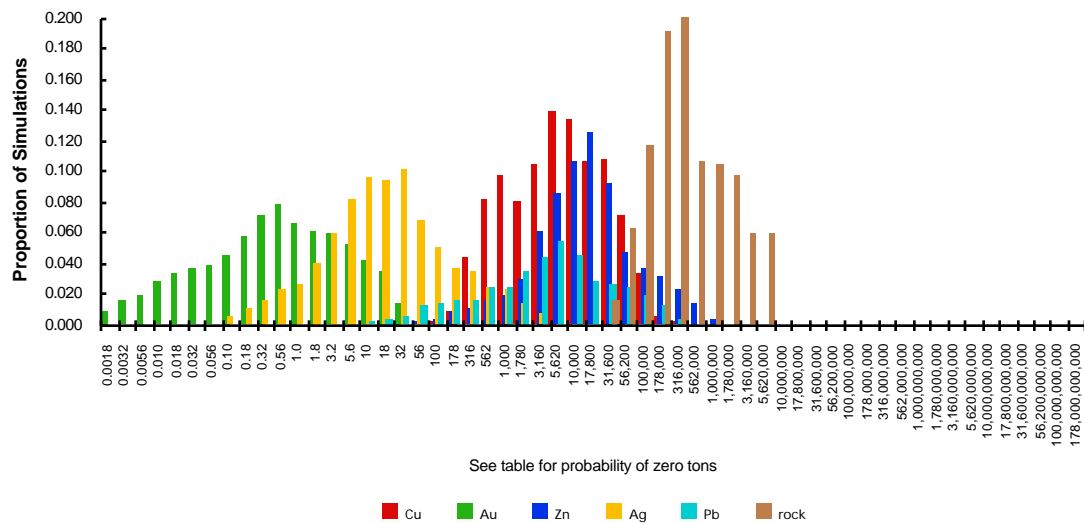
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	310	0	0	0	0	45,000
0.90	460	0	0	0	0	64,000
0.50	4,600	0	4,600	7	0	240,000
0.10	33,000	5	58,300	170	11,000	2,000,000
0.05	50,000	10	130,000	440	35,000	3,500,000
mean	12,000	2	26,000	80	5,700	720,000
Probability of mean	0.29	0.21	0.17	0.15	0.15	0.28
Probability of zero	0.00	0.26	0.31	0.22	0.62	0.00

Simulated amounts of metal in a single deposit

Mark3 Index 44: **Massive sulfide, Sierran kuroko**

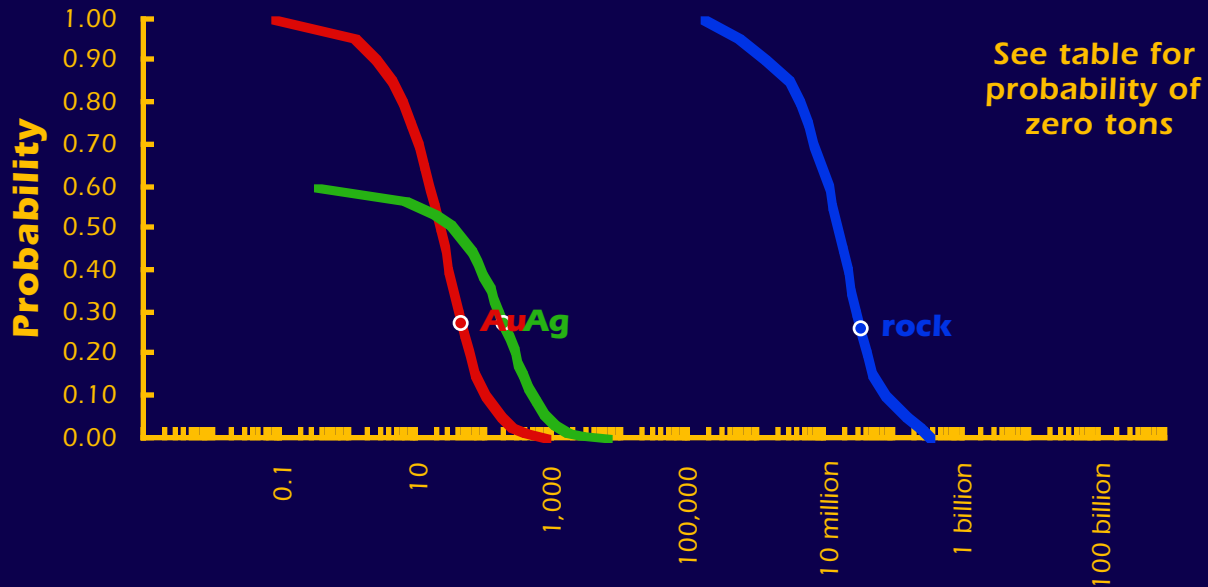
Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	310	0	0	0	0	45,000
0.90	460	0	0	0	0	64,000
0.50	4,600	0	4,600	7	0	240,000
0.10	33,000	5	58,300	170	11,000	2,000,000
0.05	50,000	10	130,000	440	35,000	3,500,000
mean	12,000	2	26,000	80	5,700	720,000
Probability of mean	0.29	0.21	0.17	0.15	0.15	0.28
Probability of zero	0.00	0.26	0.31	0.22	0.62	0.00

Simulated amounts of metal in a single deposit Mark3 Index 44: **Massive sulfide, Sierran kuroko****Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

Mark3 Index 45: Hot spring Au-Ag

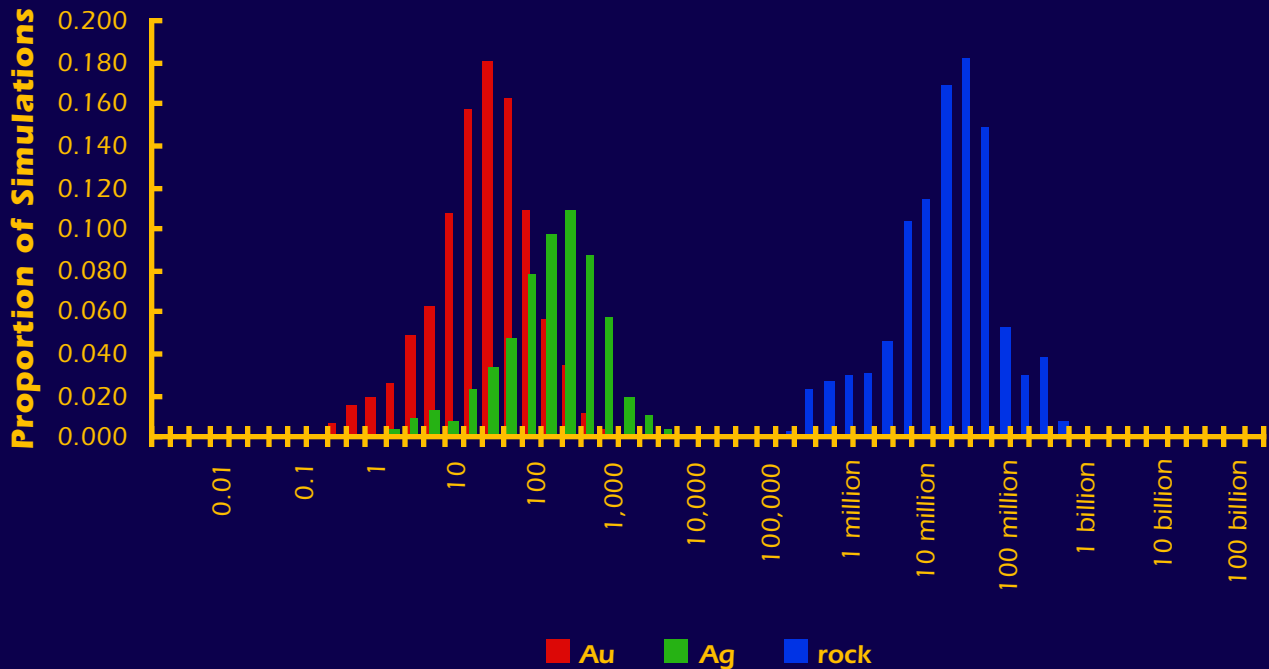
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 45: Hot spring Au-Ag

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 45: Hot spring Au-Ag

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	1	0	530,000
0.90	3	0	1,300,000
0.50	21	35	16,000,000
0.10	100	520	73,400,000
0.05	180	800	160,000,000
mean	46	190	34,000,000
Probability of mean	0.27	0.27	0.26
Probability of zero	0.00	0.40	0.00

Simulated amounts of metal in a single deposit

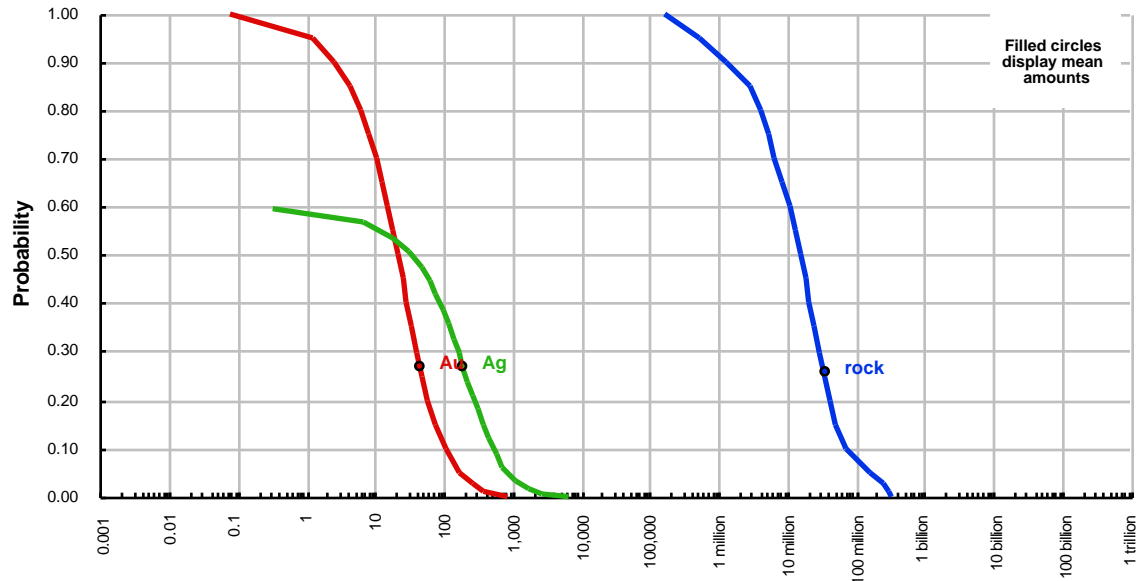
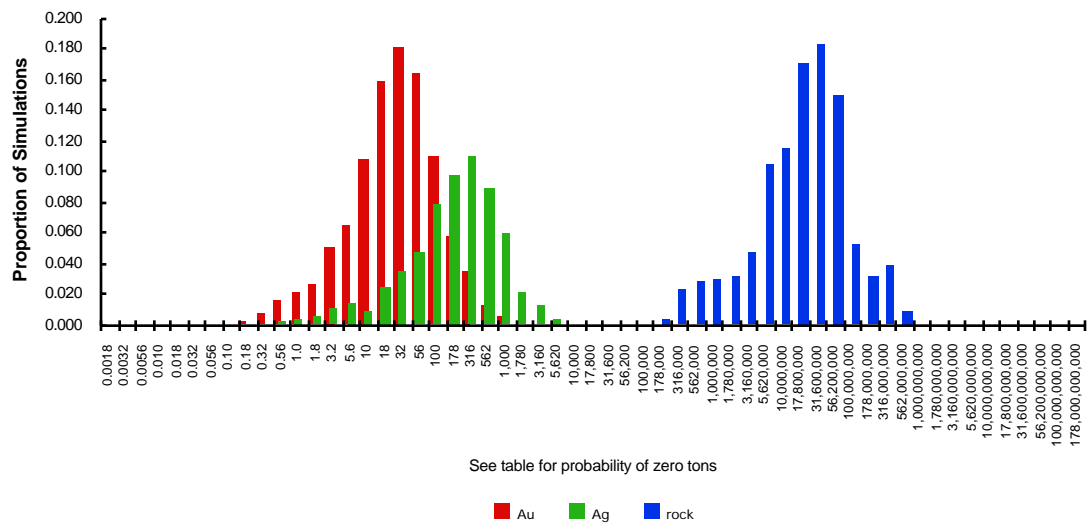
Mark3 Index 45: **Hot spring Au-Ag**

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	1	0	530,000
0.90	3	0	1,300,000
0.50	21	35	16,000,000
0.10	100	520	73,400,000
0.05	180	800	160,000,000
mean	46	190	34,000,000
Probability of mean	0.27	0.27	0.26
Probability of zero	0.00	0.40	0.00

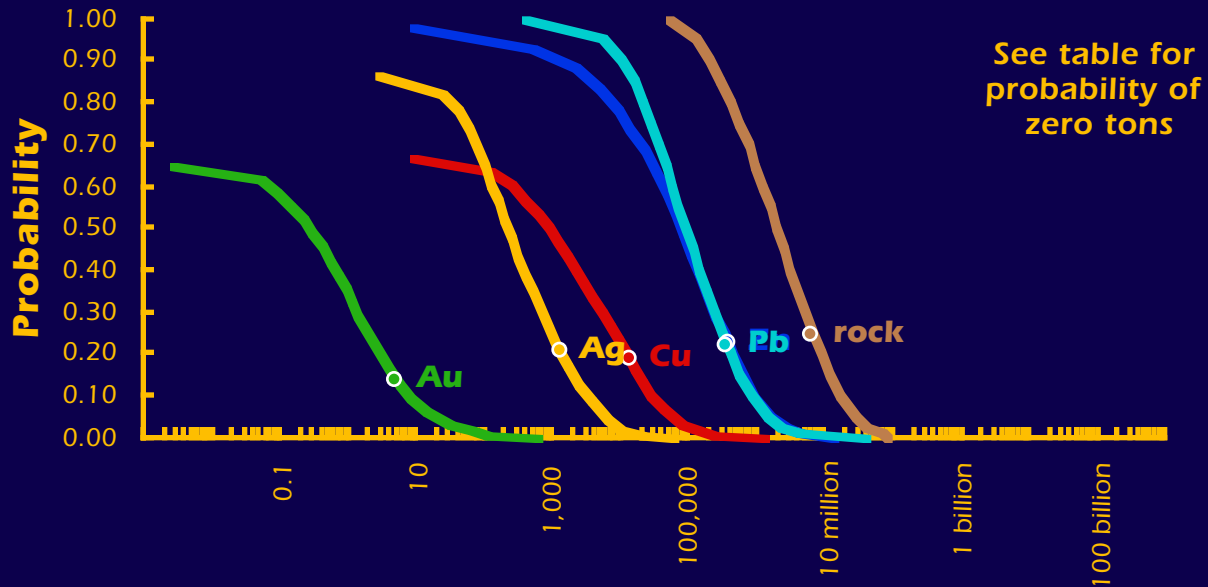
Simulated amounts of metal in a single deposit Mark3 Index 45: Hot spring Au-Ag

Cumulative Distributions of Contained Metal and Mineralized Rock

Histograms of Contained Metal and Mineralized Rock
(metric tons)

Mark3 Index 47: Polymetallic replacement

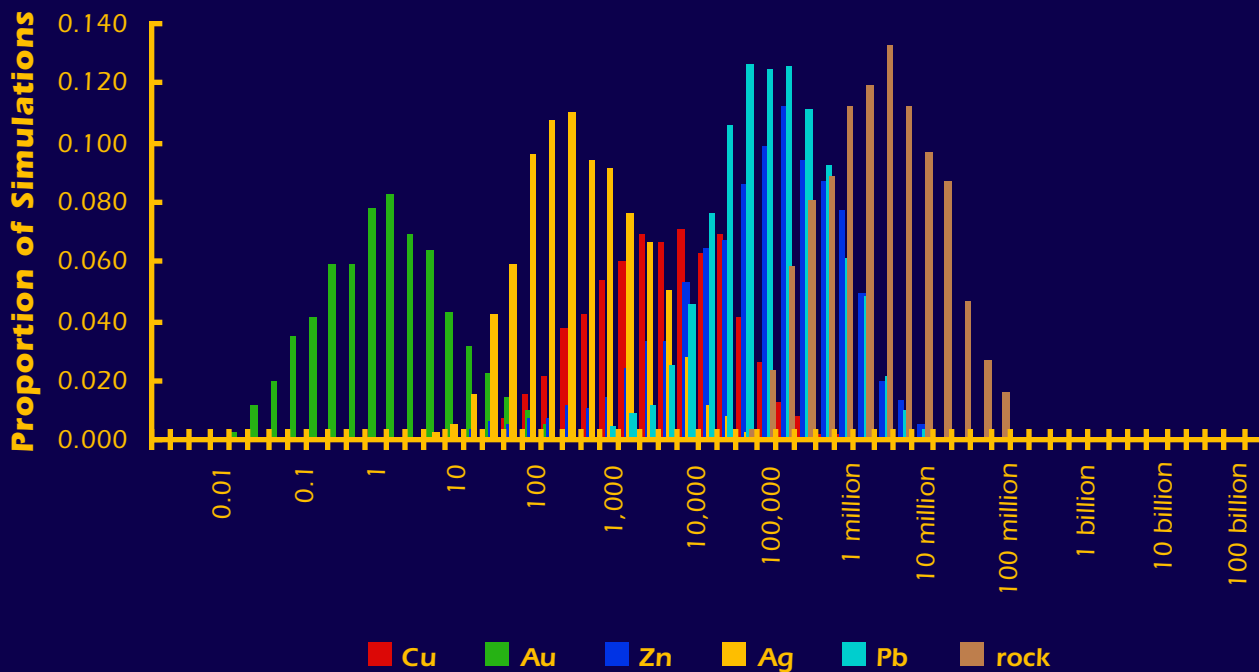
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 47: Polymetallic replacement

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 47: Polymetallic replacement

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	190	0	5,600	130,000
0.90	0	0	1,400	0	11,000	200,000
0.50	890	0	80,000	210	88,000	1,900,000
0.10	28,000	8	902,000	3,200	860,000	16,000,000
0.05	55,000	20	1,500,000	5,700	1,500,000	27,000,000
mean	13,000	5	360,000	1,300	350,000	6,300,000
Probability of mean	0.19	0.14	0.23	0.21	0.22	0.25
Probability of zero	0.33	0.35	0.02	0.13	0.00	0.00

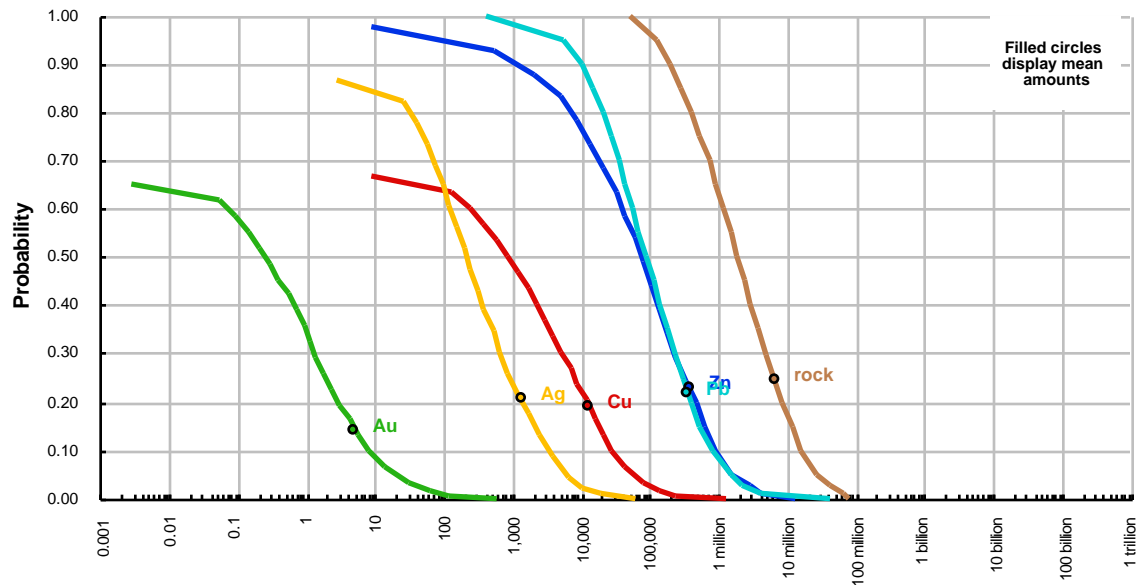
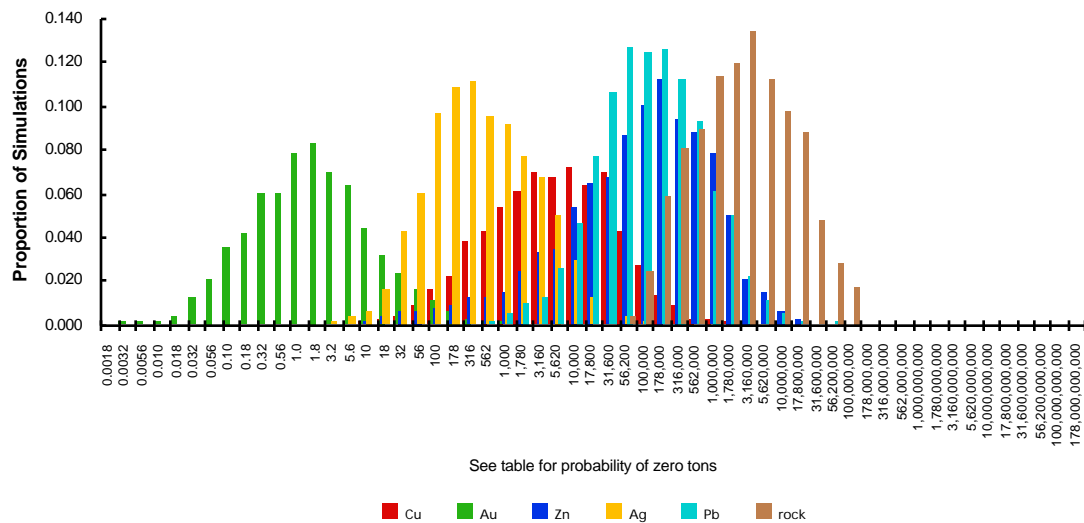
Simulated amounts of metal in a single deposit

Mark3 Index 47: **Polymetallic replacement***Estimated amounts of contained metal and mineralized rock (metric tons)*

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	190	0	5,600	130,000
0.90	0	0	1,400	0	11,000	200,000
0.50	890	0	80,000	210	88,000	1,900,000
0.10	28,000	8	902,000	3,200	860,000	16,000,000
0.05	55,000	20	1,500,000	5,700	1,500,000	27,000,000
mean	13,000	5	360,000	1,300	350,000	6,300,000
Probability of mean	0.19	0.14	0.23	0.21	0.22	0.25
Probability of zero	0.33	0.35	0.02	0.13	0.00	0.00

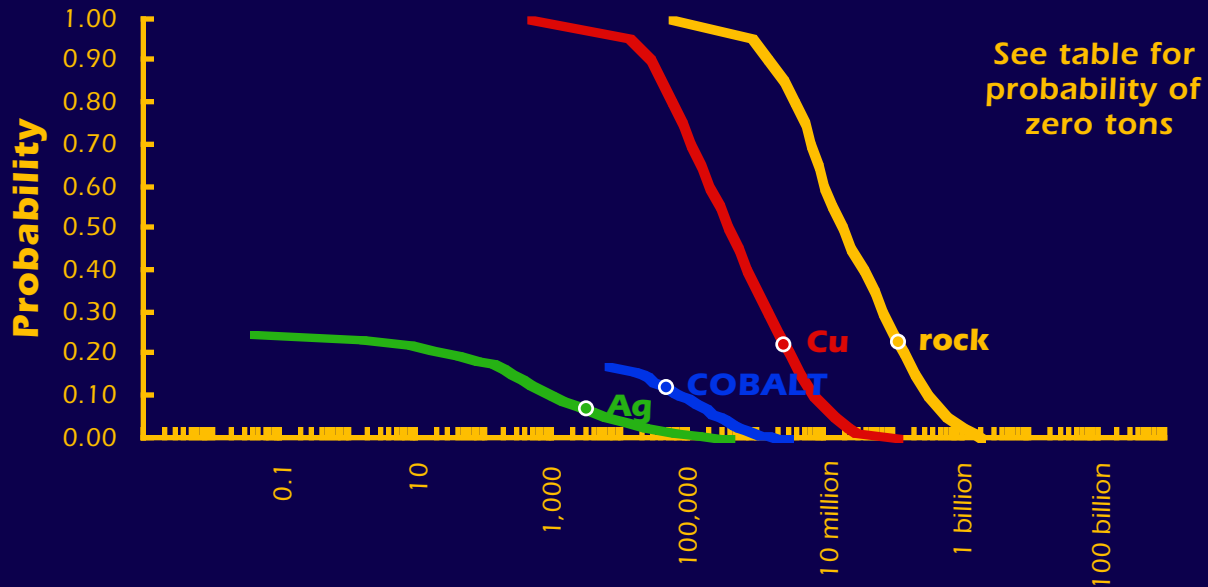
Simulated amounts of metal in a single deposit Mark3 Index 47: Polymetallic replacement

Cumulative Distributions of Contained Metal and Mineralized Rock

Histograms of Contained Metal and Mineralized Rock
(metric tons)

Mark3 Index 63: Sediment-hosted Cu

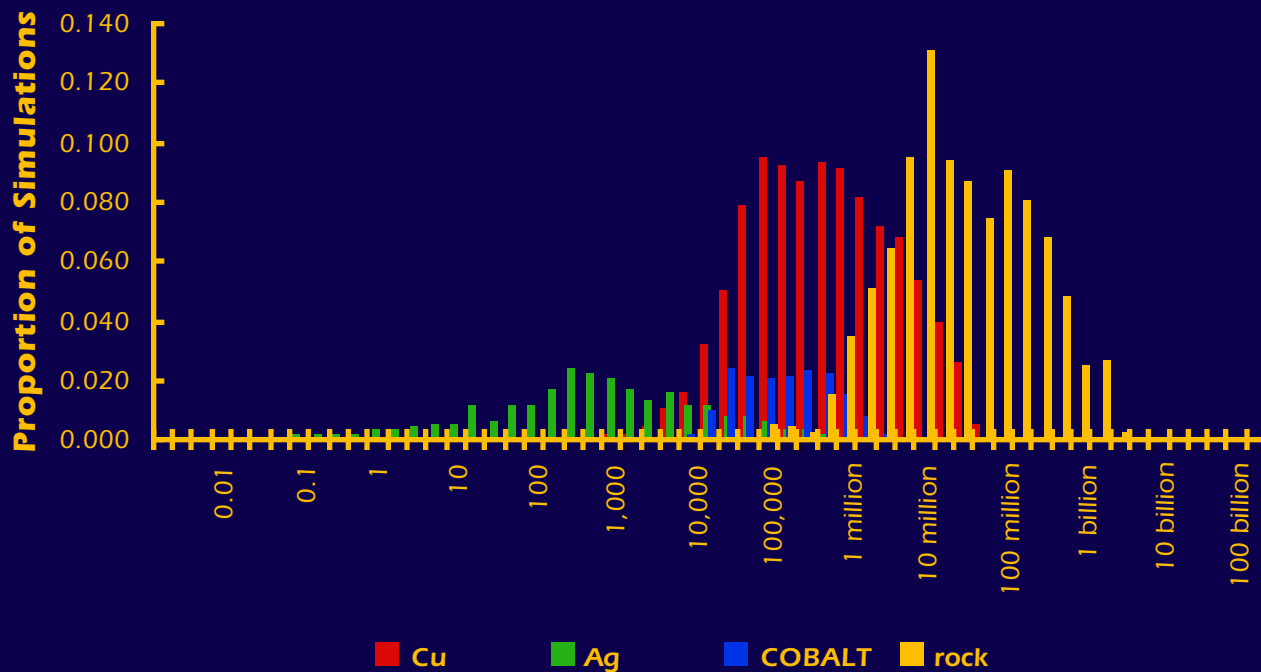
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 63: Sediment-hosted Cu

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 63: Sediment-hosted Cu

Estimated amounts of contained metal and mineralized rock (metric tons)

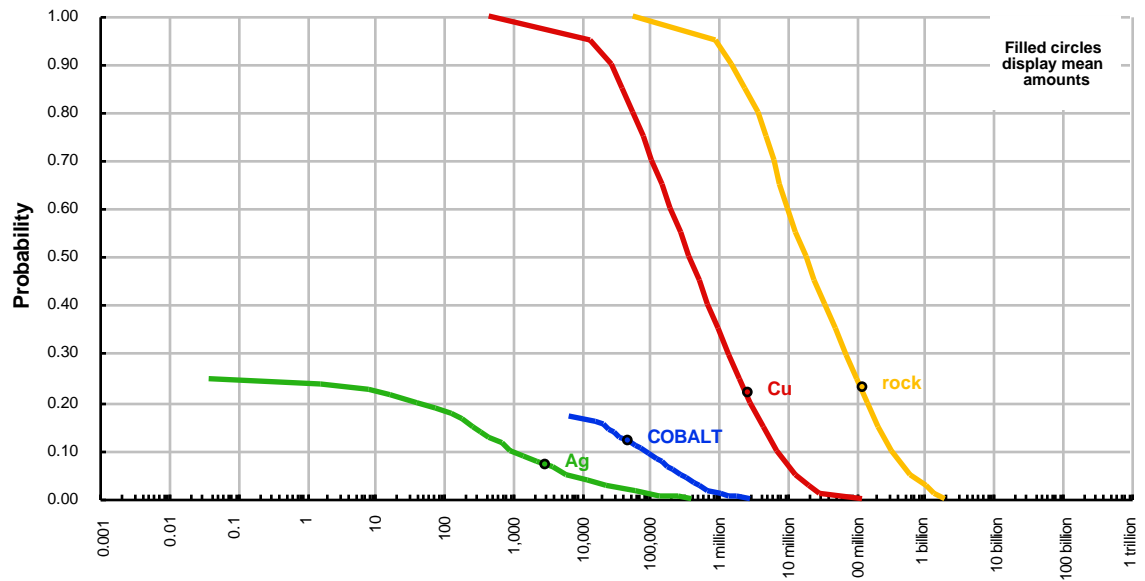
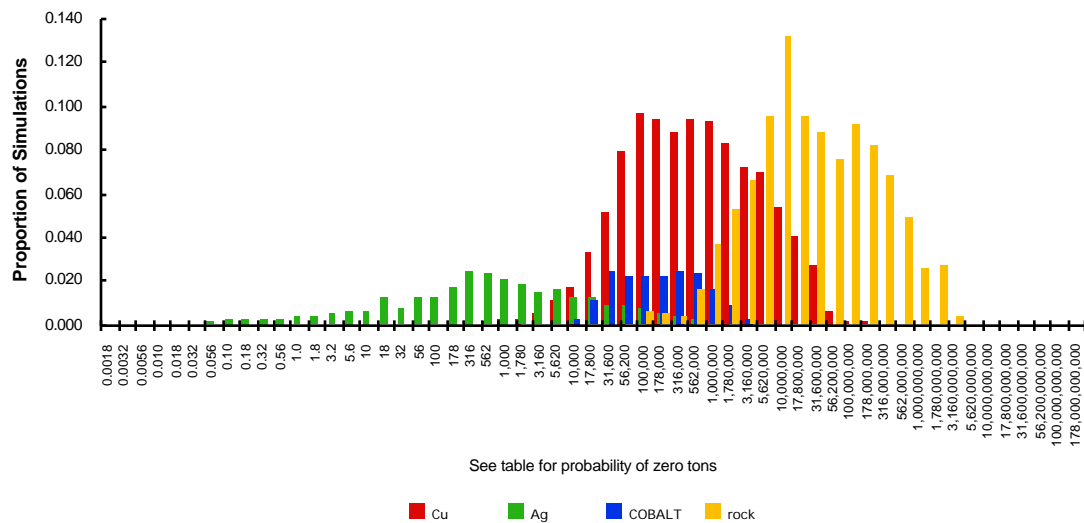
quantile	Cu	Ag	COBALT	rock
0.95	14,000	0	0	870,000
0.90	27,000	0	0	1,500,000
0.50	390,000	0	0	18,000,000
0.10	7,000,000	930	79,700	320,000,000
0.05	13,000,000	6,000	290,000	630,000,000
mean	2,500,000	3,100	46,000	120,000,000
Probability of mean	0.22	0.07	0.12	0.23
Probability of zero	0.00	0.75	0.83	0.00

Simulated amounts of metal in a single deposit

Mark3 Index 63: **Sediment-hosted Cu**

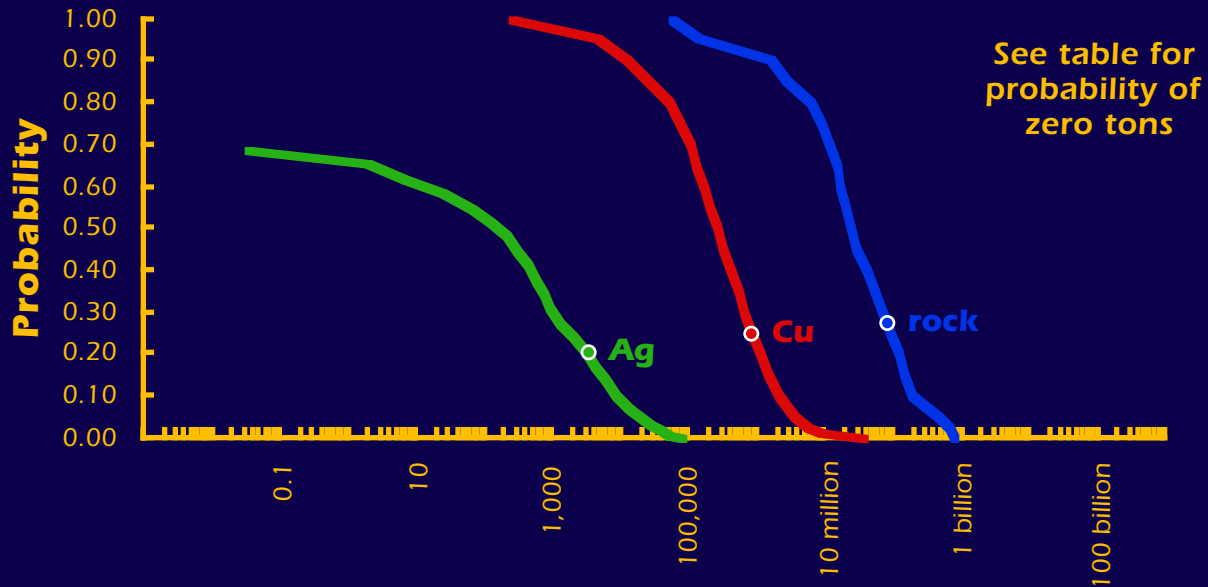
Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Ag	COBALT	rock
0.95	14,000	0	0	870,000
0.90	27,000	0	0	1,500,000
0.50	390,000	0	0	18,000,000
0.10	7,000,000	930	79,700	320,000,000
0.05	13,000,000	6,000	290,000	630,000,000
mean	2,500,000	3,100	46,000	120,000,000
Probability of mean	0.22	0.07	0.12	0.23
Probability of zero	0.00	0.75	0.83	0.00

Simulated amounts of metal in a single deposit Mark3 Index 63: **Sediment-hosted Cu****Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

Mark3 Index 64: Sediment-hosted Cu, Revett

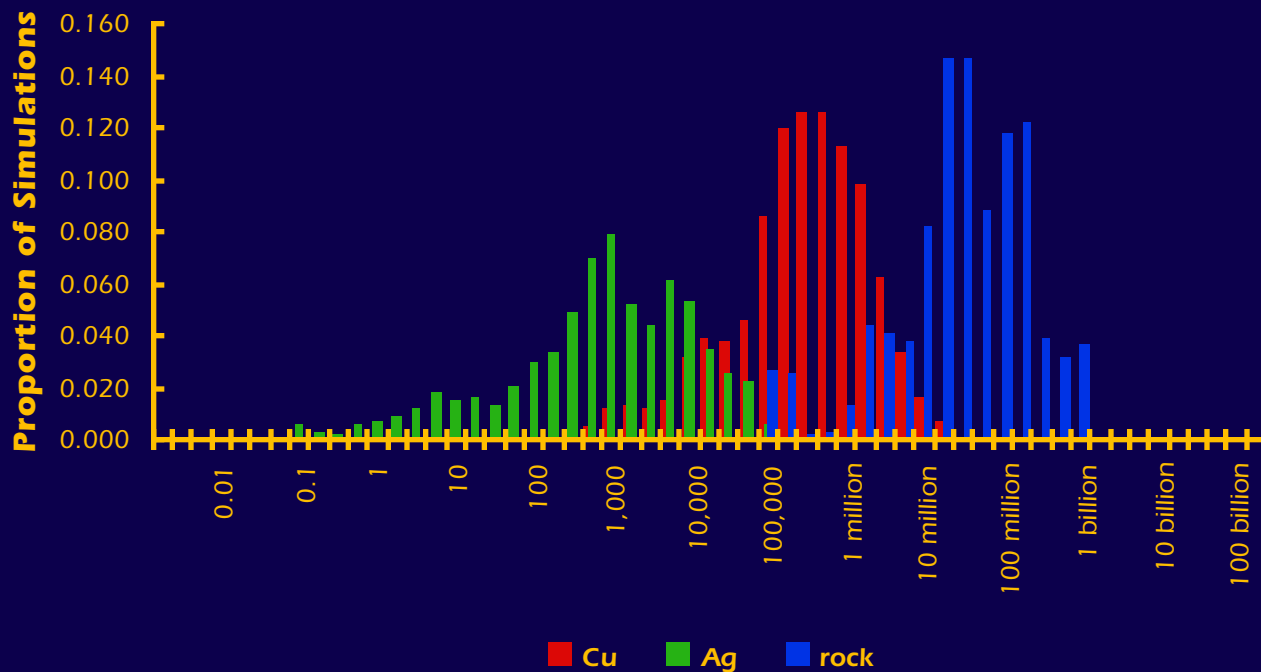
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 64: Sediment-hosted Cu, Revett

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 64: Sediment-hosted Cu, Revett

Estimated amounts of contained metal and mineralized rock (metric tons)

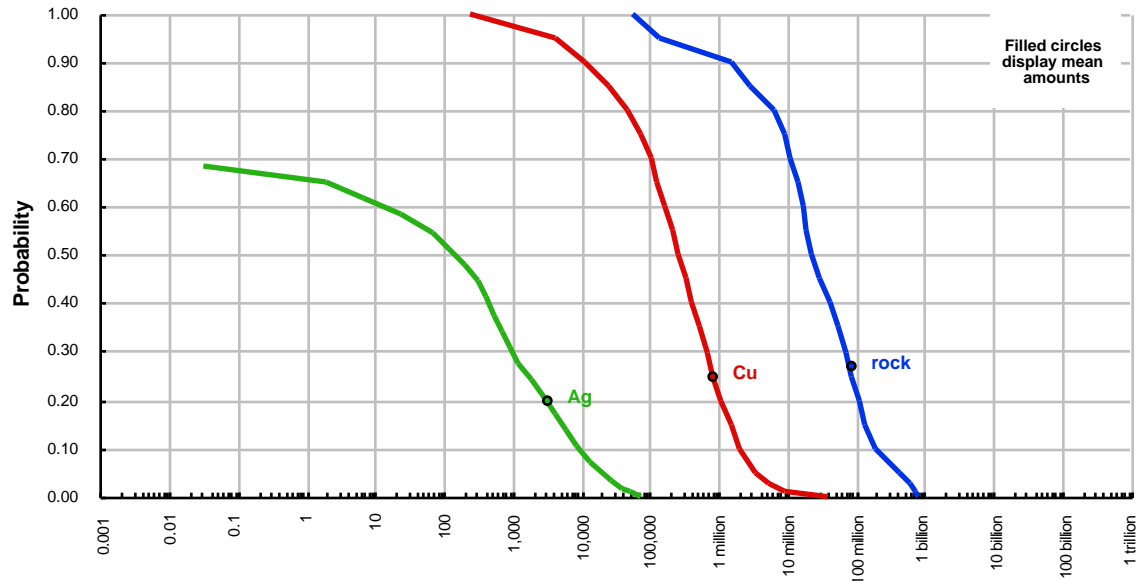
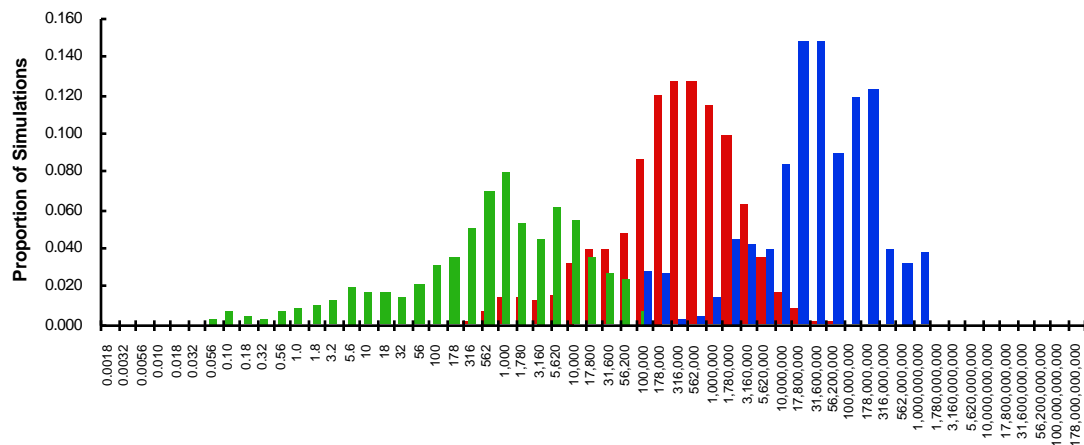
quantile	Cu	Ag	rock
0.95	4,400	0	140,000
0.90	12,000	0	1,600,000
0.50	260,000	160	23,000,000
0.10	2,100,000	8,600	185,000,000
0.05	3,600,000	20,000	450,000,000
mean	850,000	3,300	83,000,000
Probability of mean	0.25	0.20	0.27
Probability of zero	0.00	0.31	0.00

Simulated amounts of metal in a single deposit

Mark3 Index 64: **Sediment-hosted Cu, Revett**

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Ag	rock
0.95	4,400	0	140,000
0.90	12,000	0	1,600,000
0.50	260,000	160	23,000,000
0.10	2,100,000	8,600	185,000,000
0.05	3,600,000	20,000	450,000,000
mean	850,000	3,300	83,000,000
Probability of mean	0.25	0.20	0.27
Probability of zero	0.00	0.31	0.00

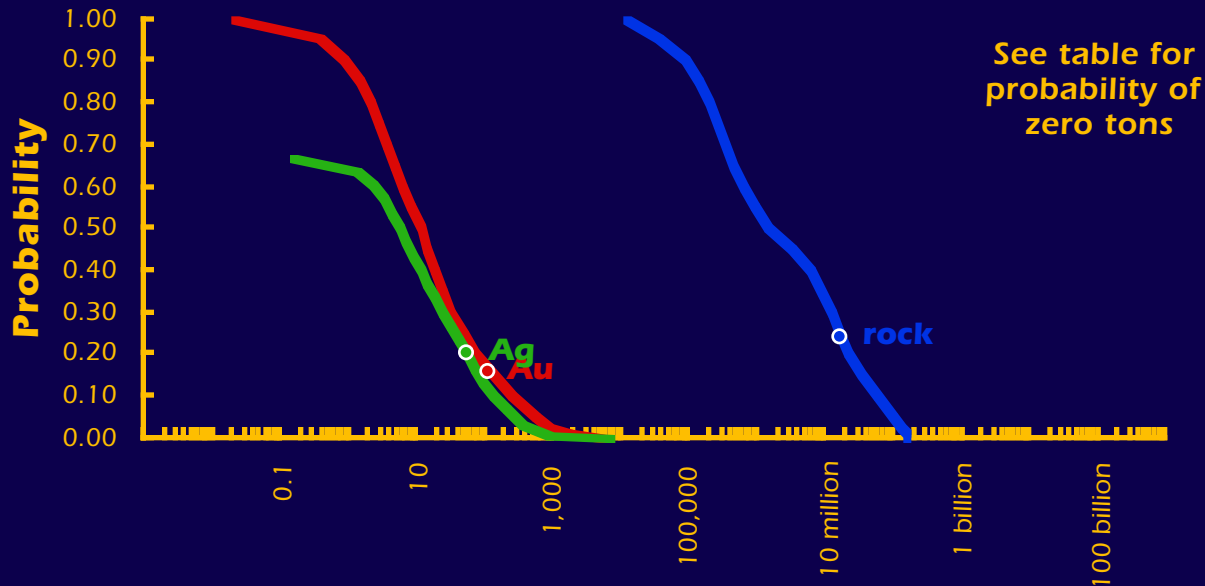
Simulated amounts of metal in a single deposit Mark3 Index 64: **Sediment-hosted Cu, Revett****Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

See table for probability of zero tons

■ Cu ■ Ag ■ rock

Mark3 Index 80: Alkaline Au-Te

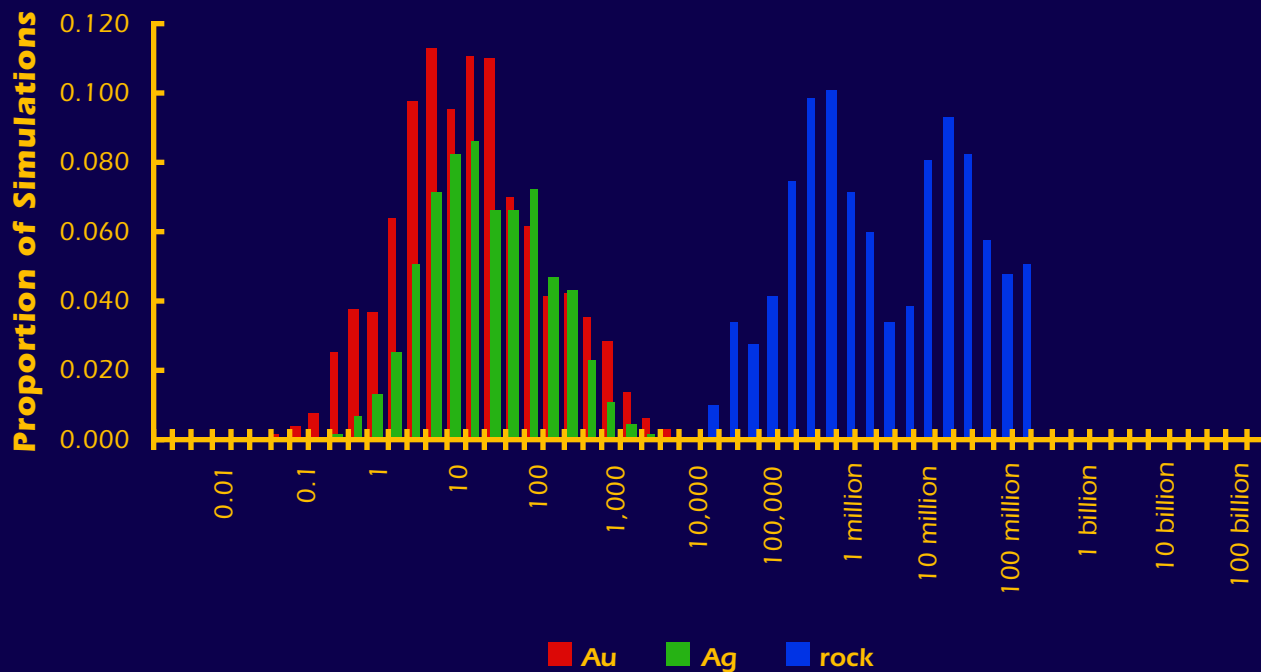
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 80: Alkaline Au-Te

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 80: Alkaline Au-Te

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	35,000
0.90	1	0	85,000
0.50	11	6	1,500,000
0.10	260	130	55,700,000
0.05	570	270	100,000,000
mean	110	56	17,000,000
Probability of mean	0.16	0.20	0.24
Probability of zero	0.00	0.33	0.00

Simulated amounts of metal in a single deposit

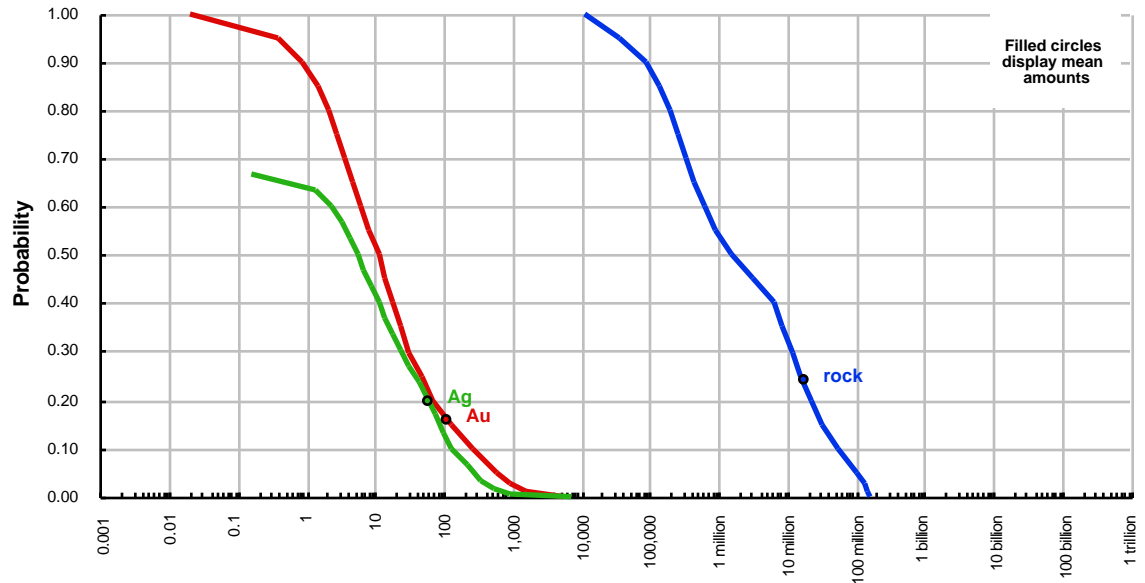
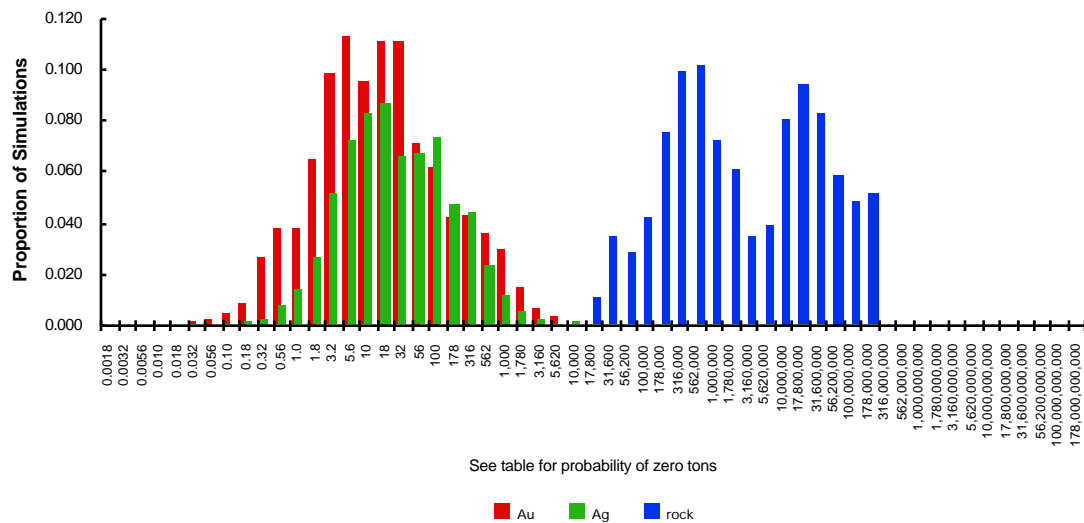
Mark3 Index 80: **Alkaline Au-Te**

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	35,000
0.90	1	0	85,000
0.50	11	6	1,500,000
0.10	260	130	55,700,000
0.05	570	270	100,000,000
mean	110	56	17,000,000
Probability of mean	0.16	0.20	0.24
Probability of zero	0.00	0.33	0.00

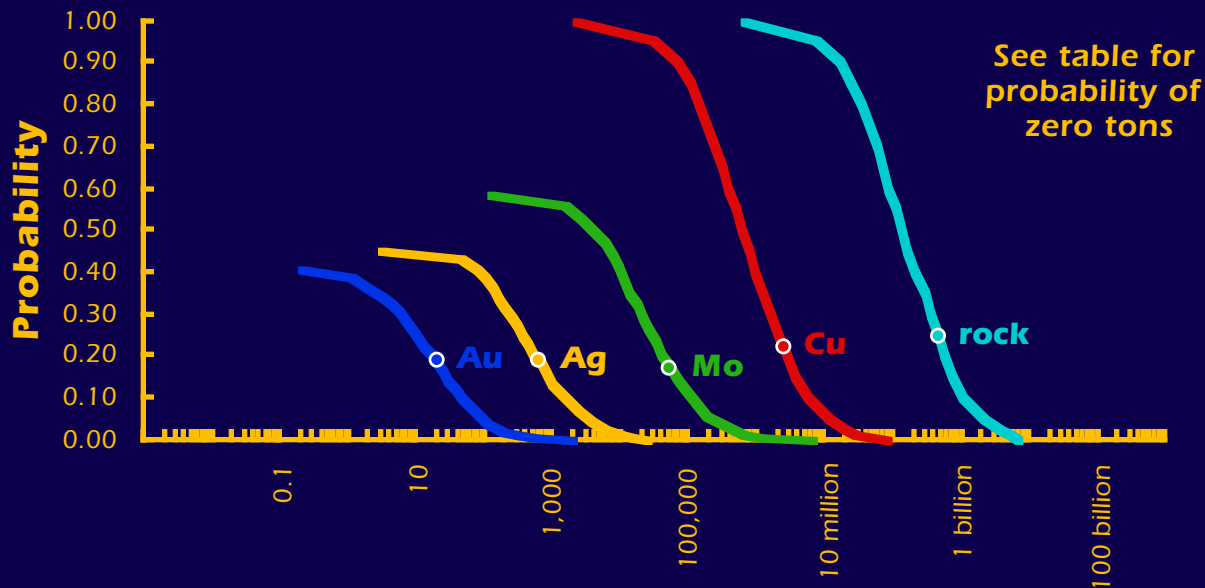
Simulated amounts of metal in a single deposit Mark3 Index 80: Alkaline Au-Te

Cumulative Distributions of Contained Metal and Mineralized Rock

Histograms of Contained Metal and Mineralized Rock
(metric tons)

Mark3 Index 81: Porphyry Cu (North America)

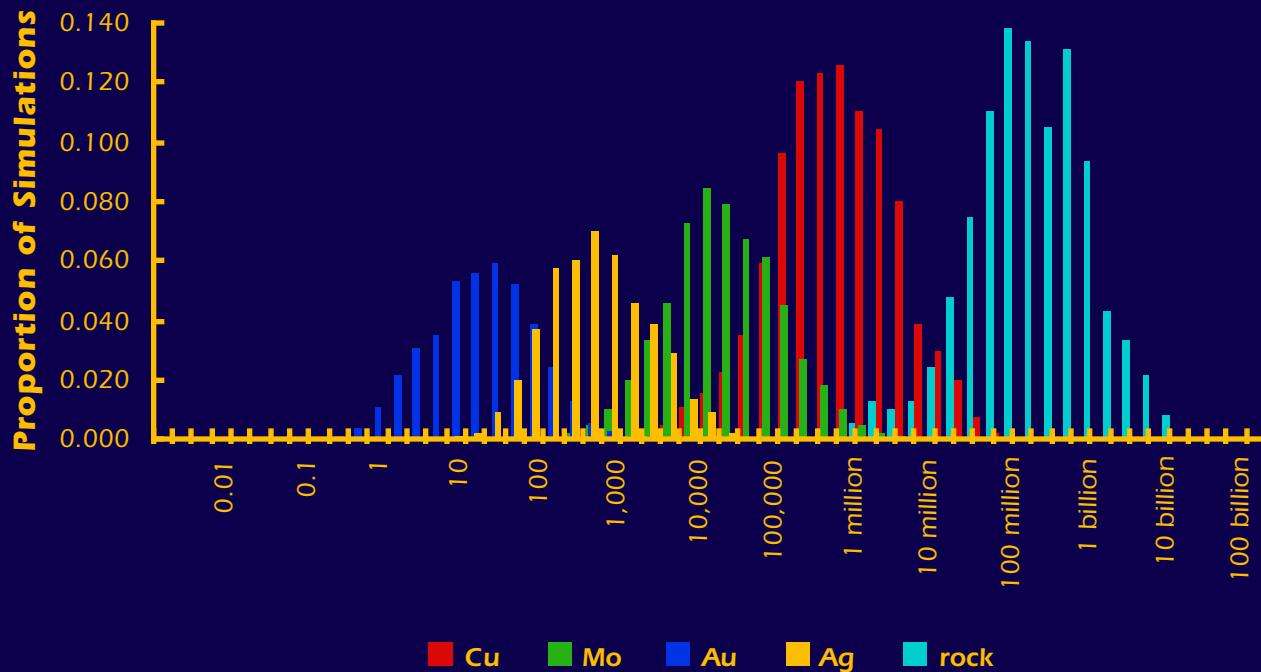
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 81: Porphyry Cu (North America)

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 81: **Porphyry Cu (North America)**

Estimated amounts of contained metal and mineralized rock (metric tons)

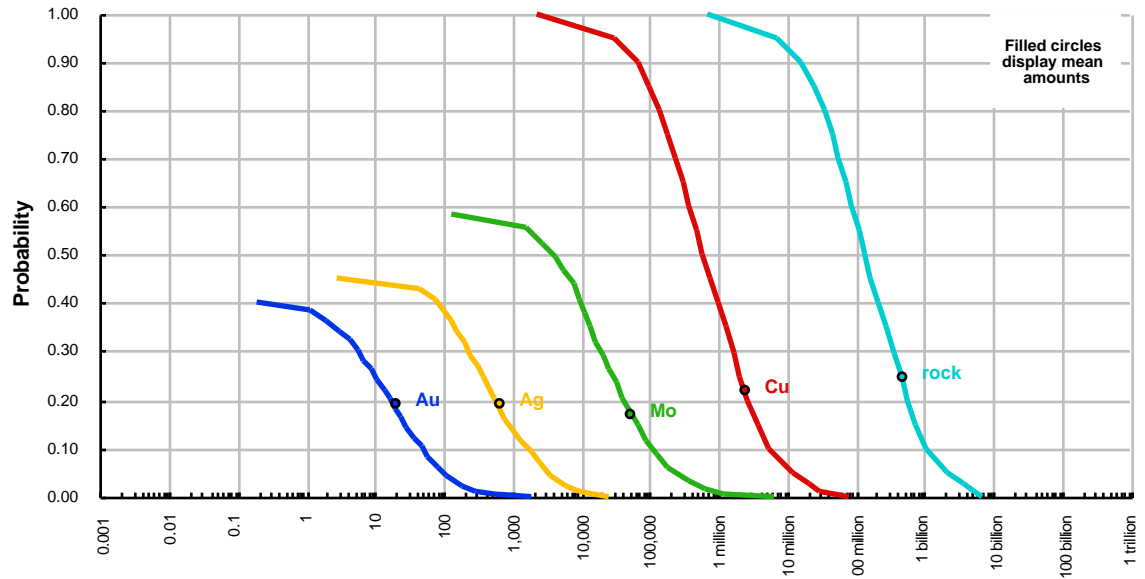
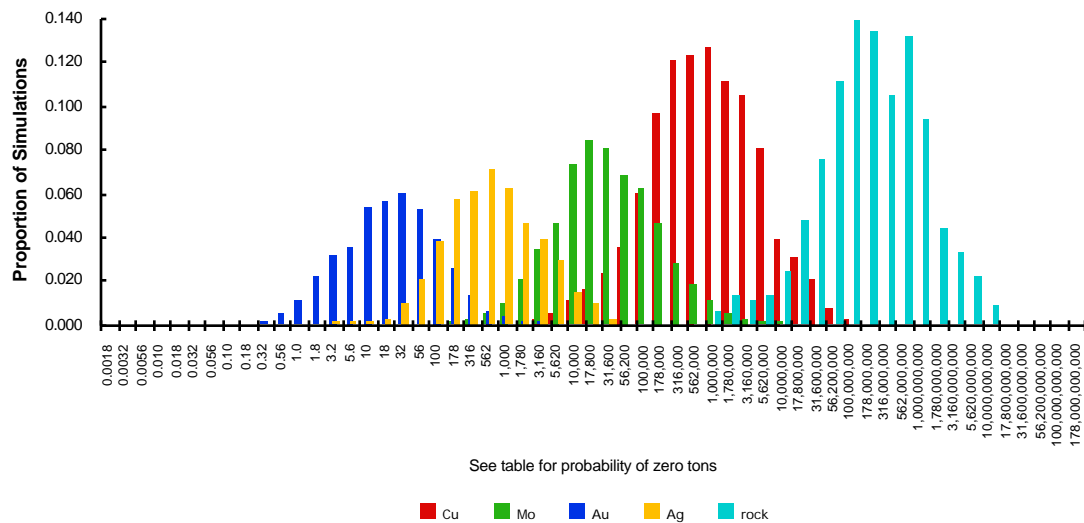
quantile	Cu	Mo	Au	Ag	rock
0.95	30,000	0	0	0	7,300,000
0.90	65,000	0	0	0	16,000,000
0.50	600,000	4,100	0	0	130,000,000
0.10	5,400,000	110,000	47	1,600	1,000,000,000
0.05	12,000,000	230,000	94	3,300	2,200,000,000
mean	2,500,000	53,000	20	630	460,000,000
Probability of mean	0.22	0.17	0.19	0.19	0.25
Probability of zero	0.00	0.41	0.60	0.55	0.00

Simulated amounts of metal in a single deposit

Mark3 Index 81: **Porphyry Cu (North America)**

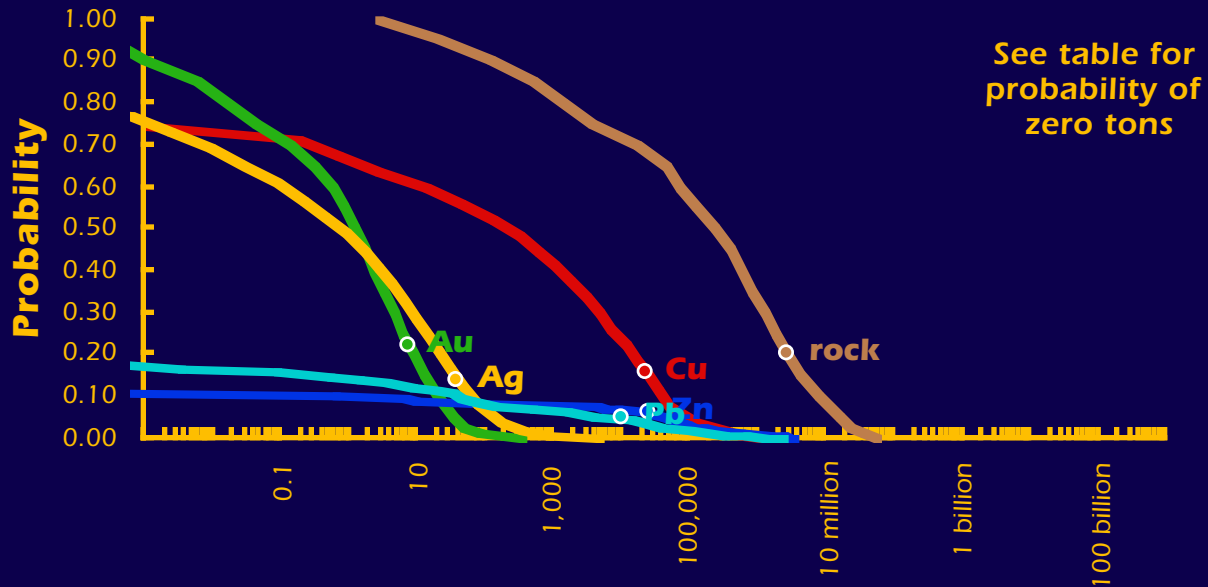
Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	30,000	0	0	0	7,300,000
0.90	65,000	0	0	0	16,000,000
0.50	600,000	4,100	0	0	130,000,000
0.10	5,400,000	110,000	47	1,600	1,000,000,000
0.05	12,000,000	230,000	94	3,300	2,200,000,000
mean	2,500,000	53,000	20	630	460,000,000
Probability of mean	0.22	0.17	0.19	0.19	0.25
Probability of zero	0.00	0.41	0.60	0.55	0.00

Simulated amounts of metal in a single deposit Mark3 Index 81: **Porphyry Cu (North America)****Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

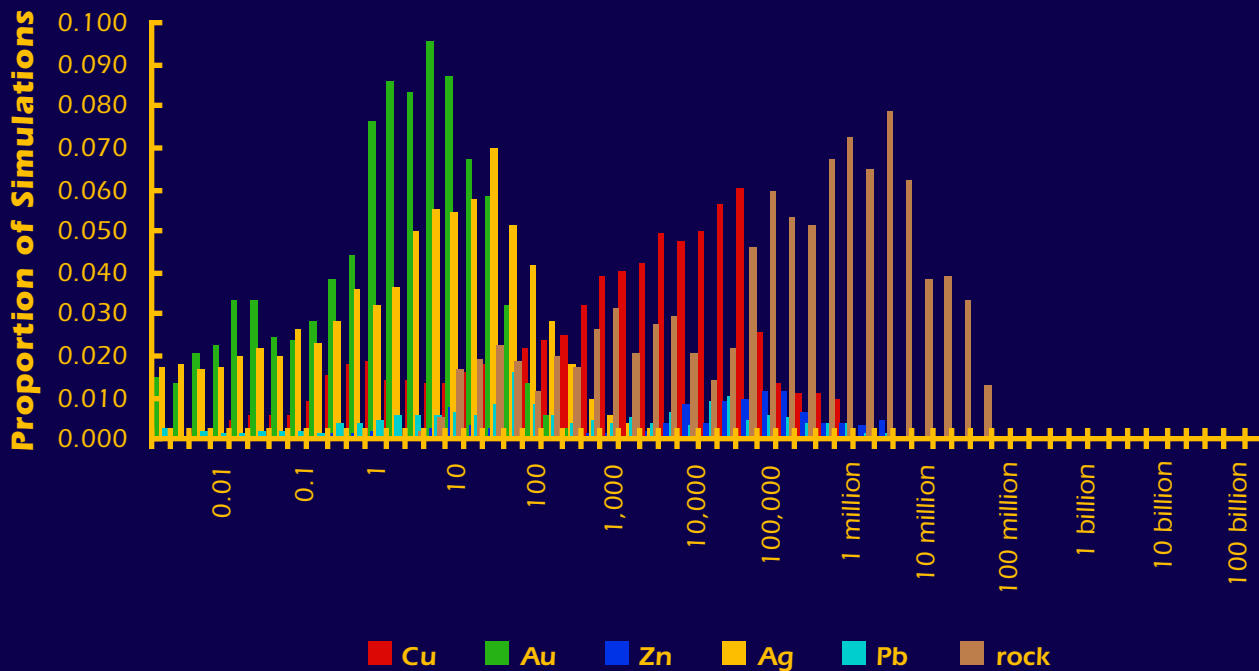
Mark3 Index 82: Skarn Au

Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Mark3 Index 82: Skarn Au

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 82: Skarn Au

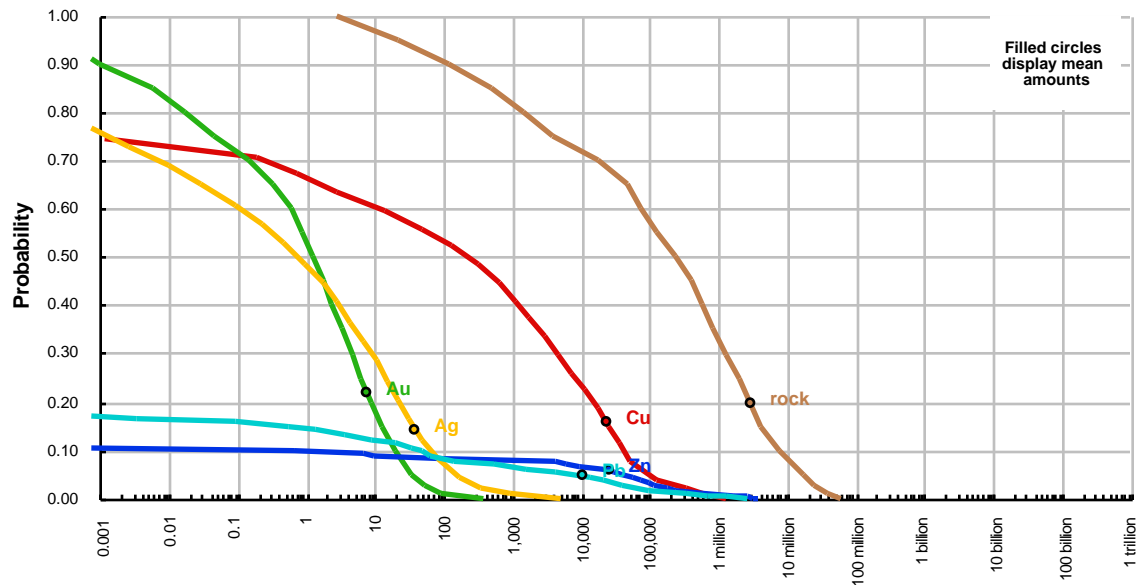
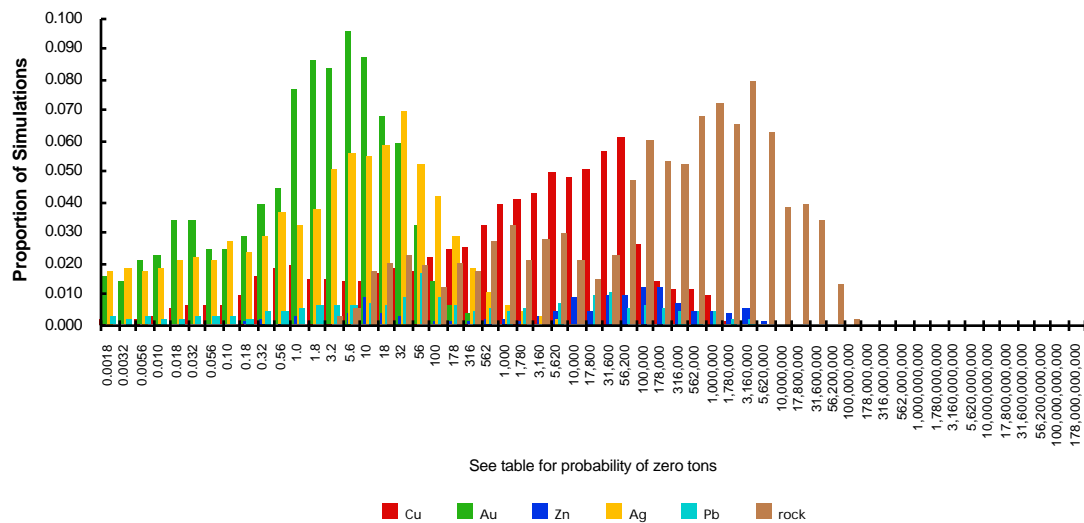
Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	21
0.90	0	0	0	0	0	120
0.50	230	1	0	1	0	230,000
0.10	41,000	20	1	62	39	8,000,000
0.05	81,000	33	42,000	140	6,500	17,000,000
mean	23,000	7	26,000	39	11,000	2,800,000
Probability of mean	0.16	0.22	0.06	0.14	0.05	0.20
Probability of zero	0.25	0.00	0.89	0.19	0.83	0.00

Simulated amounts of metal in a single deposit

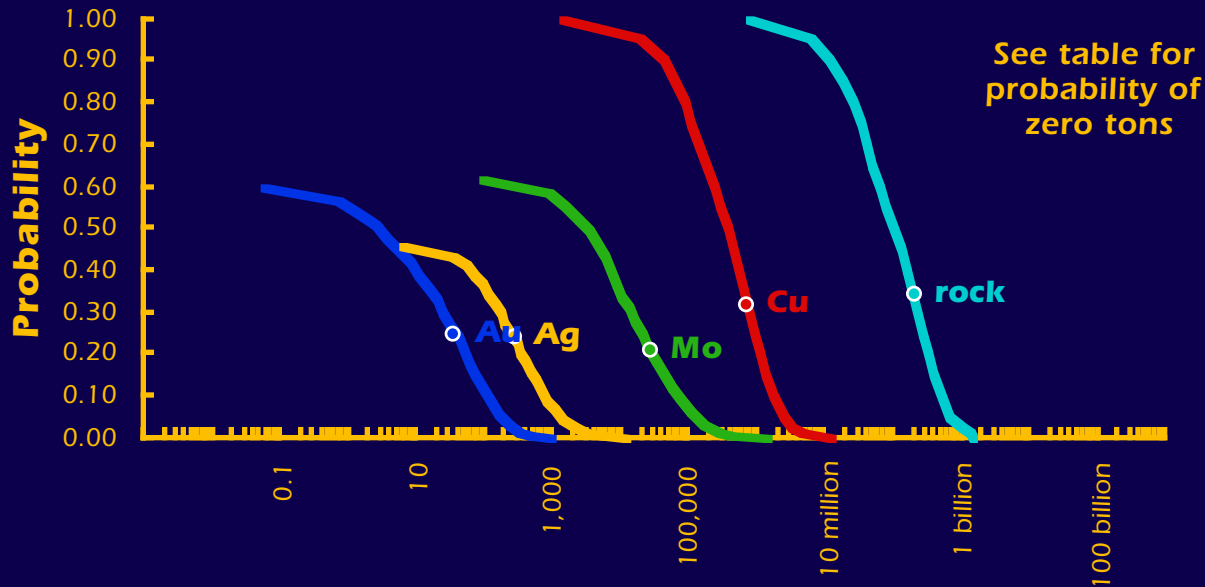
Mark3 Index 82: **Skarn Au***Estimated amounts of contained metal and mineralized rock (metric tons)*

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	0	0	0	21
0.90	0	0	0	0	0	120
0.50	230	1	0	1	0	230,000
0.10	41,000	20	1	62	39	8,000,000
0.05	81,000	33	42,000	140	6,500	17,000,000
mean	23,000	7	26,000	39	11,000	2,800,000
Probability of mean	0.16	0.22	0.06	0.14	0.05	0.20
Probability of zero	0.25	0.00	0.89	0.19	0.83	0.00

Simulated amounts of metal in a single deposit Mark3 Index 82: **Skarn Au****Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

Mark3 Index 89: Porphyry Cu (BC-AK)

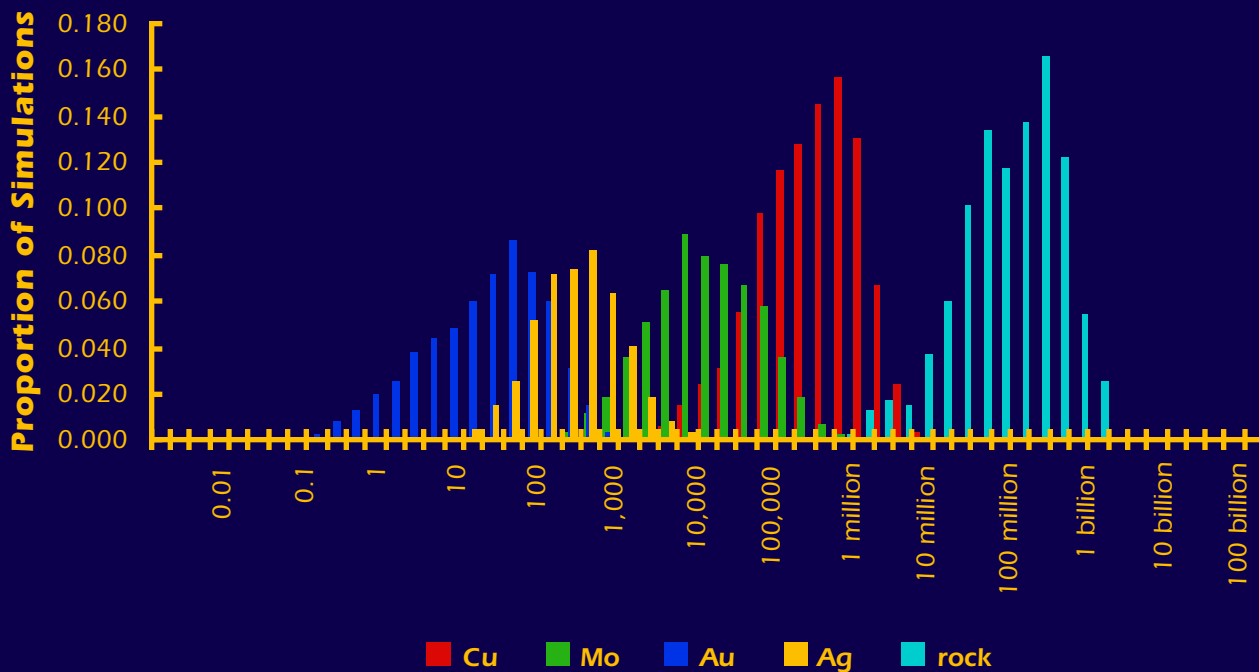
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 89: Porphyry Cu (BC-AK)

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 89: **Porphyry Cu (BC-AK)**

Estimated amounts of contained metal and mineralized rock (metric tons)

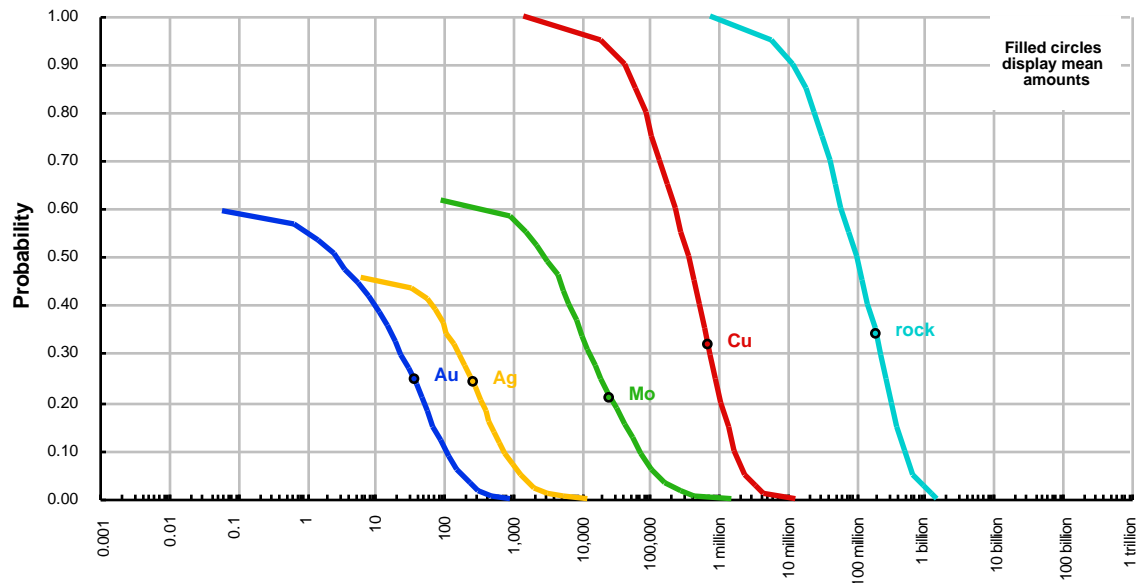
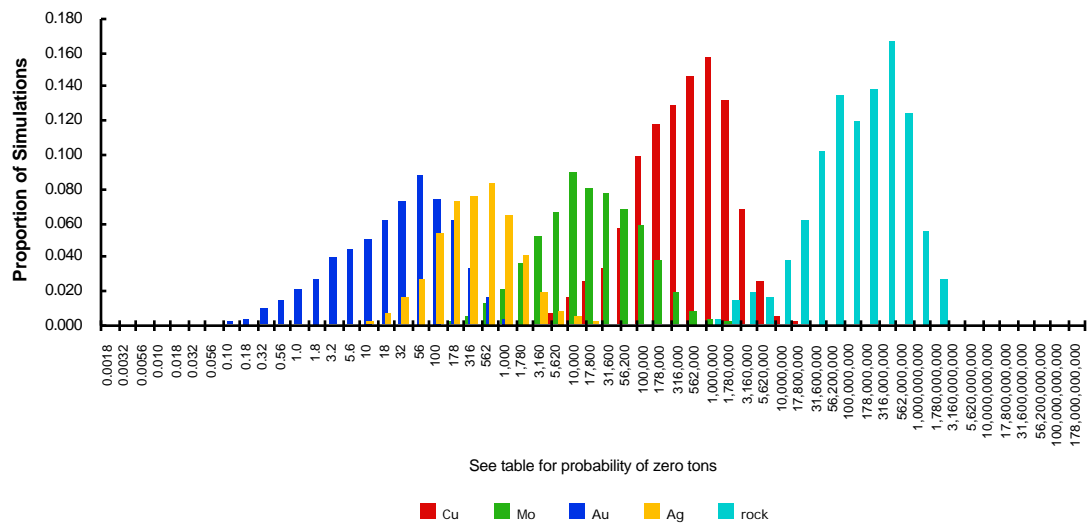
quantile	Cu	Mo	Au	Ag	rock
0.95	19,000	0	0	0	6,100,000
0.90	42,000	0	0	0	12,000,000
0.50	360,000	3,100	3	0	100,000,000
0.10	1,700,000	67,000	107	740	500,000,000
0.05	2,500,000	120,000	180	1,300	690,000,000
mean	700,000	26,000	36	280	200,000,000
Probability of mean	0.32	0.21	0.25	0.24	0.34
Probability of zero	0.00	0.38	0.40	0.54	0.00

Simulated amounts of metal in a single deposit

Mark3 Index 89: **Porphyry Cu (BC-AK)**

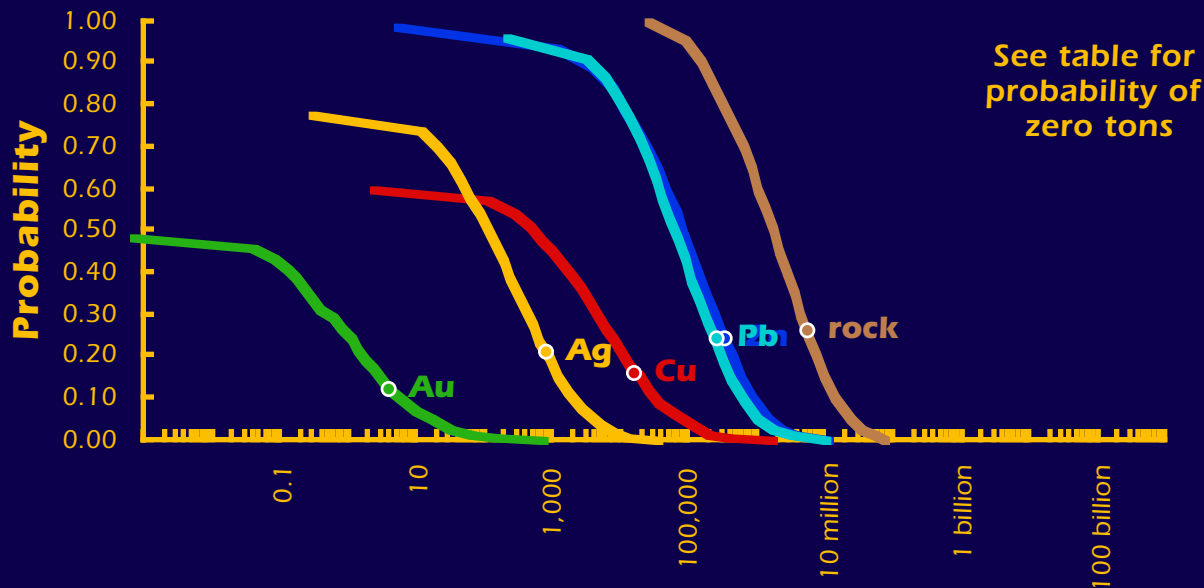
Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Mo	Au	Ag	rock
0.95	19,000	0	0	0	6,100,000
0.90	42,000	0	0	0	12,000,000
0.50	360,000	3,100	3	0	100,000,000
0.10	1,700,000	67,000	107	740	500,000,000
0.05	2,500,000	120,000	180	1,300	690,000,000
mean	700,000	26,000	36	280	200,000,000
Probability of mean	0.32	0.21	0.25	0.24	0.34
Probability of zero	0.00	0.38	0.40	0.54	0.00

Simulated amounts of metal in a single deposit Mark3 Index 89: **Porphyry Cu (BC-AK)****Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

Mark3 Index 92: Polymetallic Replacement + skarn Zn-Pb

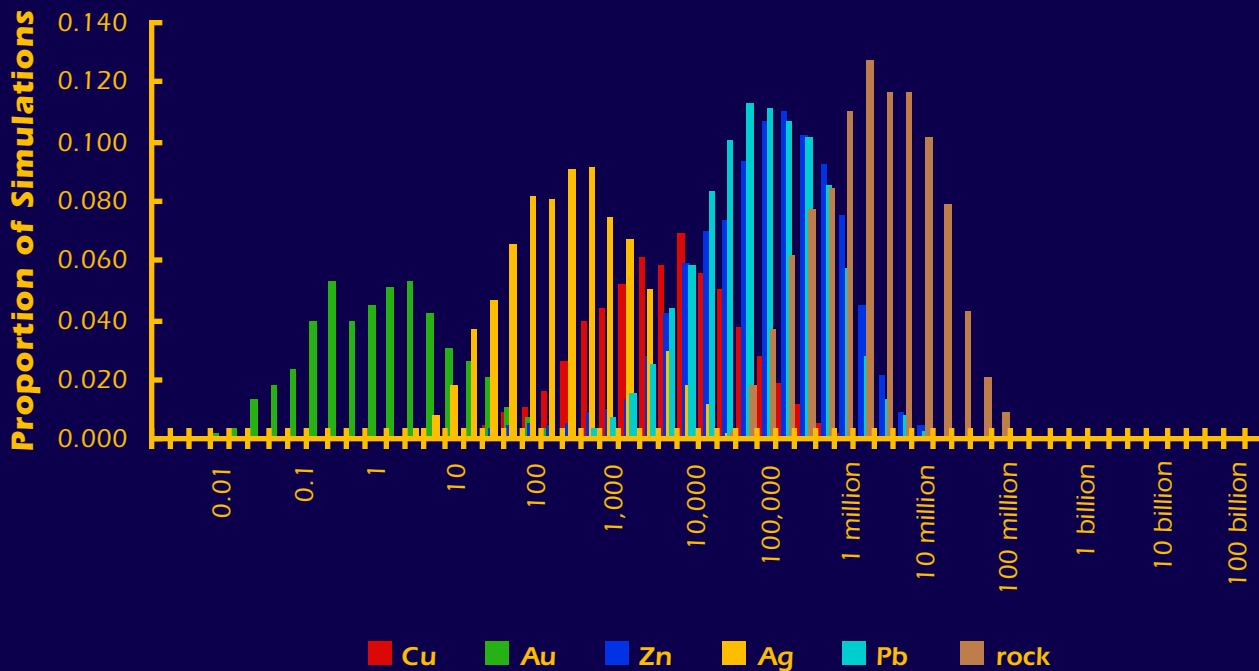
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 92: Polymetallic Replacement + skarn Zn-Pb

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 92: Polymetallic Replacement + skarn Zn-Pb

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	690	0	930	91,000
0.90	0	0	3,200	0	3,600	150,000
0.50	500	0	81,000	110	60,000	1,700,000
0.10	33,000	6	839,000	2,000	610,000	14,000,000
0.05	78,000	16	1,400,000	3,800	1,000,000	24,000,000
mean	16,000	4	330,000	790	250,000	5,300,000
Probability of mean	0.16	0.12	0.24	0.21	0.24	0.26
Probability of zero	0.40	0.52	0.01	0.23	0.04	0.00

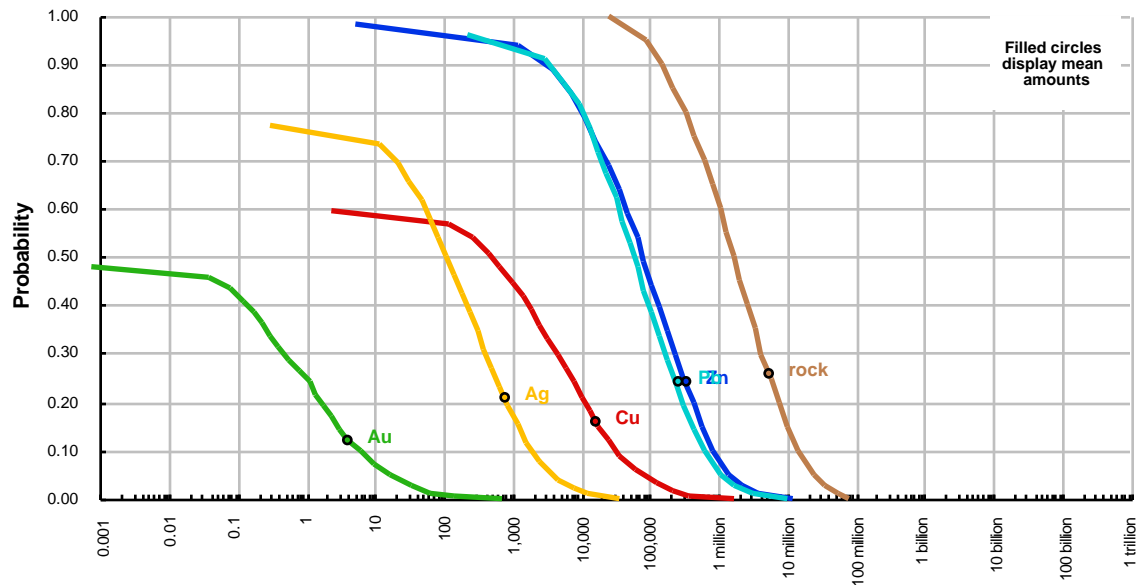
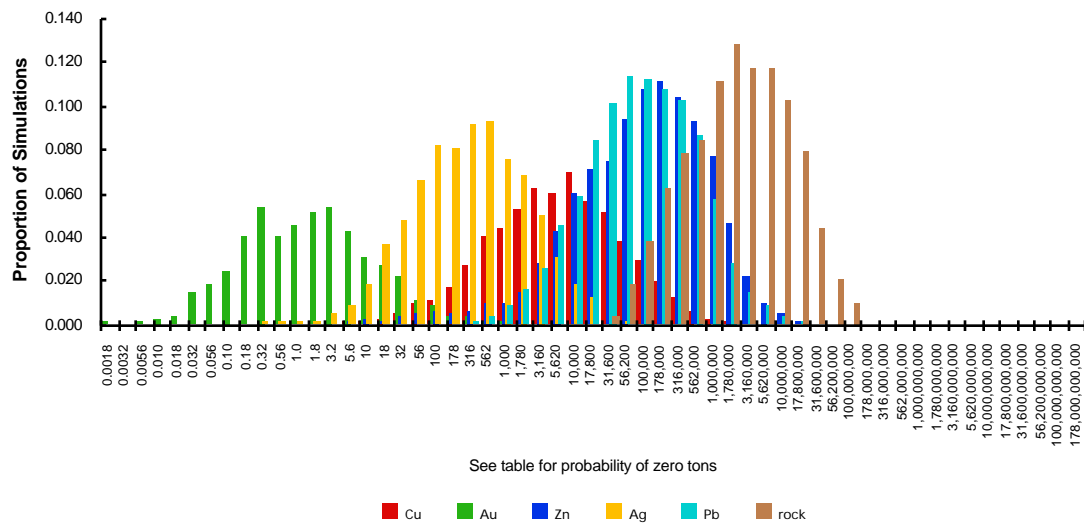
Simulated amounts of metal in a single deposit

Mark3 Index 92: **Polymetallic Replacement + skarn Zn-Pb***Estimated amounts of contained metal and mineralized rock (metric tons)*

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	0	0	690	0	930	91,000
0.90	0	0	3,200	0	3,600	150,000
0.50	500	0	81,000	110	60,000	1,700,000
0.10	33,000	6	839,000	2,000	610,000	14,000,000
0.05	78,000	16	1,400,000	3,800	1,000,000	24,000,000
mean	16,000	4	330,000	790	250,000	5,300,000
Probability of mean	0.16	0.12	0.24	0.21	0.24	0.26
Probability of zero	0.40	0.52	0.01	0.23	0.04	0.00

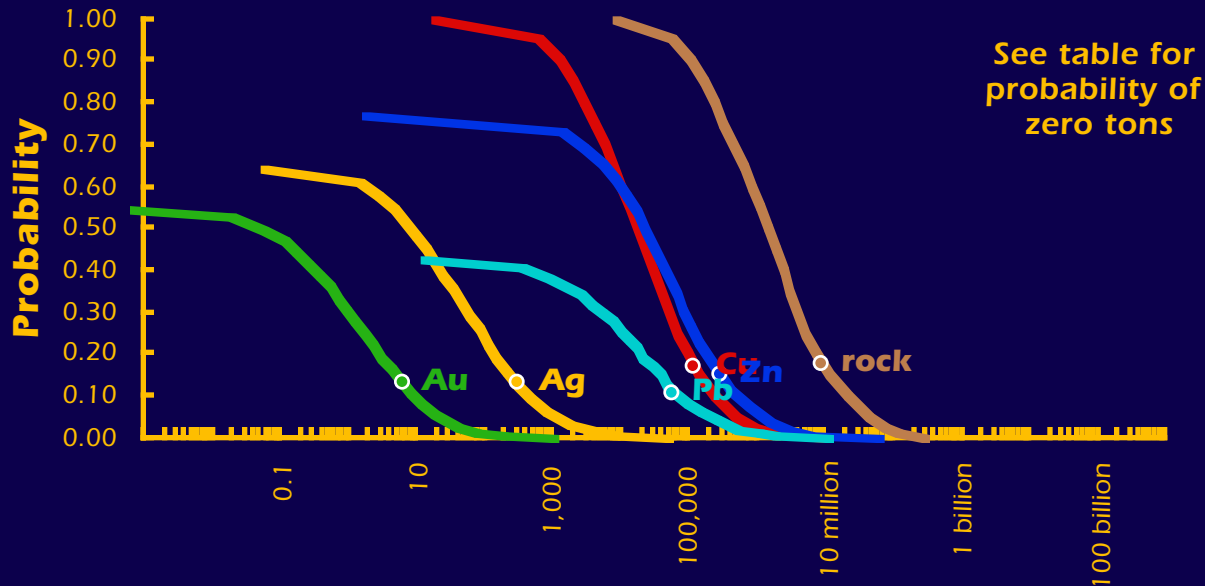
Simulated amounts of metal in a single deposit Mark3 Index 92: Polymetallic Replacement + skarn Zn-Pb

Cumulative Distributions of Contained Metal and Mineralized Rock

Histograms of Contained Metal and Mineralized Rock
(metric tons)

Mark3 Index 93: Massive sulfide, kuroko

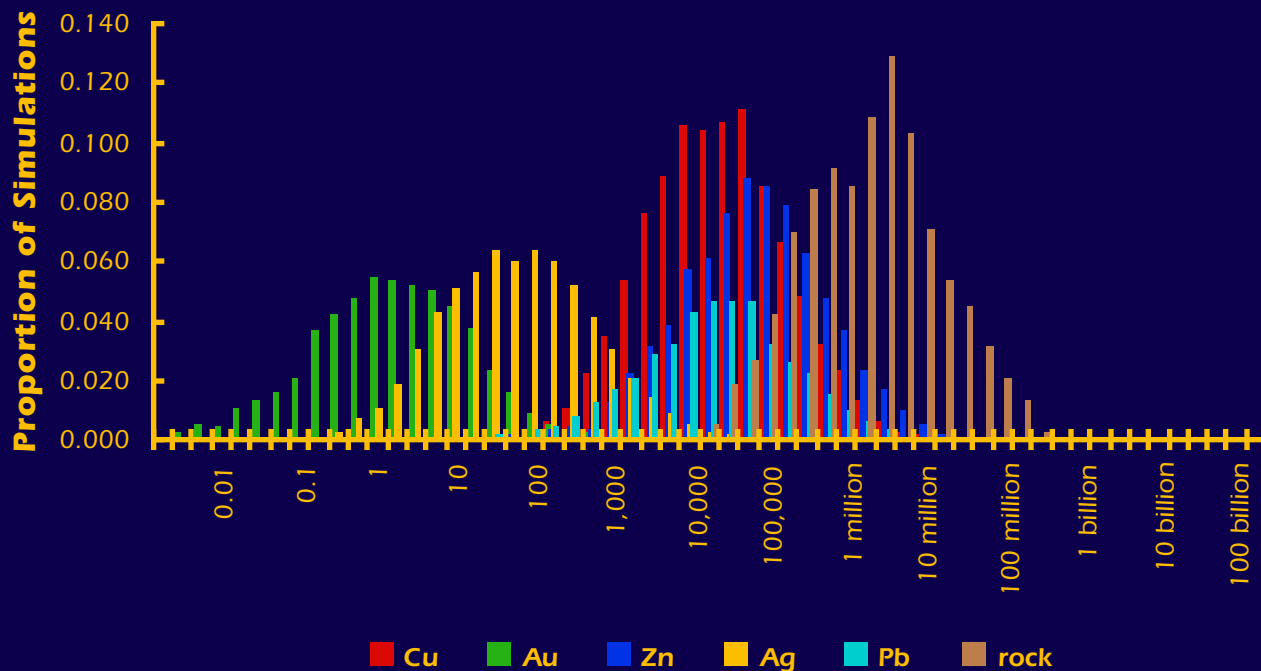
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 93: Massive sulfide, kuroko

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 93: Massive sulfide, kuroko

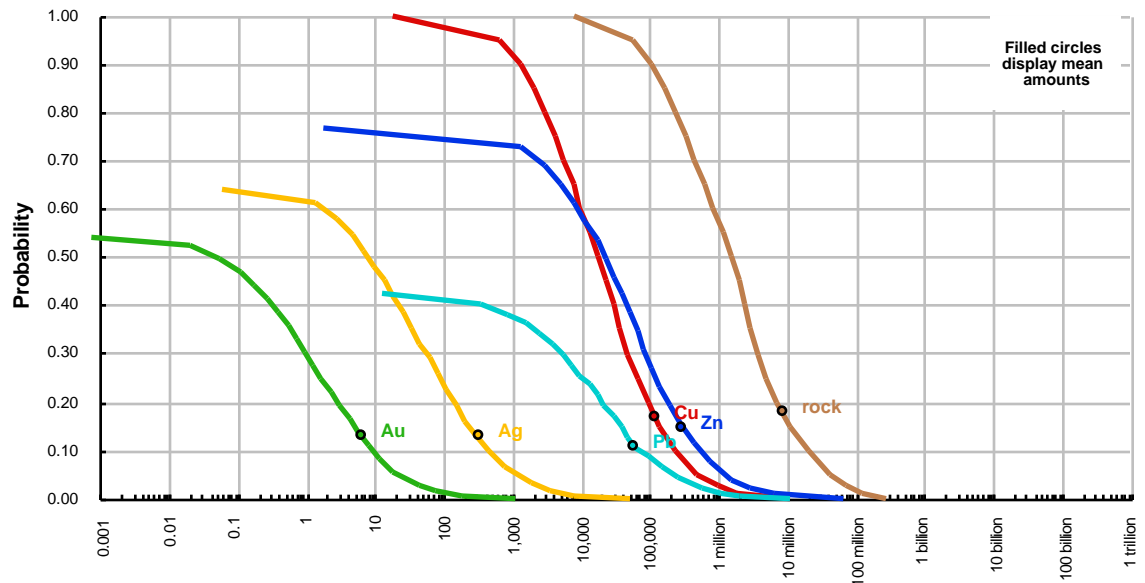
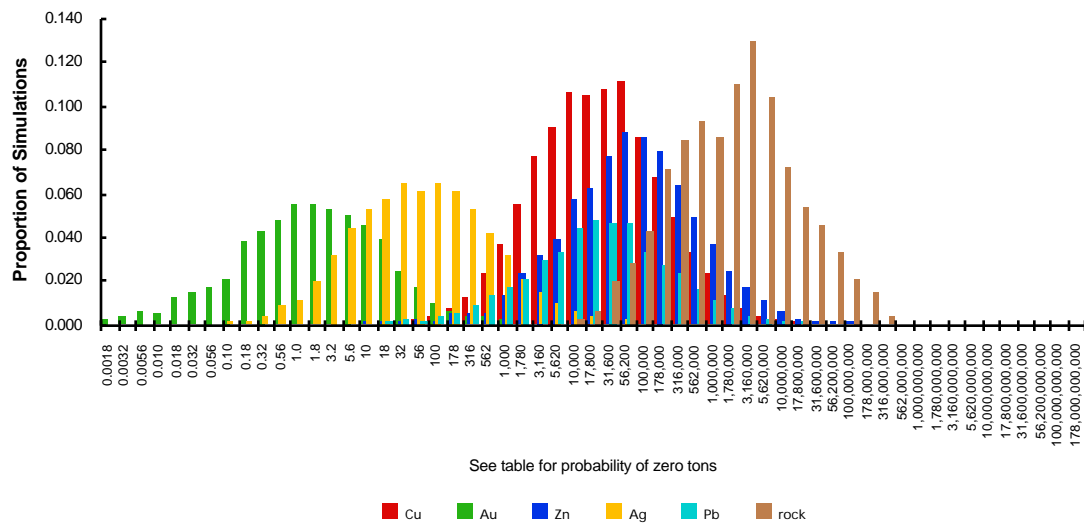
Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	640	0	0	0	0	55,000
0.90	1,300	0	0	0	0	110,000
0.50	17,000	0	23,000	8	0	1,500,000
0.10	240,000	10	515,000	440	70,000	21,000,000
0.05	500,000	22	1,200,000	1,100	210,000	43,000,000
mean	120,000	6	290,000	310	57,000	8,600,000
Probability of mean	0.17	0.13	0.15	0.13	0.11	0.18
Probability of zero	0.00	0.45	0.23	0.36	0.57	0.00

Simulated amounts of metal in a single deposit

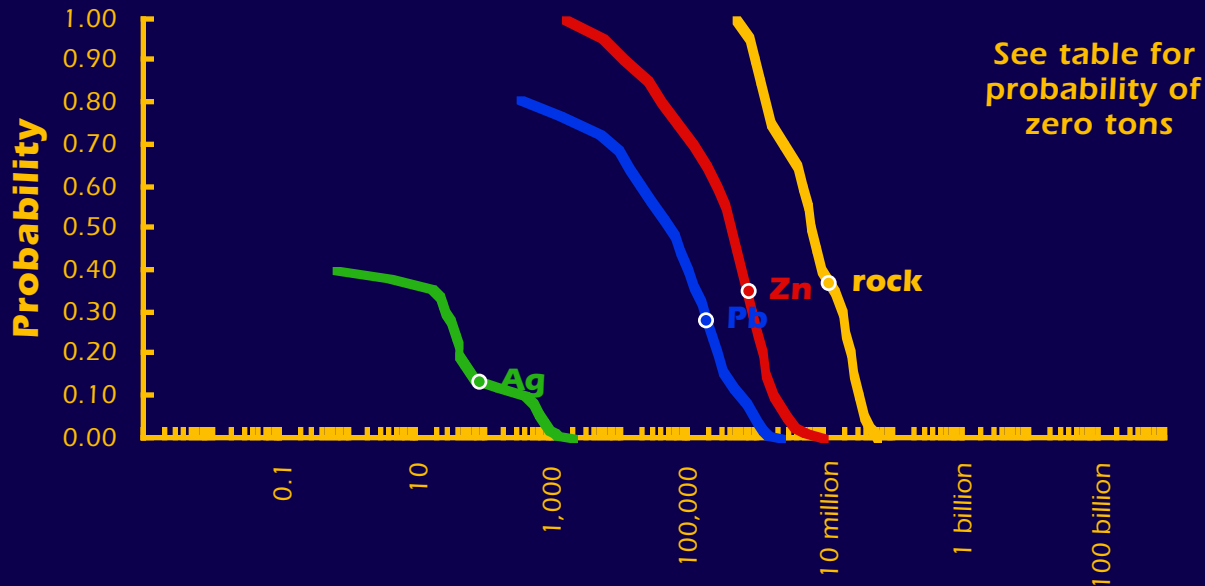
Mark3 Index 93: **Massive sulfide, kuroko***Estimated amounts of contained metal and mineralized rock (metric tons)*

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	640	0	0	0	0	55,000
0.90	1,300	0	0	0	0	110,000
0.50	17,000	0	23,000	8	0	1,500,000
0.10	240,000	10	515,000	440	70,000	21,000,000
0.05	500,000	22	1,200,000	1,100	210,000	43,000,000
mean	120,000	6	290,000	310	57,000	8,600,000
Probability of mean	0.17	0.13	0.15	0.13	0.11	0.18
Probability of zero	0.00	0.45	0.23	0.36	0.57	0.00

Simulated amounts of metal in a single deposit Mark3 Index 93: **Massive sulfide, kuroko****Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

Mark3 Index 94: Mississippi Valley, minor

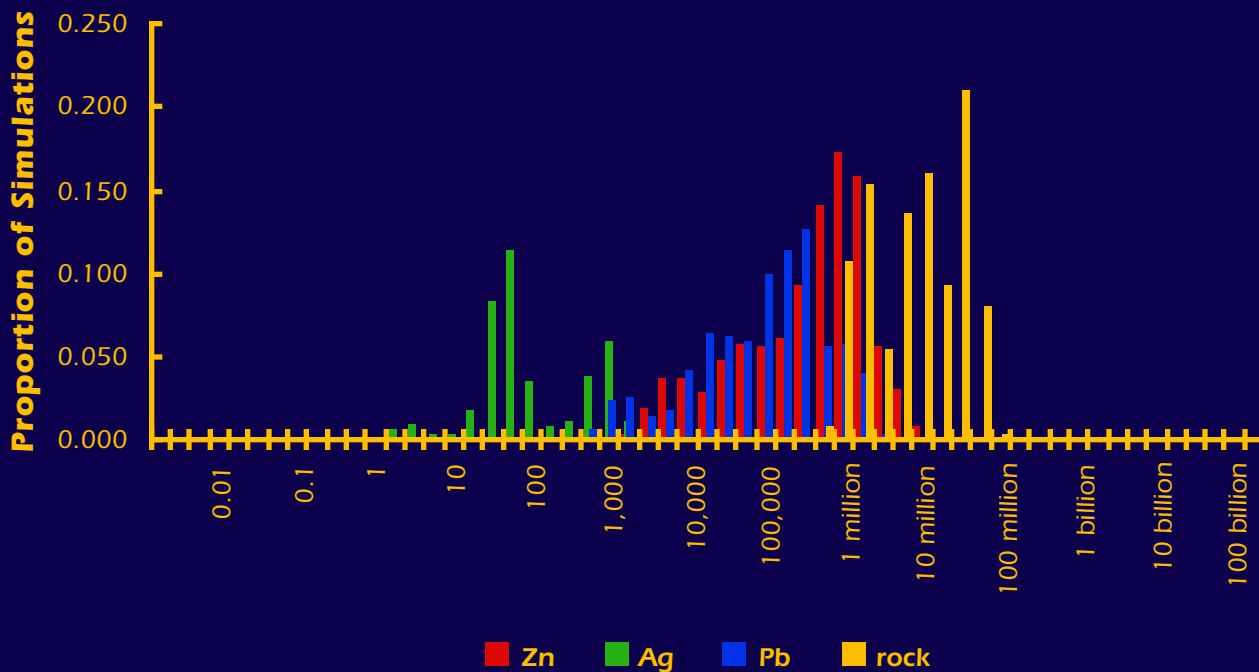
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 94: Mississippi Valley, minor

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 94: Mississippi Valley, minor

Estimated amounts of contained metal and mineralized rock (metric tons)

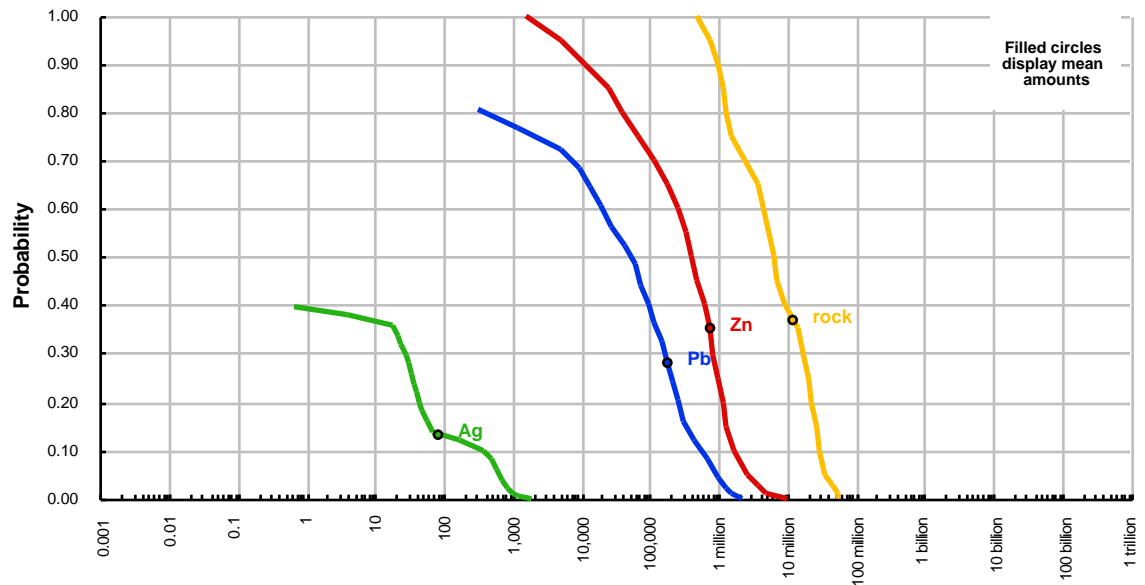
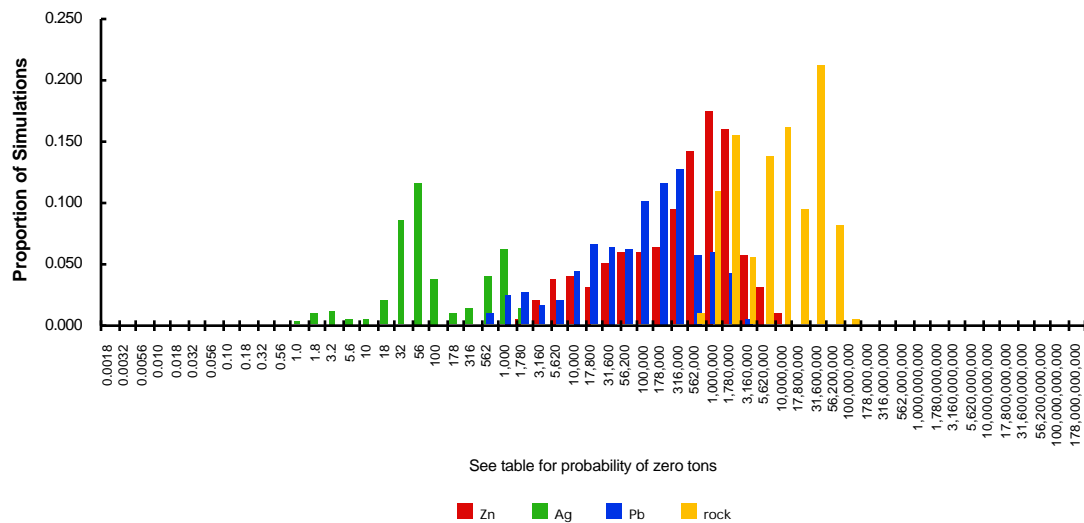
quantile	Zn	Ag	Pb	rock
0.95	5,200	0	0	780,000
0.90	11,000	0	0	960,000
0.50	410,000	0	53,000	6,400,000
0.10	1,700,000	380	559,000	30,000,000
0.05	2,600,000	650	920,000	36,000,000
mean	730,000	86	180,000	12,000,000
Probability of mean	0.35	0.13	0.28	0.37
Probability of zero	0.00	0.60	0.19	0.00

Simulated amounts of metal in a single deposit

Mark3 Index 94: **Mississippi Valley, minor**

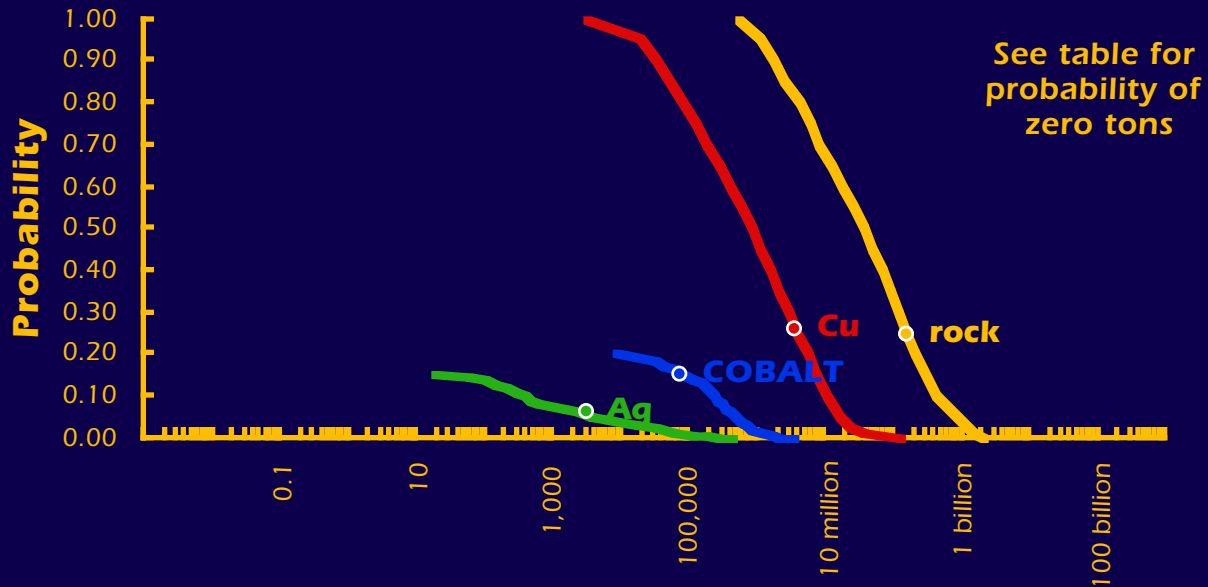
Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Zn	Ag	Pb	rock
0.95	5,200	0	0	780,000
0.90	11,000	0	0	960,000
0.50	410,000	0	53,000	6,400,000
0.10	1,700,000	380	559,000	30,000,000
0.05	2,600,000	650	920,000	36,000,000
mean	730,000	86	180,000	12,000,000
Probability of mean	0.35	0.13	0.28	0.37
Probability of zero	0.00	0.60	0.19	0.00

Simulated amounts of metal in a single deposit Mark3 Index 94: **Mississippi Valley, minor****Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

Mark3 Index 96: Sediment-hosted Cu, reduced facies

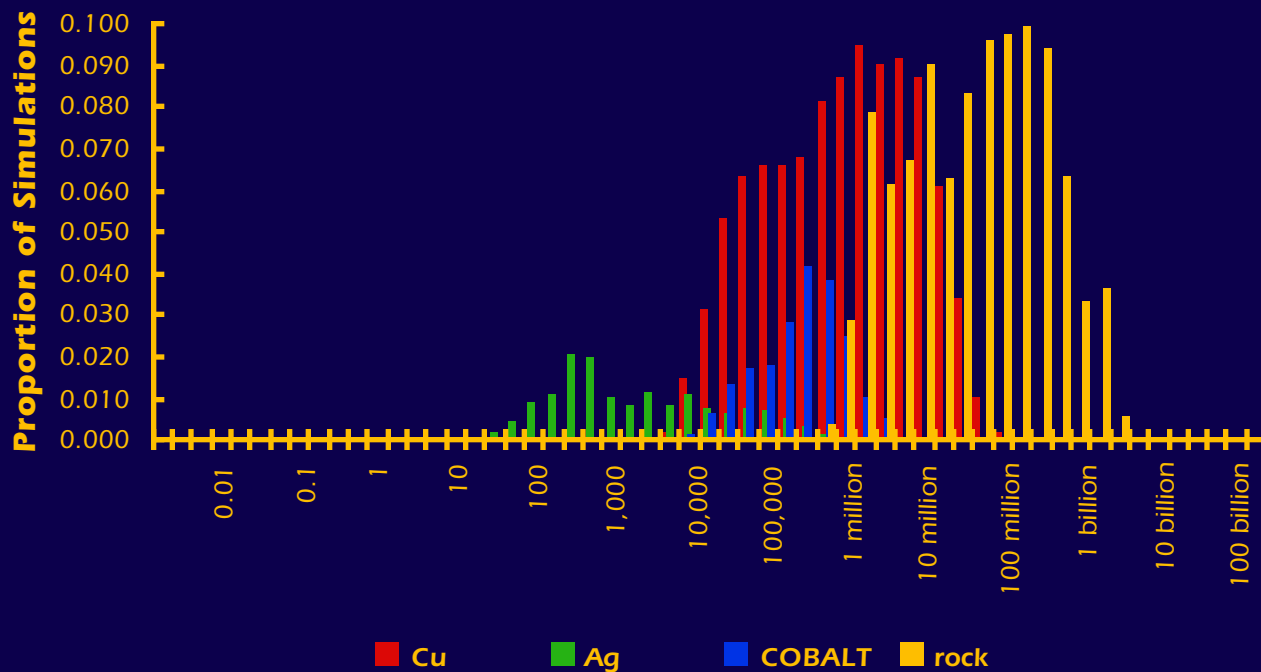
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 96: Sediment-hosted Cu, reduced facies

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 96: Sediment-hosted Cu, reduced facies

Estimated amounts of contained metal and mineralized rock (metric tons)

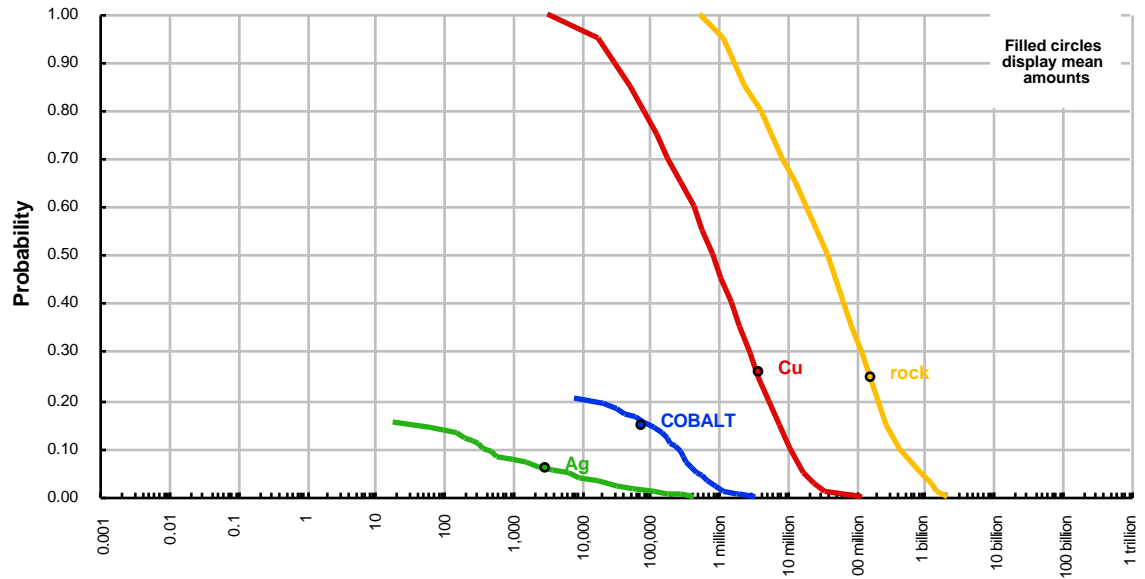
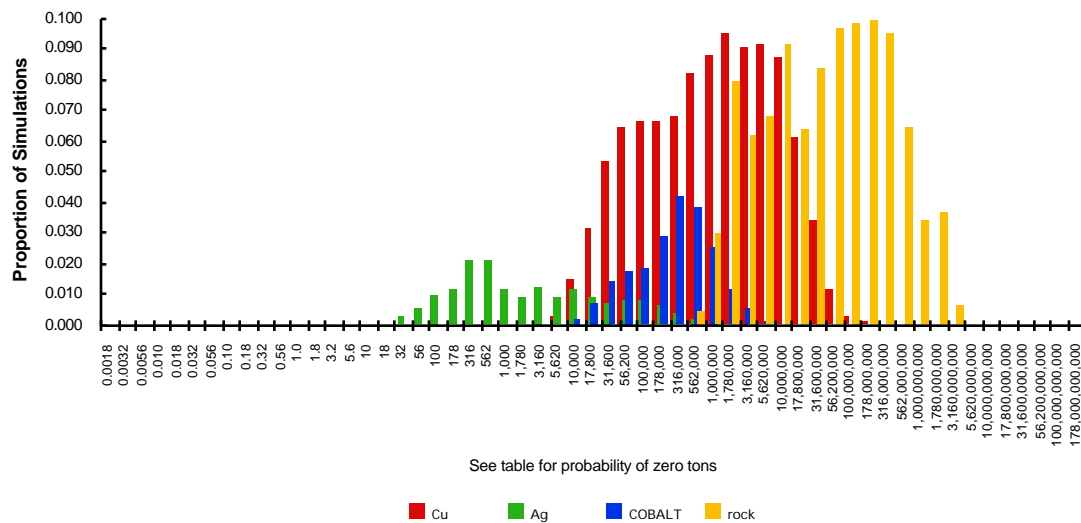
quantile	Cu	Ag	COBALT	rock
0.95	18,000	0	0	1,100,000
0.90	32,000	0	0	1,700,000
0.50	820,000	0	0	37,000,000
0.10	11,000,000	390	245,000	420,000,000
0.05	17,000,000	4,800	480,000	880,000,000
mean	3,700,000	3,100	76,000	160,000,000
Probability of mean	0.26	0.06	0.15	0.25
Probability of zero	0.00	0.85	0.80	0.00

Simulated amounts of metal in a single deposit

Mark3 Index 96: **Sediment-hosted Cu, reduced facies**

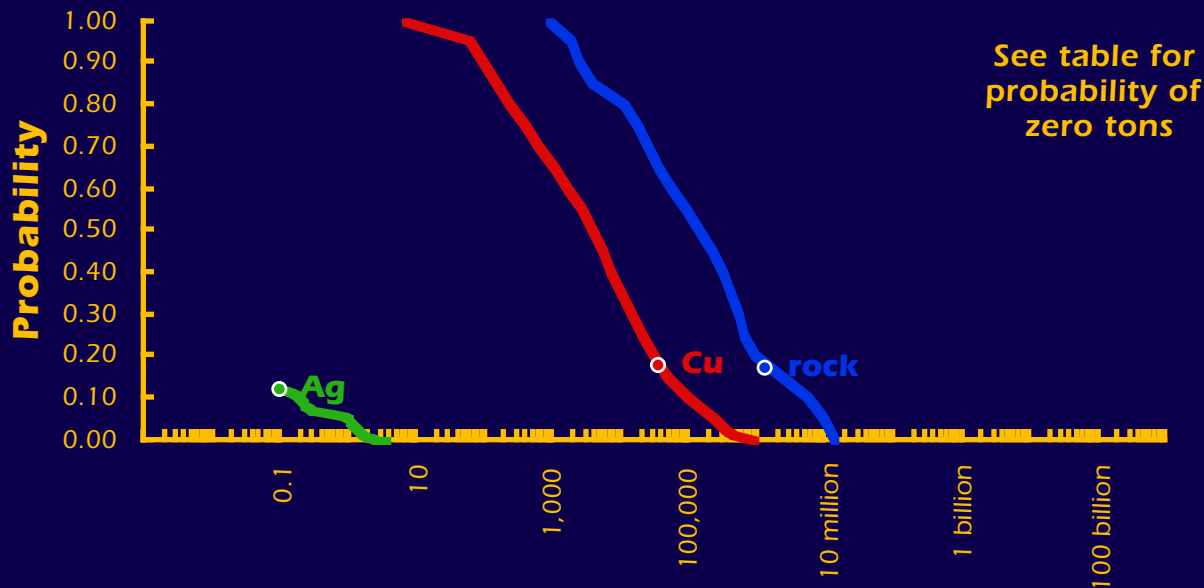
Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Ag	COBALT	rock
0.95	18,000	0	0	1,100,000
0.90	32,000	0	0	1,700,000
0.50	820,000	0	0	37,000,000
0.10	11,000,000	390	245,000	420,000,000
0.05	17,000,000	4,800	480,000	880,000,000
mean	3,700,000	3,100	76,000	160,000,000
Probability of mean	0.26	0.06	0.15	0.25
Probability of zero	0.00	0.85	0.80	0.00

Simulated amounts of metal in a single deposit Mark3 Index 96: **Sediment-hosted Cu, reduced facies****Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

Mark3 Index 97: Sediment-hosted Cu, red-bed

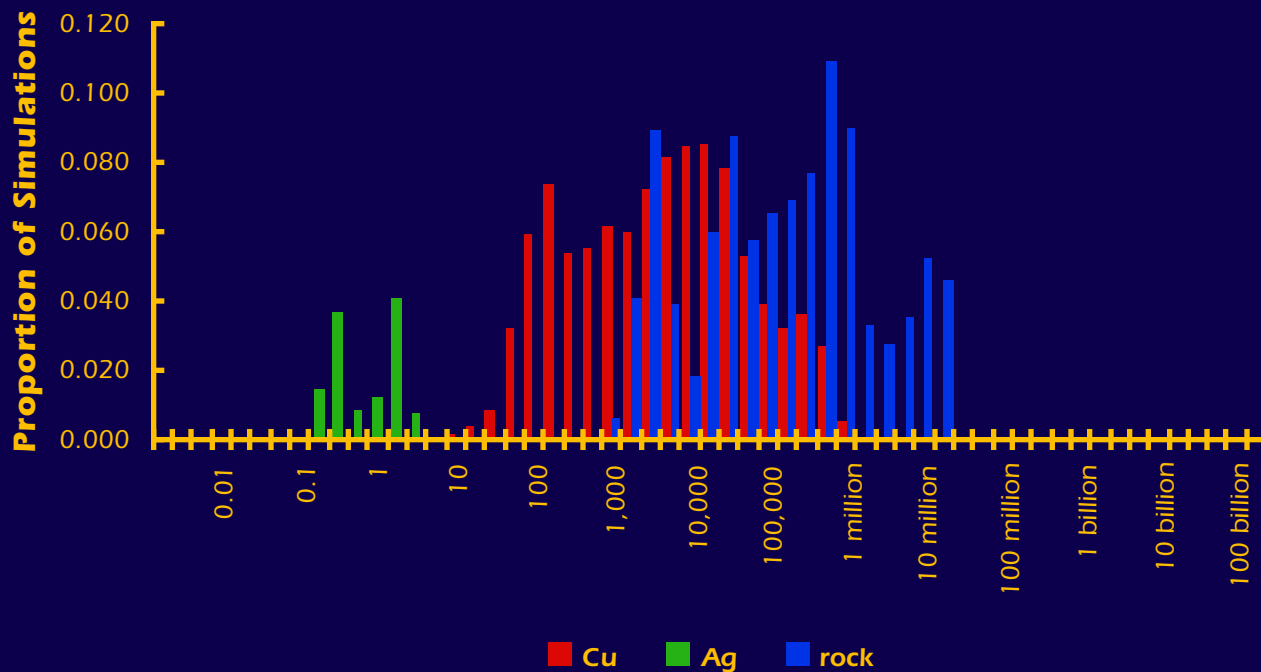
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 97: Sediment-hosted Cu, red-bed

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 97: Sediment-hosted Cu, red-bed

Estimated amounts of contained metal and mineralized rock (metric tons)

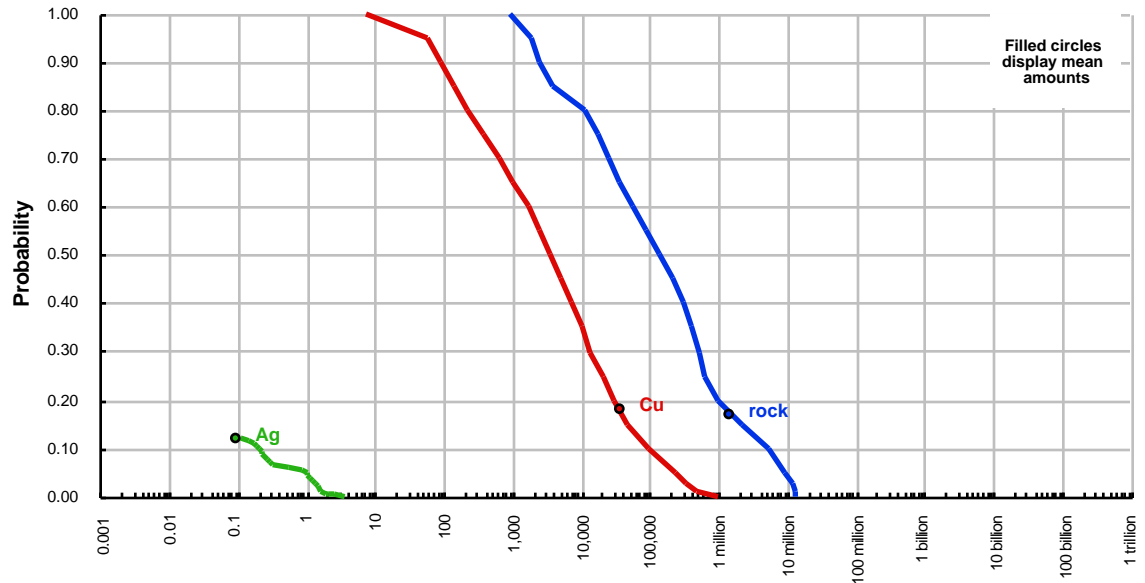
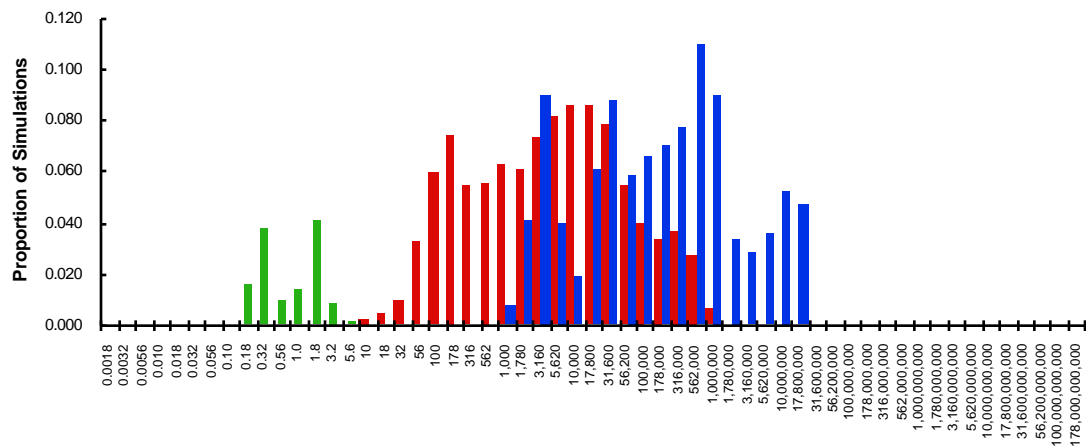
quantile	Cu	Ag	rock
0.95	60	0	1,800
0.90	95	0	2,500
0.50	3,700	0	140,000
0.10	100,000	0	5,500,000
0.05	240,000	1	9,600,000
mean	37,000	0	1,400,000
Probability of mean	0.18	0.12	0.17
Probability of zero	0.00	0.88	0.00

Simulated amounts of metal in a single deposit

Mark3 Index 97: **Sediment-hosted Cu, red-bed**

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Ag	rock
0.95	60	0	1,800
0.90	95	0	2,500
0.50	3,700	0	140,000
0.10	100,000	0	5,500,000
0.05	240,000	1	9,600,000
mean	37,000	0	1,400,000
Probability of mean	0.18	0.12	0.17
Probability of zero	0.00	0.88	0.00

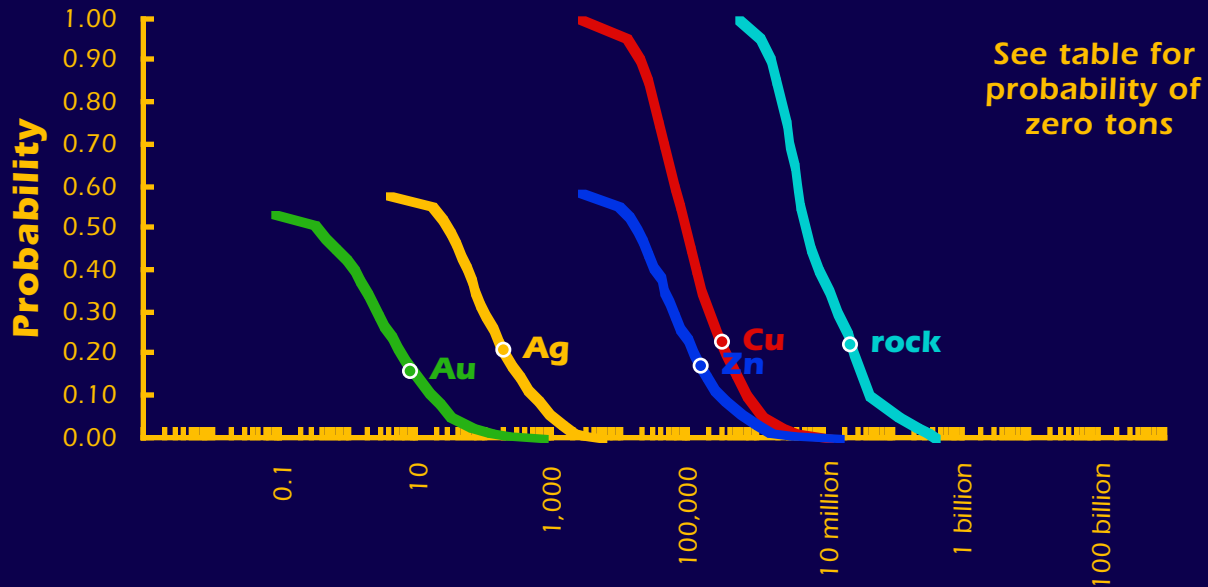
Simulated amounts of metal in a single deposit Mark3 Index 97: **Sediment-hosted Cu, red-bed****Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

See table for probability of zero tons

■ Cu ■ Ag ■ rock

Mark3 Index 98: Massive sulfide, Besshi

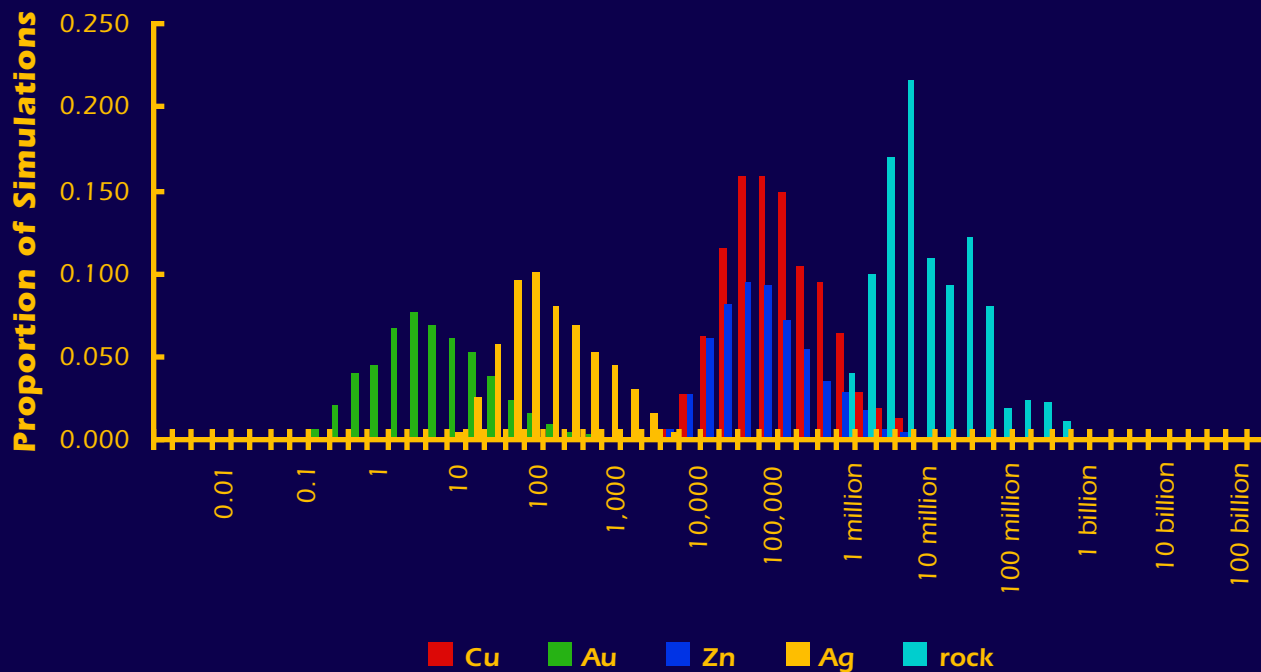
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 98: Massive sulfide, Besshi

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 98: Massive sulfide, Besshi

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	rock
0.95	12,000	0	0	0	1,100,000
0.90	18,000	0	0	0	1,500,000
0.50	90,000	0	16,000	29	5,200,000
0.10	680,000	16	294,000	530	44,000,000
0.05	1,200,000	36	680,000	1,000	120,000,000
mean	300,000	8	150,000	190	24,000,000
Probability of mean	0.23	0.16	0.17	0.21	0.22
Probability of zero	0.00	0.47	0.42	0.42	0.00

Simulated amounts of metal in a single deposit

Mark3 Index 98: **Massive sulfide, Besshi**

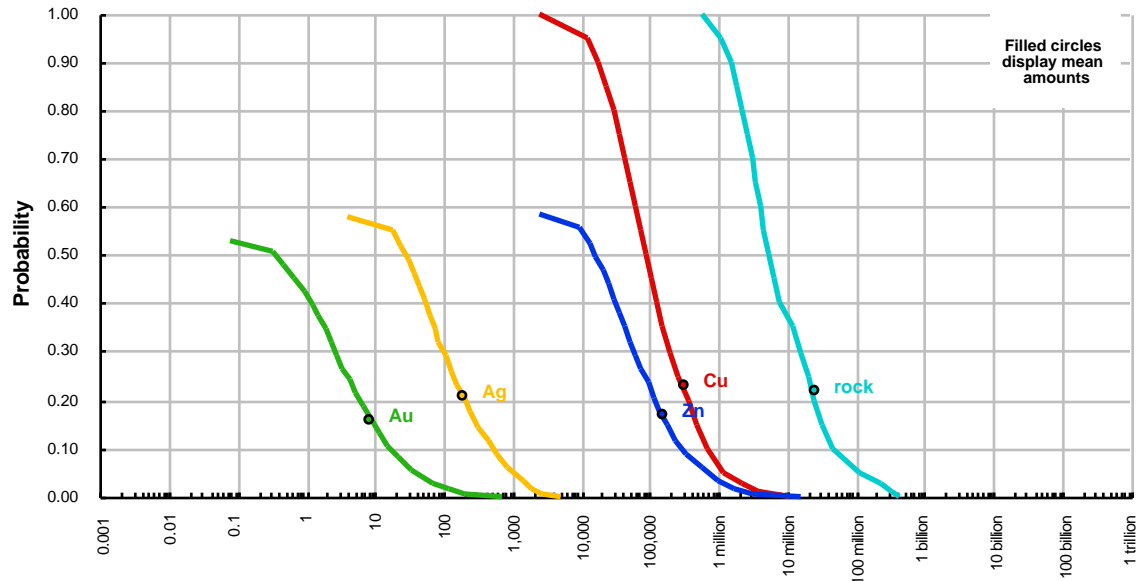
Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	rock
0.95	12,000	0	0	0	1,100,000
0.90	18,000	0	0	0	1,500,000
0.50	90,000	0	16,000	29	5,200,000
0.10	680,000	16	294,000	530	44,000,000
0.05	1,200,000	36	680,000	1,000	120,000,000
mean	300,000	8	150,000	190	24,000,000
Probability of mean	0.23	0.16	0.17	0.21	0.22
Probability of zero	0.00	0.47	0.42	0.42	0.00

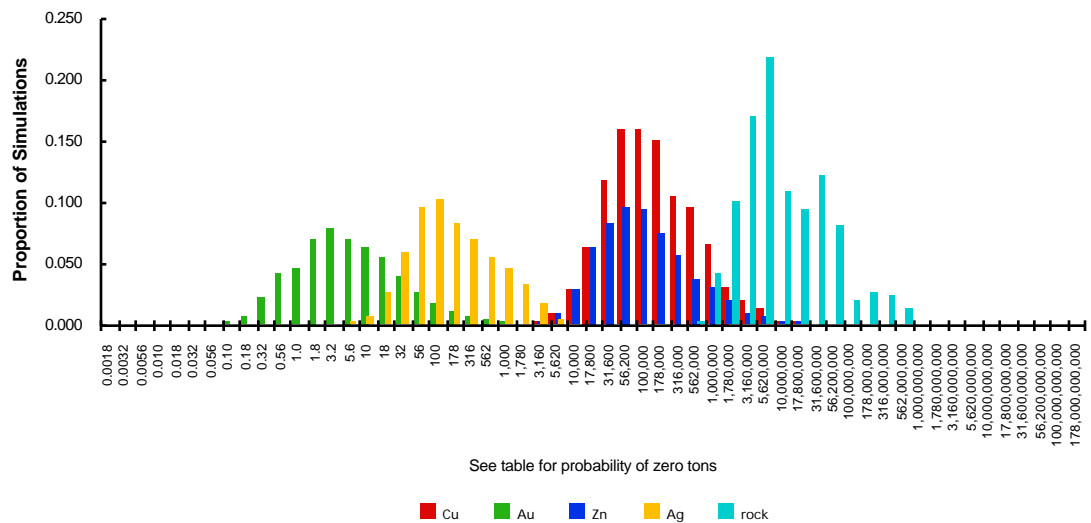
National Mineral Resource Assessment, 1995

Simulated amounts of metal in a single deposit Mark3 Index 98: **Massive sulfide, Besshi**

Cumulative Distributions of Contained Metal and Mineralized Rock

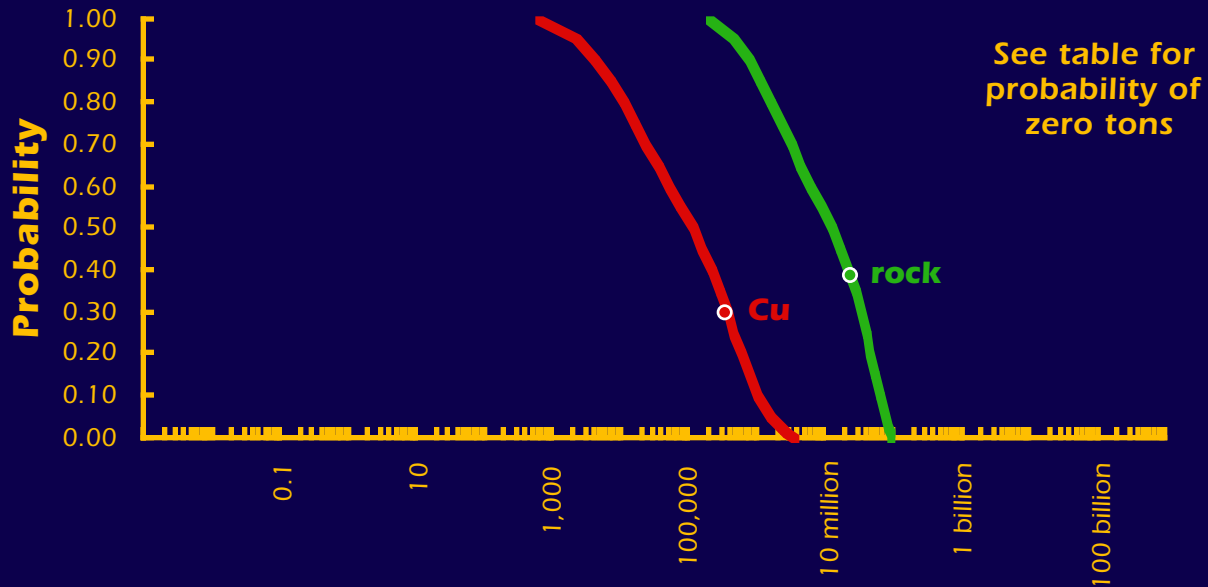


Histograms of Contained Metal and Mineralized Rock (metric tons)



Mark3 Index 99: Native Cu

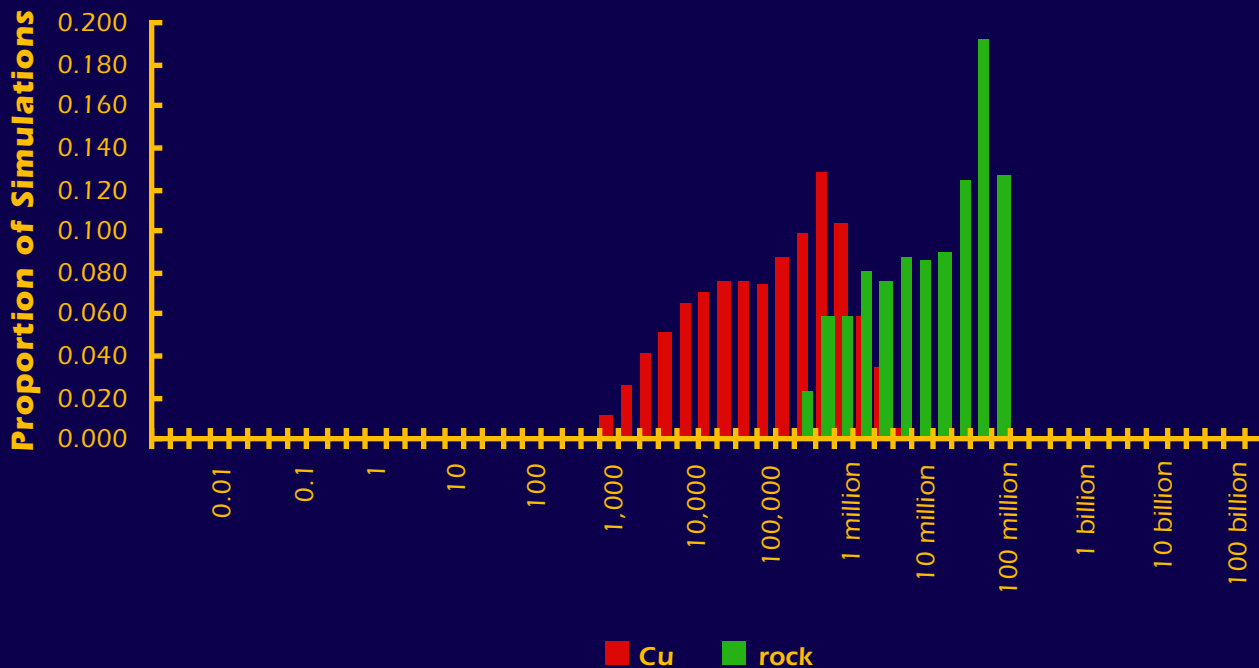
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 99: Native Cu

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 99: Native Cu

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	rock
0.95	2,200	440,000
0.90	4,200	730,000
0.50	110,000	12,000,000
0.10	990,000	61,000,000
0.05	1,600,000	74,000,000
mean	360,000	23,000,000
Probability of mean	0.30	0.39
Probability of zero	0.00	0.00

Simulated amounts of metal in a single deposit

Mark3 Index 99: **Native Cu**

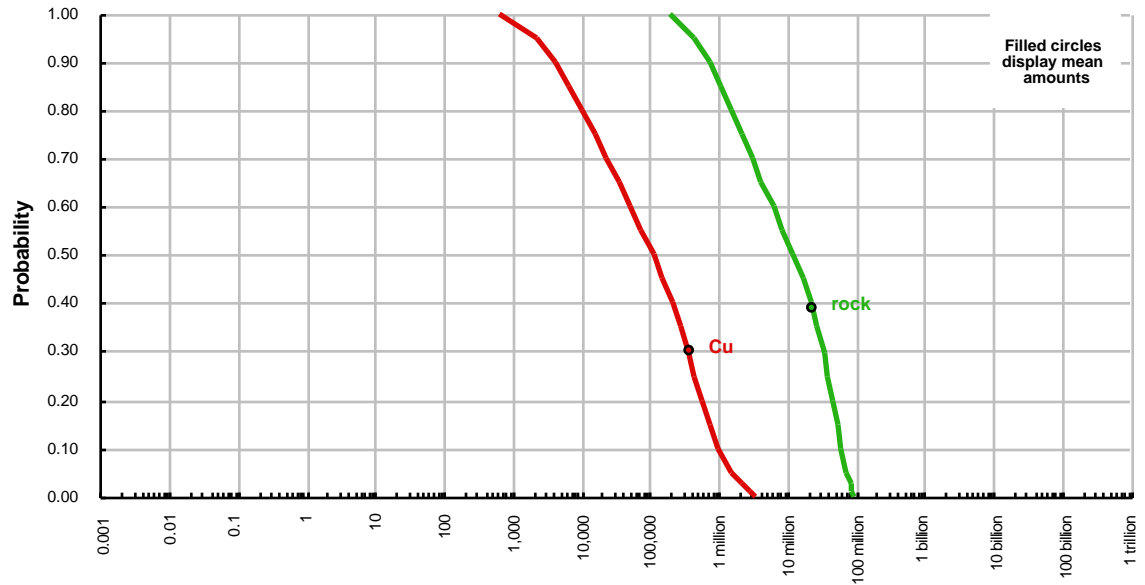
Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	rock
0.95	2,200	440,000
0.90	4,200	730,000
0.50	110,000	12,000,000
0.10	990,000	61,000,000
0.05	1,600,000	74,000,000
mean	360,000	23,000,000
Probability of mean	0.30	0.39
Probability of zero	0.00	0.00

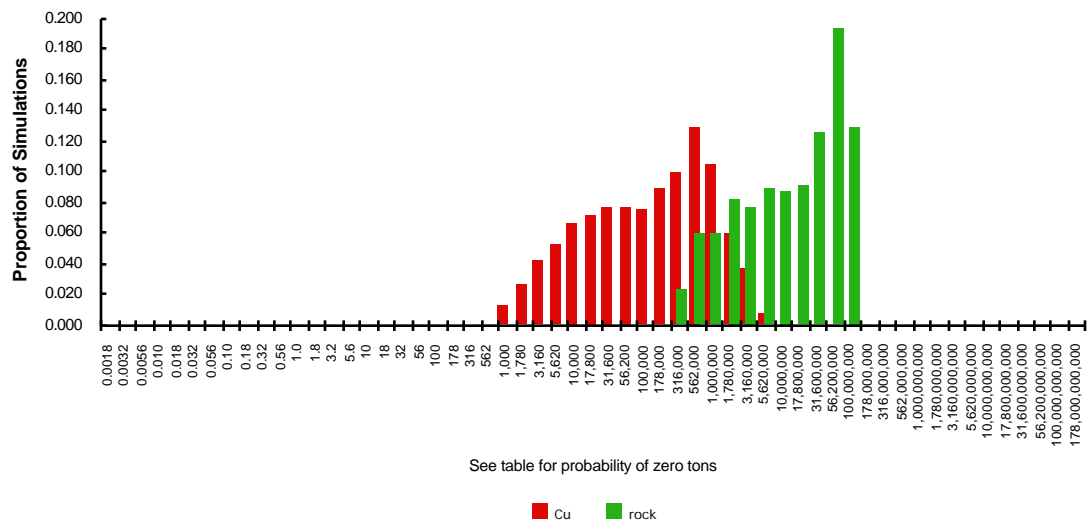
National Mineral Resource Assessment, 1995

Simulated amounts of metal in a single deposit Mark3 Index 99: **Native Cu**

Cumulative Distributions of Contained Metal and Mineralized Rock

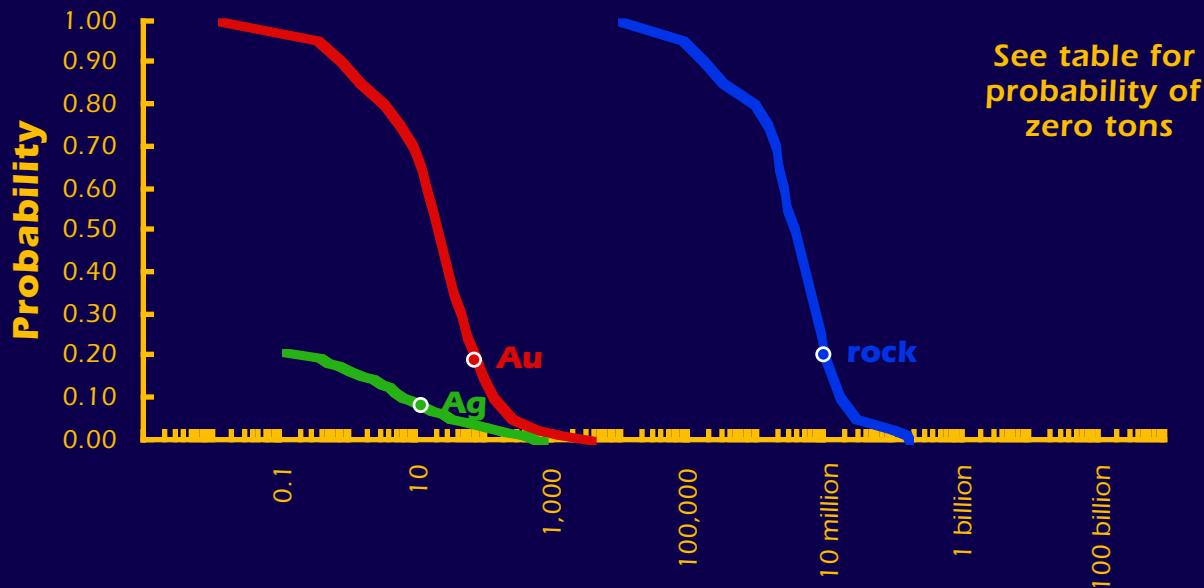


Histograms of Contained Metal and Mineralized Rock (metric tons)



Mark3 Index 100: Homestake stratiform gold

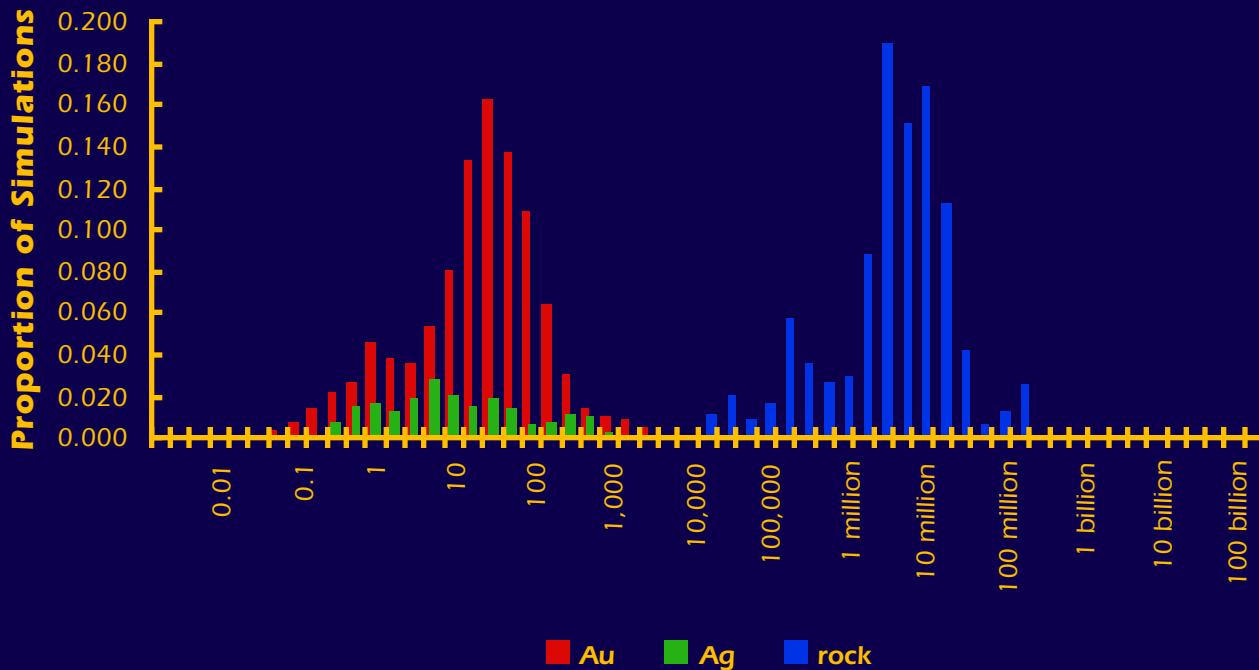
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 100: Homestake stratiform gold

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 100: Homestake stratiform gold

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	0	0	83,000
0.90	1	0	160,000
0.50	21	0	3,400,000
0.10	130	7	16,300,000
0.05	240	34	29,000,000
mean	74	12	9,900,000
Probability of mean	0.19	0.08	0.20
Probability of zero	0.00	0.79	0.00

Simulated amounts of metal in a single deposit

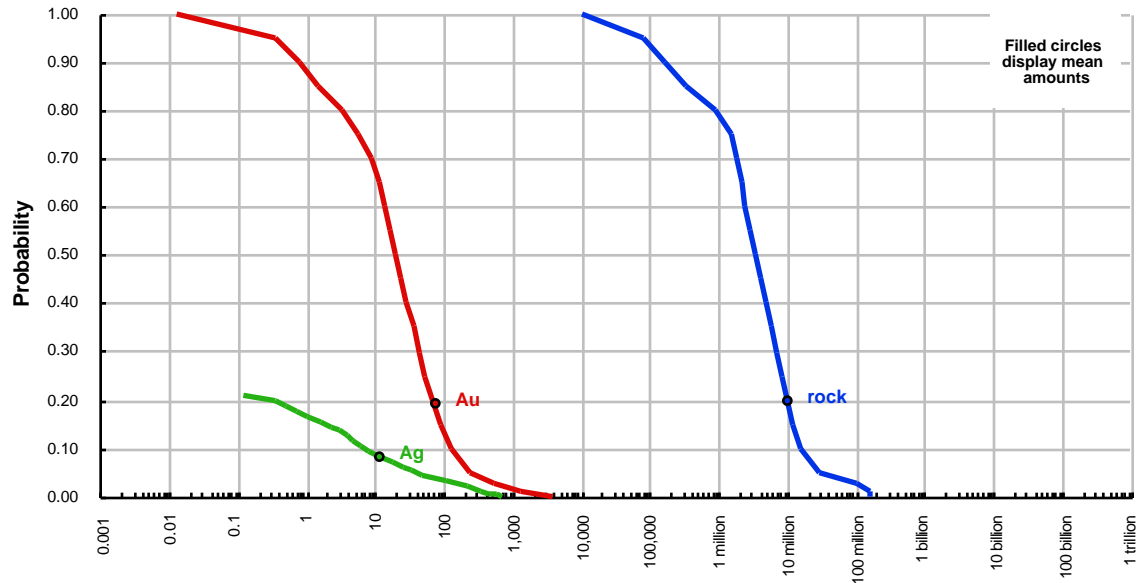
Mark3 Index 100: **Homestake stratiform gold**

Estimated amounts of contained metal and mineralized rock (metric tons)

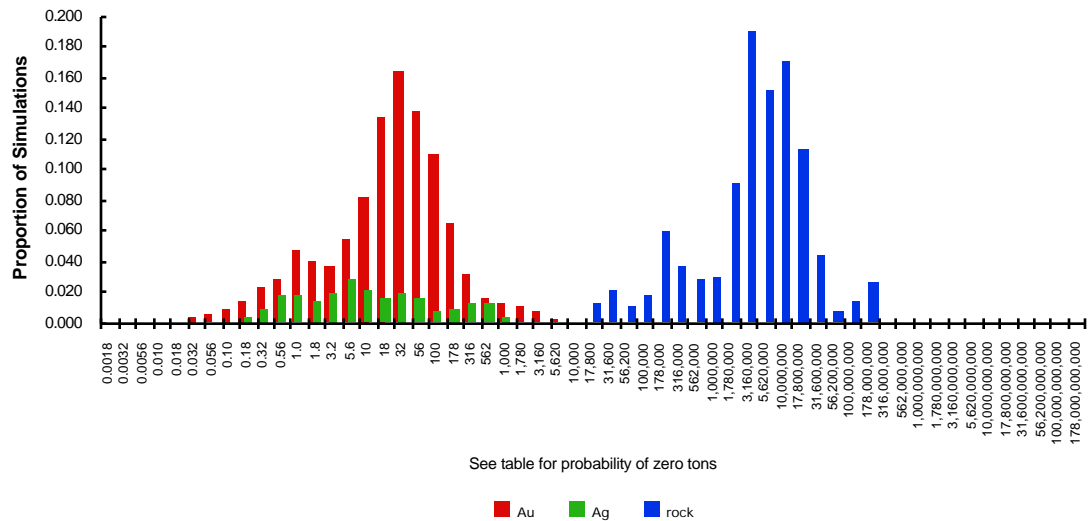
quantile	Au	Ag	rock
0.95	0	0	83,000
0.90	1	0	160,000
0.50	21	0	3,400,000
0.10	130	7	16,300,000
0.05	240	34	29,000,000
mean	74	12	9,900,000
Probability of mean	0.19	0.08	0.20
Probability of zero	0.00	0.79	0.00

Simulated amounts of metal in a single deposit Mark3 Index 100: **Homestake stratiform gold**

Cumulative Distributions of Contained Metal and Mineralized Rock

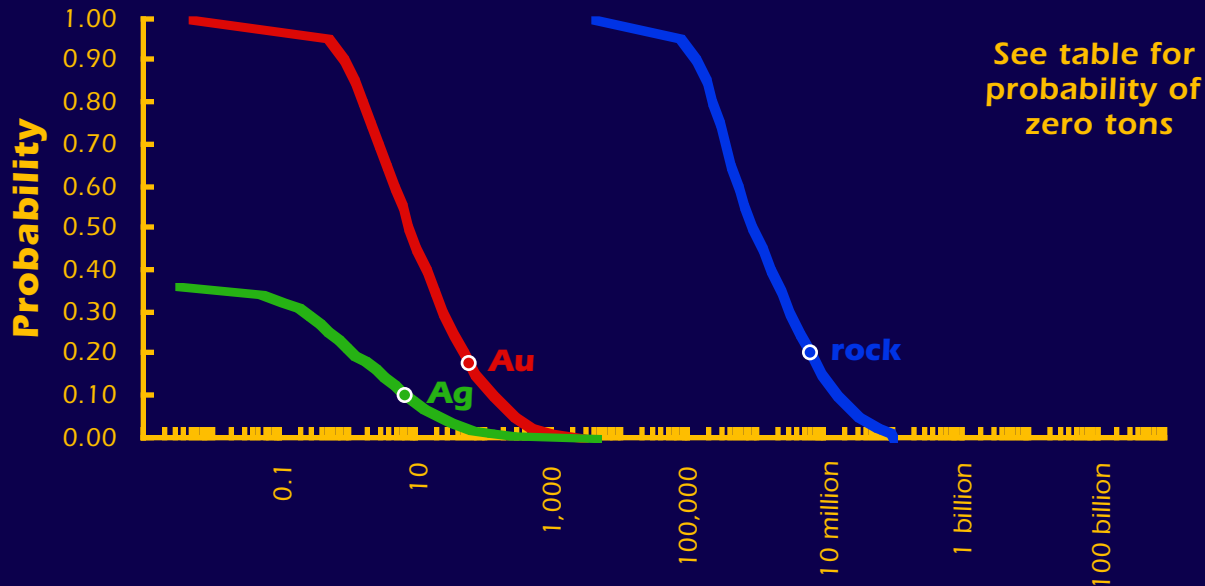


Histograms of Contained Metal and Mineralized Rock (metric tons)



Mark3 Index 101: Low-sulfide Au-quartz, Archean

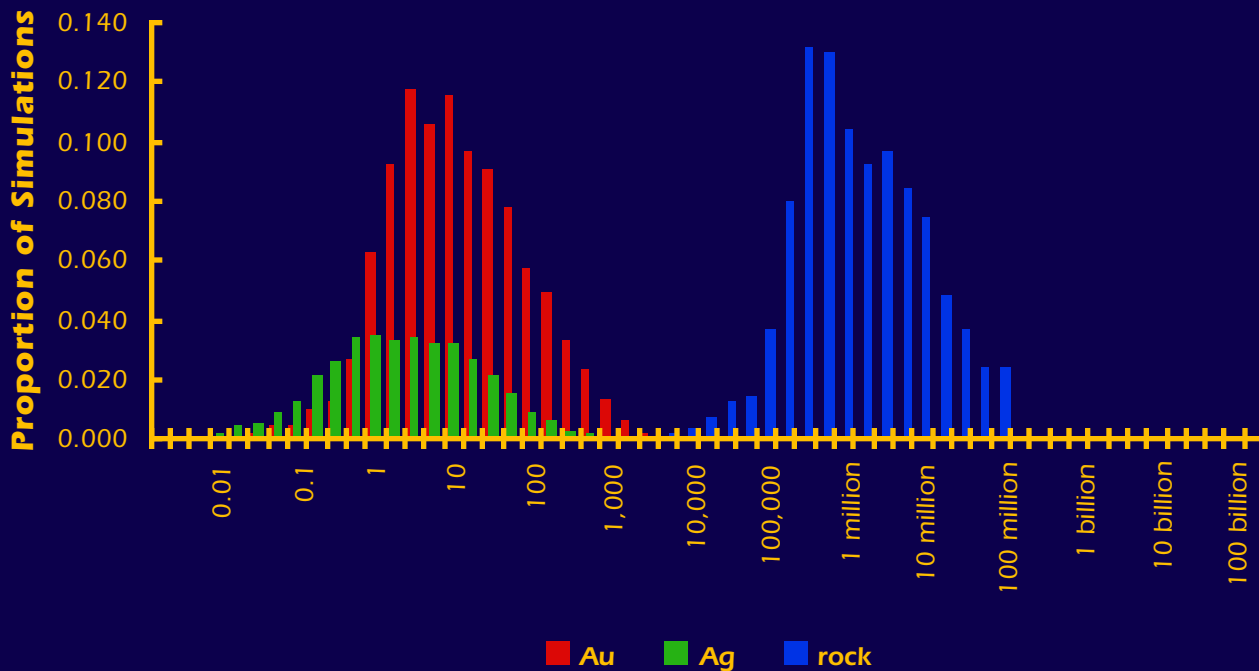
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 101: Low-sulfide Au-quartz, Archean

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 101: Low-sulfide Au-quartz, Archean

Estimated amounts of contained metal and mineralized rock (metric tons)

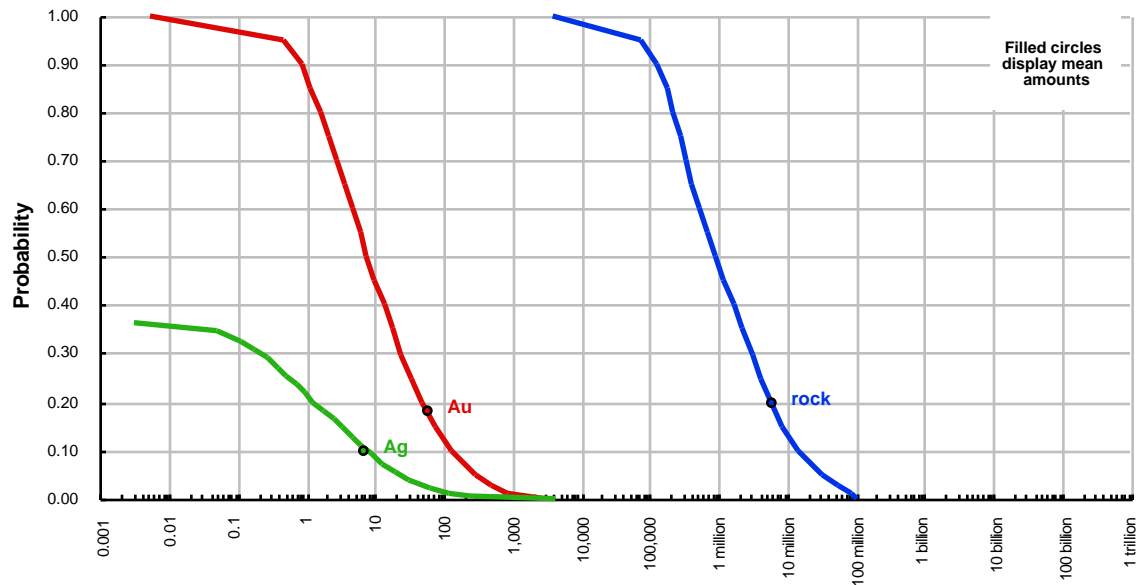
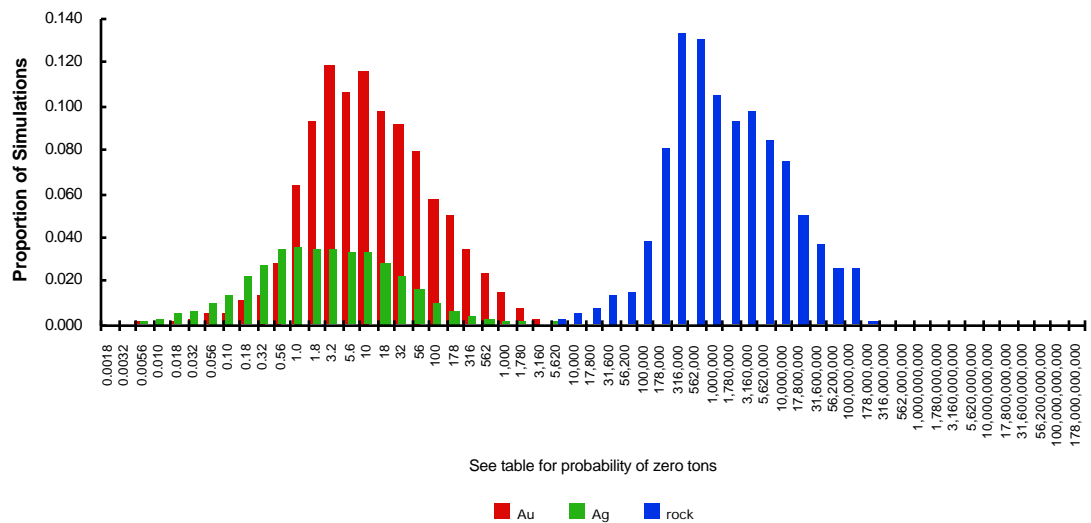
quantile	Au	Ag	rock
0.95	1	0	76,000
0.90	1	0	120,000
0.50	8	0	880,000
0.10	130	7	14,500,000
0.05	280	21	31,000,000
mean	57	7	6,000,000
Probability of mean	0.18	0.10	0.20
Probability of zero	0.00	0.64	0.00

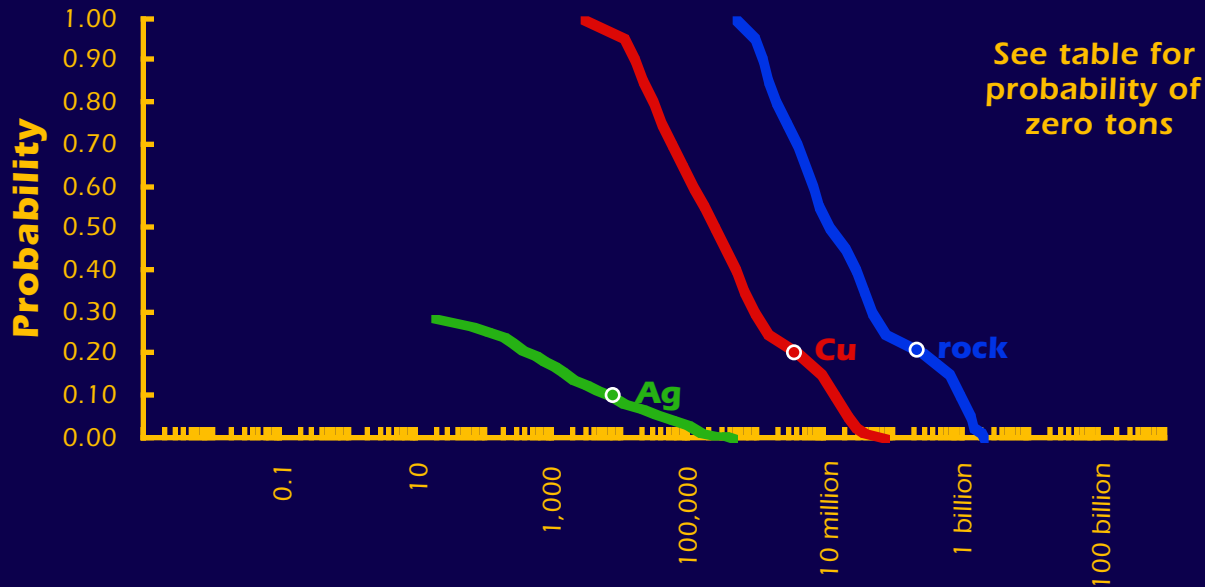
Simulated amounts of metal in a single deposit

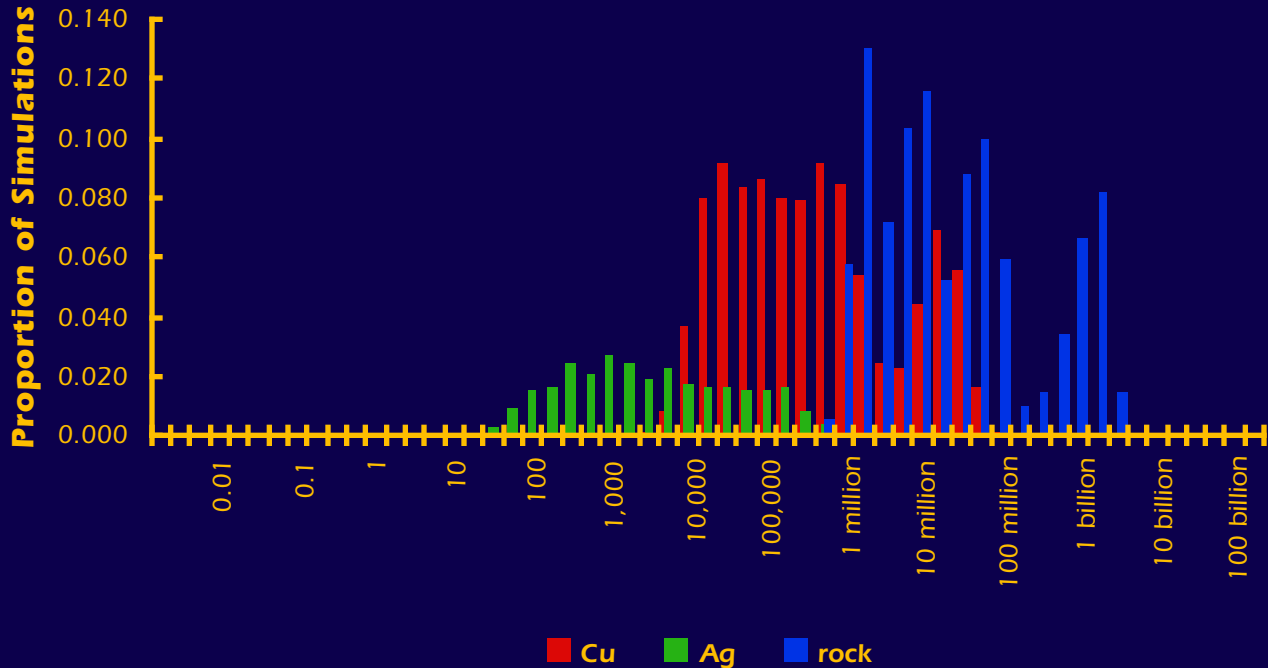
Mark3 Index 101: **Low-sulfide Au-quartz, Archean**

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Au	Ag	rock
0.95	1	0	76,000
0.90	1	0	120,000
0.50	8	0	880,000
0.10	130	7	14,500,000
0.05	280	21	31,000,000
mean	57	7	6,000,000
Probability of mean	0.18	0.10	0.20
Probability of zero	0.00	0.64	0.00

Simulated amounts of metal in a single deposit Mark3 Index 101: **Low-sulfide Au-quartz, Archean****Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

Sediment-hosted Cu, reduced facies (modified)**Cumulative Distributions of Contained Metal
and Mineralized Rock (metric tons)****Filled circles display mean amounts**

Sediment-hosted Cu, reduced facies (modified)**Histograms of Contained Metal and Mineralized Rock
(metric tons)**

Simulated amounts of metal in a single deposit

Mark3 Index 102:

Sediment-hosted Cu, reduced facies (modified)

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Ag	rock
0.95	11,000	0	930,000
0.90	15,000	0	1,200,000
0.50	230,000	0	12,000,000
0.10	14,000,000	7,000	968,000,000
0.05	21,000,000	41,000	1,400,000,000
mean	3,600,000	7,900	220,000,000
Probability of mean	0.20	0.10	0.21
Probability of zero	0.00	0.72	0.00

Simulated amounts of metal in a single deposit

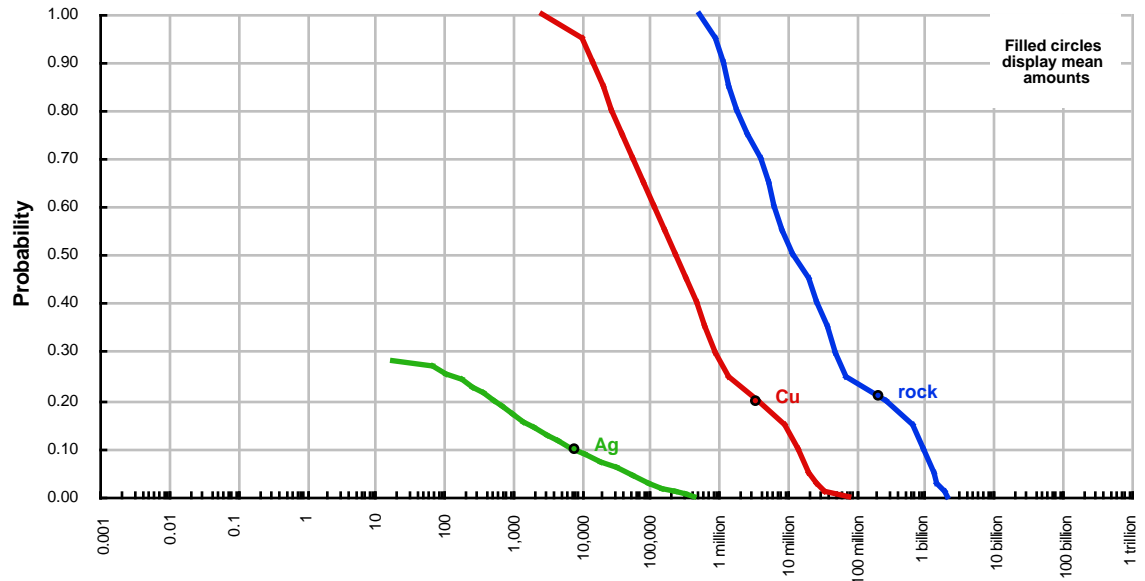
Mark3 Index 102: **Sediment-hosted Cu, reduced facies (modified)**

Estimated amounts of contained metal and mineralized rock (metric tons)

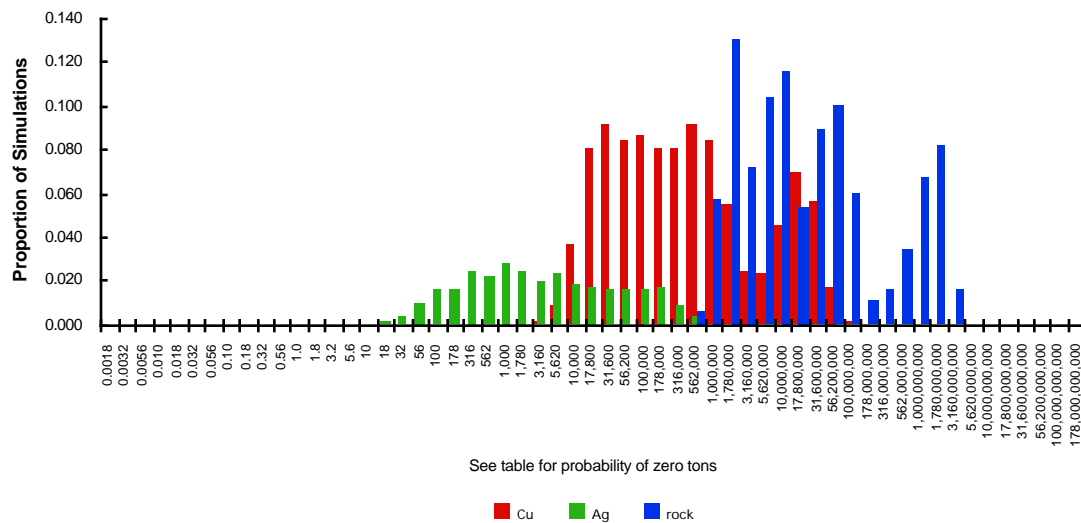
quantile	Cu	Ag	rock
0.95	11,000	0	930,000
0.90	15,000	0	1,200,000
0.50	230,000	0	12,000,000
0.10	14,000,000	7,000	968,000,000
0.05	21,000,000	41,000	1,400,000,000
mean	3,600,000	7,900	220,000,000
Probability of mean	0.20	0.10	0.21
Probability of zero	0.00	0.72	0.00

Simulated amounts of metal in a single deposit Mark3 Index 102: **Sediment-hosted Cu, reduced facies (modified)**

Cumulative Distributions of Contained Metal and Mineralized Rock

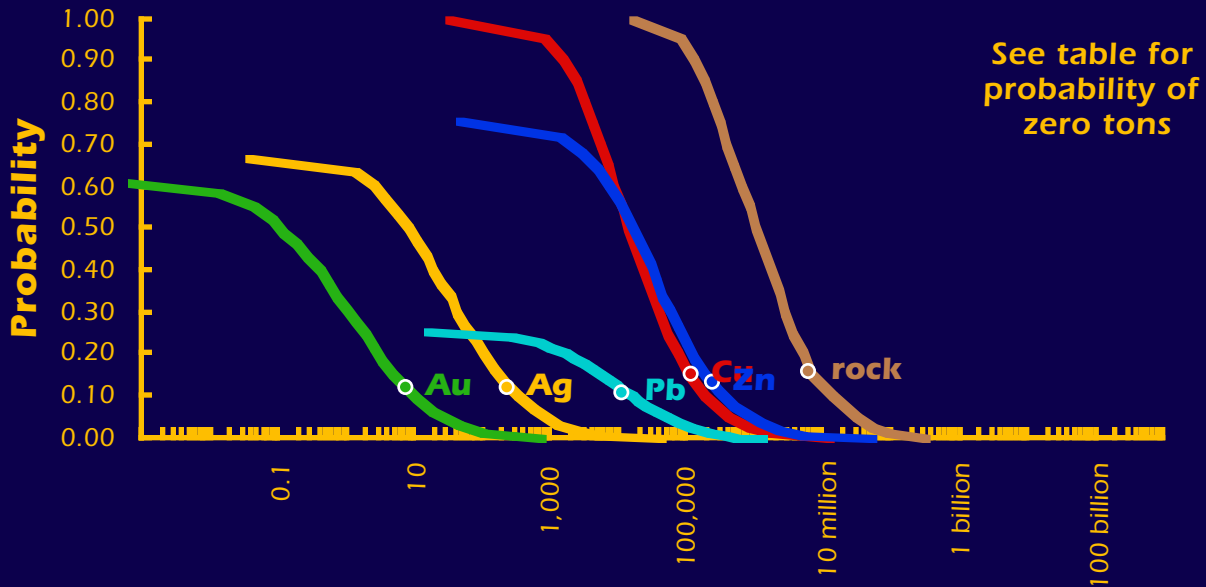


Histograms of Contained Metal and Mineralized Rock (metric tons)



Mark3 Index 103: Massive sulfide, kuroko (Precambrian)

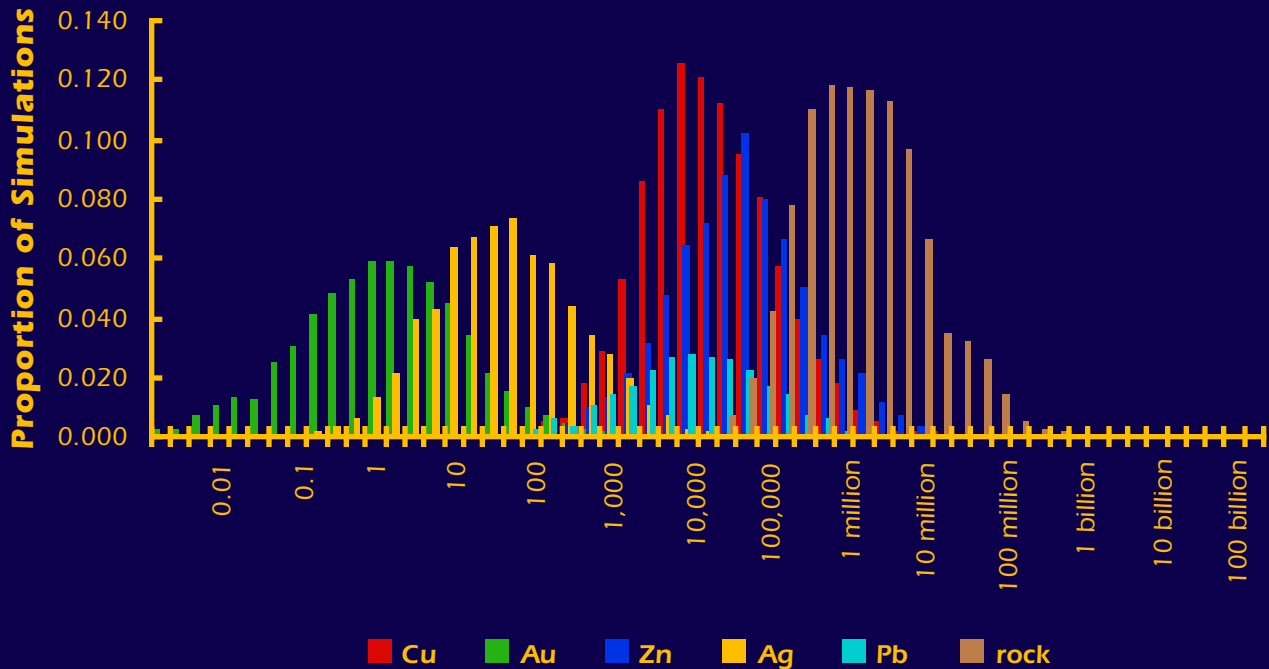
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 103: Massive sulfide, kuroko (Precambrian)

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 103: Massive sulfide, kuroko (Precambrian)

Estimated amounts of contained metal and mineralized rock (metric tons)

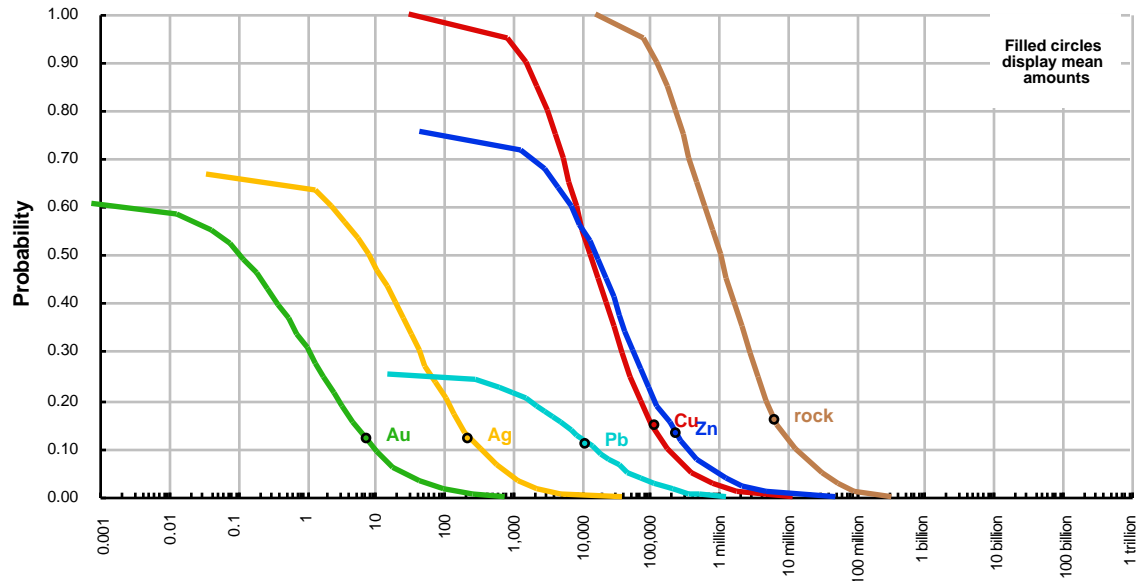
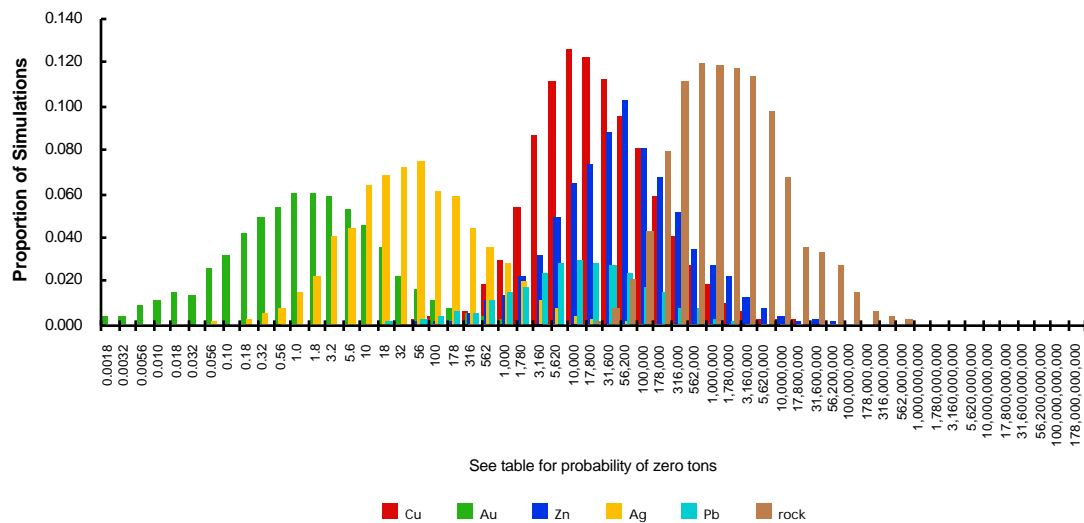
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	840	0	0	0	0	78,000
0.90	1,600	0	0	0	0	130,000
0.50	14,000	0	17,000	8	0	1,000,000
0.10	180,000	10	332,000	340	16,000	13,000,000
0.05	420,000	23	860,000	850	50,000	31,000,000
mean	120,000	8	230,000	230	11,000	6,400,000
Probability of mean	0.15	0.12	0.13	0.12	0.11	0.16
Probability of zero	0.00	0.39	0.25	0.33	0.75	0.00

Simulated amounts of metal in a single deposit

Mark3 Index 103: **Massive sulfide, kuroko (Precambrian)**

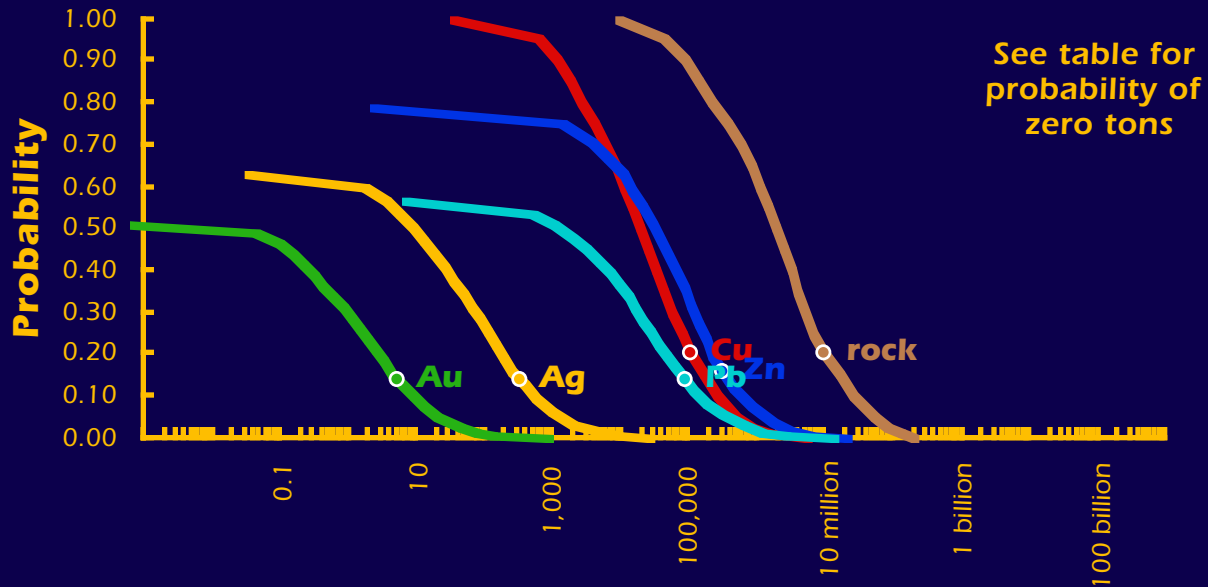
Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	840	0	0	0	0	78,000
0.90	1,600	0	0	0	0	130,000
0.50	14,000	0	17,000	8	0	1,000,000
0.10	180,000	10	332,000	340	16,000	13,000,000
0.05	420,000	23	860,000	850	50,000	31,000,000
mean	120,000	8	230,000	230	11,000	6,400,000
Probability of mean	0.15	0.12	0.13	0.12	0.11	0.16
Probability of zero	0.00	0.39	0.25	0.33	0.75	0.00

Simulated amounts of metal in a single deposit Mark3 Index 103: **Massive sulfide, kuroko (Precambrian)****Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

Mark3 Index 104: Massive sulfide, kuroko (Phanerozoic)

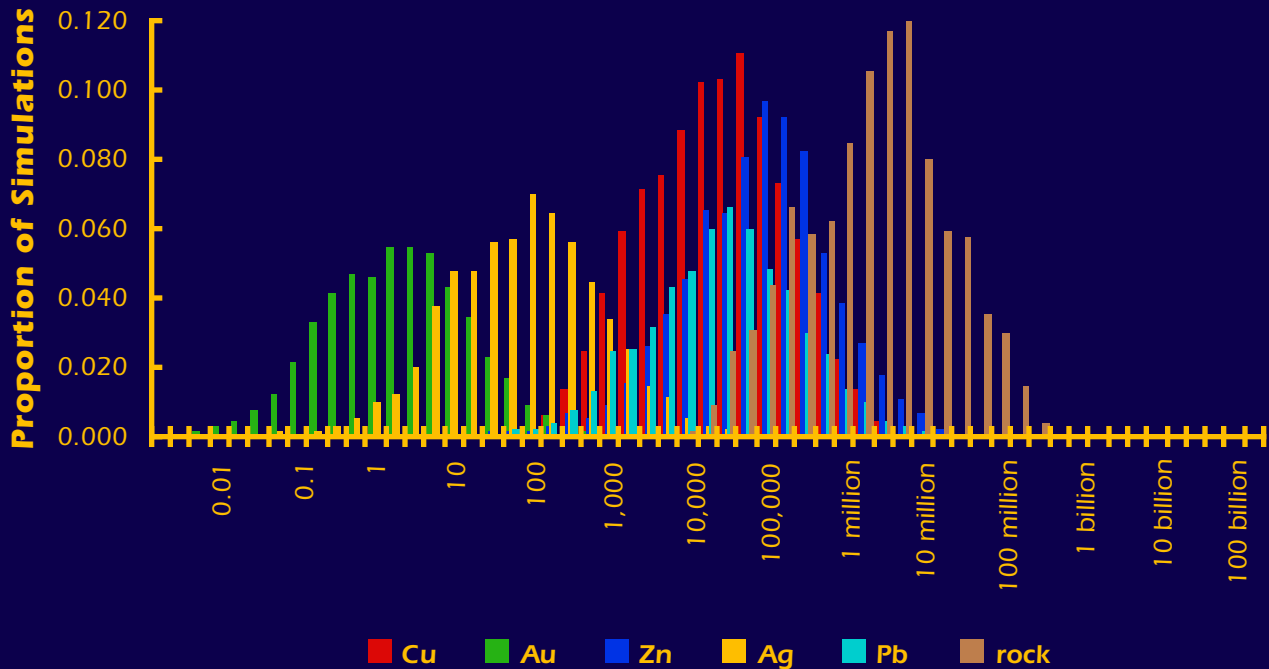
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 104: Massive sulfide, kuroko (Phanerozoic)

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 104: Massive sulfide, kuroko (Phanerozoic)

Estimated amounts of contained metal and mineralized rock (metric tons)

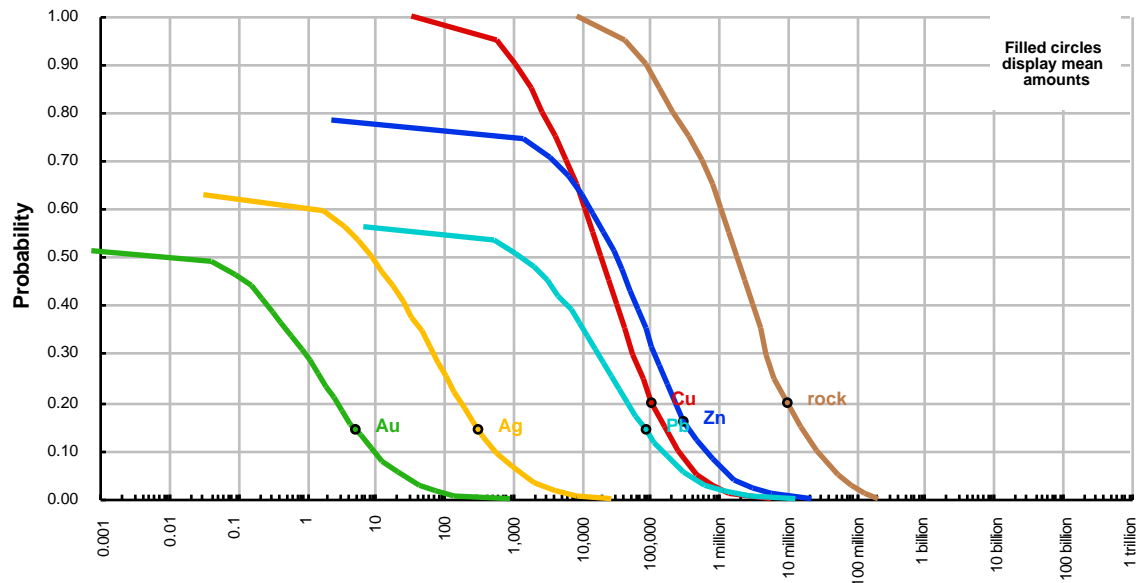
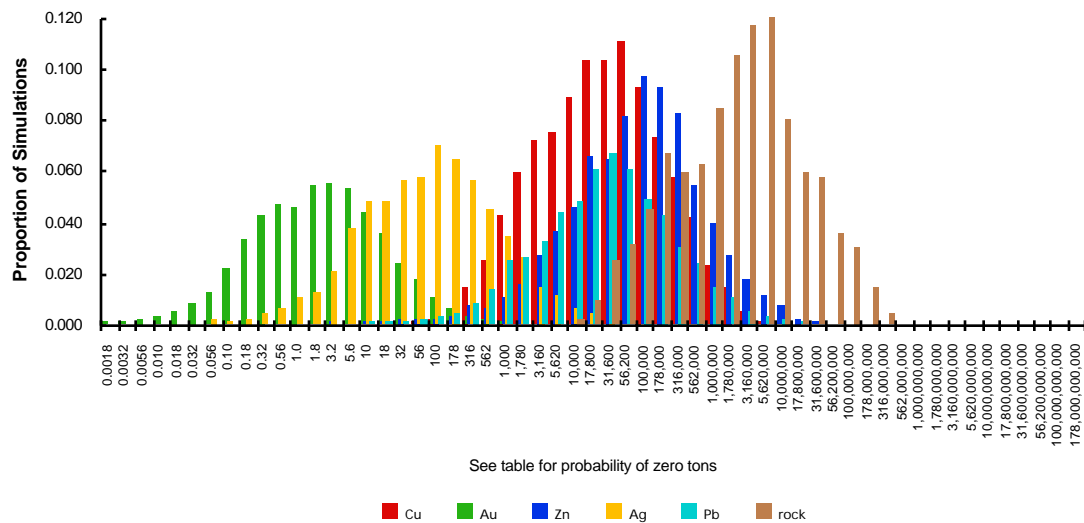
quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	590	0	0	0	0	42,000
0.90	1,100	0	0	0	0	92,000
0.50	20,000	0	33,000	9	1,200	1,900,000
0.10	260,000	9	574,000	530	150,000	27,000,000
0.05	500,000	22	1,300,000	1,200	350,000	53,000,000
mean	110,000	5	300,000	320	87,000	10,000,000
Probability of mean	0.20	0.14	0.16	0.14	0.14	0.20
Probability of zero	0.00	0.48	0.21	0.37	0.44	0.00

Simulated amounts of metal in a single deposit

Mark3 Index 104: **Massive sulfide, kuroko (Phanerozoic)**

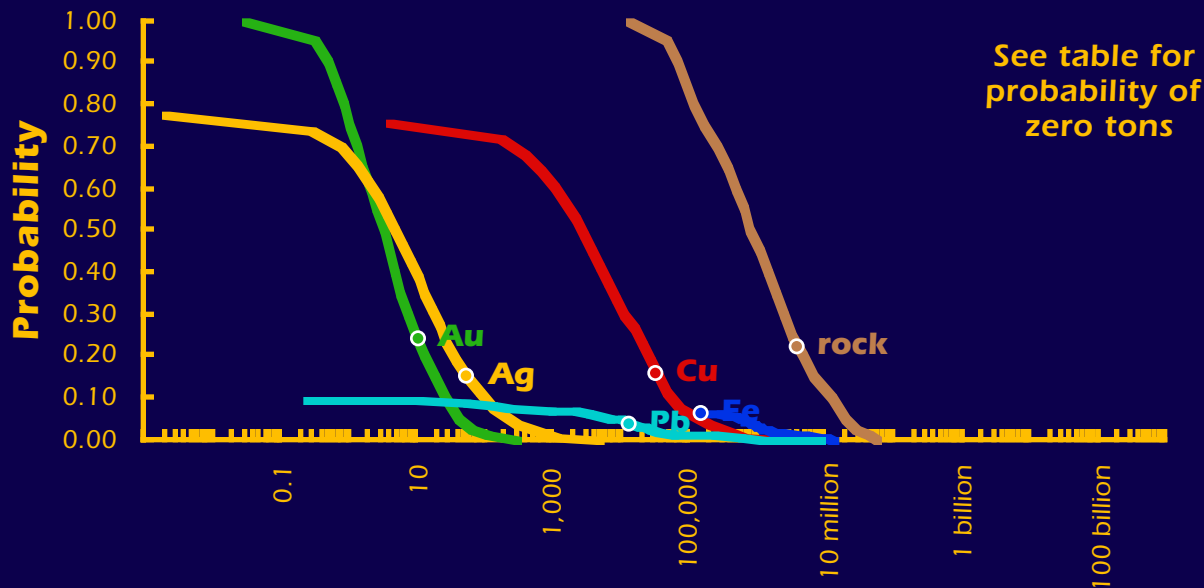
Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Zn	Ag	Pb	rock
0.95	590	0	0	0	0	42,000
0.90	1,100	0	0	0	0	92,000
0.50	20,000	0	33,000	9	1,200	1,900,000
0.10	260,000	9	574,000	530	150,000	27,000,000
0.05	500,000	22	1,300,000	1,200	350,000	53,000,000
mean	110,000	5	300,000	320	87,000	10,000,000
Probability of mean	0.20	0.14	0.16	0.14	0.14	0.20
Probability of zero	0.00	0.48	0.21	0.37	0.44	0.00

Simulated amounts of metal in a single deposit Mark3 Index 104: **Massive sulfide, kuroko (Phanerozoic)****Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

Mark3 Index 105: Skarn Au, truncated

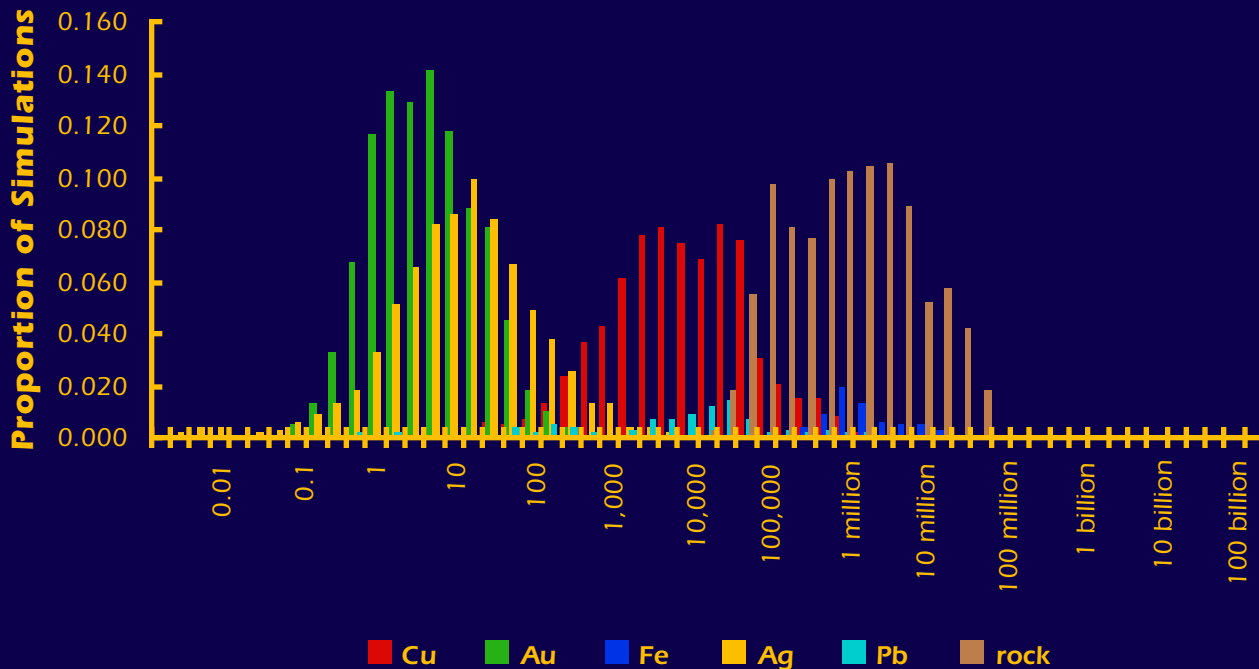
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 105: Skarn Au, truncated

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 105: Skarn Au, truncated

Estimated amounts of contained metal and mineralized rock (metric tons)

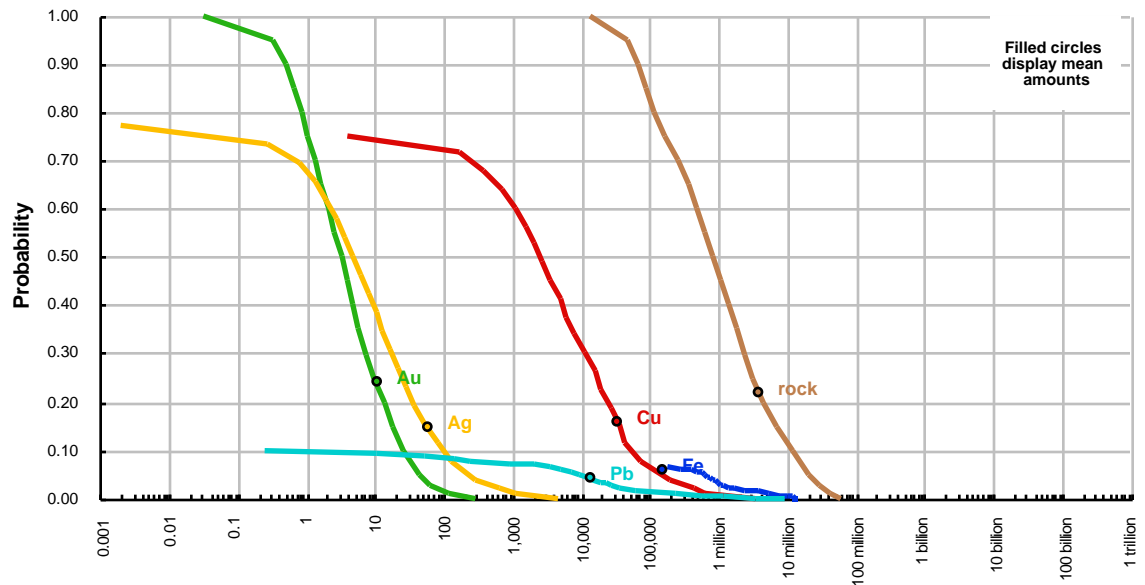
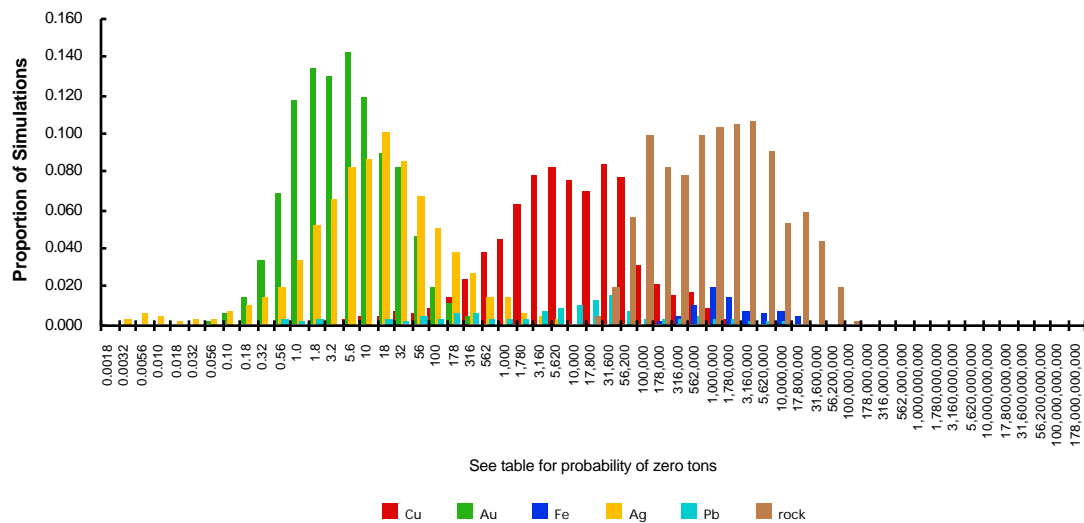
quantile	Cu	Au	Fe	Ag	Pb	rock
0.95	0	0	0	0	0	46,000
0.90	0	1	0	0	0	65,000
0.50	2,600	3	0	5	0	800,000
0.10	51,000	26	0	99	0	12,000,000
0.05	130,000	43	580,000	220	9,300	21,000,000
mean	32,000	10	150,000	57	14,000	3,900,000
Probability of mean	0.16	0.24	0.06	0.15	0.04	0.22
Probability of zero	0.25	0.00	0.94	0.23	0.90	0.00

Simulated amounts of metal in a single deposit

Mark3 Index 105: **Skarn Au, truncated**

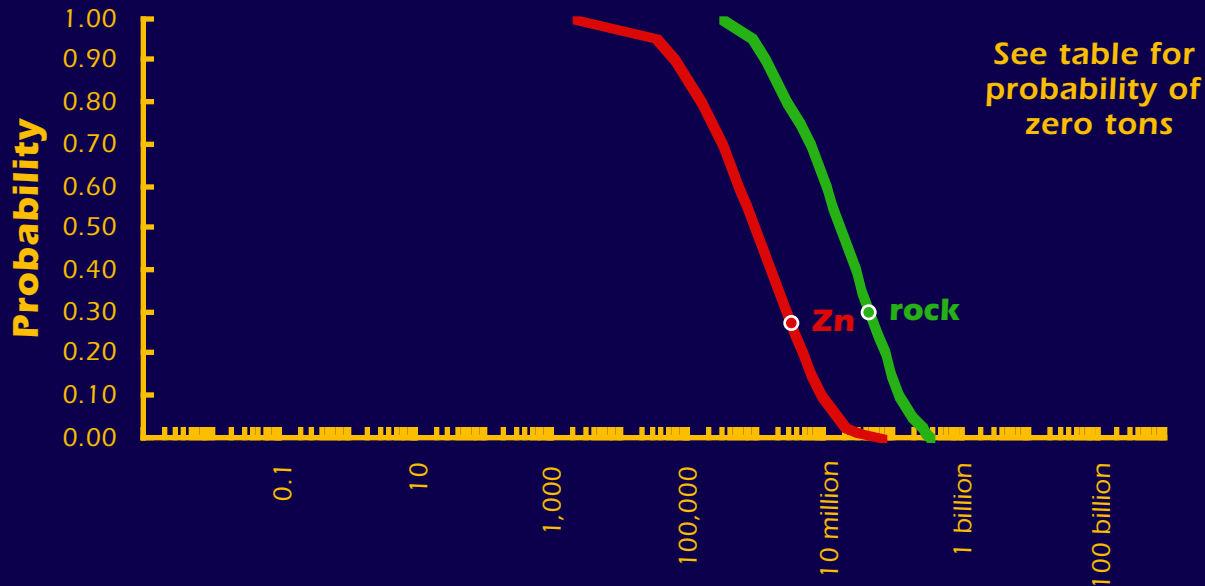
Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Cu	Au	Fe	Ag	Pb	rock
0.95	0	0	0	0	0	46,000
0.90	0	1	0	0	0	65,000
0.50	2,600	3	0	5	0	800,000
0.10	51,000	26	0	99	0	12,000,000
0.05	130,000	43	580,000	220	9,300	21,000,000
mean	32,000	10	150,000	57	14,000	3,900,000
Probability of mean	0.16	0.24	0.06	0.15	0.04	0.22
Probability of zero	0.25	0.00	0.94	0.23	0.90	0.00

Simulated amounts of metal in a single deposit Mark3 Index 105: **Skarn Au, truncated****Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

Mark3 Index 106: Sedimentary exhalative Zn

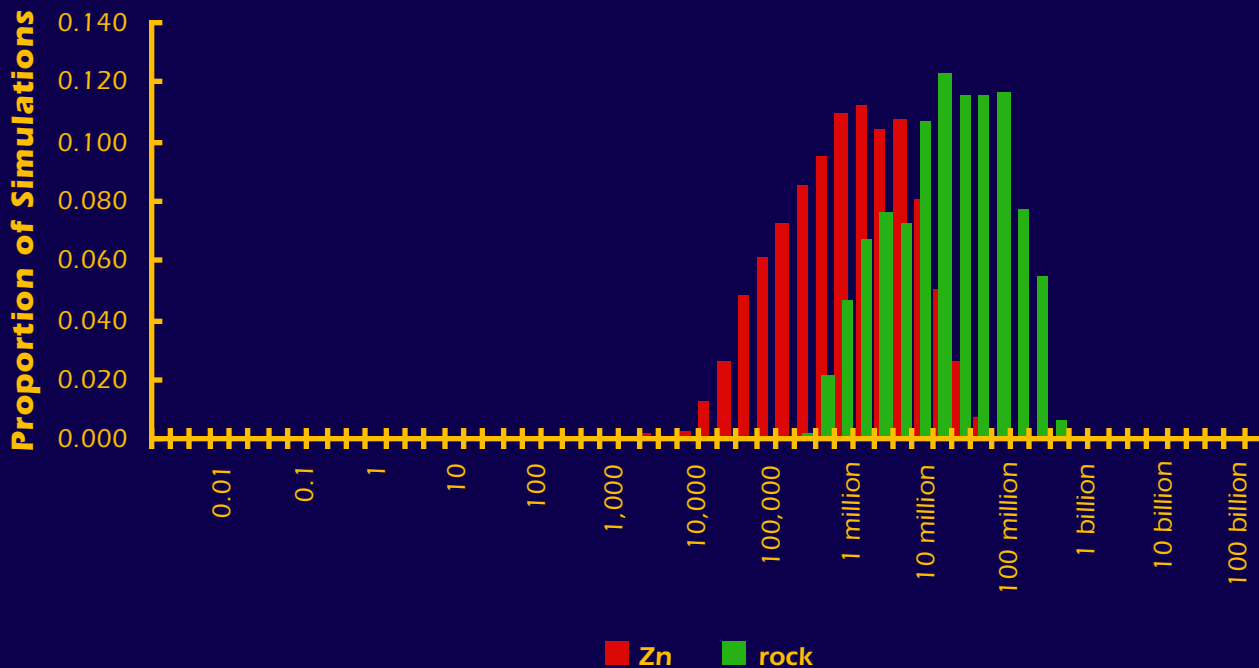
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 106: Sedimentary exhalative Zn

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 106: Sedimentary exhalative Zn

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Zn	rock
0.95	34,000	850,000
0.90	62,000	1,300,000
0.50	930,000	17,000,000
0.10	8,800,000	130,000,000
0.05	15,000,000	200,000,000
mean	3,200,000	44,000,000
Probability of mean	0.27	0.30
Probability of zero	0.00	0.00

Simulated amounts of metal in a single deposit

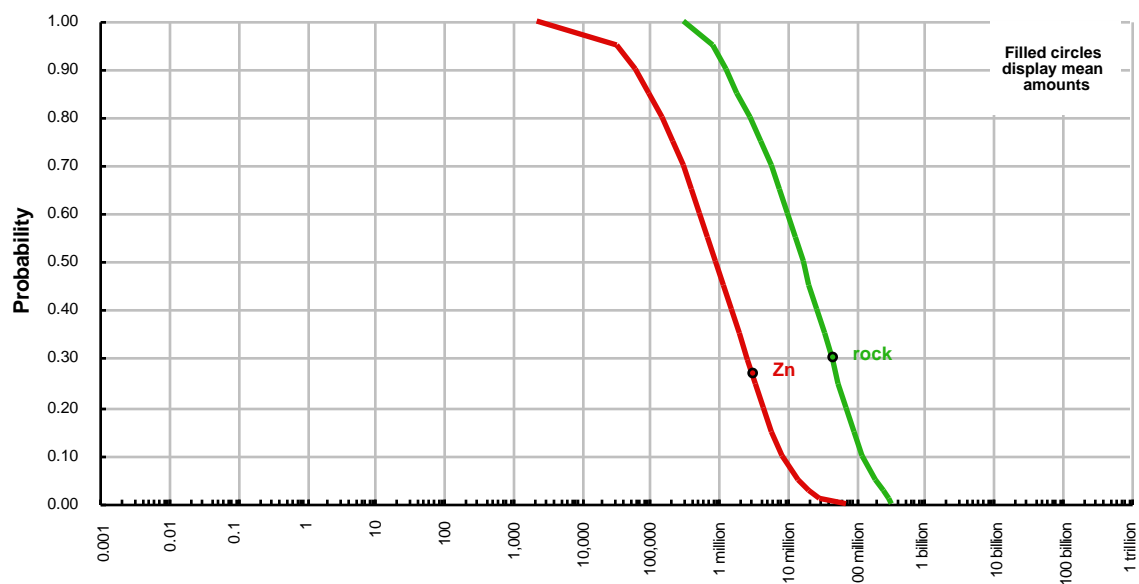
Mark3 Index 106: **Sedimentary exhalative Zn**

Estimated amounts of contained metal and mineralized rock (metric tons)

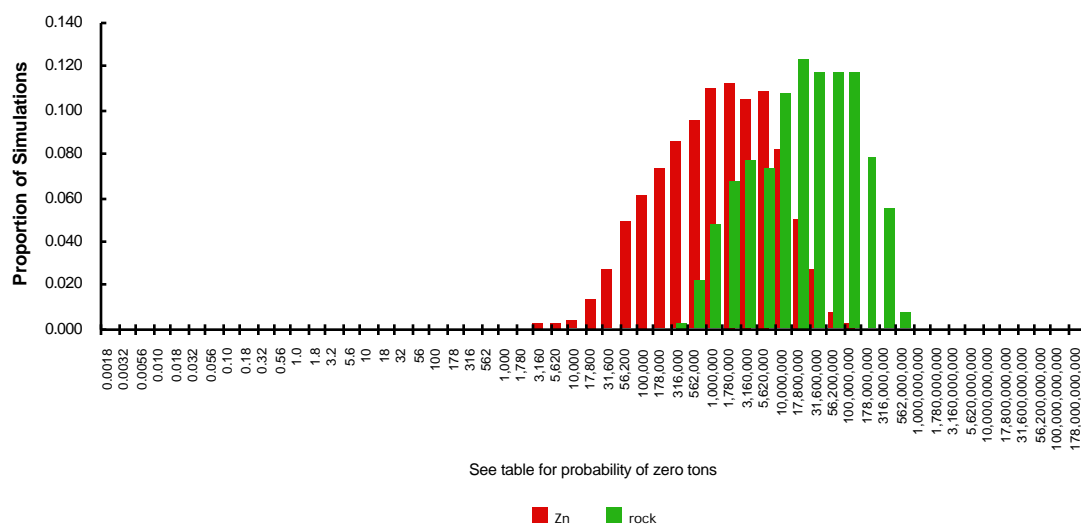
quantile	Zn	rock
0.95	34,000	850,000
0.90	62,000	1,300,000
0.50	930,000	17,000,000
0.10	8,800,000	130,000,000
0.05	15,000,000	200,000,000
mean	3,200,000	44,000,000
Probability of mean	0.27	0.30
Probability of zero	0.00	0.00

Simulated amounts of metal in a single deposit Mark3 Index 106: **Sedimentary exhalative Zn**

Cumulative Distributions of Contained Metal and Mineralized Rock

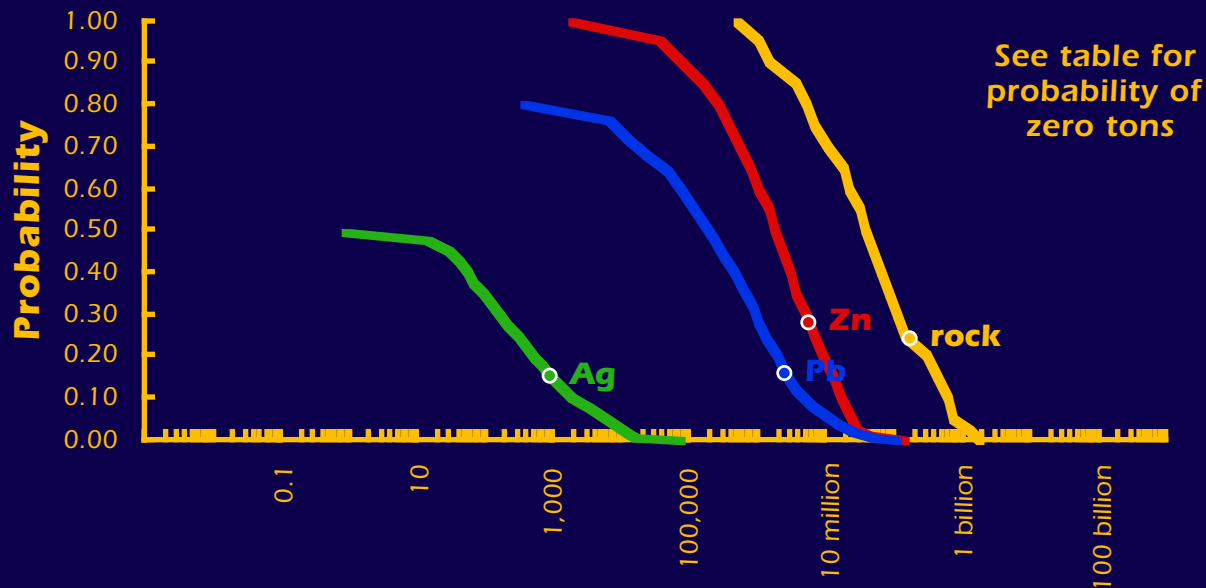


Histograms of Contained Metal and Mineralized Rock (metric tons)



Mark3 Index 108: Mississippi Valley

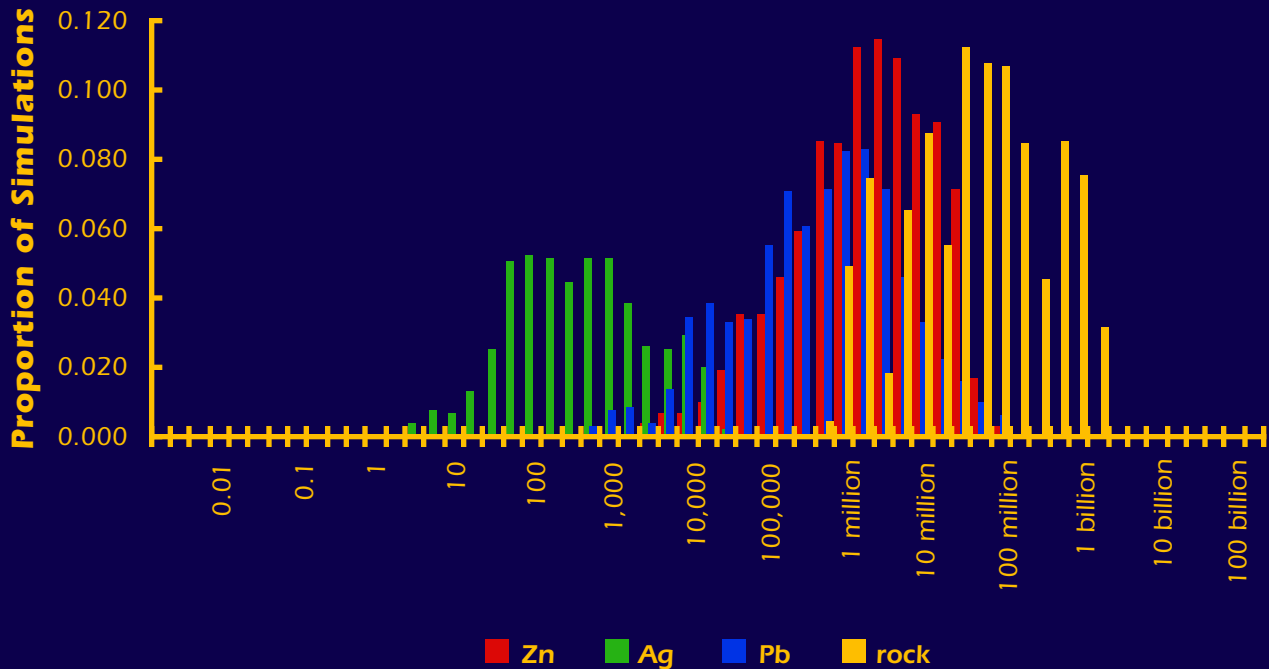
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 108: Mississippi Valley

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 108: Mississippi Valley

Estimated amounts of contained metal and mineralized rock (metric tons)

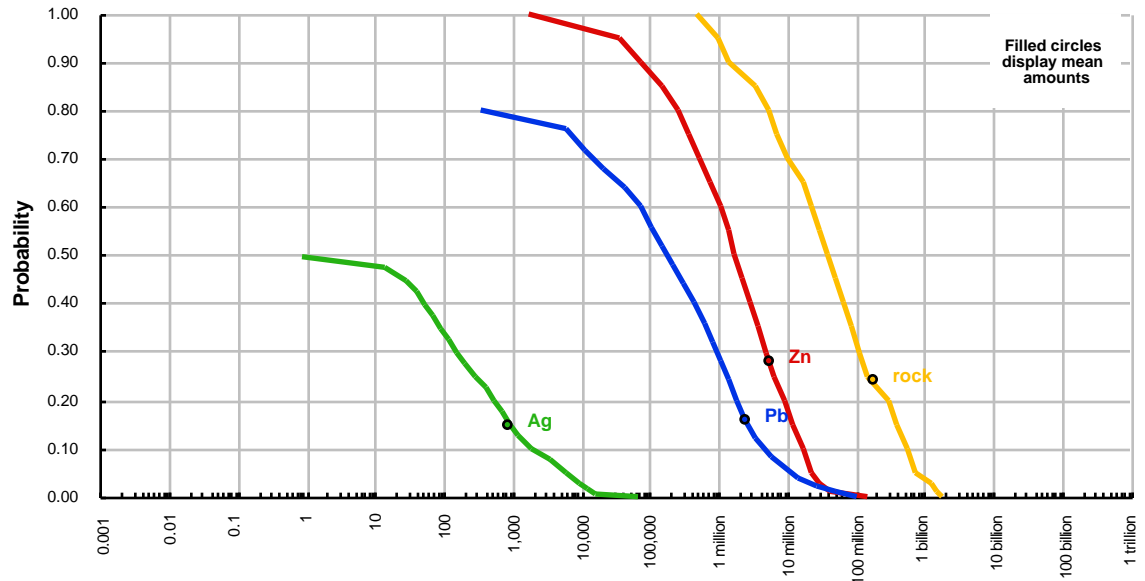
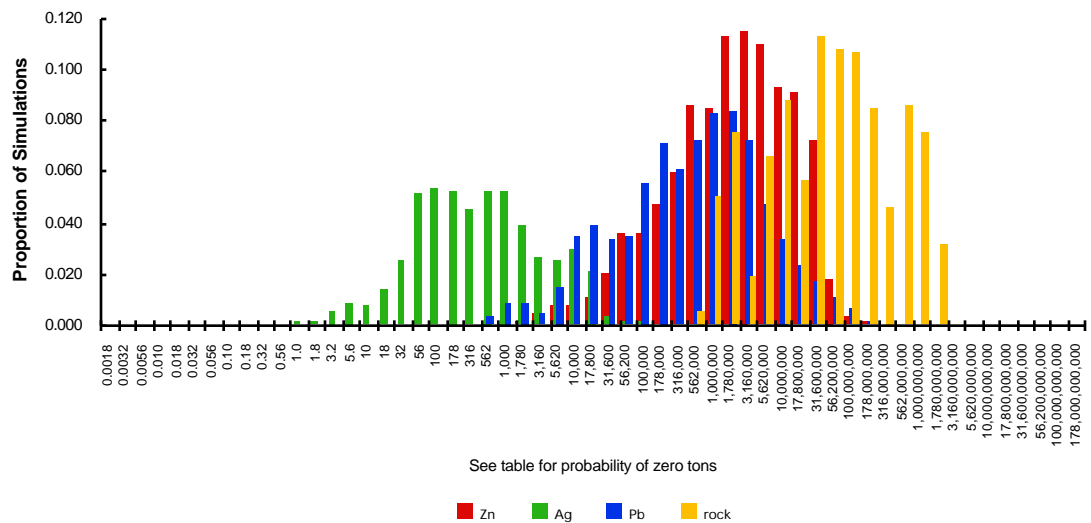
quantile	Zn	Ag	Pb	rock
0.95	35,000	0	0	970,000
0.90	74,000	0	0	1,400,000
0.50	1,800,000	0	180,000	38,000,000
0.10	17,000,000	1,900	4,390,000	580,000,000
0.05	23,000,000	5,900	11,000,000	760,000,000
mean	5,500,000	880	2,400,000	170,000,000
Probability of mean	0.28	0.15	0.16	0.24
Probability of zero	0.00	0.50	0.20	0.00

Simulated amounts of metal in a single deposit

Mark3 Index 108: **Mississippi Valley**

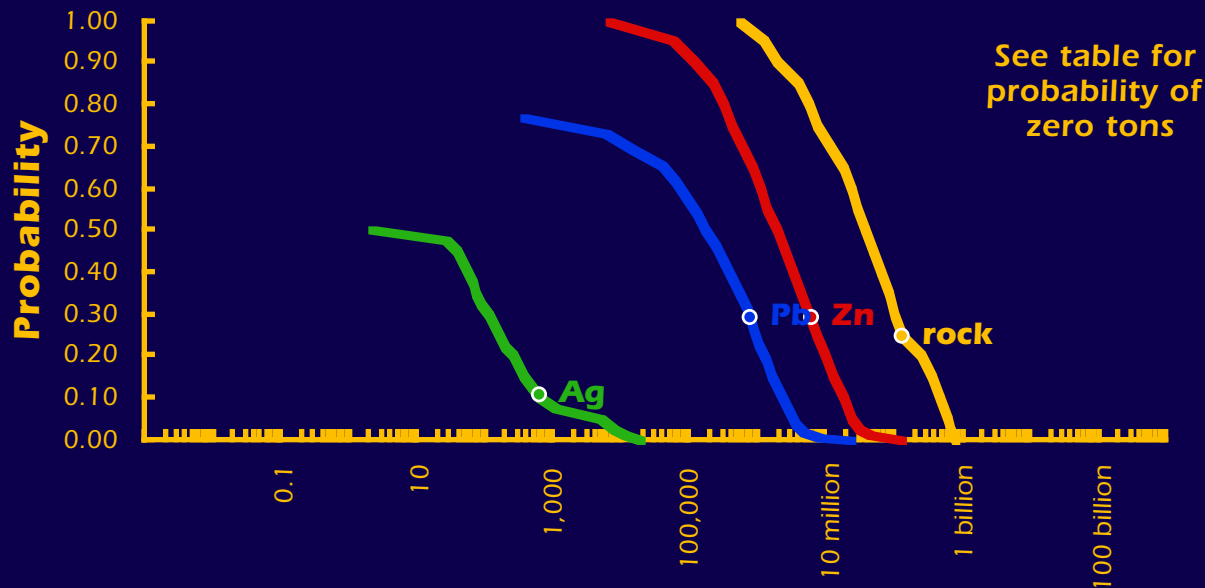
Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Zn	Ag	Pb	rock
0.95	35,000	0	0	970,000
0.90	74,000	0	0	1,400,000
0.50	1,800,000	0	180,000	38,000,000
0.10	17,000,000	1,900	4,390,000	580,000,000
0.05	23,000,000	5,900	11,000,000	760,000,000
mean	5,500,000	880	2,400,000	170,000,000
Probability of mean	0.28	0.15	0.16	0.24
Probability of zero	0.00	0.50	0.20	0.00

Simulated amounts of metal in a single deposit Mark3 Index 108: **Mississippi Valley****Cumulative Distributions of Contained Metal and Mineralized Rock****Histograms of Contained Metal and Mineralized Rock
(metric tons)**

Mark3 Index 109: Mississippi Valley (modified)

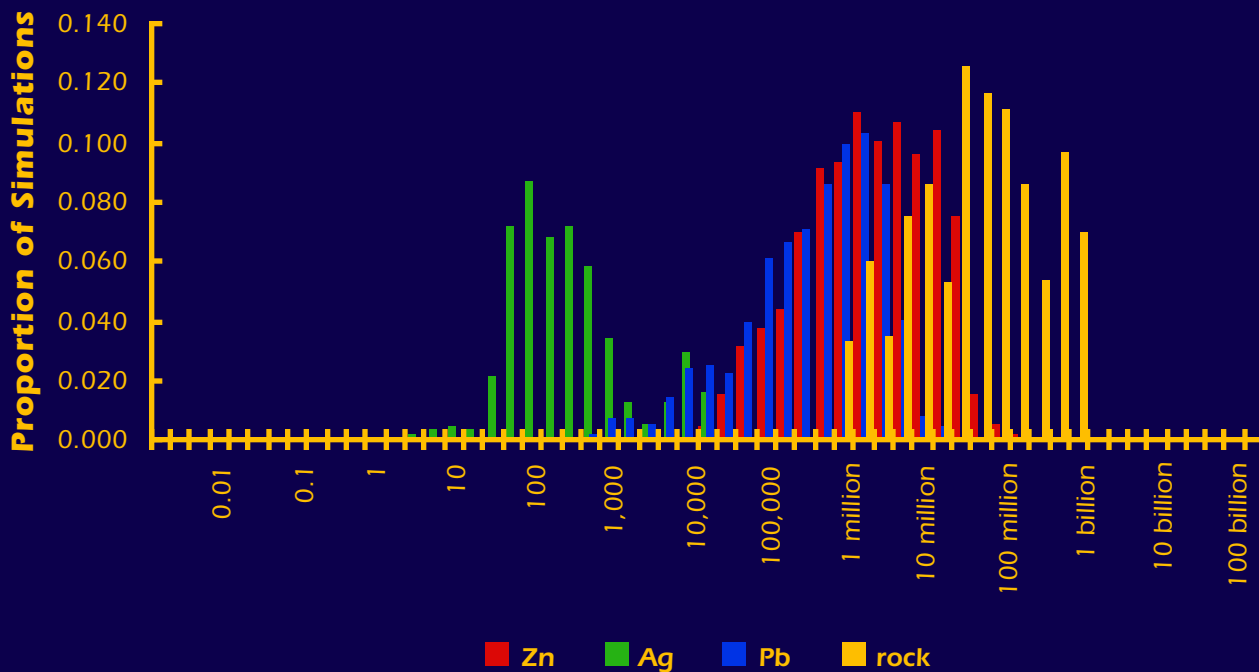
Cumulative Distributions of Contained Metal and Mineralized Rock (metric tons)



Filled circles display mean amounts

Mark3 Index 109: Mississippi Valley (modified)

Histograms of Contained Metal and Mineralized Rock (metric tons)



Simulated amounts of metal in a single deposit

Mark3 Index 109: Mississippi Valley (modified)

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Zn	Ag	Pb	rock
0.95	55,000	0	0	1,200,000
0.90	120,000	0	0	1,900,000
0.50	1,800,000	0	170,000	37,000,000
0.10	17,000,000	640	2,280,000	470,000,000
0.05	23,000,000	4,900	3,300,000	620,000,000
mean	5,900,000	590	780,000	130,000,000
Probability of mean	0.29	0.11	0.29	0.25
Probability of zero	0.00	0.50	0.23	0.00

Simulated amounts of metal in a single deposit

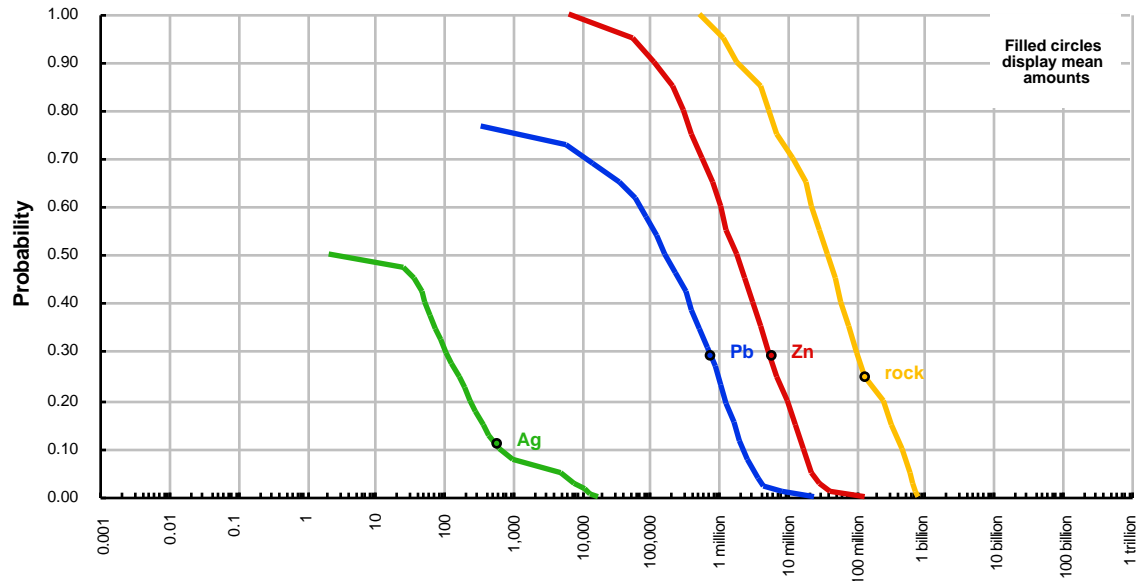
Mark3 Index 109: **Mississippi Valley (modified)**

Estimated amounts of contained metal and mineralized rock (metric tons)

quantile	Zn	Ag	Pb	rock
0.95	55,000	0	0	1,200,000
0.90	120,000	0	0	1,900,000
0.50	1,800,000	0	170,000	37,000,000
0.10	17,000,000	640	2,280,000	470,000,000
0.05	23,000,000	4,900	3,300,000	620,000,000
mean	5,900,000	590	780,000	130,000,000
Probability of mean	0.29	0.11	0.29	0.25
Probability of zero	0.00	0.50	0.23	0.00

Simulated amounts of metal in a single deposit Mark3 Index 109: **Mississippi Valley (modified)**

Cumulative Distributions of Contained Metal and Mineralized Rock



Histograms of Contained Metal and Mineralized Rock (metric tons)

