UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

INTERNATIONAL MINERALS RESOURCE ASSESSMENT PROJECT

By

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U.S. Geological Survey

INTRODUCTION:

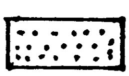
Silver, tin, cobalt, chromium, copper, nickel, platinum, iron .... Will future supplies of such metals be adequate to sustain the sinews of civilization? The limits of mineral resources and their seemingly capricious distribution are compelling witness to the need for better knowledge of total mineral endowment of the planet and the mechanisms by which that endowment has been emplaced (Fig. 1). Despite cyclic fluctuations in economic conditions, the long-term efforts of developing countries to industrialize and improve standards of living will intensify demands on the world's finite store of resources. The United States' Global 2000 Report to the President (1980) wherein "the global demand for and consumption of most major nonfuel mineral commodities is projected to increase 3-5% annually, slightly more than doubling by 2000," is but one of several studies documenting the formidable challenge these demands will present.

Much of the world's industrial base is dependent on supplies of critical minerals from geographically restricted sources, currently vulnerable to embargo and other forms of disruption. Indeed, more than 40% of the known world reserves of nearly a dozen important mineral commodities is in southern Africa and the Soviet Union (Fig. 2). Recognizing the need for more complete information on potential new and diverse sources of supply, the U.S.

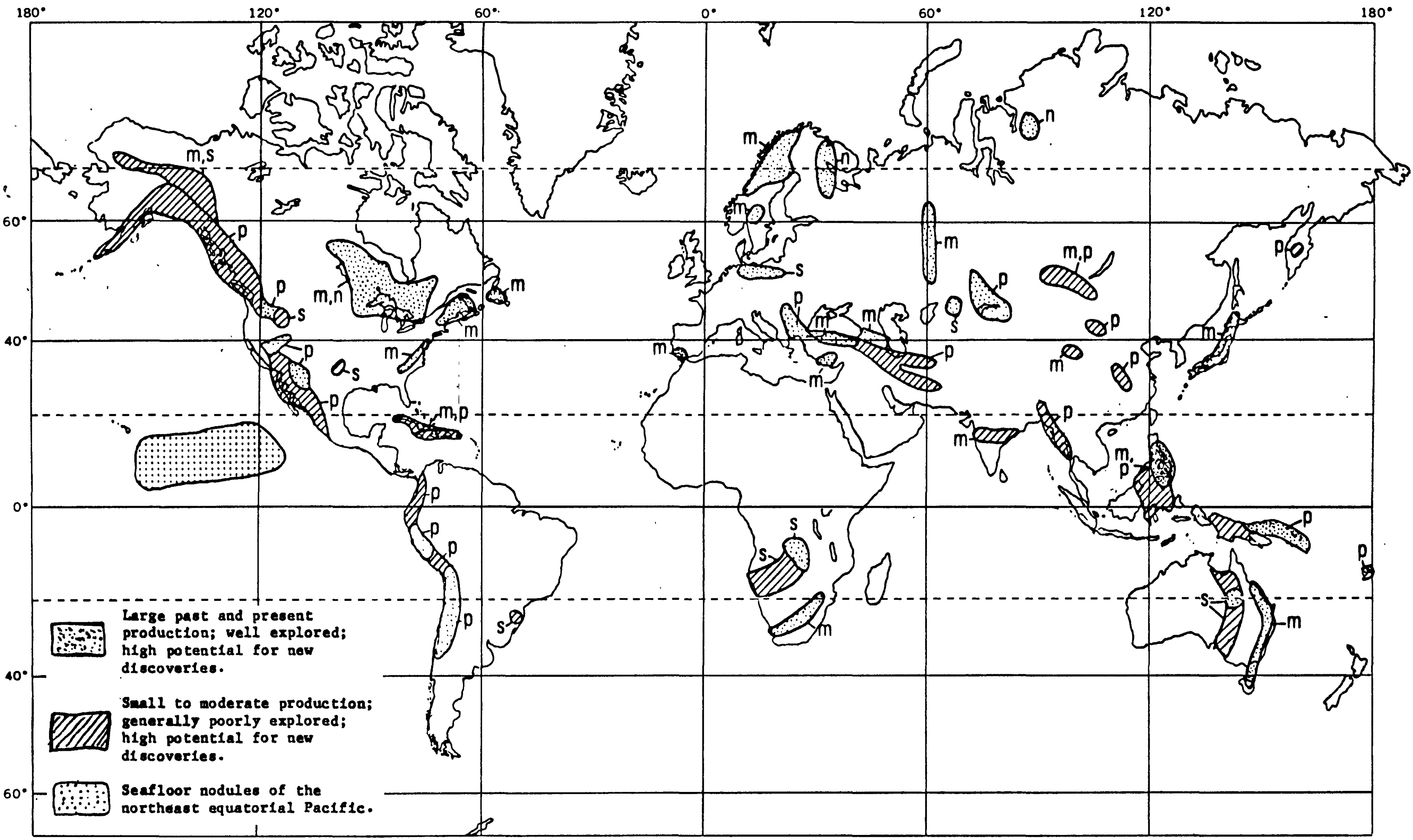
Figure 1. Distribution of world copper deposits and areas of potential mineral discoveries. Distribution of deposit types, each with its own tonnage and grade characteristics, is as unequal among countries as the distribution of copper in general. Letters indicate deposit types: p, porphyry; m, volcanogenic massive sulfide; s, sedimentary; n, magmatic copper nickel. (Modified from: Cox, D. P., 1979, The distribution of copper in common rocks and ore deposits: Nriagu, J. O., ed., Copper in the Environment, Part 1, John Wiley & Sons.)

Large past and present production; well explored; high potential for new discoveries.

Small to moderate production; generally poorly explored; high potential for new discoveries.



Seafloor nodules of the northeast equatorial Pacific.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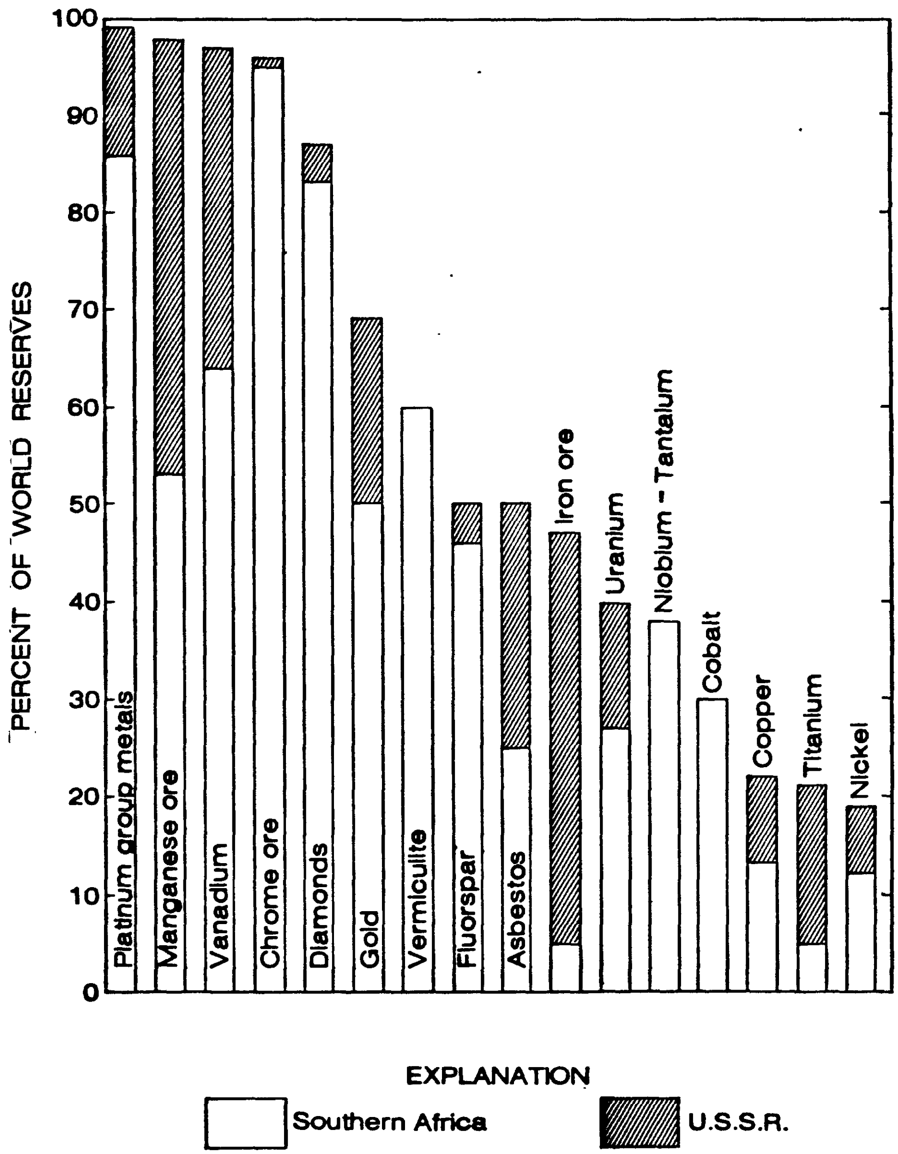
60°
Large past and present production; well explored; high potential for new discoveries.
Small to moderate production; generally poorly explored; high potential for new discoveries.
Seafloor nodules of the northeast equatorial Pacific.

Figure 1.

Figure 2. Combined southern Africa and USSR percentages of world's reserves of selected mineral commodities. (Modified from: Council on Economics and National Security, 1980, The "Resource War" and the U.S. Business Community, A White Paper, Appdx. 9)



PERCENT OF WORLD RESERVES
100
90
80
70
60
50
40
30
20
10
0
Platinum group metals
Manganese ore
Vanadium
Chrome ore
Diamonds
Gold
Vermiculite
Fluorspar
Asbestos
Iron ore
Uranium
Niobium - Tantalum
Cobalt
Copper
Titanium
Nickel
EXPLANATION
Southern Africa
U.S.S.R.

Figure 2.

Geological Survey is initiating cooperative projects to assess systematically the nature and abundance of non-fuel mineral resources in selected countries where exploration has been limited and existing data have not been fully analyzed. Identification of alternative sources potentially available must be pursued.

This project has as its long-term objective a comprehensive inventory of the world's non-fuel mineral resources, insofar as techniques now available permit. Specifically, the task requires identification of favorable mineral deposit environments that offer potential sources of supply to the free world and that can be targeted for exploration. Accomplishing this will lead inevitably to such ancillary benefits as: (a) improvement in geologic concepts and models of ore genesis and deposition; (b) development of international contacts and channels for information exchange; (c) enhancement of internal capability for assessing mineral resources within developing countries; and (d) compilation of information essential for promoting investment and development within a host country. Scope will necessarily be limited during the first year; a single country has been selected to serve as a prototype area for developing an assessment and for evaluating the methods used and products derived. This initial study will be completed within one year. Experience gained thereby will then be extended to larger geographic regions of greater geologic complexity requiring longer duration for study.

The Geological Survey has been involved with other countries in technical assistance and scientific cooperation for more than four decades. Experience gained and contacts established through its international assistance and cooperation will be utilized in carrying out this project. Close consultation and working relationships will be developed with counterpart organizations, including joint planning of activities, joint preparation of reports, and transfer of knowledge and technology. Where appropriate and feasible, the Survey will, as part of this project, install and support a computerized geodata system in the host country.

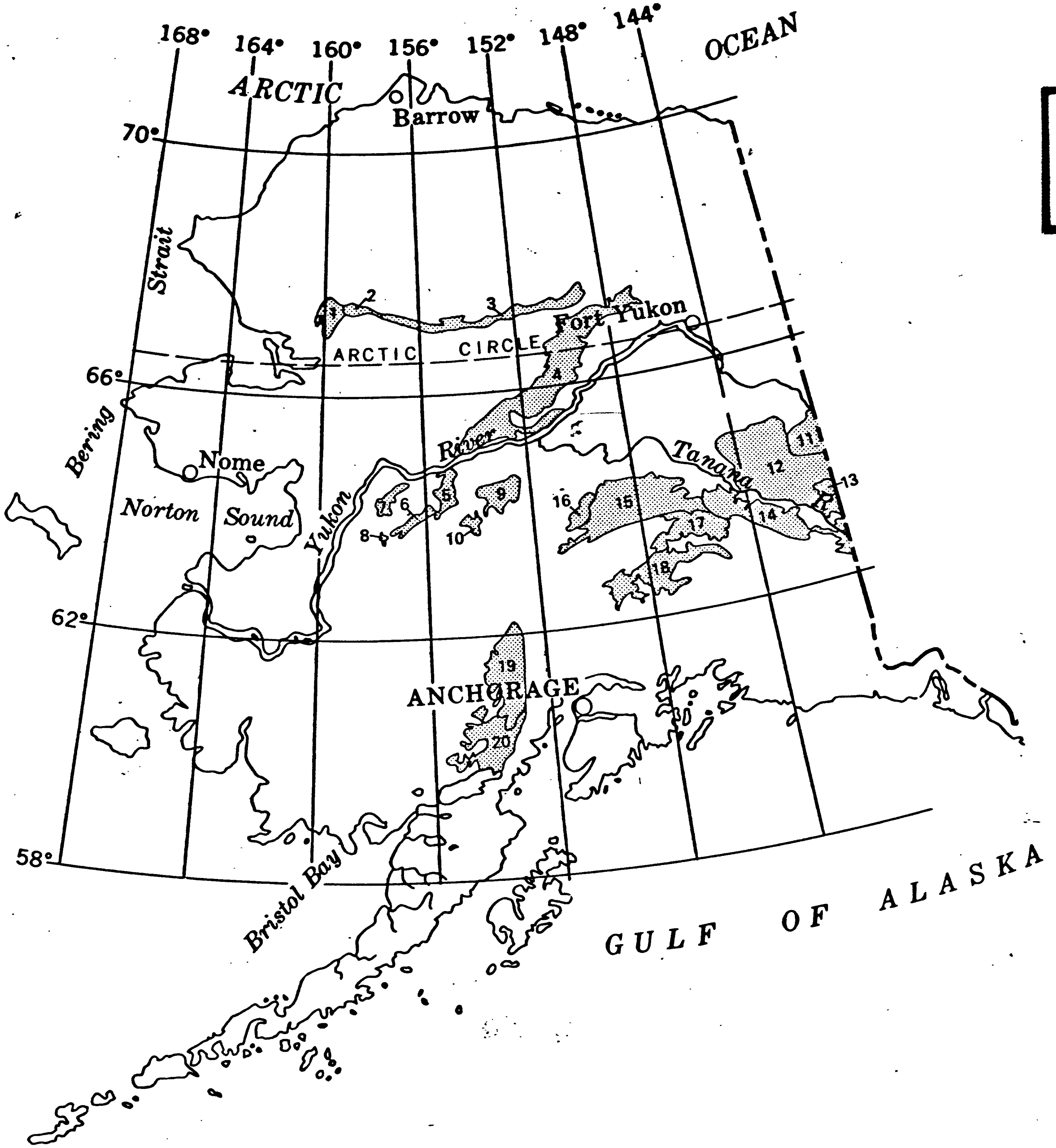
The results of this work should be of considerable benefit to the host country in evaluating its resource potential, as a basis for encouraging investment in exploration and development, and in expanding its domestic and export markets. Inasmuch as the start-up time for a major mining venture is generally on the order of 5 to 20 years, such assessment efforts should be initiated soon in order to identify targets for exploration and ensure timely development. Information generated by the project will also be valuable to the geologic and mineral exploration communities at large, charged with piecing together metallogenic histories of entire regions and environments of ore mineral deposition.

TECHNIQUES OF ANALYSIS

The fundamental assumption underlying this program is that geologic terranes permissive for particular types of mineral deposits can be delineated in poorly explored areas by analogy with better known areas having similar geologic environments. Possible target areas for exploration within these permissive terranes can be identified if there are sufficient geologic, geochemical, geophysical, and mineral occurrence data.

The USGS has developed a general method of resource assessment based on experience gained in Alaskan mineral resource appraisal programs and a similar ongoing mineral assessment program for the conterminous United States. Development of the technique for Alaska was prompted by the need to evaluate mineral resources of lands under consideration for Congressional set-aside for special use; the Survey's work was in response to a mandate from Congress to

Figure 3. Tracts of felsic volcanic rocks in Alaska designated permissive for occurrence of massive sulfide deposits. Numbers in illustration refer to specified terrane types. The general procedures for developing this kind of assessment are described by Singer, D. A., and Ovenshine, A. T., 1979, The assessment of metallic mineral resources of Alaska: American Scientist, v. 67, no. 5, p. 582-589.


168°
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Fort Yukon
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66°
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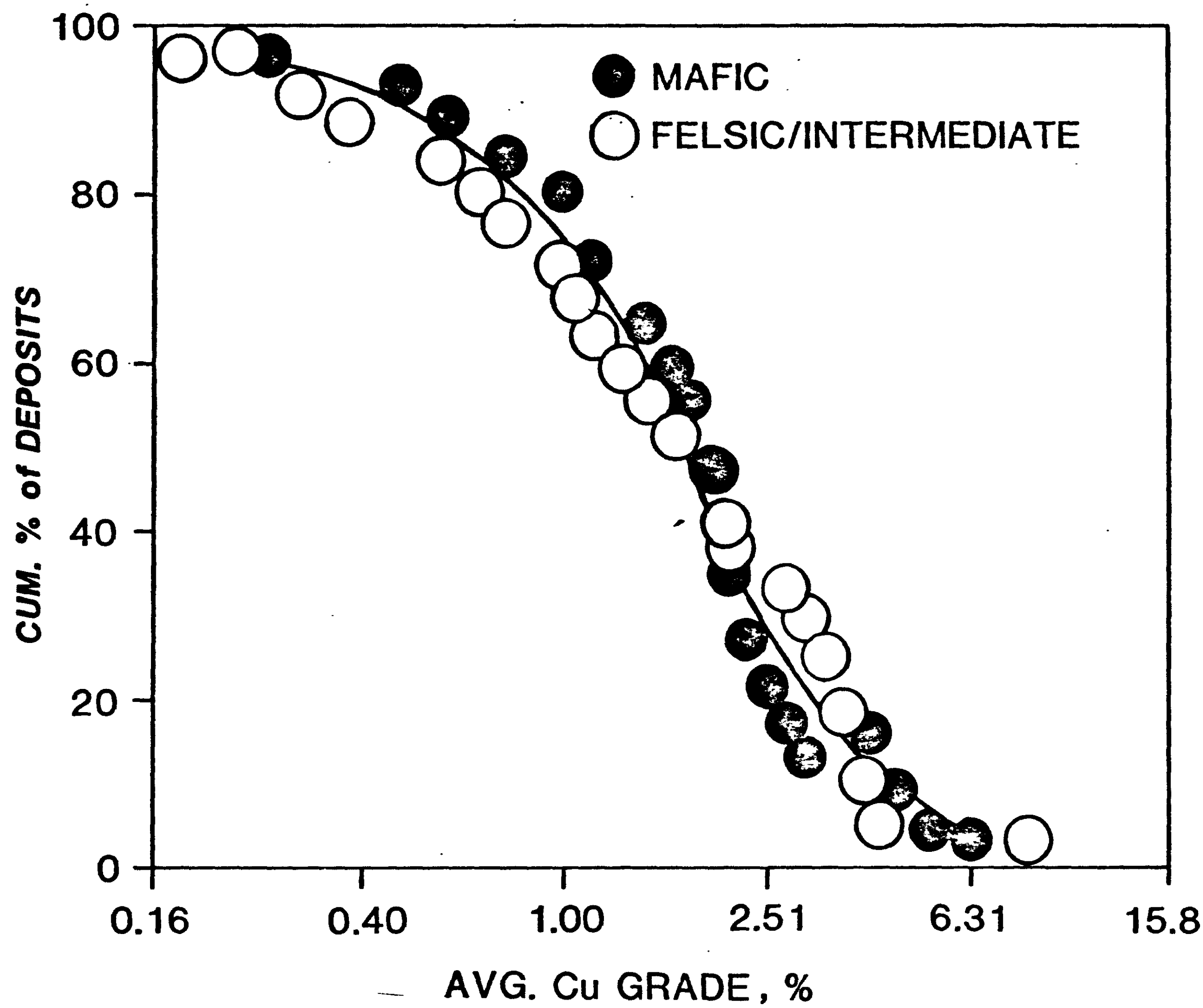
Figure 3.

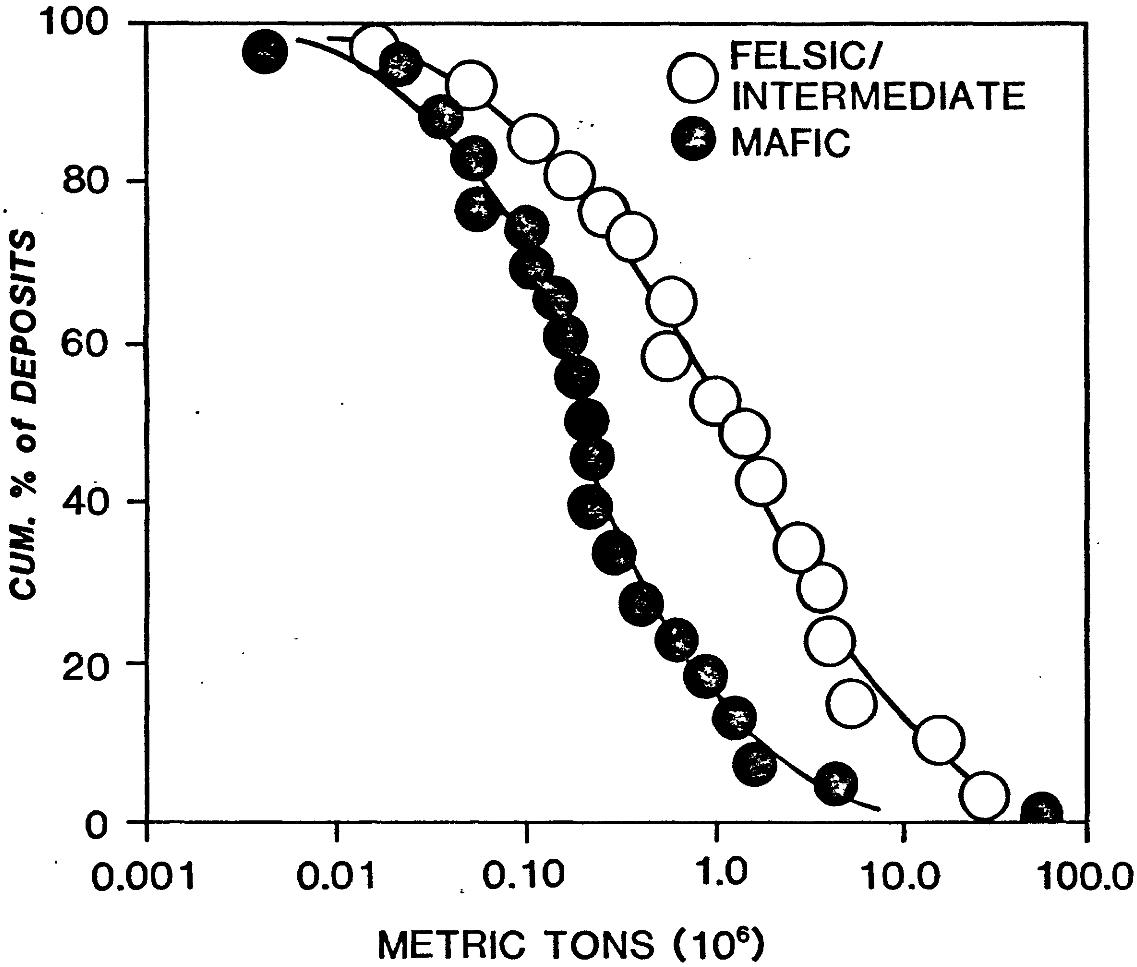
Figure 4a. Average grade of copper in Mesozoic massive sulfide deposits, based on selected worldwide data. Approximately 90% of the deposits contain an average copper grade of 0.4% or more, whereas only 10% of deposits contain 5% copper or more. (From Singer, D. A., Page, N. J, Smith, J. G., Blakely, R. J., and Johnson, M. G., 1982, Mineral Resource Assessment of the Medford 1°x2° Quadrangle, Oregon: U.S. Geol. Survey Open-file Report 82-1037, 28 p., 1:250,000 scale.)

Figure 4b. Total tonnage of ore in Mesozoic massive sulfide deposits, based on selected worldwide data. Approximately 90% of the deposits contain 10,000 metric tons of ore or more, whereas 10% of the deposits in mafic rocks have 1,000,000 tons or more. (From Singer, D. A., Page, N. J, Smith, J. G., Blakely, R. J., and Johnson, M. G., 1982, Mineral Resource Assessment of the Medford 1°x2° Quadrangle, Oregon: U.S. Geol. Survey Open-file Report 82-1037, 28 p., 1:250,000 scale.)



Cu GRADES OF MASSIVE SULFIDE DEPOSITS
CLASSIFIED BY FOOTWALL COMPOSITION

Figure 4a.



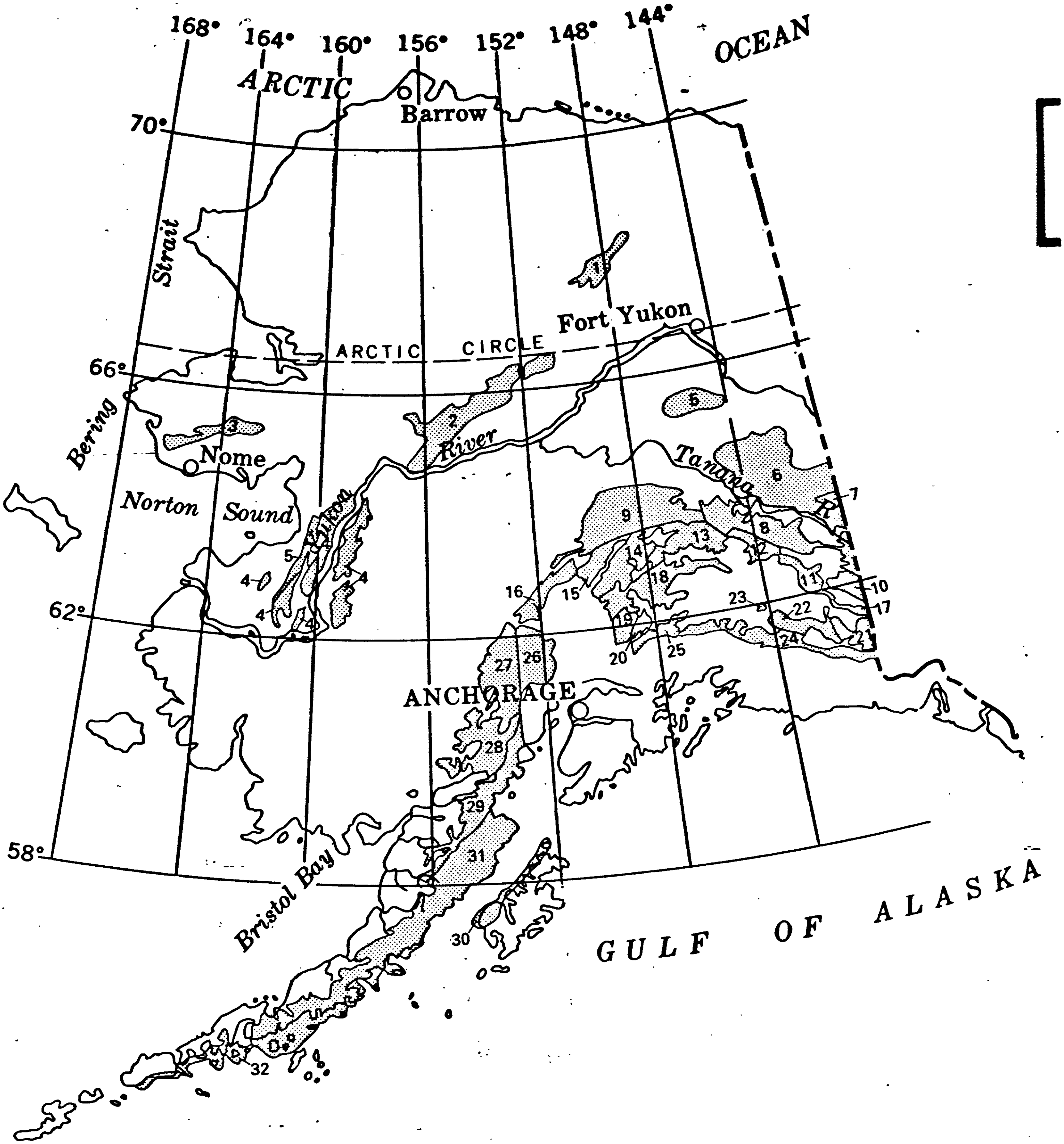
MASSIVE SULFIDE DEPOSITS
CLASSIFIED BY FOOTWALL COMPOSITION

Figure 4b.

carry out this appraisal within a limited time frame, relying largely on data already at hand. Lands found to contain potentially economic mineral resources were not to be set aside. In these studies, specific terranes, or combinations of rock units, were designated according to geologic characteristics and corresponding metallogenic affinities. Extrapolation based on experience in better known mineral districts world-wide permitted an evaluation of the kinds, and to some extent, amounts of mineral resources (based on estimated number of deposits combined with tonnage and grade models) potentially discoverable within a given terrane type. For example, felsic-volcanic terranes were identified in Alaska (fig. 3). Such terranes are known to be favorable for occurrence of massive sulfide deposits. Based on worldwide data for known massive sulfide deposits in mafic and felsic rocks (figs. 4a, b), models have been developed for predicting tonnage and grade for estimated numbers of undiscovered deposits in a given tract (fig. 3). Alaskan terranes permissible for porphyry copper mineralization are outlined in Figure 5, and the resources were assessed for these tracts using similar techniques.

The techniques developed and applied in Alaska provide a promising means of assessing the extent and ultimate productivity of both known and undiscovered resources in other regions throughout the world. Basic data required are geologic maps at a practical scale (preferably at least as large as 1:250,000), and a detailed survey of known mineral occurrences; geochemical and geophysical data are essential for a fully comprehensive assessment. Refinement of the method can be expected as it is extended to different geologic terranes and metallogenic provinces. The method is dependent on existence of a fairly inclusive basic data base, but it entails an innovative approach to compilation and analysis.

Figure 5. Tracts in Alaska identified as permissive for occurrence of porphyry copper deposits. Numbers in illustration refer to specific terrane types. Assessment method is described by Singer, D. A., and Ovenshine, A. T., 1979, The assessment of metallic mineral resources of Alaska: American Scientist, v. 67, no. 5, p. 582-589.



168° 164° 160° 156° 152° 148° 144°
ARCTIC
OCEAN
Barrow
70°
Strait
Fort Yukon
ARCTIC CIRCLE
66°
Bering
Nome
Norton
Sound
Yukon
River
Tanana
R.
62°
ANCHORAGE
58°
Bristol Bay
GULF OF ALASKA
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Figure 5.

PRODUCTS

The results of these assessment studies will be presented predominantly in map format suitable for promoting exploration, development, and general land-use planning by the host country. User needs include identification of prospective terranes by deposit types; an indication of number, magnitude, and quality of undiscovered deposits; the criteria used in making such an assessment; the constraints on development of a deposit; and an easily updated and expandable deposit inventory. The principal product of the assessment will be a comprehensive package consisting of:

1. 1:1,000,000 scale mineral resources map that combines geologic terrane maps with metallogenic, mineral occurrence, and geochemical data, and identifies tracts favorable for the occurrence of specific mineral deposit types;
2. Probabilistic estimates of tonnages and grades for undiscovered deposits of those types for which tonnage and grade models have been developed on basis of worldwide data;
3. Probabilistic estimates of the number of undiscovered deposits within each designated tract, insofar as such estimates are possible; and
4. A written summary of the data and analyses for each tract.

Such an assessment provides a basis for:

a. recommending projects for further data acquisition and research;

b. outlining a strategy for exploration and development of delineated target areas;

c. national planning of transportation and power networks with respect to sources of raw materials; and

d. making appropriate national decisions regarding long-range policy and land use.

In addition, the final product package will include:

1. All working compilation maps, independently showing geological, tectonic, geochemical, geophysical, and mineral occurrence data; and
2. A synthesis of geologic, mineralogic, tectonic, and geophysical data in a derivative geologic map (1:1,000,000 scale) showing terrane designations within the lithologic-tectonic framework;
3. A compendium of ore deposit models appropriate for geologic environments in the assessment area;
4. A computerized file listing details of each recorded mineral occurrence, if such a compilation is appropriate for the scope and time of the project;
5. An annotated bibliography, if not already available.

The procedure for developing these products is shown schematically in the accompanying illustration (Fig. 6).

ORGANIZATION AND SCHEDULE

The minerals assessment project will be developed cooperatively by a U.S.G.S. team and counterpart specialists in a host country. Survey representatives will include a regional geologist, economic geologist, geochemist, geophysicist, and a resource analyst. Following initial contact by a Survey official and agreement between organizations on a general concept, the USGS science team will visit the host country to meet with its foreign colleagues and together draw up a detailed operating plan, as well as a formal project description for official approval in each country. This introductory

Figure 6a,b,c,d. Development of a comprehensive mineral resource assessment for a hypothetical area. Final product includes both maps and written summaries.

6a. Geologic data required for delineating terrane types.

6b. Mineral deposit and geochemical data combined with terrane designations to identify tracts favorable for specific deposit types on mineral resource maps.

6c. Mineral resource map combined with tonnage and grade models for known deposit types, resulting in comprehensive resource assessment that includes written summary for each terrane tract and estimated number of potential deposits within each tract (6d).

6d. Detailed analysis of metalliferous mineral resources for given tract in Alaska (from Singer, D.A. and Ovenshine, A.T., 1979, The assessment of metallic mineral resources of Alaska: American Scientist, v. 67, no. 5, p. 582-589).

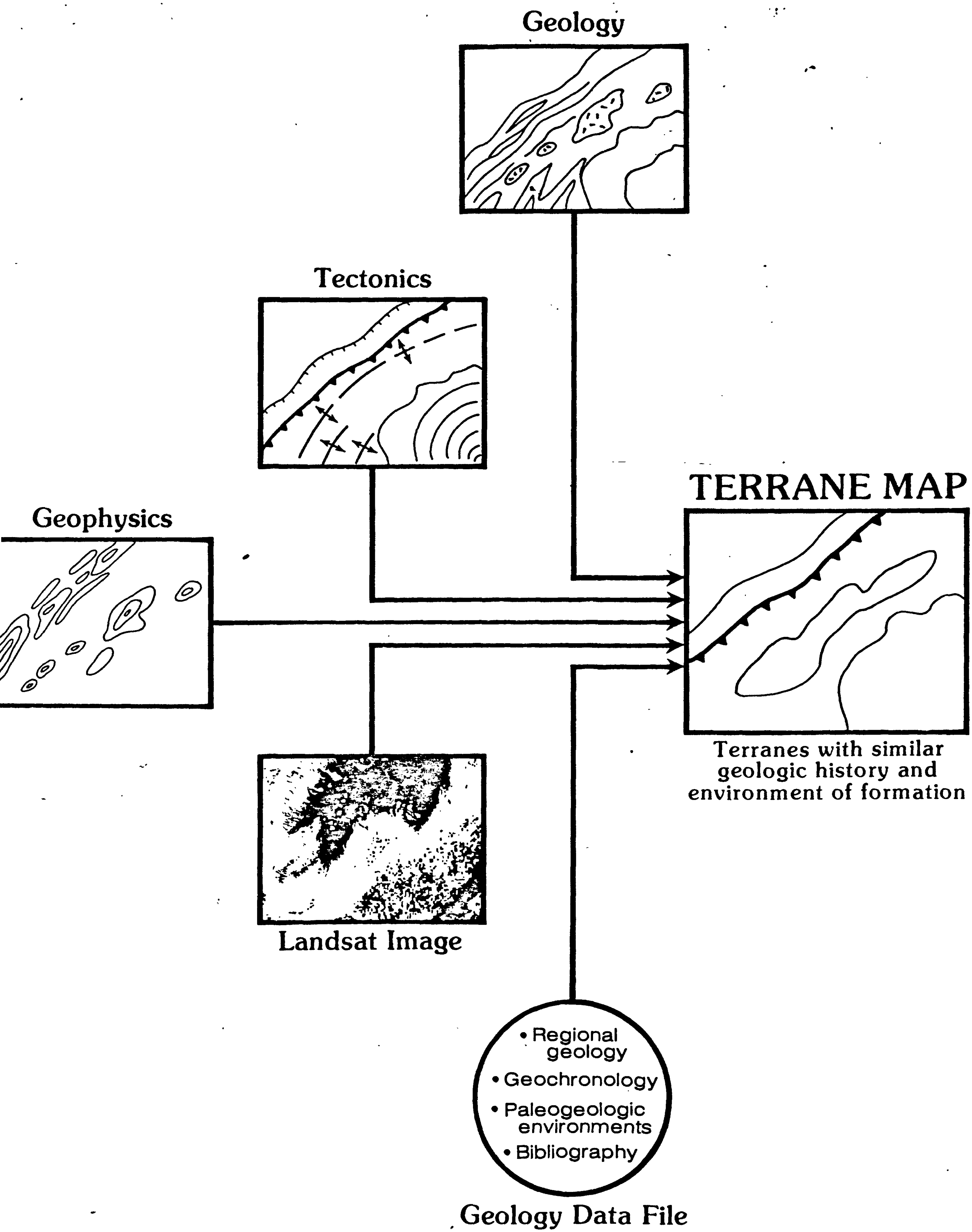
Geology
Tectonics
Geophysics
TERRANE MAP
Terranes with similar geologic history and environment of formation
Landsat Image
• Regional geology
• Geochronology
• Paleogeologic environments
• Bibliography
Geology Data File

Figure 6a.

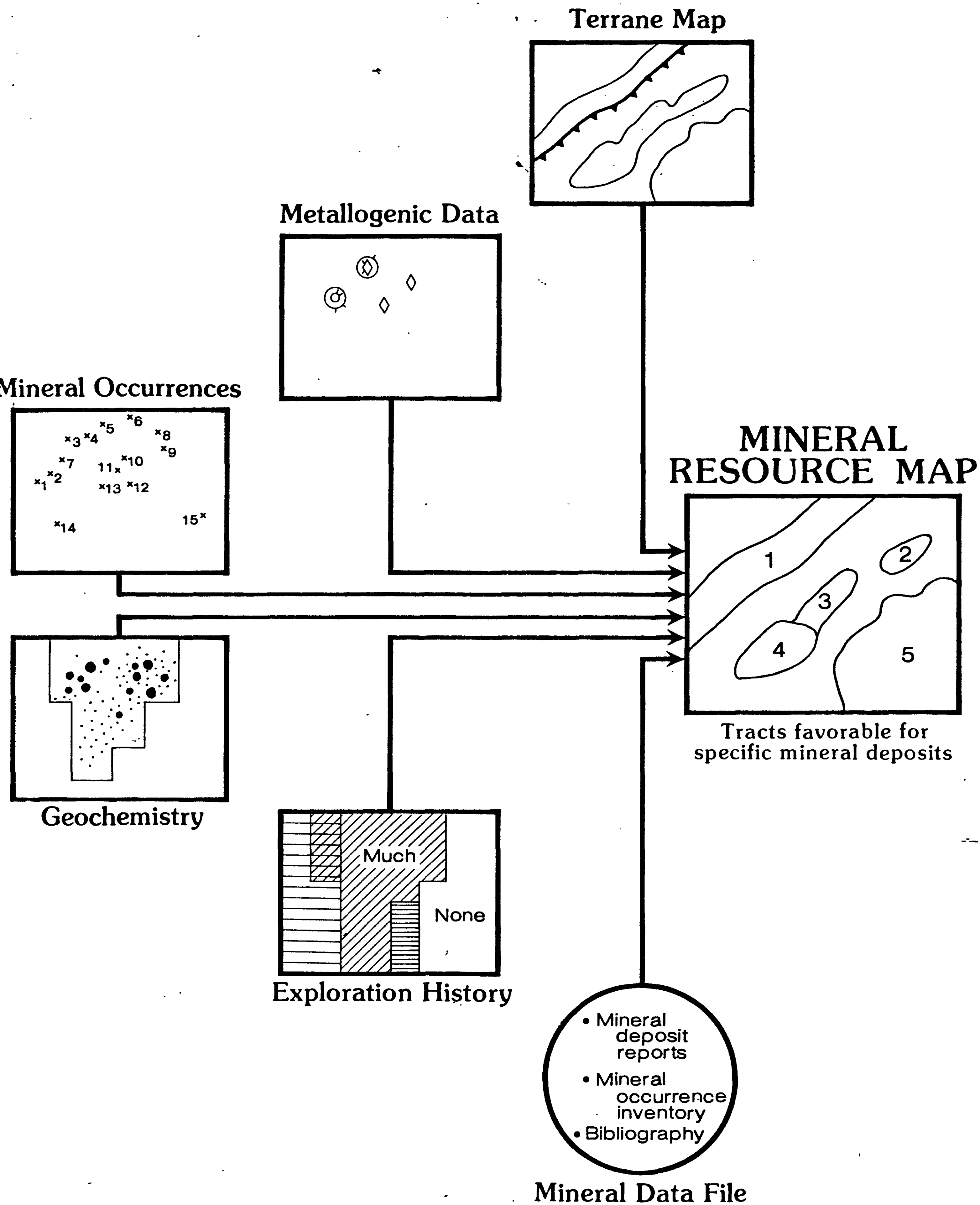
Terrane Map
Metallogenic Data
Mineral Occurrences
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
MINERAL RESOURCE MAP
1
2
3
4
5
Tracts favorable for specific mineral deposits
Geochemistry
Much
None
Exploration History
• Mineral deposit reports
• Mineral occurrence inventory
• Bibliography
Mineral Data File

Figure 6b.

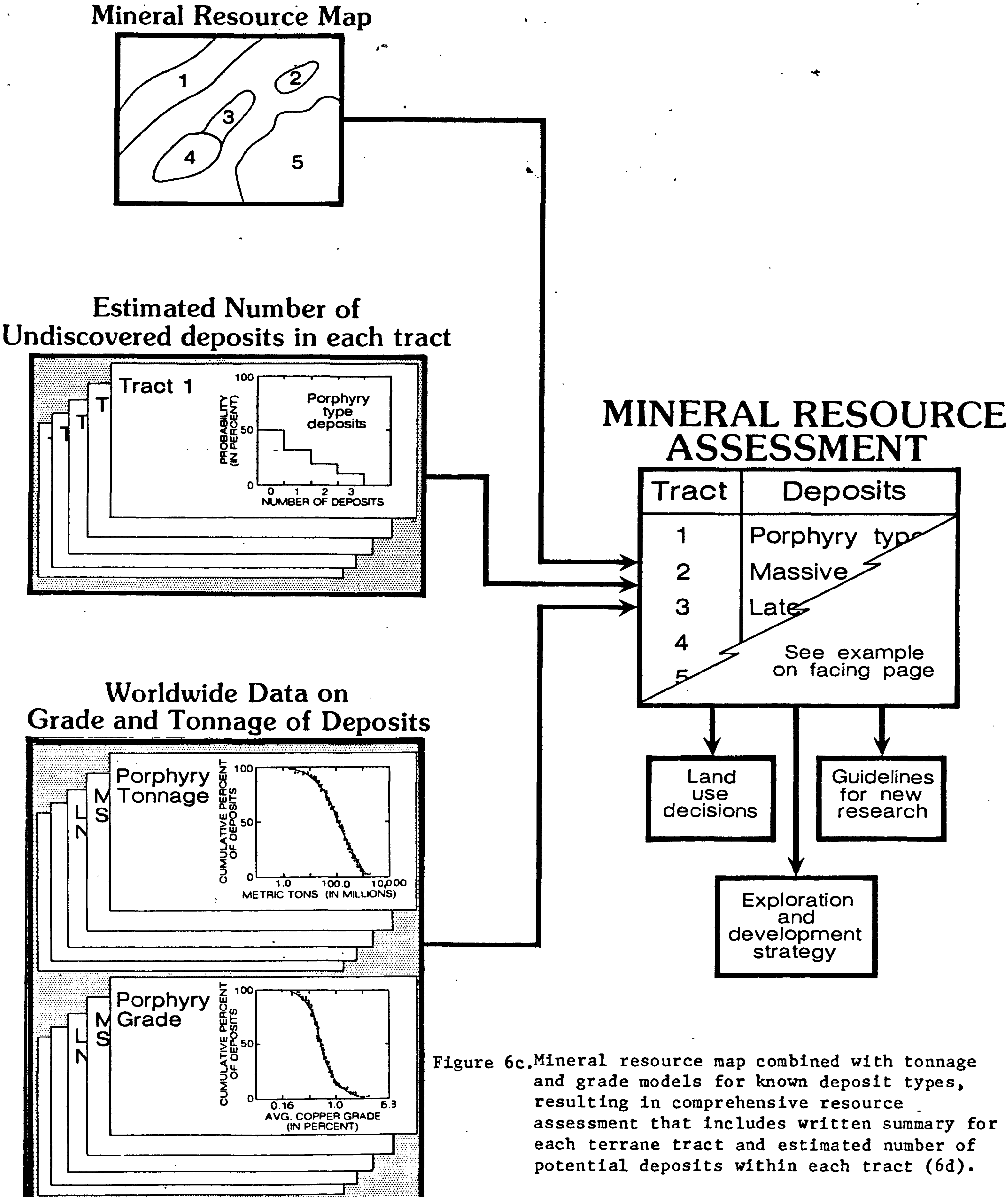

Figure 6c. Mineral resource map combined with tonnage and grade models for known deposit types, resulting in comprehensive resource assessment that includes written summary for each terrane tract and estimated number of potential deposits within each tract (6d).

MAJOR TYPES OF KNOWN DEPOSITS

(a) Cu(Ag, Au, Zu)—submarine volcanogenic

(b) Au—quartz lodes in Orca Group

(c) Zn, (Ag, Au, Cu)—breccia cemented by sulfides

SUSPECTED OR SPECULATIVE TYPES OF MINERAL DEPOSITS (INCLUDES MINOR OCCURRENCES)

Cu—magmatic; occurrence of Tertiary gabbro that contains disseminated pyrrhotite and chalcopyrite

GEOLOGIC CONTROL(S) OF MINERAL RESOURCES

Contains the most important submarine volcanogenic deposits of the Prince William Sound area; area underlain by Orca Group (Tertiary) flysch and mafic volcanic rocks and scattered Tertiary felsic plutons

(a) Consist of massive and disseminated sulfides, mainly pyrite, pyrrhotite, chalcopyrite, and sphalerite, in Orca Group; generally localized in or near shear zones; related to submarine volcanic processes

(b) Small gold-bearing quartz veins, stringers, and veinlets in Orca Group near Tertiary felsic plutons

(c) One small known deposit; on brecciated Tertiary pluton; breccia partly cemented by zinc and copper sulfides

PRODUCTION AND RESOURCE INFORMATION

Between 1900 and 1930 14 mines on the volcanogenic deposits produced about 97,000 tonnes (214 million pounds) of copper and subordinate amounts of gold, silver, and zinc; two mines, the Latouche and Ellemar, accounted for more than 96 percent of the production; the few gold mines in the area probably produced a total of not more than 31 kg (1,000 ounces) of gold; resource data are sketchy but the submarine volcanogenic deposits probably represent substantial copper resources; one prospect (Rua Cove) has estimated reserves of at least 1,020,000 tonnes (1,125,000 st) containing 1.25 percent copper

STATUS OF GEOLOGIC INFORMATION

Modern reconnaissance mapping accompanied by geochemical and geophysical studies by U.S. Geological Survey for that part of area within Deward quadrangle; U.S. Geological Survey sponsored mapping and some sampling for remainder of area; topical studies of some volcanogenic deposits by government agencies and industry; recent exploration of some volcanogenic deposits by industry

ADDITIONAL COMMENTS

The resource potential of the submarine volcanogenic deposits dwarfs that of other deposit types in the area; some of the volcanogenic deposits contain large amounts of pyrite, which have been investigated as a possible source of sulfuric acid; the main concentrations of known submarine volcanogenic deposits are in three areas: Knight and Latouche Islands and east of Valdez Arm; despite fairly thorough prospecting these largely vegetation-covered areas are favorable for new discoveries particularly of concealed deposits; the less prospected terrain west of Valdez Arm is also favorable

SUMMARY OF MINERAL RESOURCE POTENTIAL

(a) Over 50 mafic volcanogenic deposits are known; many have been incompletely explored and others probably remain to be found. Estimated number of deposits is only for deposits with tonnages comparable to those used in the grade-tonnage model.

(b) Several small-tonnage gold-quartz veins are known; others possible.

(c) One small breccia cemented by zinc and copper sulfides is known.

ESTIMATED NUMBER OF DEPOSITS (CHANCE THAT THERE ARE THE NUMBER PRESENTED OR MORE DEPOSITS)

(a)

90%	50%	10%	chance that there are
2	4	8	deposits or more

GRADES AND TONNAGES FOR THIS DEPOSIT TYPE

(a) mafic volcanogenic model

Figure 6d.

contact will also permit the Survey group to visit representative ore deposits in the country and to review kinds, amounts, and status of data available. Specific plans will call for exchange of ideas and interim products between countries during the operational phase, and foreign scientists will be encouraged to visit USGS counterparts to ensure effective communication and technology transfer.

The component maps and reports of the final assessment will be produced cooperatively. During the course of the project, USGS mineral data specialists will consult with host organizations in design and construction of a computerized mineral deposit inventory. Where appropriate, and to the extent feasible, micro-computer facilities will be installed by the USGS to enable the host country to develop and maintain the inventory on a scale necessary for continuing assessment projects.

Upon completion of all component maps, the USGS specialists and foreign counterparts will convene a session in the host country to arrive at the final mineral resource assessment and to develop appropriate recommendations for more detailed studies and exploration in areas of significant mineral potential.

Host-country geoscientists will be involved at all stages of the project -- in planning, producing, and interpreting the mineral information -- so that the resulting assessment can most easily be incorporated internally in long range projections and policy formulation.

BENEFITS

Using such a package for its own purposes, host country agencies should be better able to conduct more detailed research and exploration, encourage investment from domestic or outside sources, and stimulate further cooperative efforts with organizations outside the country. The community of economic geologists will acquire an enhanced fundamental knowledge base on which to construct models of ore genesis and deposition. And nations throughout the world ultimately will have a more reliable basis for estimating the extent and potential availability of new mineral resources.