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Grade, tonnage, and other models of Blue Mountain-type Au-Ag polymetallic veins, Blue Mountains, Oregon, for use in resource and environmental assessment

by

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Summary

•Models developed in this study for the Blue Mountain-type Au-Ag polymetallic veins of eastern Oregon can be used:

(1) to characterize the gold and silver grades and sizes in deposits yet to be discovered for use in mineral resource assessment, and

(2) to describe the maximum depths, target areas, and overall lengths of mine workings for use in environmental assessment.

•The geometric mean deposit size is 76,000 metric tons (t) (fig. 4).

•Eighty percent of the known deposits have gold grades (fig. 5) between 13 and 23 grams (g)/t.

•Silver grades (fig. 6) are reported in about 75 percent of the deposits and varies over three orders of magnitude (2 g/t to about 300 g/t)

•The median target area is 95 hectares (ha); deposits with 2 to 15 mines have a geometric mean target area of 160 hectares (fig. 8).

•Depth of mining in known deposits range from 31 to 915 m. The geometric mean depth of historic development is 170 m (fig. 9).

•Oxidized conditions in these veins generally can extend to depths of at least 150 m and mines deeper than that contain predominantly unweathered sulfides. These unoxidized sulfides can serve as a source of metal contamination when exposed to the atmosphere.

•Eighty percent of the deposits have subsurface mine workings lengths between 1,100 and 5,900 m (fig. 10). Larger mines, particularly those with significant working below 150 m, have exposed sulfides. Deposits with larger workings may have an associated surface subsidence hazard.

Preface

The models developed here in are intended to serve two purposes. The grade and tonnage model serve the traditional purpose of characterizing deposit sizes and grades for use in quantitative mineral resource assessments. The target area, depth, and length-of-workings models are proposed for use in environmental mineral assessments. Defining groups of polymetallic veins with similarities in metal grade characteristics can be extremely difficult. Vein deposits, particularly smaller-size ones, are probably among the most difficult deposit types to model. Extraction and recovery details can be incomplete with some base metals either discarded, not reported, or, in the case of zinc, possibly avoided in mining. Descriptions are commonly incomplete.

Nearly all the data for veins in this model come from mill production records which can reflect mill inefficiencies (only part of the metal is recovered). Concentrate production and smelter recovery can also be biased to selected metals. Attempting to estimate the in-place mineral deposit grade of byproduct metals under these conditions are likely to be subject to even greater inaccuracies. Modeling grades using data where a metal can be either a primary or byproduct commodity can lead to complications.

Polymetallic and other types of veins have been a favored target for small-scale mining and can occur in large numbers scattered over a region. However, their relative small size also makes them of less interest to scientists studying mineral deposits (and companies looking for large deposits) resulting in less available data.

From an environmental perspective, weathering of these veins, both worked and unworked (and perhaps undiscovered), may contribute Cu, Pb, Zn, and other trace metals (e.g, Cd in polymetallic veins) to surface and ground water, etc. The deposits grouped for this study are notable for having ores containing up to 10 percent sulfides. Oxidation of exposed sulfides will occur in old mine workings. The three models are offered as potentially useful in characterizing aspects of veins deposits possibly useful in environmental evaluation. They are models of surface (target) areas, maximum mine working depths, and cumulative mine working lengths. Be forewarned that this is the first attempt at modeling mine depth and mine size in this fashion and may undergo future modifications.

Introduction

Blue Mountain vein deposits in east central Oregon were initial considered to be members of the population of low-sulfide Au-quartz veins described by Berger (1986). However, it became apparent during data collection that many of the veins had higher silver grades than reported in most low-sulfide Au-quartz veins. Some deposits (Cliff-Flagstaff, Virtue, White Swan) give a good match but occur in the same geologic setting with other vein deposits which do not give a good match (Brooks and Ramp, 1968). The mineralogy of many of these veins also is not consistent with that of low-sulfide Au-quartz veins. Tetrahedrite is particularly prominent in the Blue Mountain veins deposits. However, it is among the least frequently reported sulfides in low-sulfide (Bliss and Jones, 1988). Other sulfides reported in the Blue Mountain vein deposits include pyrargyrite, stephanite, proustite, stibnite, and cinnabar; which are rarely reported in low-sulfide Au-quartz veins (Bliss and Jones, 1988). Some deposits in the Blue Mountains (e.g., Cable Cove) have about twice the accepted maximum sulfide content (i.e., 5 percent) of most low-sulfide Au-quartz veins. For these reasons, the data for the Blue Mountains veins were not used in the grade and tonnage model of low-sulfide Au-quartz veins (Bliss, 1986).

Data for the Blue Mountain vein deposits were again considered during preparation of the grade and tonnage model for polymetallic veins (Bliss and Cox, 1986). Many of the mines have mineralogy, textures, etc. matching that given in the descriptive model of polymetallic veins (Cox, 1986). However, most Blue Mountain vein deposits have too low a base metal content to be consistent with the grade and tonnage model for polymetallic veins (Bliss and Cox, 1986). A second type of polymetallic veins recognized by Bliss and Cox (1986), are worked primarily for gold and silver. Models for these deposits are unavailable but data are available for 22 deposits. The data are insufficient to develop models at this time. A comparison (using nonparametric statistics) of sizes and grades (Appendix A) between Blue Mountain vein deposits and 22 Au-Ag polymetallic vein deposits reveals no significant differences in size or grades between the two types **except for gold**. The Blue Mountain vein deposits have significantly higher Au grades at the 1-percent confidence level (Mann-Whitney U test, Z = -2.875, p = 0.004)[1].

About 3 out of 4 Blue Mountain vein deposits have Ag grades. A few deposits have Cu, Pb, and Zn production. Cu is reported in 3 out of 17 deposits used for grade and tonnage modeling. Pb is reported in 2 deposits and Zn in one. However, base metal data are suspect and not used for modeling.

In view of these observations, the Blue Mountain vein deposits are modeled separately; however given more data, these deposits may in the future be merged with data on other veins deposits. The Blue Mountain vein deposits have descriptive and grade characteristics which appears to be transitional between low-sulfide Au-quartz veins and Au-Ag polymetallic veins, and are identified as **Blue Mountain-type Au-Ag polymetallic veins**.

Qualification of data

•Deposit size is estimated from past production; this is the situation for most smaller vein-deposit types, reserves are commonly not determined.
•Deposits must be 1,000 metric tons (t) or larger to be included in the grade and tonnage model.
•Grades and length of workings (with one exception) are not modeled without deposit size. Estimated grades can be based on unrepresentative measurements (assays, fineness for Ag, etc.)
•Estimate of grades are based on mill data, not mineralization in the veins. Poor recovery (e.g, 67 percent at the North Pole mine) will result in grades much less than actually present in unmined deposits.
•Some grades may be high due to unreported hand sorting of ore (e.g, as reported at the Badge Mine).
•Byproduct metals (Cu, Pb, Zn) represent production from concentrate, not total base metal content in the ground. Sulfide concentrates can be prepared to maximize production of selected metals (e.g, likely Au, Ag in Blue Mountain vein deposits) and exclude other metals (e.g., Cu, Pb, Zn). Estimating base metal grades using concentrate data will likely grossly underestimate the base metal grades actually present in the veins. All base metal grades are suspect.

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[1]Z--test statistic, p--probability

•Maximum depth is often estimated from depth of mines, shaft depth, etc., which can be an expression of development not production or mineralization. Some depths are too large as they are taken from lengths of inclines.

Definition of deposit

Mines do not necessarily represent deposits. Mines are simply an expression of mineral extraction and often several nearby mines are, in fact, working the same deposit. On the other hand, mining districts are a legal entity and are not necessarily based on any type of geologic consideration. "In short, it may be a mix of the physical occurrence of metal and cultural, economic, and political factors" (Harris, 1984, p. 168). Mining districts are inappropriate because they are usually large in area and fuzzy in definition. Mines are inappropriate because they are usually relatively small compared to the area mineralized and equally fuzzy to define. The need for proximity rules (i.e., adjacent properties to be treated as working the same deposit given some previously established distance) is a necessary precondition prior to modeling vein deposits, but it is both messy and difficult. A key to defining a mineral deposit is dependent on recognizing the boundaries of the **mineral system**. This can be difficult task for some mineral deposit types. Definition of a deposit is not obvious in the data; so an arbitrary distance of 1.6 km (1 mi) or less was used to aggregate mines into deposits.

Data screening for outliers

The initial data set (Appendix A) was inspected for outliers (extreme values). Outliers are classified as (1) true but discordant, (2) bizarre (e.g, contaminants), or (3) false (i.e., mistakes) (Rock, 1988). Extreme values can also be statistical outliers which are recognized by "purely statical means...[where] their identification as true, false or bizarre has not yet been made" (Rock, 1988, p. 114). The previous discussion of data quality suggests there are plenty of opportunities for mistakes to occur and that the overall data quality is poor. Discordant outliers may also occur if a deposit is included but not a member of the deposit type. Such discordant outliers may be due to the used of a different mining and/or milling process which will effect grades and/or tonnage. A sound geological, etc. explanation of outliers may be present but given the abbreviated description of many deposits and details of mining, etc. it may not apparent!

One of the deposit (Badger) in the initial data set has an unusually high gold grade (i.e, 226 g/t) when compared to the rest (Appendix A). Ore at this mine was hand sorted to maximize gold content; therefore its grade is not comparable. However, the situation at the La Belleview deposit is less clear. Sulfide content is unusually high (15 to 20 percent of ore, see description of the deposit below) where Ag production was important and the gold grade was low (i.e., 5.8 g/t) (fig. 1). A t-test of the null hypothesis that the La Belleview gold grade is not different from the mean of the gold grades in the rest of the deposits in the data was rejected ($t=5.075$, $df=15$, $p<0.001$)[1] using a procedure described by Sokal and Rohlf (1988, p. 224-225). Therefore modeling of gold grades will exclude this value as well as its deposit size.

Evaluation of data for working lengths also suggest one value may be an outlier. This was noted when a scatter plot for deposit size and working lengths was prepared (fig. 2). Cornucopia has more workings than typical of other mines in this deposit type. A t-test of the null hypothesis that the Cornucopia working length is not different from the mean of the working lengths in the rest of the deposits in the data was rejected ($t=4.63$, $df=16$, $p<0.001$) using the same procedure used previously (Sokal and Rohlf, 1988). Therefore modeling of deposit lengths will exclude this value. Data on depth, target area, deposit size, gold grade, and silver grade from Cornucopia are used in modeling.

Descriptive notes about selected deposits

A brief description is provided for some Blue Mountain-type Au-Ag polymetallic veins as identified in this study. Some of the data for these deposits were not used in some models as discussed below:

Badger: Includes 5 properties (Badger, Golden Gate Homestake, Side Issue, Stockton) in the Susanville district. Of the properties, only Badger was significantly developed. Gold is found in quartz veins hosted by schist with some quartzite, slate, greenstone, serpentinized peridotite, and gabbro all of

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[1]t--test statistic, df--degrees of freedom, n--number of observations, p--probability.

which are cut by aplite dikes (Brooks and Ramp, 1968). Metallic minerals include pyrite, marcasite, arsenopyrite, pyrrhotite, sphalerite, galena, stibnite, tetrahedrite-tennanite, and chalcocite. Sulfides concentrates made up between 8-11 percent of the ore where most production was from oxidized material which extended to the the 500 level (~152 m) The ore was hand sorted and has the highest gold grade in the data; the deposit was excluded from the grade and tonnage model.

Ben Harrison: Includes 1 property in the Greenhorn district. Gold is found in quartz veins hosted by granodiorite cut by numerous aplite dikes. Granodiorite fragments are present within some veins. Metallic minerals include pyrite, arsenopyrite, stibnite, a little chalcopyrite, tetrahedrite, sphalerite, pyrargyrite, and stephanite (Brooks and Ramp, 1968).

Lindgren (1901) recognized that most of the value in production in the Greenhorn district was from the silver, not gold, as is found elsewhere in the Blue Mountains. He noted two different mineralization types in the Greenhorn district: (1) pyrite with arsenopyrite and sphalerite [commonly seen elsewhere], and (2) tetrahedrite bodies. It is the latter mineralization type which may account for the larger silver production.

Cable Cove: Includes 7 properties found in the Cable Cove District. Gold is found in quartz (plus a little calcite) veins hosted by brecciated and altered granodiorite (some are chloritic). Veins are found in sericitized and carbonatized white, soft granodiorite usually several inches wide (Lindgren, 1901). At the California mine, sulfides are about 10 percent of ore (Brooks and Ramp, 1968) which is twice the amount (i.e, 5 percent) of sulfides usually reported for low-sulfide Au-quartz veins. Sulfides are dominated by pyrite, arsenopyrite with a little chalcopyrite, galena, and sphalerite. Free gold is found in the oxidized zone of veins of depths between 30-50 ft (9.1-15 m). The relatively shallow occurrence has been attributed to recently glaciation. A portion of the the estimated production of not more than $200,000 for the district likely includes some material with grades up to 206 g/t at the Imperial mine; typical grades of non-oxidized material is 18 g/t (Lindgren, 1901). The current best estimate of size is 17,000 t.

Silver content has been reported as 10-13 times that for gold (Imperial Eagle mine). Some high graded material has much less silver--more like twice the Au values at the Mile High mine (Brooks and Ramp, 1968). However, this mine was a relatively small producer. As shown by Lindgren (1901), silver content is largely dependent on how much galena is present. The best estimate of Ag grade is 180 g/t. The best estimate of copper grade is 0.56 percent.

Cliff-Flagstaff: Includes 3 properties (Emma, Cliff, Flagstaff) in the Virtue area. This deposit, along with Virtue, and White Swan deposits are quartz (plus a little calcite) veins poor in sulfides (pyrite, chalcopyrite). Gold is free and with fineness can be as high as 920 (Virtue deposit). Silver content is low (Brooks and Ramp, 1968).

Connor Creek: This single property deposit in the Connor Creek District consists of a quartz vein in slate containing coarse gold with a little argentite and pyrite. Gold was 900 fine (Brooks and Ramp, 1968).

Dixie Meadows: This single property deposit is found in the Quartzburg District. The deposits is described as a quartz-sulfide replacement body along a fault in a complex of greenstone, meta-andesite, meta-tuff, metadiorite, and serpentinite (Brooks and Ramp, 1968). Gold is not free nor is the deposit much oxidized. Metallic minerals include pyrite, arsenopyrite, chalcopyrite, pyrrhotite, galena, marcasite, and sphalerite (Brooks and Ramp, 1968). Cox (1988, p. 125) notes that polymetallic veins may occur as "replacement ore bodies...where structure intersect carbonate rock." Perhaps other types of reactive host rocks might be suitable as well. In general, features noted at Dixie Meadows--occurence in a fault zone, mineralogy, size, and gold grade--are compatible this deposit type and it is included in the model at this time.

Greenhorn: This deposit includes 15 properties (Banner, Banzette, Diadem, Don Juan, Golden Eagle, Golden Gate, Harrison Gp., IXL, Owl, Phoenix, Rabbit, Roberts, Royal White, Snow Creek, West Side) in the Greenhorn district. Despite the number of properties involved, total production is relatively small made up of surface pockets and veins consisting of quartz, dolomite, and calcite and hosted by argillite, serpentine, and greenstones. Metallic minerals include pyrite, chalcopyrite, sphalerite, and galena. Cinnabar was noted at the Diadem mine. Most production was from oxidized ore (Brooks and Ramp, 1969).

Granite: Includes 9 properties (Ajax,Buffalo, Continental, Cougar, Independence, New York, Magnolia, Standard, Tillicum) in the Granite district. Gold was produced from nearly all the properties. Veins, in argillites and granodiorites, contain about 10 percent sulfides with little free gold. Metallic minerals in the Buffalo mine include pyrite with lesser arsenopyrite, chalcopyrite, galena, sphalerite, tetrahedrite in a gangue of quartz, calcite, and fragments of host rocks (Brooks and Ramp, 1968).

La Belleview: Sulfides are unusually high making up 15 to 20 percent of the ore. Veins, in quartz biotite schist and granodiorite, consist of crushed host rock with pyrite, arsenopyrite, and minor galena, chalcopyrite, and tetrahedrite. Silver is found in tetrahedrite, pyrargyite, as native silver, and possibly in proustite (Brooks and Ramp, 1968). The base and precious metal grades of this deposit (Appendix A) also do not fit those in the polymetallic veins (Bliss and Cox, 1986). This single property deposit was excluded from the data as it is atypical with a low gold grade.

Mammoth-Belle of Baker: Includes 2 properties (Mammoth, Belle of Baker) properties in the Cracker Creek district. Gold is found in quartz (plus a little calcite) veins hosted by granodiorite and argillite. Metallic minerals make up only a small part of the mineralization including pyrite, and arsenopyrite. Some wire gold has been found (Brooks and Ramp, 1968).

Mormon Basin: Includes 9 properties (Blue Mud, Cleveland, Hice, Humbolt, Overshot, Rainbow, Randall, Summut, Sunday Hill) in the Mormon Basin district. Rainbow, Sunday Hill, and Humbolt are the important mines. Numerous discontinuous quartz veins with a little ankerite and fuchsite are scattered throughout the area in quartz-rich schists, slates, and greenstones cut by numerous basic and ultrabasic dikes and sills thought to be associated with the granodiorite stock to the north of the deposit (Brooks and Ramp, 1968). Metallic minerals are dominated by pyrite and arsenopyrite associated with a some galena, sphalerite, polybasite, hessite, and tetrahedrite (Brooks and Ramp, 1968).

North Pole-Columbia: Includes 8 properties (Cracker Oregon, Climax, Columbia, Eureka and Excelsoir, Golconda, Mountain Bell, North Pole, and

Tabor Fraction) in the Cracker Creek district. Gold is found in composite veins with alternating layers of quartz and silicified argillite breccia separated by gouge or sheared country rock. The veins are hosted by argillite and granodiorite (Brooks and Ramp, 1968). Metallic minerals include pyrite, arsenopyrite, and chalcopyrite. Lesser amounts of tetrahedrite, stibnite, marcasite, and some tellurides were observed. Partial oxidation has extended to a depth of 76 m and resulted in an increase of gold content by 40 percent and a loss of silver by 42 percent ((Lindgren, 1901).

Red Boy: Includes 6 properties (Red Boy, Carbonate, Portland, Morris, Tempest, and Tiger) in the Greenhorn district. Most production was from the Red Boy mine where free gold is found in 6 veins of crushed argillite with many stringers of quartz. A large number of felsic dikes are found in the area (Brooks and Ramp, 1968). Fine pyrite is the only sulfide noted, making up about 5 percent of the ore (Brooks and Ramp, 1968).

Rock Creek: Includes 4 properties (Baisley Elkhorn, Highland, Maxwell, and Western Union) in the Rock Creek district. Gold is found in a mass of crushed and generally silicified argillite, clay, quartz, and calcite. The vein is hosted by argillites (Brooks and Ramp, 1968). Metallic minerals include pyrite, sphalerite, arsenopyrite, chalcopyrite and tetrahedrite. Comb structures and ruby silver (proustite, pyrargyrite) are seen in the Baisley Elkhorn mine.
White Swan: See Cliff-Flagstaff
Virtue: See Cliff-Flagstaff.

Grade and tonnage model

Grade and tonnage models were successfully prepared using data from 16 Blue Mountain-type Au-Ag polymetallic veins (Appendix A). Skewness and kurtosis goodness-of-fit tests (Rock, 1988) failed to provide reasons to reject the use of a lognormal distribution model at the 1-percent confidence level to characterize deposit size and grade data. The geometric mean values for deposit size and gold grade are 76,000 t (fig. 4) and 18 g/t (fig. 5) respectively. Both values are comparable to geometric mean size (30,000 t) and grade (16 g/t) of low-sulfide Au-quartz vein model (Bliss, 1986). However, a distinction between the two models can easily be based on their silver content. Recoverable silver is present in 75 percent of the Blue Mountain-type Au-Ag polymetallic veins whereas less than 15 percent of the deposits in the low-sulfide Au-quartz vein model have reported silver (Bliss, 1986). The Blue Mountain-type Au-Ag polymetallic veins are also much richer in silver reaching 210 g/t at the 90th percentile (fig. 6) in contrast to a maximum of 40 g/t in low-sulfide Au-quartz vein deposits (Bliss, 1986). The Blue Mountain-type Au-Ag polymetallic veins are distinguished from both the as yet unmodeled Au-Ag polymetallic veins deposits and the polymetallic vein deposits by Bliss and Cox (1986) through their elevated gold values and trivial base metal content. Although base metal production is cited for as many as 4 of the 16 deposits, it is of very minor importance and its accuracy is highly suspect. Base metal grades were not modeled.

Target-area model

As noted previously in the section on "Deposit Definition", deposits are neither mines nor districts for known Blue Mountain-type Au-Ag polymetallic veins. An exception is where a mine is isolated and the mine is equivalent to the deposit. The intersection of the deposit with the surface has a finite area or **target area**. Ideally, the target area is some type of cross sectional area of the mineralization system and one which can be measured. Unfortunately this type of observation is usually not available so an arbitrary area of 50 ha is assigned to single-mine deposits. The area is calculated for a circular shaped target area with a radios of 400 m (fig. 7A). This radius is one-half the arbitrary distance (i.e, the radius of 800 m (fig 7A,B)) used to group mines. The selection of this radius for target area calculation is as arbitrary as is the distance rule for grouping adjacent mines.

Clusters of known mines working Blue Mountain-type Au-Ag polymetallic veins may be linked and treated as a single deposit over a considerable distance using 1.6 km spacing rule. Linking across or using mines which lack production data is usually not done but each situation has to be judged separately. As vein-type deposit geometry tends to have an elongated form (along strike), the area between mines is more likely to be part of the mineral system. When properties are so grouped, the target area is not only the size of the circles around each mine but also the connecting segment between the mines where the connecting segments are assigned a width of 400 m wide (fig. 7C). Areas completely surround by connecting segments and circular mine areas are also included in the target area calculation (fig. 7C). Adjacent mines have target areas which includes the circular areas adjusted for overlapping areas (fig. 7D). A target area as defined here is a proxy of the area of the mineralization system and is **not** a projection of the mineralization to the surface nor is it an outcrop area. These clustered mines may include substantial space without mineralization or mines. Calculation of target area for cluster of mines (i.e., the deposit) is dependent on the level of detail in the source publications and maps and scales thereof used. Some areas which should have been included may have been missed due to incomplete reporting in the source documents.

Modeling target area is complicated as many deposits with data are represented by a single mine which is assigned a default target area of 50 ha. The hypothesis that target areas (included those with default areas) for deposits used in the grade and tonnage model (n=16) and those deposits (n=16) not used in the grade and tonnage have the same medians was not rejected at the 1-percent confidence level (Mann-Whitney U test, Z=-1.162 (corrected for ties), p=0.245). This is also true for deposits in the two data sets (each with 10 deposits, Appendix A) with target areas greater than 50 ha (Mann-Whitney U test, Z=-2.27, p=0.023). Therefore, all target area data (i.e, greater than 50 ha) are used to prepared a model (fig. 8) and described with a lognormal distribution which was not rejected using the skewness (0.82) and kurtosis (2.25) goodness-of-fit tests at the 1-percent level of significant (Rocks, 1988). High skewness may be due to the arbitrary lower boundary (greater than 50 ha) resulting in data truncation. Given the distribution of deposits with single mines and those with multiple mines (in clusters), the odds are 3 to 5 that an undiscovered deposit would have a target area of 50 ha; otherwise the model in figure 8 applies. The median target area (including deposits with single and multiple mines) is 95 ha (0.37 mi^2). Target areas for Blue Mountain-type Au-Ag polymetallic veins are 40 percent (or less) of the area of Au-Ag-Te veins deposits with a geometric mean target area of 250 ha (~1 mi^2; Bliss and others, 1992, fig. 4) and 290 ha (1.1 mi^2) for polymetallic metallic veins in the Idaho Batholith. It should be noted that target areas for these two deposits types were not calculated using the standardized procedures shown graphically in figure 8 and those values will need to be revised. Models of target areas are preliminary; detailed district, etc., maps were not examined and improvements in the models are likely. More deposits with data are also needed.

Despite the problems and limitations involved in modeling deposits target areas, the models provide a means of predicting the size of target areas that may be expected to occur if undiscovered deposits are developed. The target area model also allows a way to estimate the size of the area likely disturbed prior to deposit development. While the target area model developed here is less than ideal, it may help in environmental assessment. Other models useful in this regard are ones describing surface expressions of past mining by describing the areas of workings (shafts, etc.), tailings, mills sites, and infrastructure.

Maximum depth model

Data for depth are used from the data set for 15 deposits used in the grade and tonnage model plus data on 8 other deposits (including La Belleview) **not** used in the grade and tonnage model. The hypothesis that the two data sets have the same medians was not rejected ($Z=-0.97$, $p=0.33$) at the 1-percent confidence level using the Mann-Whitney U test (Gibbons, 1976). The lognormal distribution was not rejected for describing the maximum depths of Blue Mountain-type Au-Ag polymetallic veins ($n = 23$, Appendix A) using the kurtosis (2.91) and skewness (-0.22) goodness-of-fit tests at the one-percent level of significances (Rocks, 1988). The geometric mean maximum depth is 170 m (fig. 8). Deposits less than 150 m deep are likely oxidized (e.g, Badger, North Pole-Columbia). Unoxidized sulfides (up to 10 percent of the ore) are more likely to be present in mines with depths greater than 150 m and may contribute metals to surface and groundwater in or passing through or out of the deposits. The large number of shallow workings not included in the model are less likely to have this type of environmental expression as deep mines as they are wholly in oxidized material.

Workings length model

Data for mine workings length are used from the data set for 16 deposits used for the grade and tonnage model but **not** for data on 12 other deposits **not** used in the grade and tonnage model. The hypothesis that the two data sets have the same medians was rejected (Z=-3.343, p=0.0008) at the 1-percent confidence level using the Mann-Whitney U test (Gibbons, 1976). Most deposits lacking reporting on grades and tonnage have smaller sized workings. Note that this was not so for mine depths (see previous section). The size of the working of the Cornucopia was not used as determined in the earlier section on data screening for outliers. The lognormal distribution was not rejected for describing the distribution of composite lengths of mine workings within Blue Mountain-type Au-Ag polymetallic vein deposits (n = 26; Appendix A) using the kurtosis (1.97) and skewness (-0.289) goodness-of-fit tests at the one-percent level of significances (Rocks, 1988). The length of workings can help give an idea of the amount of exposed underground surfaces a mine may have (or had) to the atmosphere. Particular interest should be directed toward those mines with depths of 150 m or more as they are more likely to have exposed unoxidized sulfides. Care is needed in this type of interpretation as the depths of actually workings may be much shallower than the maximum depth of the mine. Some areas with recent glaciation also have shallow oxidized zones; some no thicker than 15 m (e.g, Cable Cove) and in these more mine workings can be expected to expose more unoxidized rock than elsewhere. Mines with extensive working also may have a surface subsidence hazard.

Closing Remarks

Developing grade and tonnage models for a local groupings of relatively small-sized veins deposits makes the models less applicable elsewhere. Another example of this is the Chugach-type low-sulfide Au-quartz veins in Alaska (Bliss, 1992). The La Belleview deposits may belong of a second (and possible less frequently seen) silver-rich, base metal poor deposit type of the polymetallic vein clan.

This is a first attempt at modeling depth and length of mine workings. The characteristic of the mineral deposit (grade, oxidization state, etc.) can be complex and highly variable when examined in detail with depth or as see in different parts of the mine workings. Care needs to be taken when applying these models particularly as it related to effects of recent geologic history. The models for Blue Mountain-type Au-Ag polymetallic veins contains too few deposits. I would be interested in hearing about (and receiving data on) other deposits like those found in the Blue Mountains, Ore. Please send your suggestions to Jim Bliss, U.S. Geological Survey, 210 E. 7th St., Tucson, AZ 85705-8454.

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Table 1. List of districts (underlined), deposits, and the names of mines (properties) grouped for each deposit. Presence of deposits in this table does not necessarily mean that usable data was available for modeling.

Deposit Name	Mine Name(s)
Baker district	
Tom Paine	Tom Paine -Old Soldier
	Carpender Hill
	Young American
Dale	Dale
Stub	Stub
Cable Cove district	
Cable Cove	Baby McKee
	California
	Crown Point
	Imperial Eagle
	Last Chance
	Mile High
	Oregon Chief
Canyon district	
Great Northern	Great Northern
Miller Mountain	Miller Mountain
Praire Diggings	Praire Diggings
Connor Creek district	
Bay Horse	Bay Horse
Connor Creek	Connor Creek
Cornucopia district	
Cornucopia	Cornucopia
Simmons	Simmons
Cracker Creek district	
Buckeye	Buckeye
Ibex-Bald Mt	Ibex
	Bald Moutain
North Pole-Columbia	Climax
	Columbia
	Cracker Oregon
	Eureka and Excelsior
	Golconda
	Mountain Bell
	North Pole
	Tabor Fraction
Analulu-Bunker Hill	Analulu
	Climax
Mammoth Belle of Baker	Belle of Baker
	Mammoth
Eagle Creek district	
East Eagle-Sheep Rock	East Eagle
	Sheep Rock
Sanger	Sanger
	Roy and Sturgill
Greenhorn district	
Ben Harrison	Ben Harrison
Bonanza	Bonanza
Greenhorn	Banner
	Banzette
	Diadem
	Don Juan
	Golden Eagle
	Goldern Gate
	Harrison Gp
	IXL
	Owl
	Phoenix
	Rabbit
	Roberts
	Royal White
	Snow Creek
	West Side
Red Boy	Carbonate
	Portland
	Quick Action
	Morris

	Red Boy
	Tempest
	Tiger
Ruby Creek	Ruby Creek
Stalter (Heppner)	
	Stalter
	Wray

Granite district

Granite	Ajax
	Buffalo
	Continental
	Cougar
	Independenc
	New York
	Magnolia
	Standard
	Tillicum
La Belleview	La Belleview

Mormon Basin district

Mormon Basin	Cleveland
	Blue Mud
	Hice
	Humbolt
	Overshot
	Rainbow
	Randall
	Summut
	Sunday Hill

Quartzburg district

Dixie Meadows	
	Dixie Meadows

Rock Creek district

Chloride	Chloride
Cub	Cub
Rock Creek	Baisley Elkhorn
	Highland
	Maxwell
	Western Union

Sparta district

Gold Ridge	Gold Ridge
	Del Monte
Macy	Macy

Susanville district

Badger	Badger
	Golden Gate
	Hometake
	Side Issue
	Stockton

Unity district

Bull Run-Record	
	Bull Run
	Record

Virtue area

Cliff-Flagstaff	Cliff
	Flagstaff
Emma	Emma
Hidden Treasure	
	Hidden Treasure
	Friday
	Columbian
Rachel	Rachel
	Norwood
	Cyclone
Virtue	Virtue
White Swan	White Swan

Table 2. List of mines, the name of the deposit each is a member, and the name of the district the deposit is found. Presence of deposits in this table does not necessarily mean that usable data was present for modeling.

Mine Name	Desposit Name	District/Area
Analulu	Analulu-Bunker Hill	Cracker Creek
Baby McKee	Cable Cove	Cable Cove district
Badger	Badger	Susanville district
Baisley Elkhorn	Rock Creek	Rock Creek district
Bald Mountain	Ibex-Bald Moutain	Cracker Creek district
Banner	Greenhorn	Greenhorn district
Banzette	Greenhorn	Greenhorn district
Banzette	Stalter	Greenhorn district
Bay Horse	Bay Horse	Connor Creek district
Belle of Baker	Mammoth Belle of Baker	Cracker Creek
Ben Harrison	Ben Harrison	Greenhorn district
Blue Mud	Mormon Basin	Mormon Basin district
Bonanza	Bonanza	Greenhorn district
Buckeye	Buckeye	Cracker Creek
Buffalo	Ajax	Granite district
Bull Run	Bull Run-Record	Unity district
California	Cable Cove	Cable Cove district
Carbonate	Red Boy	Greenhorn
Carpender Hill	Tom Paine	Baker district
Chloride	Chloride	Rock Creek district
Cleveland	Mormon Basin	Mormon Basin district
Cliff	Cliff-Flagstaff	Virtue district
Climax	Analulu-Bunker Hill	Cracker Creek
Climax	North Pole-Columbia	Cracker Creek
Columbia	North Pole-Columbia	Cracker Creek
Columbian	Hidden Treasure	Virtue district
Connor Creek	Connor Creek	Connor Creek district
Continental	Ajax	Granite district
Cornucopia	Cornucopia	Cornucopia district
Cougar	Ajax	Granite district
Cracker Oregon	North Pole-Columbia	Cracker Creek
Crown Point	Cable Cove	Cable Cove district
Cub	Cub	Rock Creek district
Cyclone	Rachel	Virtue district
Dale	Dale	Baker district
Del Monte	Gold Ridge	Sparta district
Diadem	Greenhorn West	Greenhorn district
Dixie Meadows	Dixie Meadows	Quartzburg district
Don Juan	Greenhorn East	Greenhorn district
East Eagle	East Eagle-Sheep Rock	Eagle Creek district
Emma	Emma	Virtue district

Eureka and Excelsior	North Pole-Columbia	Cracker Creek
Flagstaff	Cliff-Flagstaff	Virtue district
Friday	Hidden Treasure	Virtue district
Golconda	North Pole-Columbia	Cracker Creek
Gold Ridge	Gold Ridge	Sparta district
Golden Eagle	Greenhorn East	Greenhorn district
Golden Gate	Badger	Susanville district
Goldern Gate	Golden Gate-Royal White	Greenhorn district
Granite	Ajax	Granite district
Great Northern	Great Northern	Canyon district
Harrison Gp	Greenhorn West	Greenhorn district
Hice	Mormon Basin	Mormon Basin district
Hidden Treasure	Hidden Treasure	Virtue district
Highland	Rock Creek	Rock Creek district
Hometake	Badger	Susanville district
Humbolt	Mormon Basin	Mormon Basin district
Ibex	Ibex-Bald Moutain	Cracker Creek district
Imperial-Eagle	Cable Cove	Cable Cove district
Independenc	Ajax	Granite district
IXL	Greenhorn West	Greenhorn district
La Belleview	La Belleview	Granite district
Last Chance	Cable Cove	Cable Cove district
Macy	Macy	Sparta district
Magnolia	Ajax	Granite district
Mammoth	Mammoth Belle of Baker	Cracker Creek
Maxwell	Rock Creek	Rock Creek district
Mile High	Cable Cove	Cable Cove district
Miller Mountain	Miller Mountain	Canyon district
Morris	Red Boy	Greenhorn
Mountain Bell	North Pole-Columbia	Cracker Creek
New York	Ajax	Granite district
North Pole	North Pole-Columbia	Cracker Creek
Norwood	Rachel	Virtue district
Oregon Chief	Cable Cove	Cable Cove district
Overshot	Mormon Basin	Mormon Basin district
Owl	Greenhorn East	Greenhorn district
Phoenix	Greenhorn East	Greenhorn district
Portland	Red Boy	Greenhorn
Praire Diggings	Praire Diggings	Canyon district
Rabbit	Greenhorn East	Greenhorn district
Rachel	Rachel	Virtue district
Rainbow	Mormon Basin	Mormon Basin district
Randall	Mormon Basin	Mormon Basin district
RecordBull	Run-Record	Unity district
Red Boy	Red Boy	Greenhorn district
Roberts	Greenhorn West	Greenhorn district
Roy and Sturgill	Sanger	Eagle Creek district
Royal White	Golden Gate-Royal White	Greenhorn district
Ruby Creek	Ruby Creek	Greenhorn district

Sanger	Sanger	Eagle Creek district
Sheep Rock	East Eagle-Sheep Rock	Eagle Creek district
Side Issue	Badger	Susanville district
Simmons	Simmons	Cornucopia district
Snow Creek	Greenhorn West	Greenhorn district
Stalter (Heppner)	Stalter (Heppner)	Greenhorn district
Standard	Ajax	Granite district
Stockton	Badger	Susanville district
Stub	Stub	Baker district
Summut	Mormon Basin	Mormon Basin district
Sunday Hill	Mormon Basin	Mormon Basin district
Tabor Fraction	North Pole-Columbia	Cracker Creek
Tempest	Red Boy	Greenhorn
Tiger	Red Boy	Greenhorn
Tillicum	Ajax	Granite district
Tom Paine-Old Soldier	Tom Paine	Baker district
Virtue	Virtue	Virtue district
West Side	Greenhorn West	Greenhorn district
Western Union	Rock Creek	Rock Creek district
White Swan	White Swan	Virtue district
Wray	Stalter (Heppner)	Greenhorn district
Young American	Tom Paine	Baker district

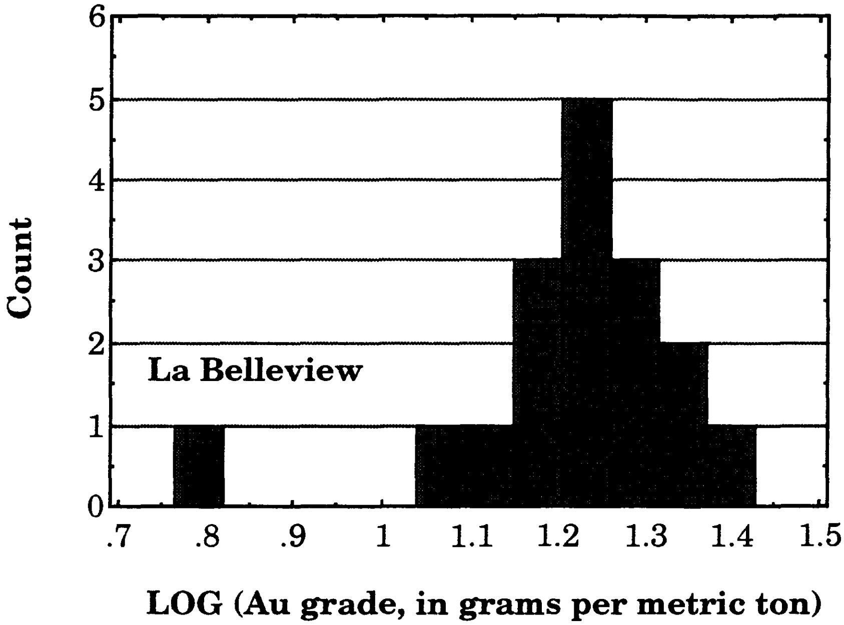

Figure 1. Histogram of of gold grades of Blue Mountain-type Au-Ag polymetallic veins.

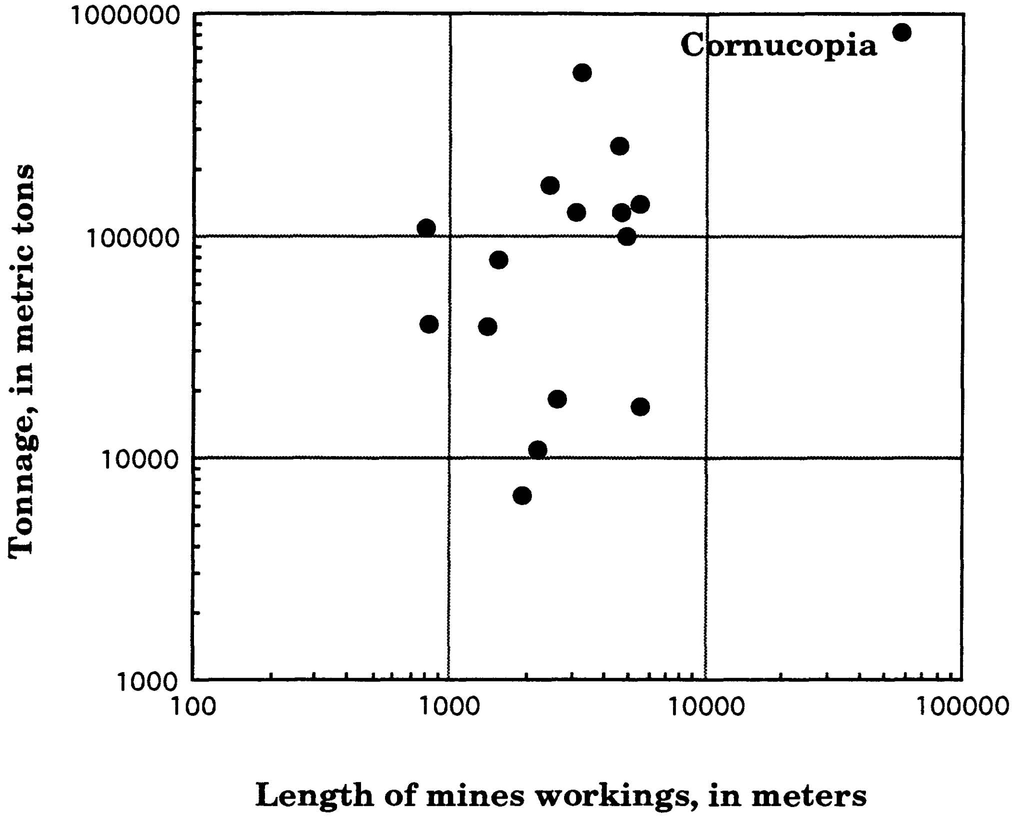

Figure 2. Scatter plot of deposit sizes and length of mine workings of Blue Mountain-type Au-Ag polymetallic veins.

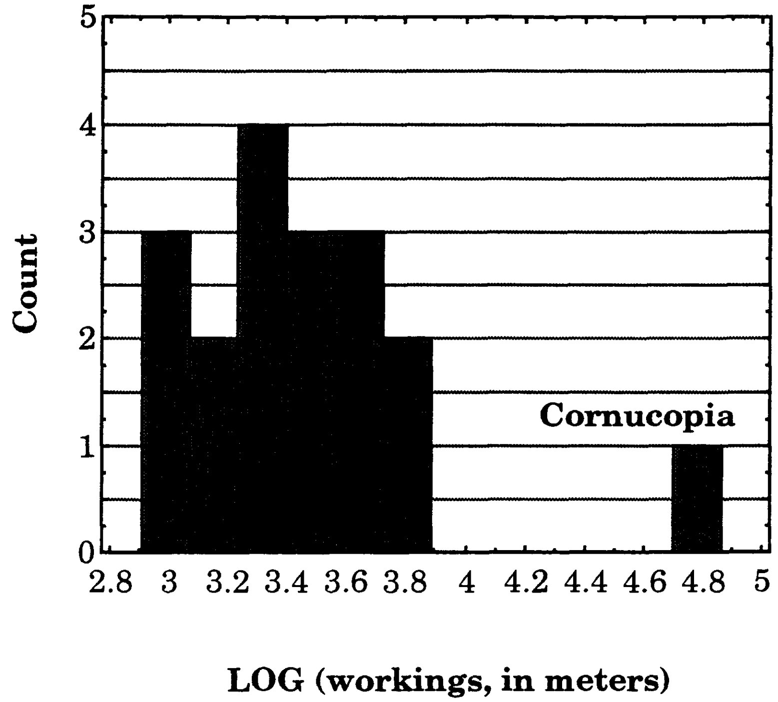

Figure 3. Histogram of of mine workings lengths of Blue Mountain-type Au-Ag polymetallic veins.

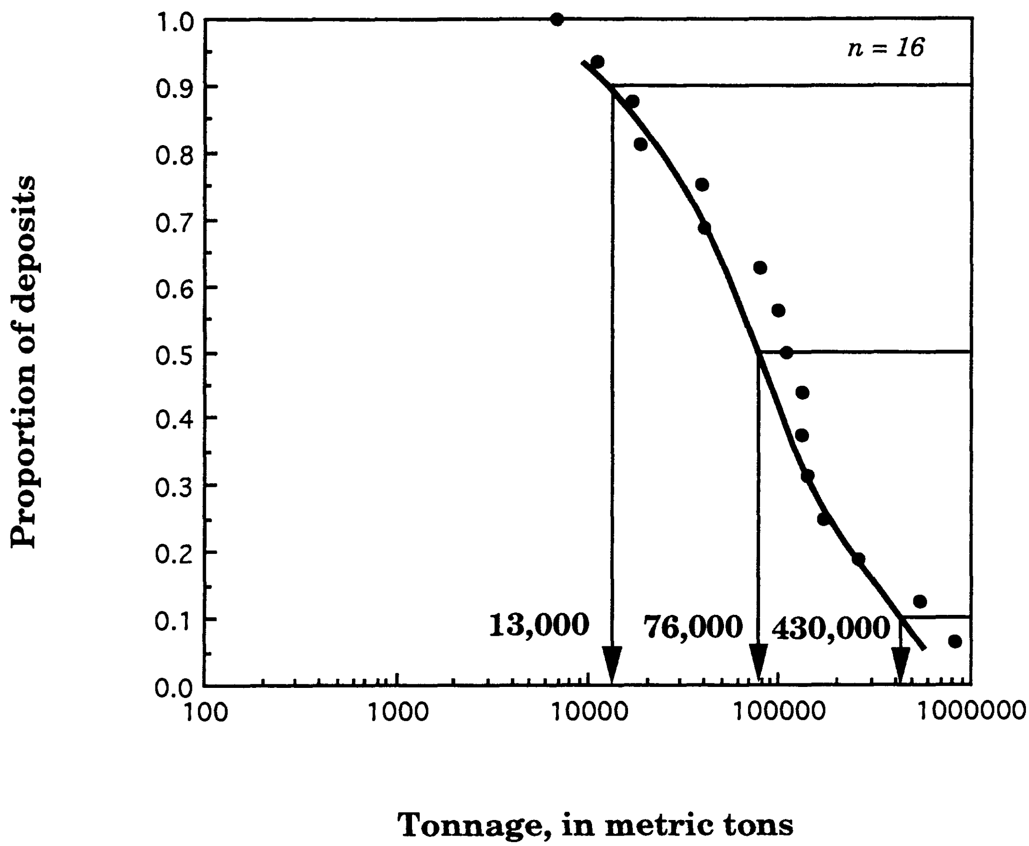

Figure 4. Tonnage of Blue Mountain-type Au-Ag polymetallic veins.

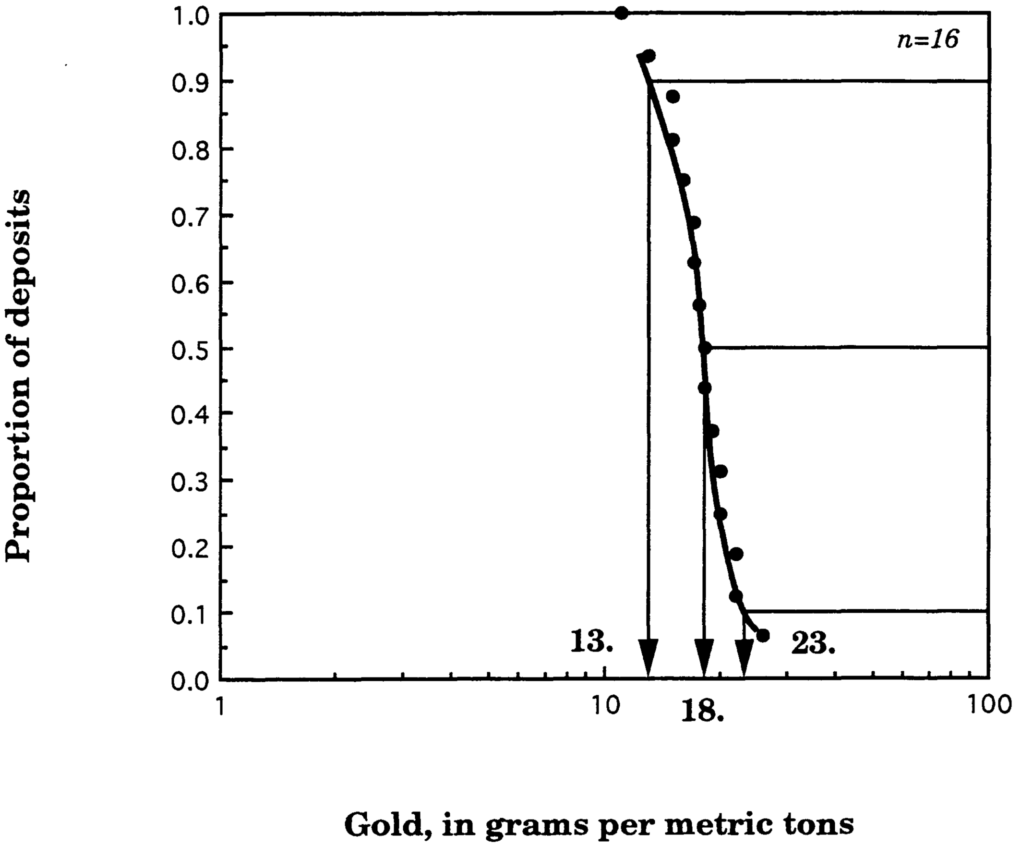

Figure 5. Gold grades of Blue Mountain-type Au-Ag polymetallic veins.

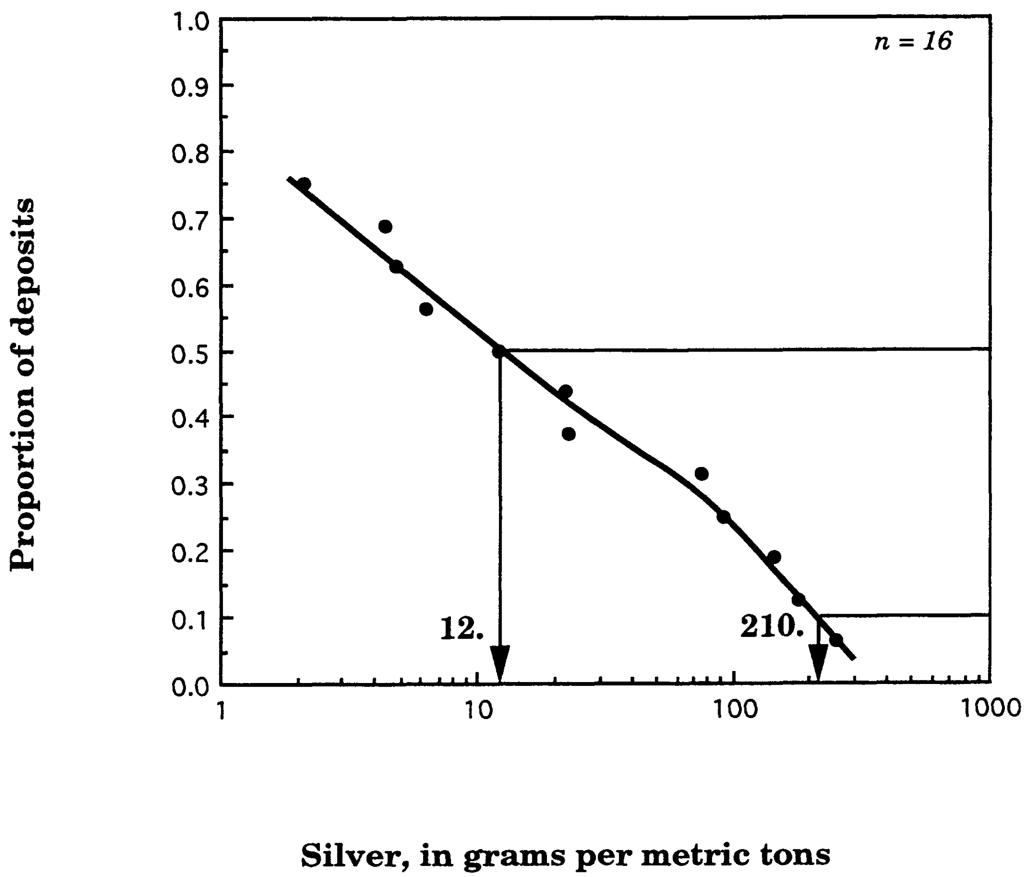

Figure 6. Silver grades of Blue Mountain-type Au-Ag polymetallic veins.

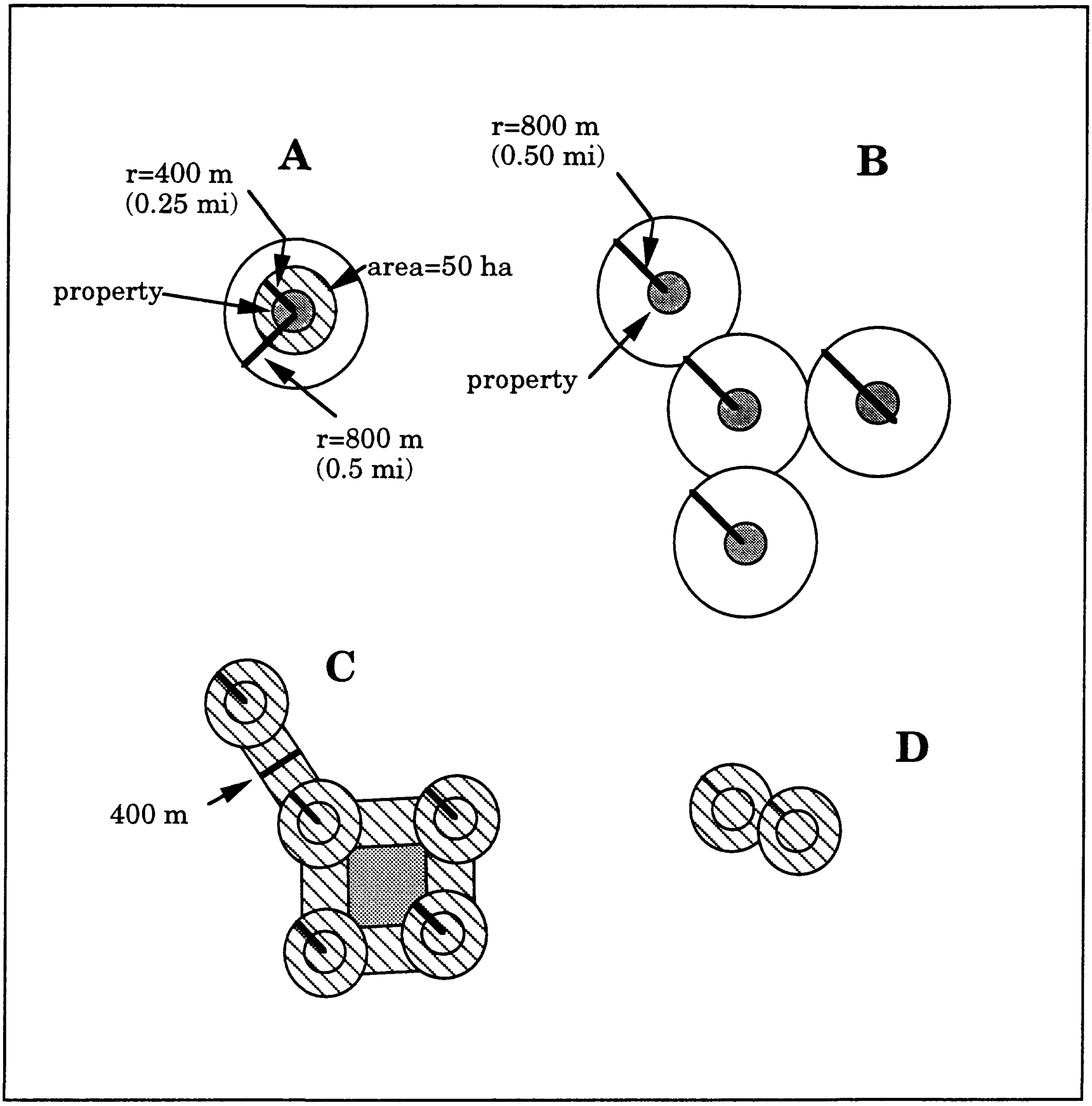

Figure 7. (A) deposit with a single mine--circles giving radii used in clustering (800 m) mines into deposits and to calculated target area (400 m, ruled plus shaded area) of a deposit with a single mine; **(B)** example of cluster properties within 1.6 km of one another to make deposits; **(C)** example of calculate of target area for a cluster of mines using circles of radii of 400 m and connecting segments of 400 m wide (applicable area ruled), include enclosed areas (gray tone); and **(D)** calculated target area for two adjacent properties (ruled).

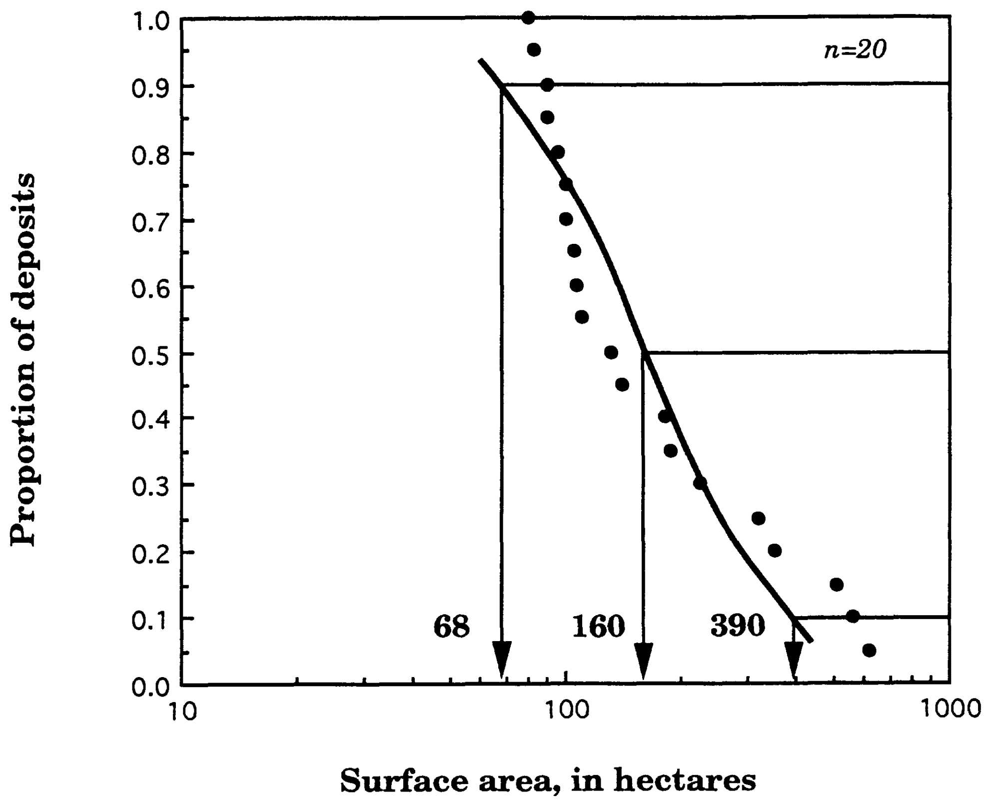

Figure 8. Target areas of Blue Mountain-type Au-Ag polymetallic veins greater than 50 hectares.

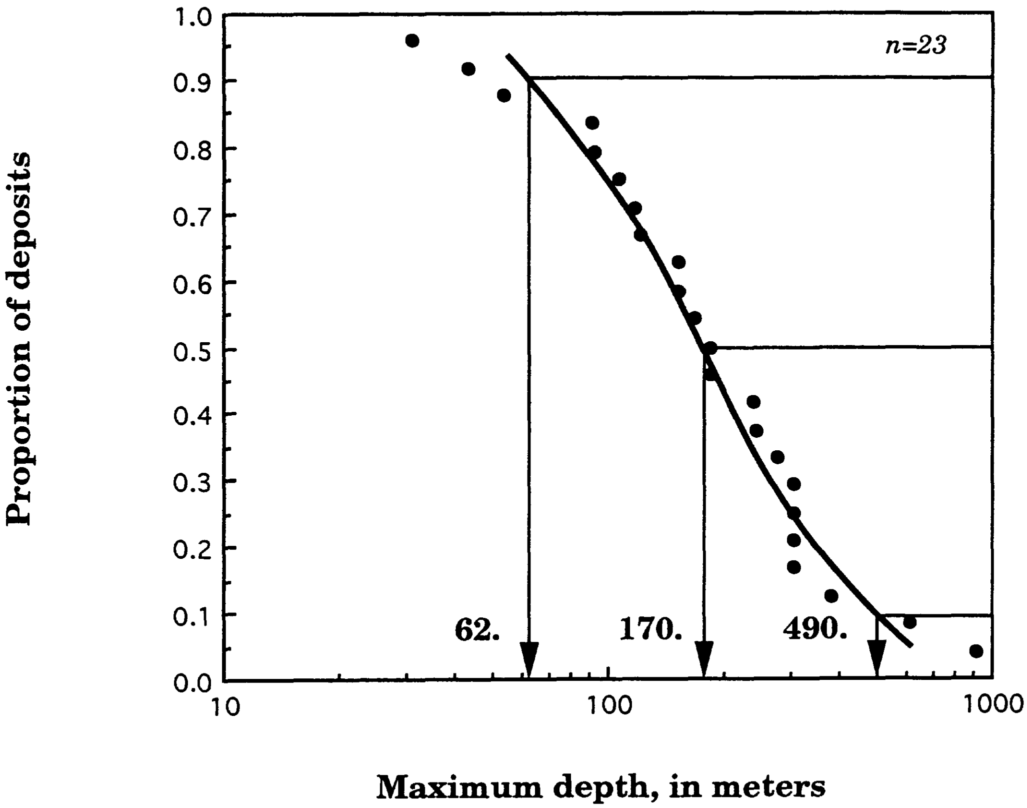

Figure 9. Maximum depth of mines in Blue Mountain-type Au-Ag polymetallic veins.

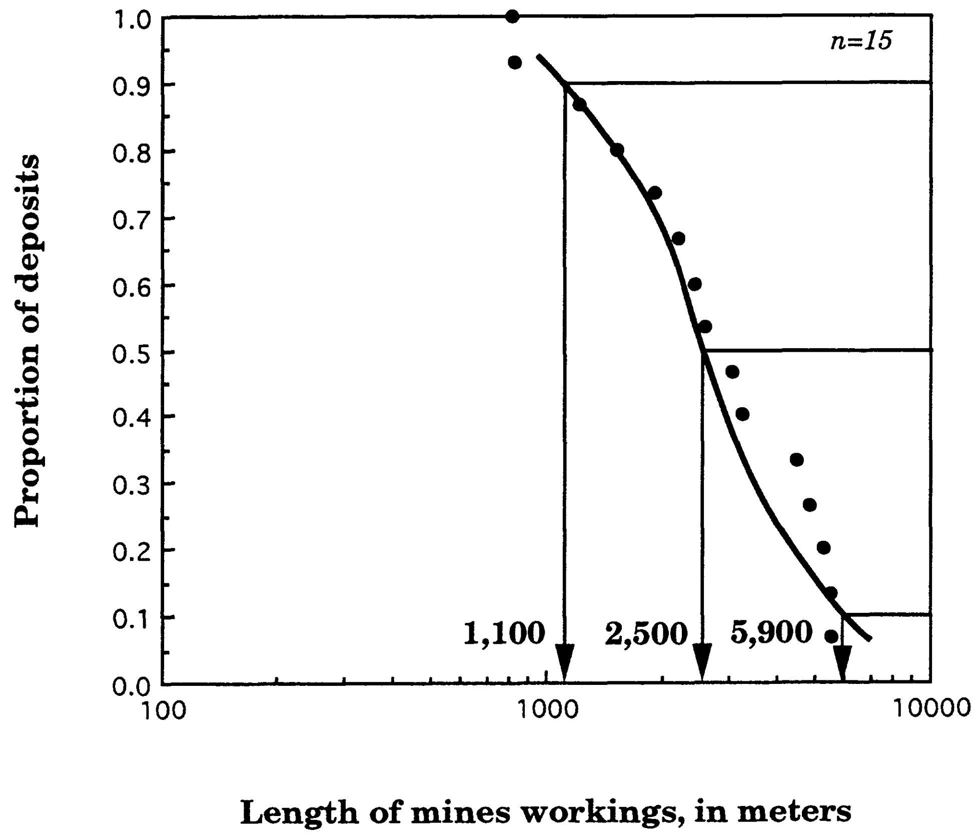

Figure 10. Length of mine workings of Blue Mountain-type Au-Ag polymetallic veins.

Apprendix A.

Grade, tonnage, and other data for Blue Mountain-type Au-Ag polymetallic veins.

[NOTE: •--deposit used in grade and tonnage model; Cu, Pb, and Zn grades (in italic) are suspect (see text) and not to be used in modeling.]

Name	County	max. depth (m)	workings est. lgth (m)	Target area (ha)	Ctd Au (t)	Size (t)	Au (g/t)	Ag (g/t)	Cu (%)	Pb (%)	Zn (%)	Comments
Analulu-Bunker Hill	Baker		490	83			8.3					
Badger	Grant	152	823	222	0.56	2,500	226					excluded from some models (see text)
•Ben Harrison	Grant	168	1218	50	0.663	39,000	17	250				
•Bonanza	Baker	381	5484	50	2.66	140,000	19	6.2				
Buckeye	Baker	274	1219	50								
Bull Run-Record	Baker		366	105	0.2115							oxidized ore
•Cable Cove	Baker, Grant	240	5500	318	0.306	17,000	18	180	*0.56*			
Chlorite Mine	Baker		61									
•Cliff-Flagstaff	Baker	91.4	1900	110	0.1496	6,800	22	4.8				
•Connor Creek	Baker	305	2437	50	1.87	170,000	11					
•Cornucopia	Baker	914	57911	141	13.12	820,000	16	75	*0.11*	*0.025*		
•Dixie Meadows	Baker		2200	50	0.143	11,000	13					
East Eagle-Sheep Rock	Baker		350	95	0.044							
Emma	Baker				0.373							
Gold Ridge (New Deal)	Baker	43		106	0.187							
•Granite	Baker	183	4875	557	1.8	100,000	18	91	*0.002*	*0.00071*	*0.000016*	
Great Northern	Baker				0.047							
•Greenhorn	Baker	53	2592	508	0.3179	18,180	17.5					
Ibex-Bald Mountain	Baker, Grant	305	3046	100			17	170				
La Belleview	Grant	183	1828	80	0.754	130,000	5.8	290	*0.086*	*0.012*		
Macy	Baker		457	50	0.135							
•Mammoth-Belle of Baker	Baker	117	819	90	0.6	40,000	15	12				
Miller Mountain	Grant		1220	50	0.075							
•Mormon Basin	Baker	152	4500	612	3.866	256,000	15	4.4				
Mountain View	Baker	31		50	0.1493							
•North Pole-Columbia	Baker	305	3217	350	11.88	540,000	22	22				
Rachel	Baker	244	915	188	0.227							
•Red Boy	Grant	92	1525	50	1.55	78,000	20	22.6				
•Rock Creek	Baker	609	5264	180	2.21	130,000	17	146				
Ruby Creek	Baker				0.0084							
•Sanger	Baker	122	807	100	2.2	110,000	20					
Simmons	Baker			50	0.0077	862	8.1	60				Excluded from some models(see text)
Stalter (Heppner)	Baker			132	0.0086	163	53					Excluded from some models(see text)
Tom Paine-Old Soldier	Baker		865	90	0.054							
•Virtue	Baker	304	3047	50	3.38	130,000	26	2.1				
White Swan	Baker	107		50	0.8397							