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# Mineral Deposit Models

U.S. GEOLOGICAL SURVEY BULLETIN 1693



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# Mineral Deposit Models

DENNIS P. COX and DONALD A. SINGER, Editors

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## PREFACE

By Paul B. Barton

Conceptual models that describe the essential characteristics of groups of similar deposits have a long and useful role in geology. The first models were undoubtedly empirical attempts to extend previous experiences into future success. An example might be the seeking of additional gold nuggets in a stream in which one nugget had already been found, and the extension of that model to include other streams as well. Emphasis within the U.S. Geological Survey on the synthesis of mineral deposit models (as contrasted with a long line of descriptive and genetic studies of specific ore deposits) began with the collation by R. L. Erickson (1982) of 48 models. The 85 descriptive deposit models and 60 grade-tonnage models presented here are the culmination of a process that began in 1983 as part of the USGS-INGEOMINAS Cooperative Mineral Resource Assessment of Colombia (Hodges and others, 1984). Effective cooperation on this project required that U.S. and Colombian geologists agree on a classification of mineral deposits, and effective resource assessment of such a broad region required that grade-tonnage models be created for a large number of mineral deposit types. A concise one-page format for descriptive models was drawn up by Dennis Cox, Donald Singer, and Byron Berger, and Singer devised a graphical way of presenting grade and tonnage data. Sixty-five descriptive models (Cox, 1983a and b) and 37 grade-tonnage models (Singer and Mosier, 1983a and b) were applied to the Colombian project. Because interest in these models ranged far beyond the Colombian activity, it was decided to enlarge the number of models and to include other aspects of mineral deposit modeling. Our colleagues in the Geological Survey of Canada have preceded this effort by publishing a superb compilation of models of deposits important in Canada (Eckstrand, 1984). Not surprisingly, our models converge quite well, and in several cases we have drawn freely from the Canadian publication.

It is a well-known axiom in industry that any excuse for drilling may find ore; that is, successful exploration can be carried out even though it is founded upon an erroneous model. Examples include successful exploration based on supposed (but now proven erroneous) structural controls for volcanogenic massive sulfide deposits in eastern Canada and for carbonate-hosted zinc in east Tennessee. As the older ideas have been replaced, additional ore has been found with today's presumably more valid models.

Although models have been with us for centuries, until recently they have been almost universally incomplete when descriptive and unreasonably speculative when genetic. What is new today is that, although we must admit that all are

incomplete in some degree, models can be put to rigorous tests that screen out many of our heretofore sacred dogmas of mineral formation. Examples are legion, but to cite a few: (1) fluid-inclusion studies have shown conclusively that the classic Mississippi Valley-type ores cannot have originated from either syngenetic processes or unmodified surface waters; (2) epithermal base- and precious-metal ores have been proved (by stable-isotope studies) to have formed through the action of meteoric waters constituting fossil geothermal systems; and (3) field and laboratory investigations clearly show that volcanogenic massive sulfides are the products of syngenetic, submarine, exhalative processes, not epigenetic replacement of sedimentary or volcanic rocks. Economic geology has evolved quietly from an "occult art" to a respectable science as the speculative models have been put to definitive tests.

Several fundamental problems that may have no immediate answers revolve around these questions: Is there a proper number of models? Must each deposit fit into one, and only one, pigeon-hole? Who decides (and when?) that a model is correct and reasonably complete? Is a model ever truly complete? How complete need a model be to be useful?

In preparing this compilation we had to decide whether to discuss only those deposits for which the data were nearly complete and the interpretations concordant, or whether to extend coverage to include many deposits of uncertain affiliation, whose characteristics were still subjects for major debate. This compilation errs on the side of scientific optimism; it includes as many deposit types as possible, even at the risk of lumping or splitting types incorrectly. Nevertheless, quite a few types of deposits have not been incorporated.

The organization of the models constitutes a classification of deposits. The arrangement used emphasizes easy access to the models by focusing on host-rock lithology and tectonic setting, the features most apparent to the geologist preparing a map. The system is nearly parallel to a genetic arrangement for syngenetic ores, but it diverges strongly for the epigenetic where it creates some strange juxtapositions of deposit types. Possible ambiguities are accommodated, at least in part, by using multiple entries in the master list in table 1.

In considering ways to make the model compilation as useful as possible, we have become concerned about ways to enhance the ability of the relatively inexperienced geoscientist to find the model(s) applicable to his or her observations. Therefore, we have included extensive tables of attributes in which the appropriate models are identified.

Our most important immediate goal is to provide assistance to those persons engaged in mineral resource assessment or exploration. An important

secondary goal is to upgrade the quality of our model compilation by encouraging (or provoking?) input from those whose experience has not yet been captured in the existing models. Another target is to identify specific research needs whose study is particularly pertinent to the advance of the science. We have chosen to err on the side of redundancy at the expense of neatness, believing that our collective understanding is still too incomplete to rule out some alternative interpretations. Thus we almost certainly

have set up as separate models some types that will ultimately be blended into one, and there surely are groupings established here that will subsequently be divided. We also recognize that significant gaps in coverage still exist. Even at this stage the model compilation is still experimental in several aspects and continues to evolve. The product in hand can be useful today. We anticipate future editions, versions, and revisions, and we encourage suggestions for future improvements.

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# Mineral Deposit Models

Dennis P. Cox and Donald A. Singer, *Editors*

## INTRODUCTION

By Dennis P. Cox, Paul B. Barton,  
and Donald A. Singer

The U.S. Geological Survey has a long and distinguished history in assessing the mineral resources of the public domain, and that role remains active today in programs designed to assess the mineral resources of the lands administered by the U.S. Bureau of Land Management and Forest Service, the Alaska Mineral Resource Assessment Program, and the Conterminous United States Mineral Assessment Program. The Survey has thus an immediate and constantly recurring need to upgrade and maintain the capability of its staff to identify and assess areas favorable for mineral deposits. One major step toward fulfilling this need is the assembly of a comprehensive group of mineral deposit models that enable any geologist to compare his or her observations with the collective knowledge and experience of a much wider group of geoscientists.

This report deals exclusively with nonfuel minerals (including uranium), for these show a commonality of geologic expressions that differ markedly from those of the areally much larger (and economically even more important) coal, oil, and gas deposits.

## CITATION AND ACKNOWLEDGMENTS

This report has been assembled through the generous efforts of many persons. The authors of the individual models and many of the other sections are indicated. We all would appreciate it if the individual authors could be cited whenever practical rather than simply referring to the whole compilation.

Among the editors, Dennis Cox had the lead in soliciting the model authors and in assembling the brief models; Donald Singer played a similar role for all of the grade and tonnage models; and Paul Barton provided the attribute cross-indexes and carefully reviewed the overall package. The editors greatly appreciate the encouragement and suggestions from (in alphabetical order) Larry Bernstein, John H. DeYoung, Jr., Bob Earhart, Ralph Erickson, Fred Fisher, Bill Greenwood, Carroll Ann Hodges, Kate Johnson, Steve Ludington, Dick McCammon, Hal Morris, Rob Robinson, Don White, and many others. The editors were greatly helped by suggestions from geologists outside the USGS, particularly D. F. Sangster, R. V. Kirkham, and J. M. Franklin of the Geological Survey of Canada, and by Ryoichi Kouda, Takeo Sato, and

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## SOME FUNDAMENTAL DEFINITIONS

A "mineral occurrence" is a concentration of a mineral (usually, but not necessarily, considered in terms of some commodity, such as copper, barite or gold) that is considered valuable by someone somewhere, or that is of scientific or technical interest. In rare instances (such as titanium in a rutile-bearing black sand), the commodity might not even be concentrated above its average crustal abundance.

A "mineral deposit" is a mineral occurrence of sufficient size and grade that it might, under the most favorable of circumstances, be considered to have economic potential.

An "ore deposit" is a mineral deposit that has been tested and is known to be of sufficient size, grade, and accessibility to be producible to yield a profit. (In these days of controlled economies and integrated industries, the "profit" decision may be based on considerations that extend far beyond the mine itself, in some instances relating to the overall health of a national economy.)

On one hand, the field observations usually begin with "mineral occurrences" (or with clues to their existence) and progress with further study to "mineral deposits" and only rarely to "ore deposits," but we must present information that helps us deal with all classes of "mineral occurrences," not just "ore deposits." On the other hand, in terms of accessible information our sample is strongly biased toward "ore deposits," for it is only in them that sufficient exposure is available to develop a real knowledge of the overall character of the mineralization process. Some mineral occurrences are, therefore, unrecognized mineral deposits, while others are simply mineralized localities where ore-forming processes were so weak or incomplete that a deposit was not formed. Thus we summarize the state of knowledge regarding ore deposit models, and we call them "mineral deposit models" with the hope that what we have learned about large and high-grade metal concentrations will help us sort out all mineral occurrences to identify their true character and, we hope, to recognize which have potential to constitute ore deposits.

The attributes or properties of a mineral occurrence are, of course, those features exhibited by the occurrence. When applied to a model, these terms refer to those features possessed by the class of deposits represented by the model. It is useful to consider attributes on at least two scales: the first deals with local features that may be observed directly in the field (mineralogy, zonal patterns, local chemical haloes, and so on); the second is those features concerning the regional geologic setting and which must be interpreted from the local studies or may be inferred from global tectonic considerations (for instance, that the rock sequence under study represents a deep-water, back-arc rift environment, or that the area is underlain by anomalously radioactive high-silica rhyolite and granite). Two of the most prominent attributes, the commodities/geochemical patterns and the mineralogy, are cross-indexed to model types in Appendixes C and D, respectively.

To the greatest extent possible, models were constructed so as to be independent of site-specific attributes and therefore contain only those features which are transferable from one deposit to another. This goal is difficult to attain, because we do not always know which features are site specific.

The term "model" in an earth-science context elicits a wide variety of mental images, ranging from the physical duplication of the form of a subject, as in a scale model of the workings of a mine, to a unifying concept that explains or describes a complex phenomenon. In this context we shall apply only the latter usage. Therefore, let us propose a working definition of "model" in the context of mineral deposits, the overriding purpose being to communicate information that helps mankind find and evaluate mineral deposits. A mineral deposit model is the systematically arranged information describing the essential attributes (properties) of a class of mineral deposits. The model may be empirical (descriptive), in which instance the various attributes are recognized as essential even though their relationships are unknown; or it may be theoretical (genetic), in which instance the attributes are interrelated through some fundamental concept.

One factor favoring the genetic model over the simply descriptive is the sheer volume of descriptive information needed to represent the many features of complex deposits. If all such information were to be included, the number of models would escalate until it approached the total number of individual deposits considered. Thus we should no longer have models, but simply descriptions of individual deposits. Therefore, the compilers must use whatever sophisticated or rudimentary genetic concepts are at their disposal to distinguish the critical from the incidental attributes. It is commonly necessary to carry some possibly superficial attributes in order not to preclude some permissible but not necessarily favored, multiple working concepts.

The following example illustrates the problem. One of the commonly accepted attributes of the model for the carbonate-hosted lead-zinc deposits of the Mississippi Valley type is the presence of secondary dolomite. But do we know that this is essential? Suppose a deposit were found in limestone; would we reject its assignment to the Mississippi Valley class?

Or could it be correct that the critical property is permeability and that the formation of dolomite either (1) enhances permeability (and thereby makes the ground more favorable), or (2) reflects pre-existing permeability that is exploited by both the dolomite and the ore? Perhaps the dolomite merely records a particular range of Ca/Mg ratio in the fluid which in turn is characteristic of the basinal brines that constitute the ore fluid. In any event, the dolomite is a powerful ore guide and belongs somewhere in the "final model."

## CLASSIFICATION OF MODELS USED IN THIS COMPILATION

For the purpose at hand the classification scheme has two requirements: (1) it must be open so that new types of deposits can be added in the future, and (2) the user must be able to find easily the appropriate models to apply to the rock and tectonic environments being investigated.

Figure 1 maps out the four logic trees that constitute a broad lithotectonic classification; this system is similar to one developed by Page and others (1982c). The classification of deposits by the environment of formation of their host rocks is continued on a finer scale in table 1. This classification scheme is relatively straightforward for deposits formed essentially contemporaneously with their host rock. However, for epigenetic deposits a conflict arises between the lithotectonic environment of the formation of the host and the lithotectonic environment of the mineralization process. Therefore, for epigenetic deposits we have selected the most important aspect of the lithotectonic alternatives and classified the deposit accordingly. This procedure

GEOLOGIC-TECTONIC ENVIRONMENT		DEPOSIT MODELS
Igneous	Intrusive	Mafic - ultramafic { Stable area ..... 1 to 4 Unstable area ..... 5 to 10
		Alkaline and basic ..... 11 to 12
		Felsic { Phanocrystalline ..... 13 to 15 Porphyrophanitic ..... 16 to 22
	Extrusive	Mafic ..... 23 to 24
		Felsic - mafic ..... 25 to 28
Sedimentary	Clastic rocks ..... 29 to 31	
	Carbonate rocks ..... 32	
	Chemical sediments ..... 33 to 35	
Regional metamorphic	Metavolcanic and metasedimentary ..... 36	
	Metapelite and metaarenite ..... 37	
Surficial	Residual ..... 38	
	Depositional ..... 39	

**Figure 1.** Tree diagram showing relationship of broad geologic-tectonic environments to models. These deposit models are classified on a finer scale in table 1.

Table 1. Classification of deposit models by lithologic-tectonic environment

[\*indicates that model is not included in this bulletin]

Deposit environment	Model No.
---------------------	-----------

Mafic and ultramafic intrusions

## A. Tectonically stable area; stratiform complexes

## Stratiform deposits

Basal zone	
Stillwater Ni-Cu -----	1
Intermediate zone	
Bushveld chromitite -----	2a
Merensky Reef PGE -----	2b
Upper zone	
Bushveld Fe-Ti-V -----	3
Pipe-like deposits	
Cu-Ni pipes -----	4a*
PGE pipes -----	4b*

## B. Tectonically unstable area

## Intrusions same age as volcanic rocks

Rift environment	
Duluth Cu-Ni-PGE -----	5a
Noril'sk Cu-Ni-PGE -----	5b
Greenstone belt in which lowermost rocks of sequence contain ultramafic rocks	
Komatiitic Ni-Cu -----	6a
Dunitic Ni-Cu -----	6b
Intrusions emplaced during orogenesis	
Synorogenic in volcanic terrane	
Synorogenic-synvolcanic Ni-Cu -----	7a
Synorogenic intrusions in non-volcanic terrane	
Anorthosite-Ti -----	7b
Ophiolites	
Podiform chromite -----	8a
Major podiform chromite -----	8b
(Lateritic Ni) -----	(38a)
(Placer Au-PGE) -----	(39a)
Serpentine	
Limassol Forest Co-Ni -----	8c
Serpentine-hosted asbestos -----	8d
(Silica-carbonate Hg) -----	(27c)
(Low-sulfide Au-quartz vein) -----	(36a)
Cross-cutting intrusions (concentrically zoned)	
Alaskan PGE -----	9
(Placer PGE-Au) -----	(39b)

## C. Alkaline intrusions in stable areas

Carbonatite -----	10
Alkaline complexes -----	11*
Diamond pipes -----	12

Felsic intrusions

## D. Mainly phanerocrystalline textures

Pegmatitic	
Be-Li pegmatites -----	13a*
Sn-Nb-Ta pegmatites -----	13b*
Granitic intrusions	
Wallrocks are calcareous	
W skarn -----	14a
Sn skarn -----	14b
Replacement Sn -----	14c

Table 1. Classification of deposit models by lithologic-tectonic environment  
--Continued

Deposit environment	Model No.
D. Mainly phanerocrystalline textures--Continued	
Granitic intrusions--Continued	
Other wallrocks	
W veins -----	15a
Sn veins -----	15b
Sn greisen -----	15c
(Low-sulfide Au-quartz vein) -----	(36a)
(Homestake Au) -----	(36b)
Anorthosite intrusions	
(Anorthosite Ti) -----	(7b)
E. Porphyroaphanitic intrusions present	
High-silica granites and rhyolites	
Climax Mo -----	16
(Fluorspar deposits) -----	(26b*)
Other felsic and mafic rocks including alkalic	
Porphyry Cu -----	17
Wallrocks are calcareous	
Deposits near contact	
Porphyry Cu, skarn-related -----	18a
Cu skarn -----	18b
Zn-Pb skarn -----	18c
Fe skarn -----	18d
Carbonate-hosted asbestos -----	18e
Deposits far from contact	
Polymetallic replacement -----	19a
Replacement Mn -----	19b
(Carbonate-hosted Au) -----	(26a)
Wallrocks are coeval volcanic rocks	
In granitic rocks in felsic volcanics	
Porphyry Sn -----	20a
Sn-polymetallic veins -----	20b
In calcalkalic or alkalic rocks	
Porphyry Cu-Au -----	20c
(Epithermal Mn) -----	(25g)
Wallrocks are older igneous and sedimentary rocks	
Deposits within intrusions	
Porphyry Cu-Mo -----	21a
Porphyry Mo, low-F -----	21b
Porphyry W -----	21c*
Deposits within wallrocks	
Volcanic hosted Cu-As-Sb -----	22a
Au-Ag-Te veins -----	22b
Polymetallic veins -----	22c
(Epithermal quartz-alunite Au) -----	(25e)
(Low-sulfide Au-quartz vein) -----	(36a)
<u>Extrusive rocks</u>	
F. Mafic extrusive rocks	
Continental or rifted craton	
Basaltic Cu -----	23
(Sediment-hosted Cu) -----	(30b)
Marine, including ophiolite-related	
Cyprus massive sulfide -----	24a
Besshi massive sulfide -----	24b
Volcanogenic Mn -----	24c
Blackbird Co-Cu -----	24d
(Komatiitic Ni-Cu) -----	(6a)



Table 1. Classification of deposit models by lithologic-tectonic environment  
--Continued

Deposit environment	Model No.
G. Felsic-mafic extrusive rocks	
Subaerial	
Deposits mainly within volcanic rocks	
Hot-spring Au-Ag -----	25a
Creede epithermal vein -----	25b
Comstock epithermal vein -----	25c
Sado epithermal vein -----	25d
Epithermal quartz-alunite Au -----	25e
Volcanogenic U -----	25f
Epithermal Mn -----	25g
Rhyolite-hosted Sn -----	25h
Volcanic-hosted magnetite -----	25i
(Sn polymetallic veins) -----	(20b)
Deposits in older calcareous rocks	
Carbonate-hosted Au-Ag -----	26a
Fluorspar deposits -----	26b*
Deposits in older clastic sedimentary rocks	
Hot-spring Hg -----	27a
Almaden Hg -----	27b
Silica-carbonate Hg -----	27c
Simple Sb -----	27d
Marine	
Kuroko massive sulfide -----	28a
Algoma Fe -----	28b
(Volcanogenic Mn) -----	(24c)
(Volcanogenic U) -----	(25f)
(Low-sulfide Au-quartz vein) -----	(36a)
(Homestake Au) -----	(36b)
(Volcanogenic U) -----	(25f)
Sedimentary rocks	
H. Clastic sedimentary rocks	
Conglomerate and sedimentary breccia	
Quartz pebble conglomerate Au-U -----	29a
Olympic Dam Cu-U-Au -----	29b
(Sandstone U) -----	(30c)
(Basaltic Cu) -----	(23)
Sandstone	
Sandstone-hosted Pb-Zn -----	30a
Sediment-hosted Cu -----	30b
Sandstone U -----	30c
(Basaltic Cu) -----	(23)
(Kipushi Cu-Pb-Zn) -----	(32c)
(Unconformity U-Au) -----	(37a)
Shale-siltstone	
Sedimentary exhalative Zn-Pb -----	31a
Bedded barite -----	31b
Emerald veins -----	31c
(Basaltic Cu) -----	(23)
(Carbonate-hosted Au-Ag) -----	(26a)
(Sediment-hosted Cu) -----	(30b)
I. Carbonate rocks	
No associated igneous rocks	
Southeast Missouri Pb-Zn -----	32a
Appalachian Zn -----	32b
Kipushi Cu-Pb-Zn -----	32c
(Replacement Sn) -----	(14c)

Table 1. Classification of deposit models by lithologic-tectonic environment  
--Continued

Deposit environment	Model No.
I. Carbonate rocks--Continued	
No associated igneous rocks--Continued	
(Sedimentary exhalative Zn-Pb) -----	(31a)
(Karst bauxite) -----	(38c)
Igneous heat sources present	
(Polymetallic replacement) -----	(19a)
(Replacement Mn) -----	(19b)
(Carbonate-hosted Au-Ag) -----	(26a)
(Fluorspar deposits) -----	(26b*)
J. Chemical sediments	
Oceanic	
Mn nodules -----	33a*
Mn crusts -----	33b*
Shelf	
Superior Fe -----	34a
Sedimentary Mn -----	34b
Phosphate, upwelling type -----	34c
Phosphate, warm-current type -----	34d
Restricted basin	
Marine evaporite -----	35a*
Playa evaporite -----	35b*
(Sedimentary exhalative Zn-Pb) -----	(31a)
(Sedimentary Mn) -----	(34b)
<u>Regionally metamorphosed rocks</u>	
K. Derived mainly from eugeosynclinal rocks	
Low-sulfide Au-quartz vein -----	36a
Homestake Au -----	36b
(Serpentine-hosted asbestos) -----	(8d)
(Gold on flat faults) -----	(37b)
L. Derived mainly from pelitic and other sedimentary rocks	
Unconformity U-Au -----	37a
Gold on flat faults -----	37b
<u>Surficial and unconformity-related</u>	
M. Residual	
Lateritic Ni -----	38a
Bauxite, laterite type -----	38b
Bauxite, karst type -----	38c
(Unconformity U-Au) -----	(37a)
N. Depositional	
Placer Au-PGE -----	39a
Placer PGE-Au -----	39b
Shoreline placer Ti -----	39c
Diamond placers -----	39d
Stream placer Sn -----	39e
(Quartz pebble conglomerate Au-U) -----	(29a)

inevitably introduces a substantial bias on the part of the classifier, thus we have followed a system of including, parenthetically, alternative classifications less favored by the compiler at the appropriate alternative points in the classification scheme.

#### MODEL NAMES

Each model has been assigned a name that is derived either from the special characteristics of the classes or from a type locality. The latter strategy

was employed to avoid excessively long descriptive names. The use of type names derived from specific deposits does produce confusion in some readers, however, who may feel, for example, that a deposit that does not look "exactly" like Comstock cannot be represented by a "Comstock epithermal vein" model. This confusion may be minimized by realizing that most models are blends of attributes from a large number of deposits and that the names are only conveniences, not constrictions. The contributors to this report and the literature in general are not without disagreements regarding nomenclature (as well as genetic aspects and some facets of the groupings made here), but provision for alternative names is made in the model format under the heading of approximate synonyms.

## DESCRIPTIVE MODELS

Because every mineral deposit, like every fingerprint, is different from every other in some finite way, models have to progress beyond the purely descriptive in order to represent more than single deposits. Deposits sharing a relatively wide variety and large number of attributes come to be characterized as a "type," and a model representing that type can evolve. As noted above, generally accepted genetic interpretations play a significant role in establishing model classes. Here we shall emphasize the more descriptive aspects of the deposits because our goal is to provide a basis for interpreting geologic observations rather than to provide interpretations in search of examples. The attributes listed are intended to be guides for resource assessment and for exploration, both in the planning stage and in the interpretation of findings.

The descriptive models have two parts. The first, the "Geological Environment," describes the environments in which the deposits are found; the second gives the identifying characteristics of the deposits. The headings "Rock Types" and "Textures" cover the favorable host rocks of deposits as well as source rocks believed to be responsible for hydrothermal fluids which may have introduced epigenetic deposits. "Age" refers to the age of the event responsible for the formation of the deposit. "Tectonic Setting" is concerned with major features or provinces (perhaps those that might be portrayed only at 1:1,000,000 or smaller scale), not ore control by structures that are local and often site-specific. "Associated Deposits" are listed as deposits whose presence might indicate suitable conditions for additional deposits of the type portrayed by the model.

The second part of the model, the "Deposit Description," provides the identifying characteristics of the deposits themselves, particularly emphasizing aspects by which the deposits might be recognized through their geochemical and geophysical anomalies. In most cases the descriptions also contain data useful in project planning for mineral assessment or exploration; this aspect is especially important where limited financial and manpower resources must be allocated to the more significant tasks.

## GRADE-TONNAGE MODELS

Estimated pre-mining tonnages and grades from over 3,900 well-explored, well-characterized deposits were used to construct 60 grade-tonnage models. Where several different estimates were available for a deposit, the estimated tonnages associated with the lowest cutoff grades were used. Grades not available (always for by-products) were treated as zero. Except for a few instances, the data base is so large as to preclude specific references. Several published compilations of data were particularly useful sources for multiple deposit types (Canada Department of Energy, Mines and Resources, 1980; DeYoung and others, 1984; Krauss and others, 1984; Laughlin, 1984; Menzie and Mosier, 1985; Mosier and others, 1983; Mosier and others, in press; Singer and others, 1980; Yamada and others, 1980). The U.S. Geological Survey has a great deal of data available in the Mineral Resources Data System.

The grade-tonnage models are presented in graphical format to make it easy to compare deposit types and to display the data. All plots show either grade or tonnage on the horizontal axis, while the vertical axis is always the cumulative proportion of deposits. Plots of the same commodity or tonnages are presented on the same scale; a logarithmic scale is used for tonnage and most grades. Each dot represents an individual deposit (or, rarely, a district), cumulated in ascending grade or tonnage. Where a large number of deposits is plotted, individual digits represent the number of deposits. Smoothed curves are plotted through arrays of points, and intercepts for the 90th, 50th, and 10th percentiles are constructed. For tonnages and most grades, the smoothed curves represent percentiles of a lognormal distribution that has the same mean and standard deviation as the observed data; exceptions are plots where only a small percentage of deposits had reported grades and grade plots that are presented on an arithmetic scale, such as iron or manganese, for which the smoothed curve was fit by eye. Summary statistics by deposit type are provided in Appendix B. The number of deposits in each type is indicated at the upper right of each diagram. The deposits used to construct each model are listed with the model and cross-indexed to model types in Appendix E. Correlations among grades and between tonnage and each grade are indicated only when significant at the 1 percent level.

There are important limitations inherent in the data base used for all grade-tonnage models. Estimates of cutoff grades within individual deposit types can vary because of regional, national, or operator differences. All too commonly there is no mention of the actual cutoff grades or mining widths that are incorporated into published reserve figures; nevertheless, the grade-tonnage figures given do represent material that the company or the government believed might someday be economic to mine. Stratiform deposits of large areal extent, such as phosphate or sedimentary manganese, are special problems because of differences in opinion and practice regarding how closely drilled they must be to "prove" ore tonnages and regarding the thicknesses and depths of what may be considered for eventual mining. Effects of another source of variation, mining

methods, are recognized in some of the placer models; typically, however, mining methods are fairly consistent within a deposit type. In a few instances, irregular cumulative frequency plots reflect mixing of economic and scientific data sources, such as in the plot of gold in porphyry copper deposits. In spite of the current difficulty of quantifying variation of grades and tonnages with respect to changes in cutoff grades or mining methods, the models presented here are believed to account for the main source of variation in grades and tonnages of mineral deposits--variation due to differences among types of deposits.

The question of whether one counts deposits within a cluster of related deposits as individuals or as a total will probably never be resolved to everyone's satisfaction. Some geostatisticians would separate each ore body (and then argue about whether two operations on the same body should be counted separately), whereas some economic geologists would lump everything from a single district (and then argue about district boundaries). For the most part the entities summarized are individual deposits, but in some instances such data are mixed with data representing entire districts. Because of these inconsistencies, some care is necessary in comparing grade-tonnage models between deposit types or in comparing this summary with those prepared using alternative methods.

Care is also warranted in interpreting the grade distributions for which data are missing; this concerns principally by-product grades. In some instances, such as the platinum-group element (PGE) contents in podiform chromite and the cobalt content of laterites, the fragmentary information given probably represents the entire class. In other instances, such as the lead content of Cyprus massive sulfide deposits, the missing grades probably represent values below the lowest reported grades. The grades derived from studies of trace elements in ores more probably represent the former situation rather than the latter.

Deposits strongly suspected to be small or very low grade are seldom sampled well enough to be characterized in terms of grade and tonnage, thus the sample of many deposit classes is truncated by economics. Nonetheless, probably 40 percent of the deposits used in these models are, in fact, non-economic today; and a perusal of the figures will discover examples of both small deposits and low-grade deposits.

Potential metal supply is dominated by the very few largest tonnage deposits, as shown by Singer and DeYoung (1980), who also pointed out that inverse correlations between grade and tonnage are surprisingly rare. Thus the fact that a deposit is large does not necessarily mean that it will prove to be of low grade. This means that most low-grade deposits are not likely to have huge resources and also that the omission of a few low-grade or small tonnage deposits will not seriously degrade the predictions of potential national supplies for most commodities. In contrast, the missing low-grade and small deposits suggest that the grade-tonnage models represent a biased sample of the large number of low-grade or small-tonnage occurrences and prospects found by exploration. This fact must be considered in cases where the number of undiscovered deposits is estimated. In order for the

estimated number of deposits to be consistent with a grade-tonnage model, approximately half of the deposits estimated should have greater than the model's median tonnage or grade. Thus the probability that an untested prospect represents a significant deposit can too easily be overestimated.

## OTHER TYPES OF MODELS AND THEIR INTERRELATIONSHIPS

The bulk of this report deals with descriptive mineral deposit models and their grade-tonnage counterparts, but there are other useful aspects which we wish to discuss even though we have not yet had the opportunity to develop or exploit them. They are the genetic, occurrence probability, and quantitative process models.

Many authors prefer to keep a clear distinction between descriptive and genetic models, apparently feeling that the descriptive models somehow represent "pure truth" whereas the genetic constitute a less objective philosophical position (or at least make the investigator "skate on thin ice"). It is altogether desirable to avoid confusing interpretation with fact; but it is well to remember, for example, that each time a field geoscientist extrapolates geology across a covered area he or she adds an element of "interpretation" to a "factual" map, and that this interpretation is not necessarily any more "real" (or "unreal") than, for example, an isotope geologist's conclusion that a given oxygen and hydrogen isotopic signature extracted from fluid inclusions points to a meteoric origin for the fluid. The point is that the whole of our professional knowledge rests on a broad continuum of interpretations; many of them are so commonly accepted that they are no longer questioned, but many others still evoke challenges. Thus we suggest that a combination descriptive-genetic model is not inconsistent with professional practice. The model begins as a description, but various aspects of the model become genetic as they acquire satisfactory genetic explanations. Eventually much of the model becomes genetic, as has happened, for example, with the Cyprus-type massive sulfide deposits or the sandstone uranium deposits of the Colorado Plateau.

As the attributes of a model become understood in a genetic sense, the descriptive model evolves to a genetic model:

1. Genetic models are compilations of the properties of a group of related deposits in which the reasons for certain attributes being favorable are identified. Descriptive models evolve into genetic models, and as such they become far more flexible and powerful.

We have presented the three model subtypes above as if they constituted a linear logical sequence leading toward the "final" model, but in fact there must be an iterative relationship among descriptive, genetic, and grade/tonnage models. The consequence of examining any of these three may be a reassessment of the groupings of deposits chosen to be represented by a model type and the redesignation of the attributes diagnostic for that type.

With a dominantly genetic model in hand, two



more model types can be generated:

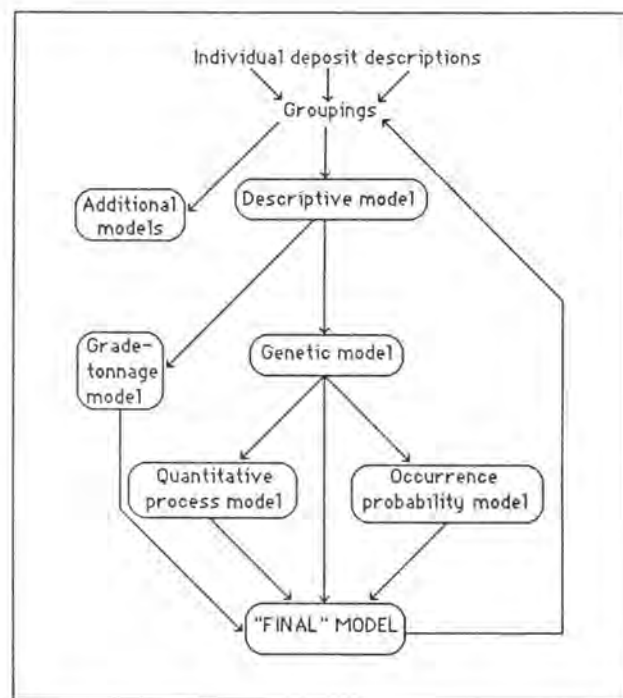
2. Occurrence probability models are models that predict the probability of a deposit (of a size and grade indicated by the appropriate grade-tonnage models) occurring within a given area. As with the descriptive and genetic models, probability models that are tied to lithic or structural geologic entities (that is, they are genetic) are far more focused; in fact, it is probably impossible to generate a useful probability model before the establishment of a genetic model. Accurate probability models are very difficult to construct because although the technical community has very complete data on mineral producers (mines), the data on non-producing mineral deposits (prospects and mineral shows) are much less well documented, a point also covered in the discussion of grade-tonnage models. Even more importantly, data on barren areas are sparse. We must extrapolate from a very fragmentary base toward a completely unseen target.

There is much to learn before the probability model can be made a dependable tool; yet the successful targeting of exploration programs by industry demonstrates that, at least on a qualitative basis, areas with better-than-average probabilities can be identified. It is worth noting, also, that mineral fuels are much more predictable and now can have realistic probability-of-occurrence values attached to specific volumes of sediments provided that the initial character and postdepositional histories of the sediments are well known. It is a distant but not unreasonable dream to anticipate that some day we shall approach that level of certainty for some types of nonfuel mineral deposits.

3. Quantitative process models are models that describe quantitatively some process related to mineral deposit formation; they are offshoots of the genetic model. Examples would be models of heat or fluid flow around a cooling pluton; rates of crystal growth as functions of supersaturation, impurities, and temperature; or sequences and amounts of minerals deposited from evaporating seawater.

All five of these model subtypes can be parts of the "final" model, and recycling of the model back to the original groupings stage helps refine the selection process. Figure 2 shows the flow of information that results in the generation of the models we have discussed.

Table 2 compares the five model subtypes with five distinct types of uses for the information. Note that persons engaged in research guidance and especially exploration and development have broad-ranging needs, whereas those dealing with the availability of minerals or of land-use allocation have less use for genetic or quantitative process models. Overall there is a need for a comprehensive array of mineral deposit models to meet these individual objectives.



**Figure 2.** Flow sheet showing evolution of model types. Individual model subtypes are discussed in text. It is essential that such a structure represents the repetitive cycling of information leading to continual refinement of groupings of deposits that represent each model type.

#### MATURITY OF DESCRIPTIVE-GENETIC MODELS

The rate at which we gain understanding and the current levels of genetic knowledge vary considerably from one deposit type to another, as figures 3 and 4 show. Such types as placers and evaporites are well known genetically and the problems in their exploration and utilization concern local site-specific geologic issues rather than mineral genesis or the degree of maturation of the model. In contrast, others such as the Coeur d'Alene Ag-Pb-Zn veins, or the massive Zn-Mn-Fe oxide/silicate bodies at Franklin and Sterling Hill, or the Cu-U-Au at Olympic Dam, or the Cu-Zn-Pb-Ge ores of Kipushi and the Tsumeb pipe remain genetic enigmas despite, in the instances of the first two, extensive research spanning many years. Still others, such as the diamond-bearing kimberlite pipes, are geologically well understood regarding their origin yet very poorly understood in terms of the reasons for their existing at any particular site. Our rate of acquisition of information is very irregular, as the schematic diagram in figure 3 shows. The several scarps between plateaus in the knowledge curve for the marine phosphate model might mark, successively, the recognition that the phosphate was a chemical precipitate, that it occurred on continental shelves where upwelling of deep marine waters occurred, and that the upwelling regions were related to wind and current patterns that were tied to the global configuration of the continents and ocean basins. A

Table 2. Comparison of application of the five model subtypes by various users

[Level of use: Major, X; minor, x; minimal, x]

Uses	Subtypes of models				
	Grade/tonnage	Descriptive	Genetic	Probability of occurrence	Quantitative process
Exploration/development	X	X	X	X	X
Supply potential	X	x	x	X	x
Land use	X	X	x	X	x
Education	x	X	X	X	X
Research guidance	X	X	X	X	X

second example from the Mississippi Valley-type ores might involve scarps marking the recognition (from fluid-inclusion evidence) that the ores were deposited from warm (about 100 °C) highly saline solutions that could represent neither simple surface nor marine waters. A second scarp might be associated with the recognition that the deposits were integral parts of a regional hydrologic regime whose distribution and character was susceptible to interpretation.

Figures 3 and 4 bring out another point: some aspects of any model always remain to be determined, thus we never acquire a "complete" model. Indeed, the approach to "complete" understanding is asymptotic, and a lot of additional effort to clear up the "last" uncertainty in a nearly perfect model is probably unwarranted. But, as the examples in figure 3 show, new ideas and new technologies can provide the impetus for new spurts in knowledge for heretofore incomplete models.

Note that the horizontal axis in figure 3 is simply "years of effort" devoted to fundamental geologic investigation. The scale certainly needs to be exponential in order to fit the intensively studied and sparsely studied deposit types, but this figure is strictly schematic, there being no source of documentation for either coordinate. The figure also indicates that different deposit types may require different amounts of effort to achieve a similar level of genetic understanding.

Figure 4 shows a hypothetical growth curve along which different types of deposits have been schematically arrayed. Because some deposits (such as volcanogenic massive sulfides) are so much more difficult to understand than others (gold placers), the horizontal axis has been "normalized" by plotting a ratio of effort done to effort needed thereby permitting a smooth, although admittedly subjective

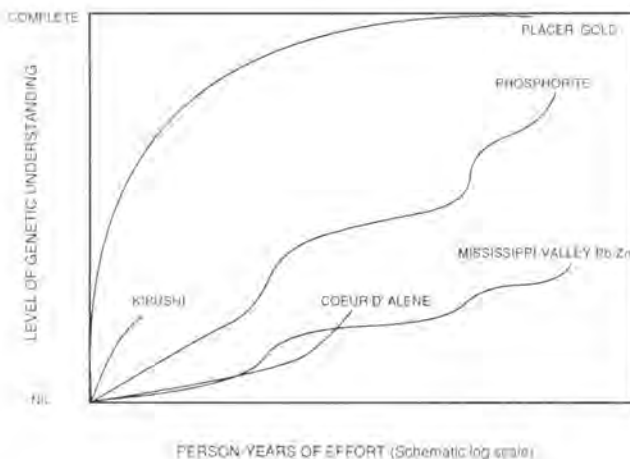


Figure 3. Schematic growth patterns for understanding of some typical genetic models. Individual curves discussed in text.

and schematic, curve to be illustrated. As with figure 3, there is no documentation to support this diagram, although the general concept meets with agreement among most contributors to this volume.

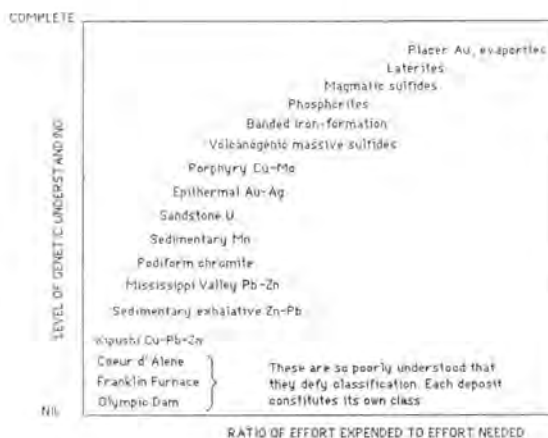


Figure 4. Comparison of relative levels of understanding of some important model types. Vertical coordinate same as for figure 3; but because difficulty of acquiring the genetic information differs so widely among model types, the horizontal coordinate is "normalized" as noted in text.

## DESCRIPTIVE MODEL OF STILLWATER Ni-Cu

By Norman J Page

APPROXIMATE SYNONYM Stratiform mafic-ultramafic Ni-Cu.

DESCRIPTION Ni, Cu sulfides at base of large repetitively layered mafic-ultramafic intrusion. (see fig. 5).

GENERAL REFERENCES Geological Society of South Africa, Special Publication 1 (1969); Economic Geology, v. 77, no. 6 (1982) and v. 71, no. 7 (1976).

GEOLOGICAL ENVIRONMENT

Rock Types Layered intrusion contains norite, gabbro-norite, dunite, harzburgite, peridotite, pyroxenite, troctolite, anorthosite, and gabbro.

Textures Cumulate textures; layers with gradational proportions of euhedral crystals; locally with poikilitic matrix.

Age Range Generally Precambrian, but may be as young as Tertiary.

Depositional Environment Intruded into granitic gneiss or volcanic-sedimentary terrane.

Tectonic Setting(s) Cratonal, mostly in Precambrian shield areas.

Associated Deposit Types Bushveld Cr, Merensky Reef PGE, Bushveld Fe-Ti-U. PGE placers.

DEPOSIT DESCRIPTION

Mineralogy Pyrrhotite + chalcopyrite + pentlandite + cobalt sulfides, by-product platinum group metals (PGE).

Texture/Structure Locally massive; interstitial to silicates; disseminated.

Alteration None related to ore.

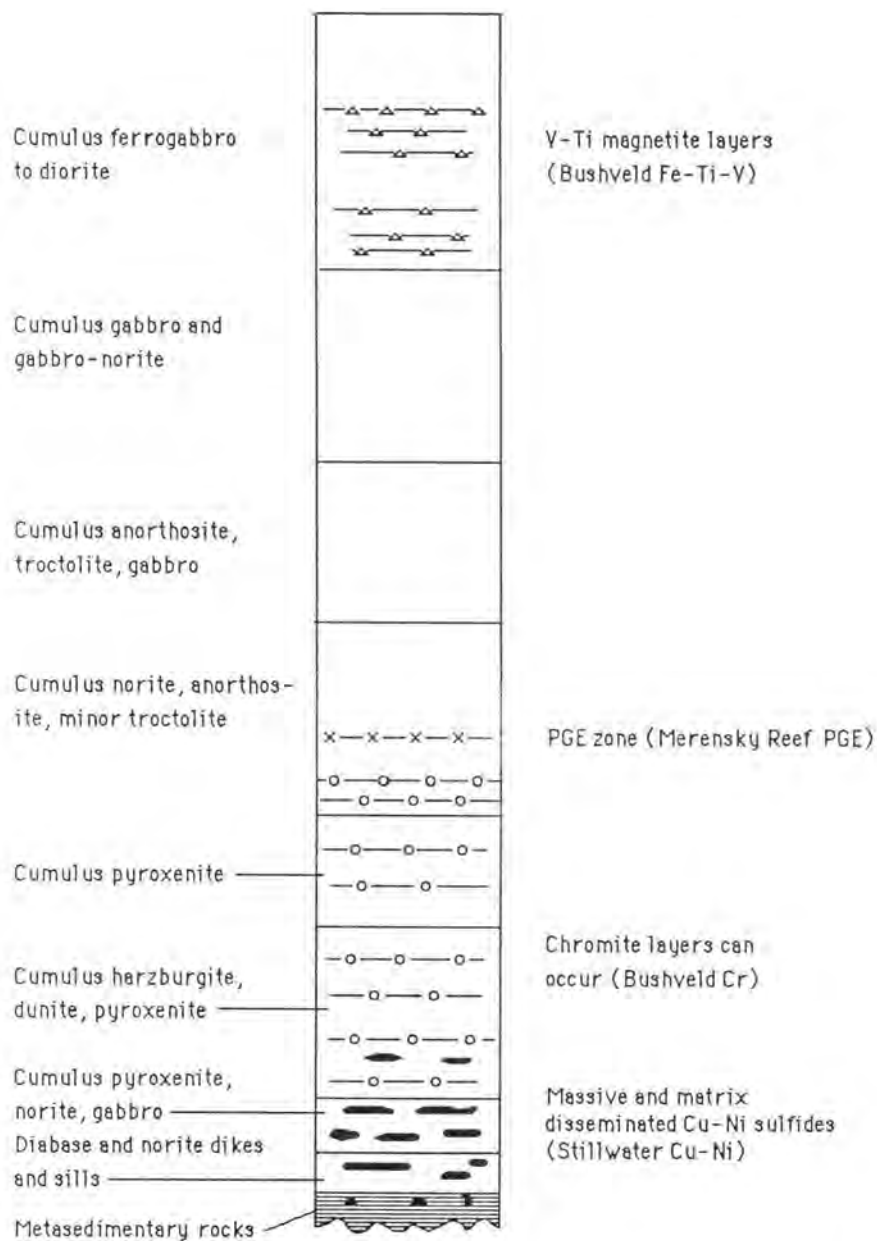
Ore Controls Basins in basal contact of intrusion with rapidly varying lithologies. Sulfides may intrude fractures in footwall country rock. Ingress of sulfur through fractures in footwall may be important ore control.

Weathering Gossan.

Geochemical Signature Cu, Ni, PGE, Co. High Mg; low Na, K, and P.

EXAMPLES

Stillwater Complex, USMT (Page, 1977)



**Figure 5.** Diagram of typical mafic-ultramafic stratiform complex, 500 to 1,500 m thick, showing stratigraphic relations of rock units and mineral deposits. Deposit models shown in parentheses.



## DESCRIPTIVE MODEL OF BUSHVELD Cr

By Norman J Page

SYNONYM Stratiform mafic-ultramafic Cr.DESCRIPTION Layered chromitite in lower intermediate zone of large repetitively layered mafic-ultramafic intrusions (see fig. 5).GEOLOGICAL ENVIRONMENTRock Types Intrusion may contain norite, gabbro-norite, dunite, harzburgite, peridotite, pyroxenite, troctolite, anorthosite, and gabbro.Textures Cumulate textures; layers with gradational proportions of euhedral crystals; locally with poikilitic matrix.Age Range Generally Precambrian, but may be as young as Tertiary.Depositional Environment Intruded into granitic gneiss or into volcanic-sedimentary terrane.Tectonic Setting(s) Cratonal, mostly in Precambrian shield areas.Associated Deposit Types Stillwater-Ni-Cu, Merensky Reef PGE, and Bushveld Fe-Ti-V deposits. PGE placers.DEPOSIT DESCRIPTIONMineralogy Chromite  $\pm$  ilmenite  $\pm$  magnetite  $\pm$  pyrrhotite  $\pm$  pentlandite  $\pm$  chalcopyrite  $\pm$  PGE minerals (dominantly laurite, cooperite, and braggite).Texture/Structure Massive to disseminated layers, cumulus texture.Alteration None related to ore.Ore Controls May be in dunite, orthopyroxenite, or anorthosite. Thickness of chromite increases in basinal depressions in layering.Weathering Abundant blocks of chromitite in soil and alluvium.Geochemical Signature Cr, PGE. High Mg; low Na, K, P.EXAMPLES

Bushveld Complex, SAFR	(Cameron and Desborough, 1969)
Stillwater Complex, USMT	(Jackson, 1969)
Great Dyke, ZIMB	(Bichan, 1969)

## DESCRIPTIVE MODEL OF MERENSKY REEF PGE

By Norman J Page

SYNONYM Stratiform mafic-ultramafic PGE.

DESCRIPTION Disseminated PGE-rich sulfides in olivine-rich rocks in anorthosite-gabbro zone of large layered intrusions (see fig. 5).

### GEOLOGICAL ENVIRONMENT

Rock Types Norite, gabbro-norite, dunite, harzburgite, peridotite, pyroxenite, troctolite, anorthosite, and gabbro.

Textures Cumulate textures; layers with gradational proportions of euhedral crystals; locally with poikilitic matrix.

Age Range Generally Precambrian, but may be as young as Tertiary.

Depositional Environment Intruded into granitic gneiss or into volcanic-sedimentary terrane.

Tectonic Setting(s) Cratonal, mostly in Precambrian shield areas.

Associated Deposit Types Stillwater Ni-Cu, Bushveld Cr, and Bushveld Fe-Ti-V. PGE placers.

### DEPOSIT DESCRIPTION

Mineralogy Pyrrhotite + chalcopyrite + pentlandite ± chromite ± graphite. PGE minerals are braggite, cooperite, kotulskite, vysotskite, sperrylite, moncheite, and alloys of platinum-group metals.

Texture/Structure Clots of massive sulfide and disseminated grains.

Alteration None related to ore.

Ore Controls In layers near first reappearance of olivine as a cumulate phase after thick accumulation of plagioclase pyroxene rocks. May be related to introduction of new magma. Locally associated with pipes of Fe-rich olivine.

Weathering Difficult to see ore zone on weathered surface, exploration requires extensive sampling and chemical analysis.

Geochemical Signature PGE, Cu, Ni, Cr, Ti. High Mg; low Na, K, F.

### EXAMPLES

Bushveld Complex, SAFR	(Vermaak and Hendriks, 1976)
Stillwater Complex, USMT	(Todd and others, 1982)

## DESCRIPTIVE MODEL OF BUSHVELD Fe-Ti-V

By Norman J Page

SYNONYM Stratiform mafic-ultramafic Fe-Ti-V.

DESCRIPTION Layers of Ti-V-rich magnetite in upper parts of large repetitively layered mafic-ultramafic intrusions (see fig. 5).

GEOLOGICAL ENVIRONMENT

Rock Types Norite, gabbro-norite, dunite, harzburgite, peridotite, pyroxenite, troctolite, anorthosite, and gabbro.

Textures Cumulate textures; layers with gradational proportions of euhedral crystals; locally with poikilitic matrix.

Age Range Generally Precambrian, but may be as young as Tertiary.

Depositional Environment Intruded into granitic gneiss or into volcanic-sedimentary terrane.

Tectonic Setting(s) Cratonal, mostly in Precambrian shield areas.

Associated Deposit Types Bushveld Cr, Stillwater Ni-Cu, and Merensky Reef PGE. PGE placers.

DEPOSIT DESCRIPTION

Mineralogy Vanadium-bearing magnetite  $\pm$  ilmenite  $\pm$  traces of sulfides.

Texture/Structure Massive magnetite-ilmenite, cumulus textures.

Ore Controls Layers near top of intrusion. Layers may be cut by pipes and veins rich in ilmenite.

Weathering Blocks of magnetite in soil and alluvium.

Geochemical Signature Fe, Ti, V.

EXAMPLES

Bushveld Complex, SAFR

(Williams, 1969; Molyneux, 1969)

DESCRIPTIVE MODEL OF DULUTH Cu-Ni-PGE

By Norman J Page

DESCRIPTION Sporadically distributed massive to disseminated sulfides associated with basal portion of large layered intrusions in rift environments.

GENERAL REFERENCE Weiblen and Morey (1980).

GEOLOGICAL ENVIRONMENT

Rock Types Peridotite, harzburgite, pyroxenite, norite, augite, troctolite, anorthosite. Associated with pyritic shale, anhydrite, or recognizable source of sulfur to contaminate magma.

Textures Cumulus textures, locally diabasic or ophitic textures.

Age Range Precambrian to Tertiary(?).

Depositional Environment Intruded during rifting into metasedimentary (slate, argillite, graywacke) and metavolcanic rocks.

Tectonic Setting(s) Rift environment.

DEPOSIT DESCRIPTION

Mineralogy Pyrrhotite + pentlandite + chalcopyrite + cubanite ± PGE minerals ± graphite.

Texture/Structure Disseminated, matrix, and massive sulfides.

Alteration Locally sulfides may show evidence of hydrothermal remobilization.

Ore Controls Zone of active syn-intrusion faulting forming basins, in basal part of intrusion; source of external sulfur; source of silicic material to contaminate magma.

Geochemical Signature Ni/Cu approximately 1/3, Cu, Ni; PGE, Co, Ti; sulfur isotopes show non-magmatic sulfur.

EXAMPLES

Duluth Complex, USMN  
(Dunka Road deposits)

(Weiblen and Morey, 1980;  
Bonnichsen, 1972; Ripley, 1981)

## DESCRIPTIVE MODEL OF NORIL'SK Cu-Ni-PGE

By Norman J Page

DESCRIPTION Massive to disseminated sulfides in small shallow mafic to ultramafic intrusives with an external source of sulfur.

GEOLOGICAL ENVIRONMENT

Rock Types Flood basalts, picritic intrusive rocks, picritic gabbro, norite, olivine gabbro, dolerite, intrusive and volcanic breccias. Associated with evaporites or some external source of sulfur.

Textures Ophitic, subophitic, gabbroic, cumulate.

Age Range Paleozoic.

Depositional Environment Magma has intruded through evaporites or pyritic shale, and formed sills in flood basalts during active faulting.

Tectonic Setting(s) Rift environment.

DEPOSIT DESCRIPTION

Mineralogy Pyrrhotite + pentlandite + chalcopyrite + cubanite + millerite + vallerite + pyrite + bornite + gersdorffite + sperrylite + PGE alloys + polarite + PGE tellurides, arsenides, and antimonides.

Texture/Structure Lenses, layers of massive, matrix, and disseminated sulfide.

Alteration None related to ore.

Ore Controls External source of sulfur; sulfides form persistent basal layers to intrusion and dike-like bodies into country rock; and form in fault-bounded depressions.

Geochemical Signature Ni/Cu = 1.5 to 0.5, Co/Ni = 1/16; Pt/(Pd/Ni) = 1/500

EXAMPLES

Noril'sk, USSR

(Krauss and Schmidt, 1979)



## DESCRIPTIVE MODEL OF KOMATIITIC Ni-Cu

By Norman J Page

DESCRIPTION Lenticular, irregular elongate to tabular, pipelike Ni-Cu sulfides associated with komatiitic volcanic extrusive rocks (see fig. 6).

GENERAL REFERENCE Arndt and Nisbet (1982).

### GEOLOGICAL ENVIRONMENT

Rock Types Dunite, pyroxenite, peridotite, basalt, komatiites, komatiitic basalts. Rocks contain more than 15 percent and may approach 40 percent MgO.

Textures Bladed olivine or pyroxene with skeletal appearance in random or parallel orientations; spinifex textures, fracture or joint patterns that resemble pillows.

Age Range Archean or Proterozoic generally, but some may be Cretaceous or Tertiary.

Depositional Environment Mafic to felsic rock sequences with numerous volcanic events.

Tectonic Setting(s) Greenstone belts.

Associated Deposit Types Dunitic Ni.

### DEPOSIT DESCRIPTION

Mineralogy Pyrite + pyrrhotite + chalcopyrite + pentlandite, by-product PGE.

Texture/Structure Sulfide contents vary from base to top of deposit. Base contains massive sulfide grading into net-textured or matrix sulfide into disseminated sulfide.

Alteration None related to ore.

Ore Controls In lowermost flows more than 10 m thick; in zones of increased spinifex development; and near feeder areas for the flows. Orebodies show evidence of active faulting at the time the flows were deposited and have thickening and thinning of flows along strike. Ore occurs in irregularities at bottom of flows. Unit contains greater than 1,000 ppm sulfur or is associated with sulfide-bearing chert and argillite. Shale or iron carbonate sequences occur below flows.

Weathering Develop gossans, laterites.

Geochemical Signature High Mg, Ni, Cu, Mg, PGE. Gossans contain 15 to 30 ppb Pd and 5 to 10 ppb Ir over known Ni-Cu deposits where Cu and Ni are leached out of the gossan.

### EXAMPLES

Kambalda, AUWA	(Gresham and Loftus-Hills, 1981)
Damba, ZIMB	(Williams, 1979)
Langmuir, CNON	(Green and Naldrett, 1981)

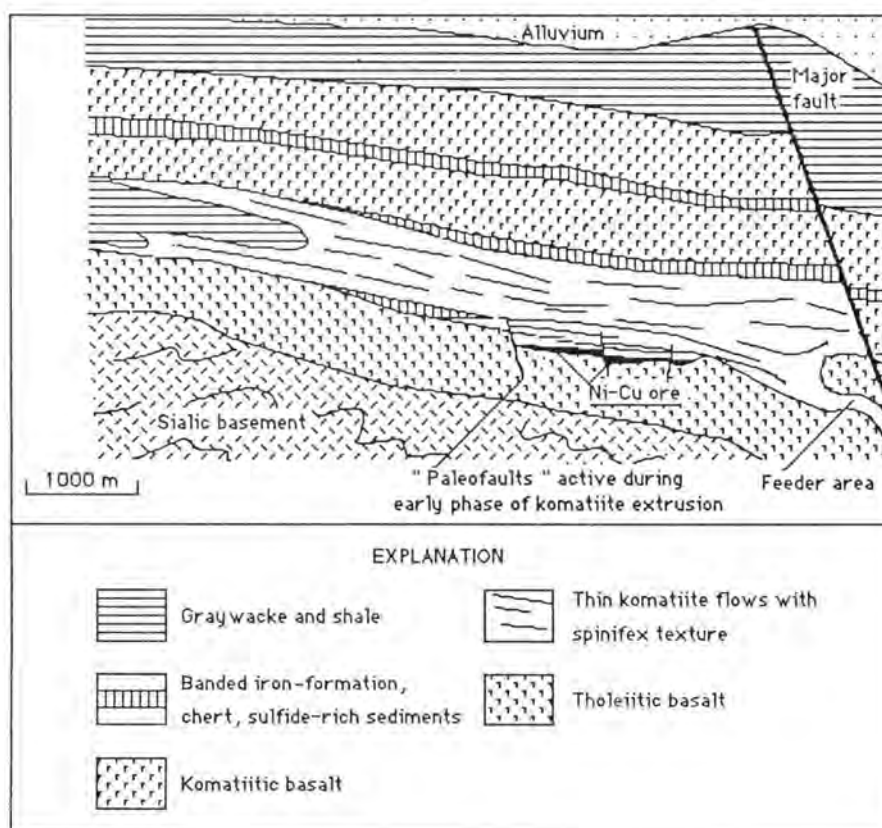
## GRADE AND TONNAGE MODEL OF KOMATIITIC Ni-Cu

By Donald A. Singer, Norman J Page, and W. David Menzie

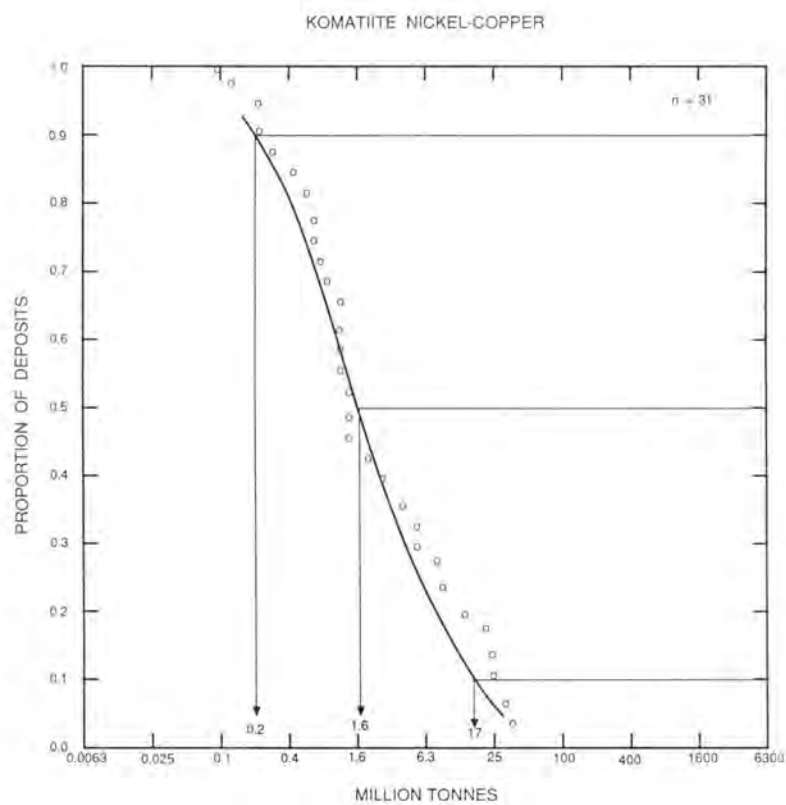
COMMENTS Nickel grade is correlated with tonnage ( $r = -0.47$ ) and with copper grade ( $r = 0.59$ ,  $n = 21$ ). Au, Ir, Pt, and Pd grades are based on reported analyses of samples from the deposits. See figs. 7-10.

DEPOSITS

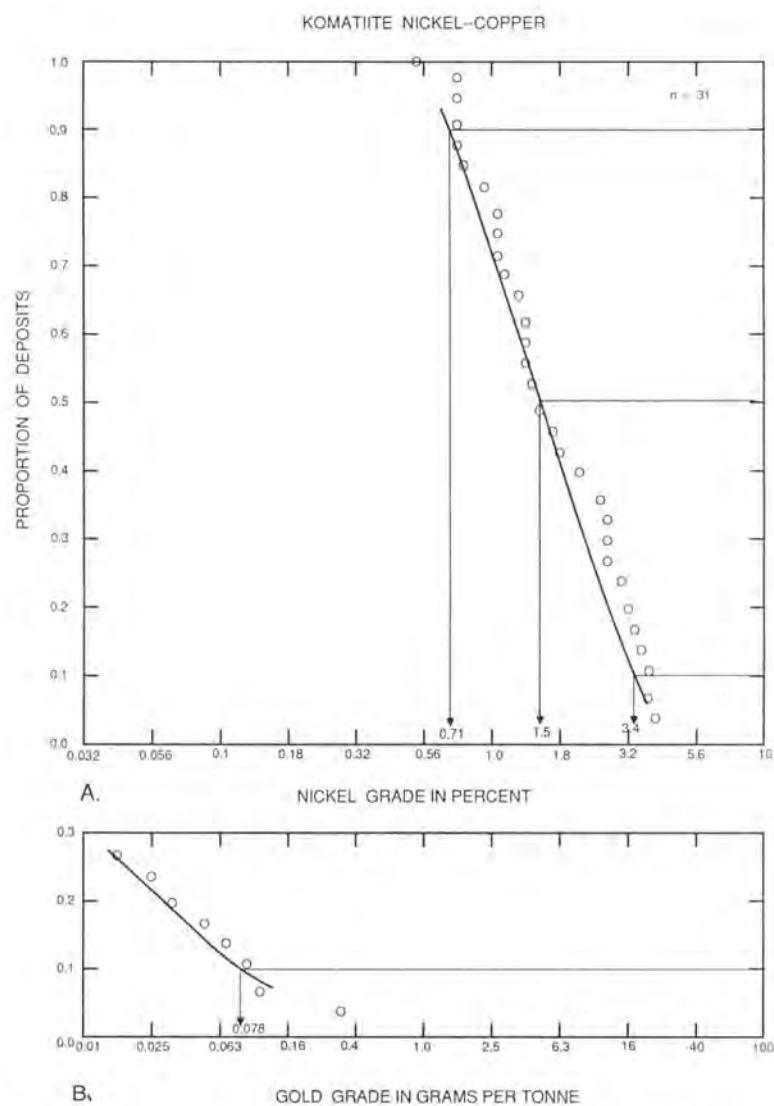
<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Carnilya E.	AUWA	Munda	AUWA
Carnilya Hill	AUWA	Nepean	AUWA
Damba	ZIMB	Perseverance	ZIMB
Epoch	ZIMB	Rankin Inlet	CNNT
E. Scotia	AUWA	Redross	AUWA
Hitura	FNLD	Scotia	AUWA
Hunters Road	ZIMB	Selukwe	ZIMB
Kambalda	AUWA	Shangani	ZIMB
Kotalahti	FNLD	Sothman Twp.	CNON
Langmuir 1	CNON	Spargoville	AUWA
Langmuir 2	CNON	S. Windarra	AUWA
Marbridge	CNQU	Textmont	CNON
McWatters	CNON	Trojan	ZIMB
Miriam	AUWA	Wannaway	AUWA
Mt. Edwards	AUWA	Wigie 3	AUWA
Mt. Windarra	AUWA		



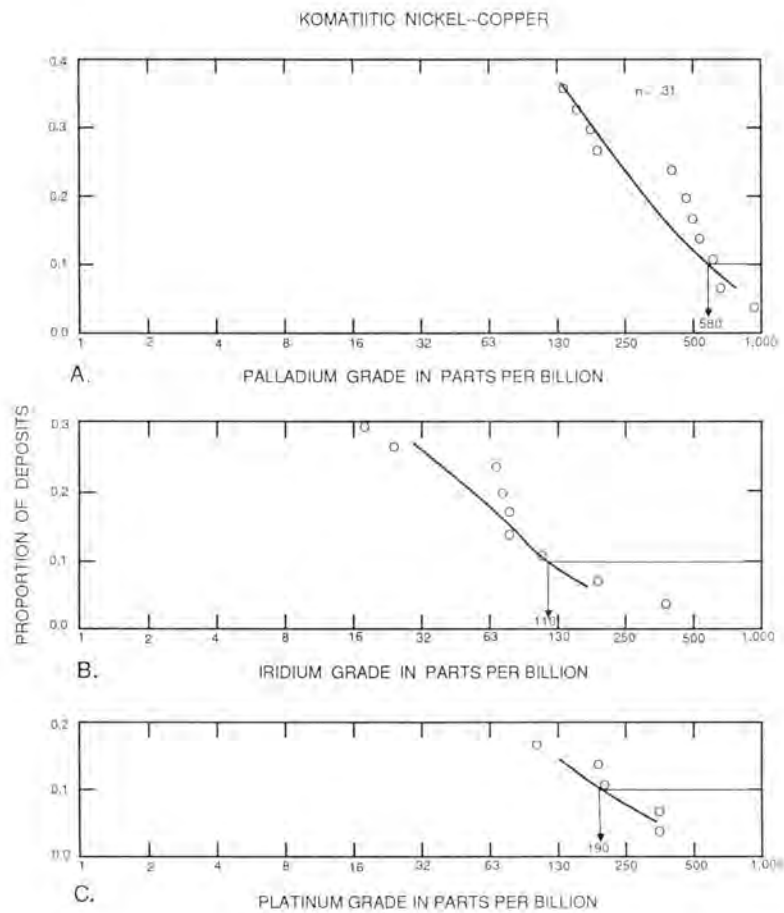
**Figure 6.** Cartoon cross section of typical komatiitic volcanic sedimentary sequence showing ore controls of komatiitic Ni-Cu deposits. Modified from Marston and others (1981).



**Figure 7.** Tonnages of komatiitic Ni-Cu deposits.

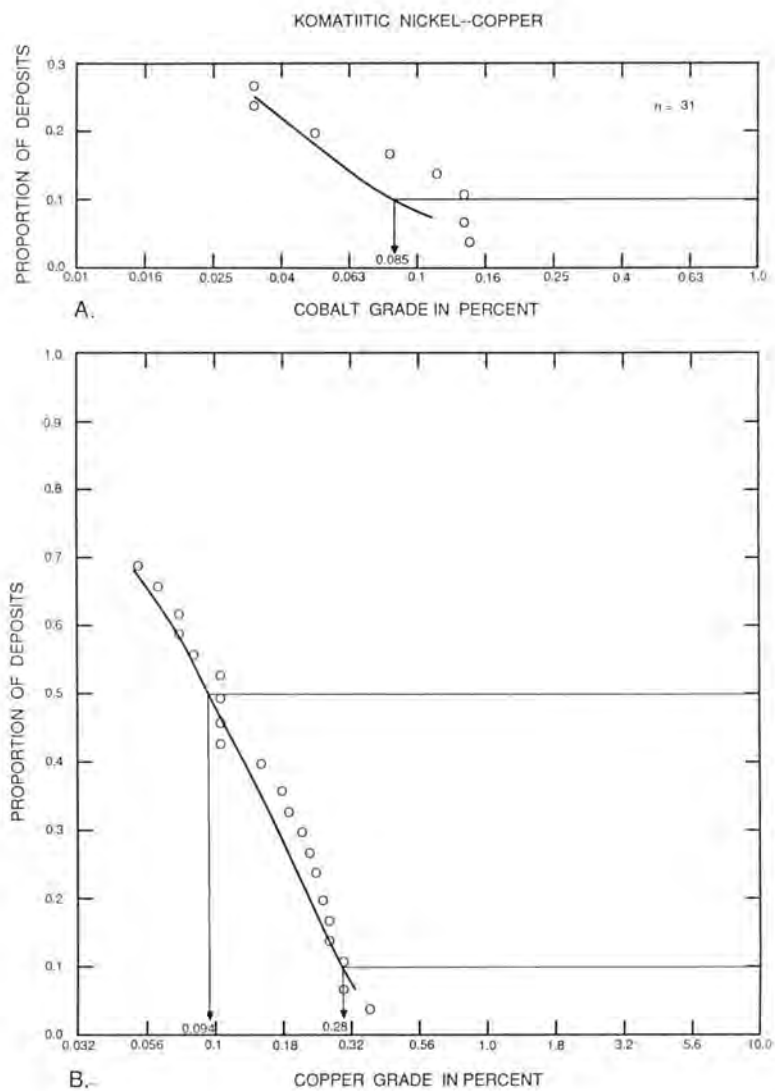


**Figure 8.** Nickel and gold grades of komatiitic Ni-Cu deposits. A, Nickel. B, Gold.



**Figure 9.** PGE grades of komatiitic Ni-Cu deposits. A, Palladium. B, Iridium. C, Platinum.





**Figure 10.** Base-metal grades among komatiitic Ni-Cu deposits. A, Cobalt. B, Copper.

## DESCRIPTIVE MODEL OF DUNITIC Ni-Cu

By Norman J Page

DESCRIPTION Disseminated sulfide mineralization in intrusive dunites.

GENERAL REFERENCE Marston and others (1981); Ross and Travis (1981).

### GEOLOGICAL ENVIRONMENT

Rock Types Dunite, olivine peridotite in subconcordant lenses 500-1,000 m long, 50-100 m thick.

Textures Dunite; coarse-grained (2-20 mm) subequant olivine ( $Fe_{87-95}$ ) interlocked to give polygonal to mosaic texture; olivine peridotite; ovate olivine with intercumulus pyroxene, sulfide and oxide minerals.

Age Range Precambrian.

Depositional Environment Intruded into contacts between clastic sedimentary and felsic volcanic rocks and mafic to ultramafic volcanic rocks.

Tectonic Setting(s) Greenstone belts.

Associated Deposit Types Komatiitic Ni, synorogenic-synvolcanic-Ni talc-carbonate Ni-Au, layered sedimentary Ni.

### DEPOSIT DESCRIPTION

Mineralogy High grade (1-9 percent Ni): pyrrhotite + pentlandite + magnetite + pyrite + chalcopyrite + chromite. Low grade (0.4-1 percent Ni): the same minerals  $\pm$  millerite  $\pm$  heazlewoodite  $\pm$  godlevskite  $\pm$  polydymite  $\pm$  vaesite  $\pm$  awaruite  $\pm$  bravoite  $\pm$  cobaltite  $\pm$  nickeliferous linnaeite  $\pm$  cubanite  $\pm$  Fe-Ni arsenides.

Texture/Structure Lenticular shoots of massive, matrix, and breccia ores are fine to medium grained, also occurs as interstitial films. Olivine is commonly rounded when sulfide is present.

Alteration Prograde and retrograde serpentization after deposition; usually metamorphosed.

Ore Controls Dunitic lenses close to major strike-slip faults and at high stratigraphic position in volcanic pile; most Ni-rich ores concentrated at one margin, perhaps at base of intrusion.

Weathering Lateritic zones may be enriched in PGE.

Geochemical Signature Ni, Cu, PGE, Cr, Co, Mg. Ni/Cu = 19-70+, Ni/Co=30-70. Massive sulfide ores 6-9 percent Ni, disseminated ores up to 3 percent Ni.

### EXAMPLES

Agnew (Perseverance), AUWA  
Mt. Keith, AUWA

(Martin and Allchurch, 1975)  
(Burt and Sheppy, 1975)

## GRADE AND TONNAGE MODEL OF DUNITIC Ni-Cu

By Donald A. Singer and Norman J Page

COMMENTS Nickel grade is correlated with tonnage ( $r = -0.54$ ) and copper grade ( $r = 0.84$ ,  $n = 12$ ). Ir, Pd, Au, and Co grades are based on reported analyses of samples from the deposits. See fig. 11-14.

DEPOSITS

<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Agnew (Perseverance)	AUWA	Honeymoon Well	AUWA
Amax	CNMN	Manibridge	CNMN
Birch Tree	CNMN	Moak	CNMN
Black Swan	AUWA	Mt. Keith	AUWA
Bowden Lake	CNMN	Mystery Lake	CNMN
Bucko	CNMN	Pipe	CNMN
Discovery	CNMN	Six Mile	AUWA
Dumont	CNQU	Soab N.	CNMN
Forrestania Group	AUWA	Soab S.	CNMN
Geol. Reser. No. 34	CNMN	Thompson	CNMN
Hambone	CNMN	Weebo Bore	AUWA

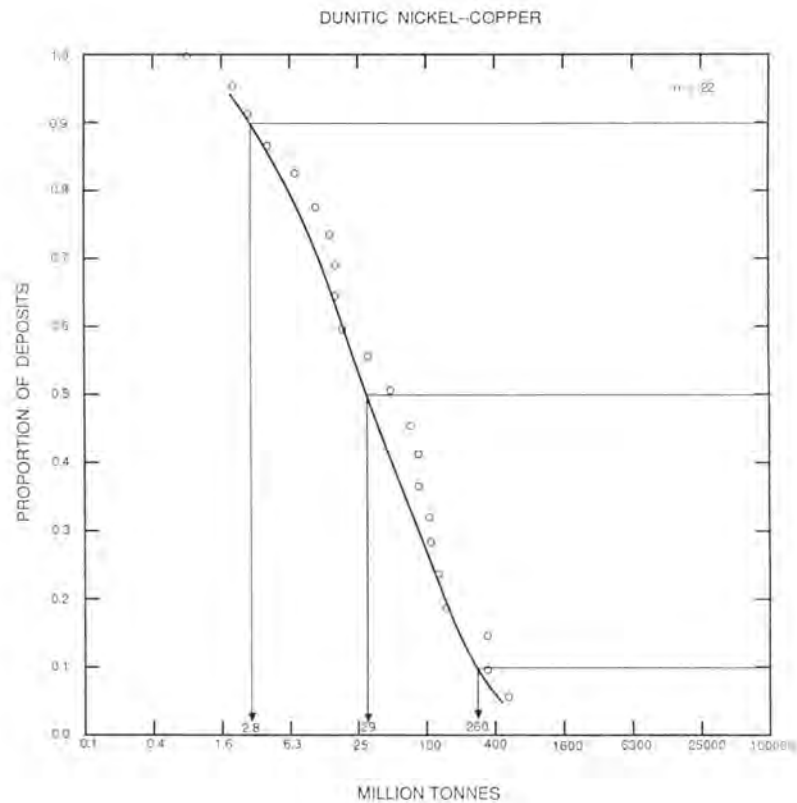


Figure 11. Tonnages of dunitic Ni-Cu deposits.

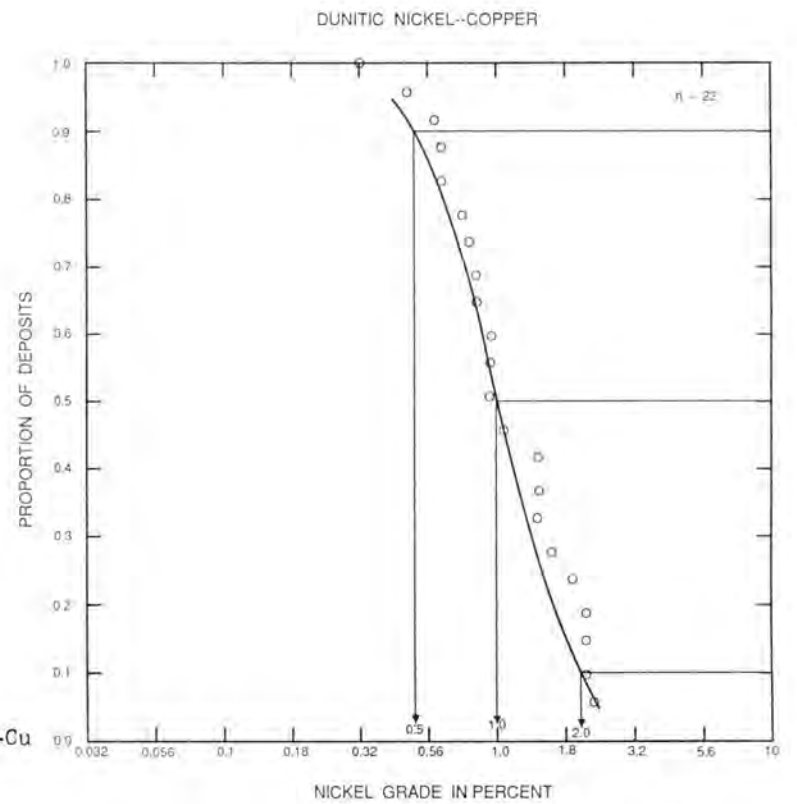


Figure 12. Nickel grades of dunitic Ni-Cu deposits.

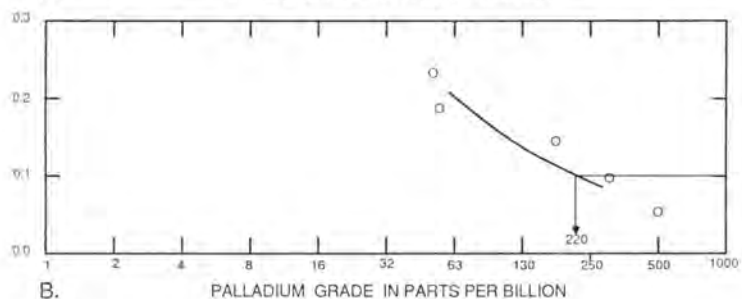
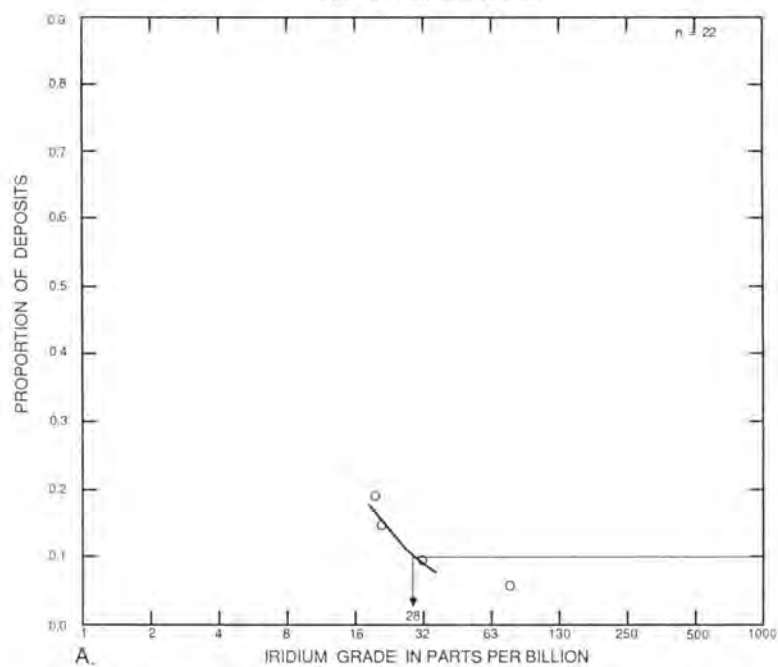


Figure 13. PGE grades of dunitic Ni-Cu deposits. A, Iridium. B, Palladium.

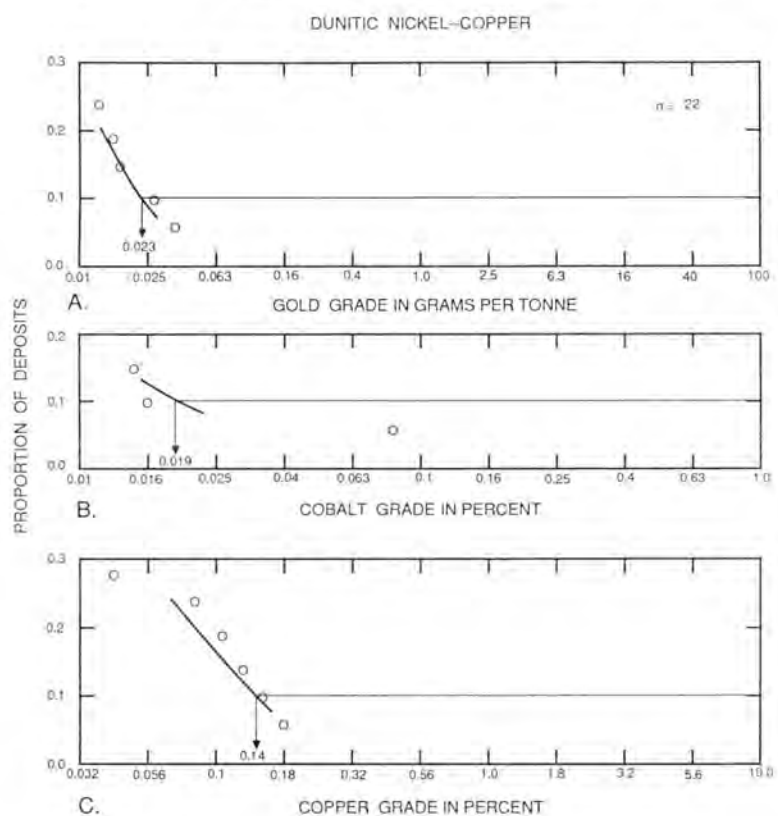


Figure 14. By-product grades of dunitic Ni-Cu deposits. A, Gold. B, Cobalt. C, Copper.



# DESCRIPTIVE MODEL OF SYNOROGENIC-SYNVOLCANIC Ni-Cu

By Norman J Page

APPROXIMATE SYNONYMS Gabbroid class (Ross and Travis, 1981), gabbroid associated (Marston and others, 1981).

DESCRIPTION Massive lenses, matrix and disseminated sulfide in small to medium sized gabbroic intrusions in greenstone belts.

## GEOLOGICAL ENVIRONMENT

Rock Types Norite, gabbro-norite, pyroxenite, peridotite, troctolite, and anorthosite forming layered or composite igneous complexes.

Textures Phase and cryptic layering sometimes present, rocks usually cumulates.

Age Range Archean to Tertiary, predominantly Archean and Proterozoic.

Depositional Environment Intruded synvolcanically or during orogenic development of a metamorphic terrane containing volcanic and sedimentary rocks.

Tectonic Setting(s) Metamorphic belts, greenstone belts, mobile belts.

Associated Deposit Types Komatiitic Ni-Cu, dunitic Ni-Cu, tale-carbonate Ni-Au (no model available).

## DEPOSIT DESCRIPTION

Mineralogy Pyrrhotite + pentlandite + chalcopyrite + pyrite + Ti-magnetite + Cr-magnetite + graphite--by-product Co and PGE.

Texture/Structure Predominantly disseminated sulfides; commonly highly deformed and metamorphosed so primary textures and mineralogy have been altered. Deformation about the same age as the deposit.

Ore Control Sulfides commonly are in the more ultramafic parts of the complex and near the basal contacts of the intrusion.

Weathering Lateritic.

Geochemical Signature Ni, Cu, Co, PGE.

## EXAMPLES

Sally Malay, AUWA	(Thornett, 1981)
Rana, NRWY	(Boyd and Mathiesen, 1979)
Moxie pluton, USMA	(Thompson and Naldrett, 1984)

# GRADE AND TONNAGE MODEL OF SYNOROGENIC-SYNVOLCANIC Ni-Cu

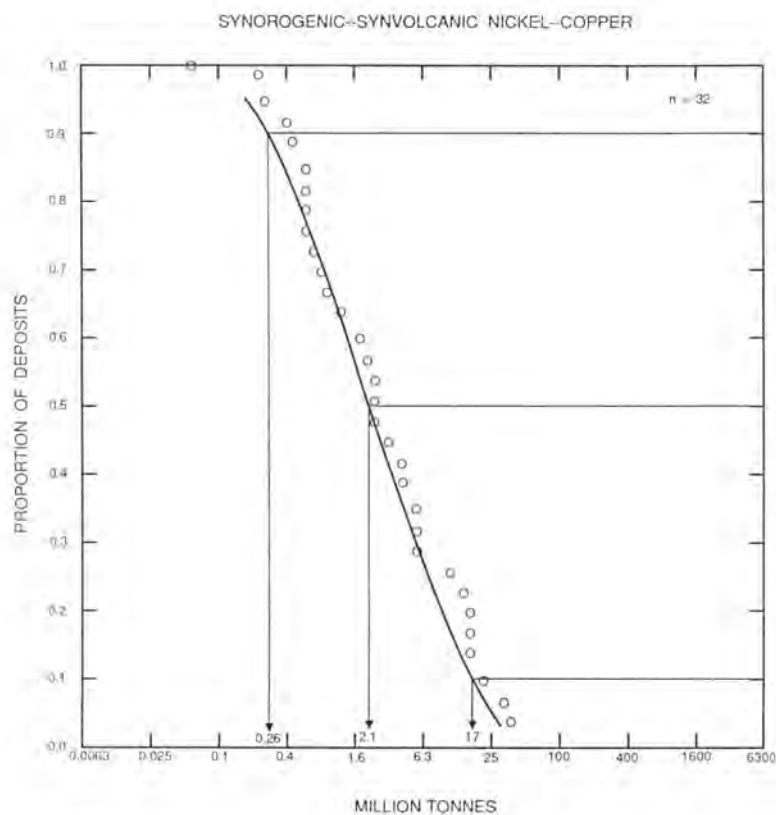
By Donald A. Singer, Norman J Page, and W. David Menzie

COMMENTS Pd, Pt, Au, and Co grades are based on reported analyses of samples from the deposits. See figs. 15-18.

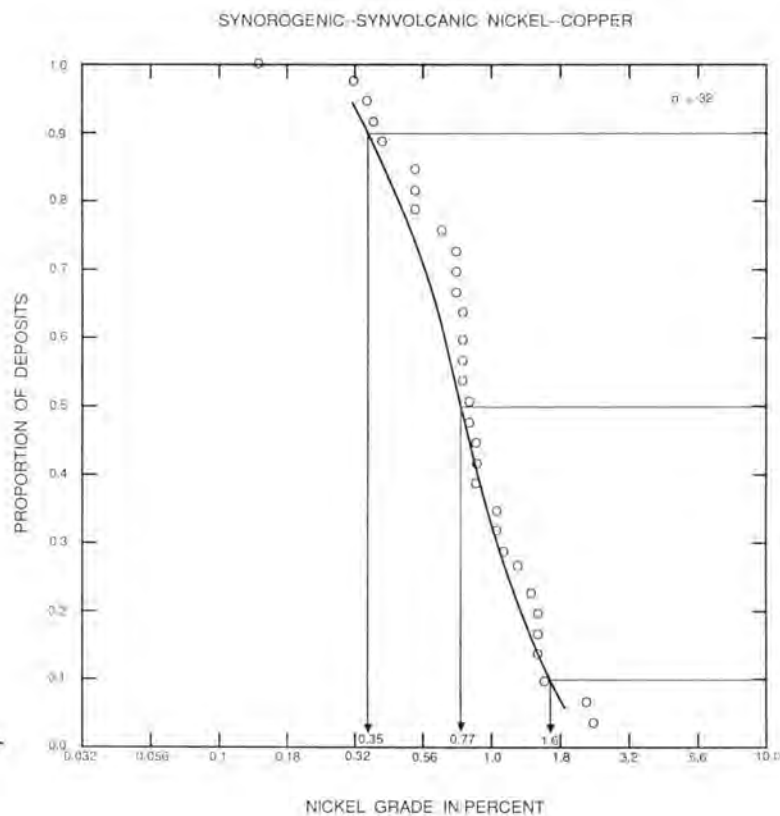
## DEPOSITS

<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Bamble	NRWY	Funter Bay	USAK
Carr Boyd	AUWA	Gap	USPA
Empress	ZIMB	Giant Mascot	CNBC
Flaat	NRWY	Hosanger	NRWY

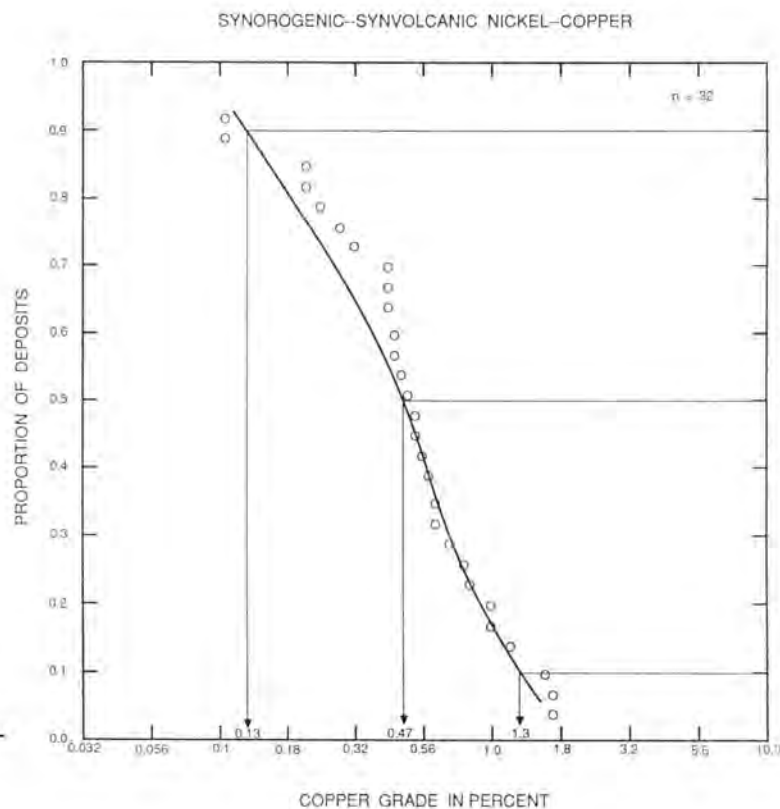
Kenbridge	CNON	Phoenix	BOTS
Kylmakoski	FNLD	Pikwe	BOTS
Lainijaur	SWDN	Renzy	CNQU
Lappuattnet	SWDN	Risliden	SWDN
Laukunkawges	FNLD	Selebi	BOTS
Lorraine	CNQU	Selebi N.	BOTS
Lynn Lake	CNMN	Selkirk	BOTS
Madziwa	ZIMB	Tekwane	BOTS
Makola	FNLD	Thierry	CNON
Mjodvattnet	SWDN	Vakkerlien	NRWY
Montcalm	CNON	Vammala	FNLD
Mt. Sholl	AUWA	Yakobi Island	USAK



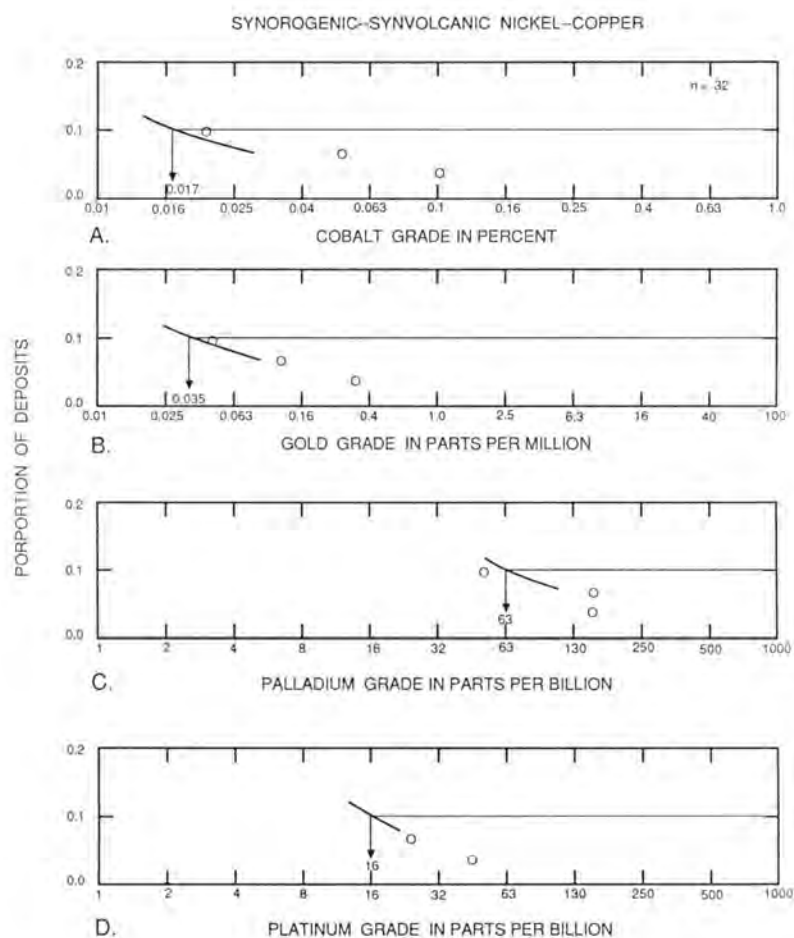
**Figure 15.** Tonnages of synorogenic-synvolcanic Ni-Cu deposits.



**Figure 16.** Nickel grades of synorogenic-synvolcanic Ni-Cu deposits.



**Figure 17.** Copper grades of synorogenic-synvolcanic Ni-Cu deposits.



**Figure 18.** By-product grades of synorogenic-synvolcanic Ni-Cu deposits. A, Cobalt. B, Gold. C, Palladium. D, Platinum.

## DESCRIPTIVE MODEL OF ANORTHOSITE Ti

By Eric R. Force

DESCRIPTION Ilmenite (and rutile) deposits in granulite metamorphic terranes intruded by anorthosite-ferrodiorite-clan plutons. Two subsets (1 and 2) distinguished below (see fig. 19).

### GEOLOGICAL ENVIRONMENT

Rock Types (1) Andesine anorthosite massifs in granulite-facies country rocks (associated mineralization includes rutile if andesine is antiperthitic).

(2) Ferrodiorite-type intrusive rocks (gabbro, charnockite, jotunite) generally younger than anorthosite, with associated ilmenite  $\pm$  apatite mineralization.

Textures Granulation in anorthosite, quartz platy and blue where present.

Age Range Most, and perhaps all, between 900 and 1,500 m.y. in age.

Depositional Environment Lower crust, intrusion under hot, dry conditions.

Tectonic Setting(s) Not well known.

Associated Deposit Types None known.

### DEPOSIT DESCRIPTION

Mineralogy: (1) Ilmenite  $\pm$  rutile

(2) Ilmenite  $\pm$  apatite

Deposit value is much greater if intergrown magnetite and ulvospinel are absent.

Texture/Structure (1) Disseminations to veinlets along anorthosite margins, hosted by both impure anorthosite and adjacent country rock.

(2) Both concordant layers within or at base of ferrodiorite-clan sheets, and vein-like massive bodies in underlying structural units (especially anorthosite).

Alteration None related to ore.

Ore Controls (1) High-temperature metasomatism between Ti-Fe oxides-rich country rock, and anorthosite, coupled with unknown processes in anorthosite magma. Especially concentrated in swarms of anorthosite sills.

(2) Immiscible Ti, P liquid in ferrodioritic magma, forming both cumulate-like bodies and fracture fillings.

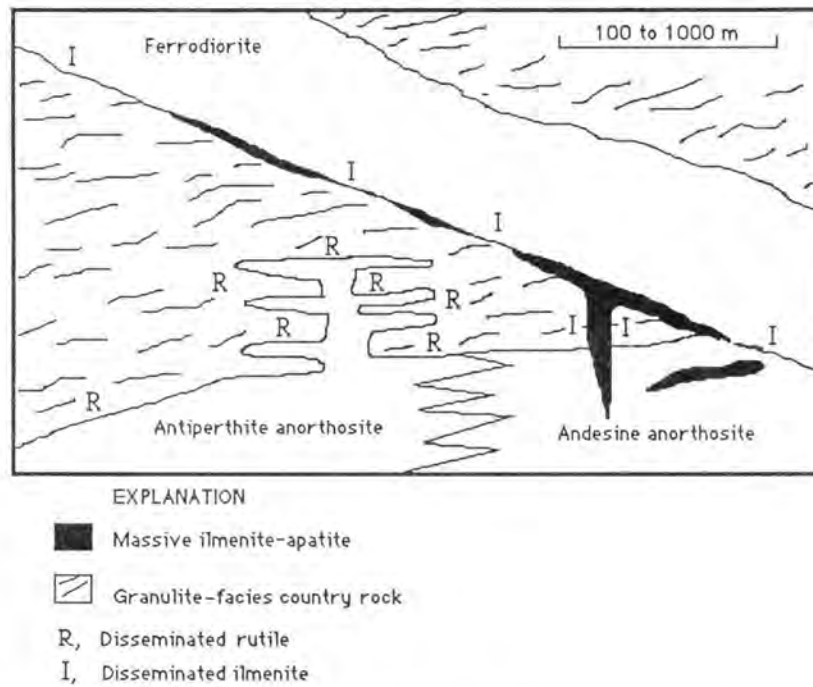
Weathering Residual enrichment may occur in weathering zone.

Geochemical and Geophysical Signature (2) High Ti, P, and Zr. Magnetic anomalies.

### EXAMPLES

- |                     |                             |
|---------------------|-----------------------------|
| (1) Roseland, USVA  | (Herz and Force, 1984)      |
| Pluma Hidalgo, MXCO | (Paulson, 1964)             |
| (2) Roseland, USVA  | (Herz and Force, 1984)      |
| Sanford Lake, USNY  | (Gross, S. O., 1968)        |
| Laramie Range, USWY | (Eberle and Atkinson, 1983) |





**Figure 19.** Cartoon cross section of a typical anorthosite ferro-diorite intrusion showing relation between different forms of Ti concentrations.

## DESCRIPTIVE MODEL OF PODIFORM CHROMITE

By John P. Albers

APPROXIMATE SYNONYM Alpine type chromite (Thayer, 1964).

DESCRIPTION Podlike masses of chromitite in ultramafic parts of ophiolite complexes (see fig. 20).

GENERAL REFERENCE Dickey (1975).

### GEOLOGICAL ENVIRONMENT

Rock Types Highly deformed dunite and harzburgite of ophiolite complexes; commonly serpentinized.

Textures Nodular, orbicular, gneissic, cumulate, pull-apart; most relict textures are modified or destroyed by flowage at magmatic temperatures.

Age Range Phanerozoic.

Depositional Environment Lower part of oceanic lithosphere.

Tectonic Setting(s) Magmatic cumulates in elongate magma pockets along spreading plate boundaries. Subsequently exposed in accreted terranes as part of ophiolite assemblage.

Associated Deposit Types Limassol Forest Co-Ni-S-As.

### DEPOSIT DESCRIPTION

Mineralogy Chromite  $\pm$  ferrichromite  $\pm$  magnetite  $\pm$  Ru-Os-Ir alloys  $\pm$  laurite.

Texture/Structure Massive coarse-grained to finely disseminated.

Alteration None related to ore.

Ore Controls Restricted to dunite bodies in tectonized harzburgite or lower portions of ultramafic cumulate (see fig. 99).

Weathering Highly resistant to weathering and oxidation.

Geochemical Signature None recognized.

### EXAMPLES

High Plateau, Del Norte Cty, USCA (Wells and others, 1946)  
Coto Mine, Luzon, PLPN (LeBlanc and Violette, 1983)

## GRADE AND TONNAGE MODEL OF MINOR PODIFORM CHROMITE

By Donald A. Singer and Norman J Page

DATA REFERENCES Singer and others (1980); Calkins and others (1978); Carlson and others (1985).

COMMENTS All deposits in this grade-tonnage compilation are from California and Oregon. The two largest tonnage deposits are actually districts rather than individual deposits. The majority of the grades represent shipping grades. Grades less than 35 percent typically represent in-place "ore". The mixture of shipping grades and in-place grades may explain the significant negative correlation ( $r = -0.25$ ) between grade and tonnage. Rh, Ir, Ru, Pd, and Pt grades are based on reported analyses of samples from the deposits. Unreported PGE grades are probably similar to those presented here. Rhodium is correlated with chromite ( $r = 0.35$ ,  $n = 69$ ), platinum ( $r = 0.69$ ,  $n = 31$ ), iridium ( $r = 0.47$ ,  $n = 35$ ), ruthenium ( $r = 0.56$ ,  $n = 28$ ). Ruthenium is correlated with palladium ( $r = 0.72$ ,  $n = 21$ ) and iridium ( $r = 0.59$ ,  $n = 29$ ). See figs. 21-23.

DEPOSITS

<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Ace of Spades	USCA	Castro Mine	USCA
Adobe Canyon Gp.	USCA	Cattle Springs	USCA
Ajax	USOR	Cavyell Horse C	USOR
Alice Mine	USCA	Cavyell Horse Mountain	USOR
Allan (Johnson)	USCA	Cedar Creek	USOR
Alta Hill	USCA	Celebration	USOR
Althouse	USOR	Challange area	USCA
Alyce and Blue Jay	USCA	Chambers	USOR
American Asbestos	USCA	Chicago	USCA
Anti Axis	USCA	Christian Place	USCA
Apex (Del Norte Co.)	USCA	Chrome Camp	USCA
Apex (El Dorado Co.)	USCA	Chrome Gulch	USCA
Applegate	USOR	Chrome Hill	USCA
Associated Chromite	USOR	Chrome King (Josephine Co.)	USOR
Babcock	USOR	Chrome King (Jackson Co.)	USOR
Babyfoot	USOR	Chrome No. 3	USOR
Beat	USCA	Chrome Ridge	USOR
Big Bear	USOR	Clara H	USCA
Big Bend	USCA	Clary and Langford	USCA
Big Chief	USOR	Cleopatra	USOR
Big Dipper (Robr)	USCA	Clover Leaf	USCA
Big Four	USOR	Codd Prospect	USCA
Big Pine Claim	USCA	Coggins	USCA
Big Yank No. 1	USOR	Collard Mine	USOR
Binder No. 1	USCA	Commander	USCA
Black Bart (Great Western)	USCA	Coon Mt. Nos. 1-3	USCA
Black Bart Claim (Avery)	USCA	Copper Creek (Low Divide)	USCA
Black Bart Group	USCA	Courtwright	USCA
Black Bear	USCA	Courtwright (Daggett)	USCA
Black Beauty	USOR	Cow Creek Gp.	USCA
Black Boy	USOR	Crouch	USOR
Black Chrome	USCA	Crown	USOR
Black Diamond	USOR	Cyclone Gap	USCA
Black Diamond (Grey Eagle Gp.)	USCA	Cynthia	USOR
Black Hawk	USOR	Daisy (Aldelabron)	USCA
Black Otter	USOR	Dark Star	USOR
Black Rock Chrome	USCA	Darrington	USCA
Black Streak	USOR	Deep Gorge Chrome	USOR
Black Warrior	USOR	Delare Prospect	USOR
Blue Brush	USCA	Detert	USCA
Blue Creek Tunnel	USCA	Diamond	USCA
Blue Sky (Lucky Strike)	USCA	Dickerson	USCA
Boiler Pit	USCA	Dickey and Drisbach	USCA
Bonanza	USCA	Dirty Face	USOR
Booker Lease	USCA	Doe Flat	USCA
Bowden Prospect	USCA	Don Pedro	USCA
Bowie Estate	USCA	Dorriss	USCA
Bowser	USOR	Dozier	USCA
Bragdor	USCA	Dry Creek	USOR
Briggs Creek	USOR	Earl Smith	USCA
Brown Scratch	USOR	Early Sunrise	USOR
Bunker	USCA	Edeline	USCA
Burned Cabin	USOR	Eden	USCA
Butler Claims	USCA	Eggling and Williams	USCA
Butler, Estate Chrome, etc	USCA	El Primero	USCA
Buttercup Chrome	USCA	Elder Claim	USCA
Camden Mine	USCA	Elder Creek	USCA
Campbell	USOR	Elder Creek Gp.	USCA
Camptonville area	USCA	Elk Creek Claim	USCA
		Elkhorn Chromite	USOR

Model 8a--Con.

Ellingwood	USCA	Jim Bus	USOR
Ellis	USCA	Johns	USOR
Esterly Chrome	USOR	Josephine	USCA
Esther and Phyllis	USCA	Josephine No. 4	USOR
Fairview	USCA	Judy (Hicks)	USCA
Fiddler's Green	USCA	Julian	USCA
Fields and Stoker	USCA	Kangaroo Court Mine	USCA
Finan	USCA	Kingsley	USOR
Forest Queen	USCA	Kleinsorge Cp.	USCA
Foster	USOR	Kremmel and Froelich	USCA
Four Point	USOR	Lacey	USCA
Fourth of July	USCA	Lambert	USCA
French Hill	USCA	Langley Chrome	USOR
Friday	USOR	Lassie Peak	USCA
Gallagher	USOR	Last Buck	USOR
Gardner Mine	USOR	Last Chance (Coos)	USOR
Gas Canyon	USCA	Last Chance (Josephine)	USOR
Geach	USCA	Laton	USCA
Gibsonville	USCA	Letty	USCA
Gill (Gill Ranch)	USCA	Liberty	USCA
Gillan	USCA	Liberty Bond Claim	USCA
Gillis Prospect	USCA	Linda Marie	USOR
Glory Ho	USOR	Little Boy	USOR
Golconda Fraction	USCA	Little Castle Creek	USCA
Gold Bug Claim	USCA	Little Hope	USCA
Goncolda	USOR	Little Rock Mine	USCA
Gray Boy	USOR	Little Siberia	USOR
Gray Buck Gp.	USOR	Lone Gravel	USCA
Green (Americus)	USCA	Long Ledge Cp.	USCA
Green Mine	USCA	Lost Lee	USOR
Green Ridge	USCA	Lotty	USCA
Green's Capco Leases	USCA	Lucky Boy	USCA
Griffin Chromite	USOR	Lucky Friday	USOR
Gunn Claims	USCA	Lucky Girl	USCA
Half Chrome	USCA	Lucky Hunch	USOR
Hanseum	USOR	Lucky L. & R.	USOR
Happy Go Lucky	USCA	Lucky Nine Gp.	USOR
Harp and Sons Ranch	USCA	Lucky Star	USOR
Hawks Rest View	USOR	Lucky Strike (Lake Co.)	USCA
Hayden and Hilt	USCA	Lucky Strike (S.L.O. Co.)	USCA
Helemar	USCA	Lucky Strike (Curry Co.)	USOR
Hendricks No. 2	USCA	Lucky Strike	USOR
High Dome	USCA	Mackay	USCA
High Plateau	USCA	Madeira	USCA
Hill-Top Chrome	USCA	Madrid	USCA
Hodge Ranch	USCA	Manchester	USCA
Hoff	USCA	Maralls Capro Leases	USCA
Holbrook and McGuire	USCA	Marks & Thompson	USOR
Holseman (and others)	USCA	Mary Jane	USCA
Holston (Vaughn)	USCA	Mary Walker	USOR
Horseshoe	USCA	Maxwell	USCA
Horseshoe Chrome	USOR	Mayflower	USCA
Houser & Burges	USOR	McCaleb's Sourdough	USOR
Hudson (Fuller Claims)	USCA	McCarty	USCA
I-Wonder	USCA	McCormick	USCA
Illinois River	USOR	McGuffy Creek Gp.	USCA
Independence	USOR	McMurty	USCA
Irene Chromite	USOR	Meeker (Sonoma Chrome)	USCA
Iron King	USOR	Merrifield	USCA
Iron Mountain	USOR	Mighty Joe	USOR
Jack Forth	USCA	Milton	USCA
Jack Sprat Gp.	USCA	Mockingbird	USOR
Jackson	USOR	Moffatt Creek Gp.	USCA

Mohawk Claim	USOR	Ray (Tip Top)	USOR
Moore	USCA	Ray Spring	USOR
Moscatelli	USCA	Red Ledge	USCA
Moscatelli No. 2	USCA	Red Mountain	USOR
Mountain View	USCA	Red Slide Gp.	USCA
Mountain View Gp.	USCA	Redskin	USCA
MuNaly	USCA	Richards	USCA
Mulcahy Prospect	USCA	Richey, U.S. & S.J.	USCA
Mule Creek	USCA	Robt. E.	USOR
Mum and Alice June Claim	USCA	Rock Creek	USOR
Murphy	USCA	Rock Wren Mine	USCA
Muzzleloader (Stevens		Rose Claim	USCA
No. 1)	USCA	Rosie Claim	USOR
New Hope	USCA	Round Bottom	USCA
New Hope Claim	USOR	Roupe	USCA
Newman	USCA	Sad Sack	USOR
Nichelini Mine	USCA	Saddle Chrome	USOR
Nickel Mountain	USOR	Saint	USCA
Nickel Ridge	USOR	Sally Ann	USOR
No. 5	USCA	Salt Rock	USOR
Noble Electric Co.	USCA	Saturday Anne	USOR
Norcross	USCA	Schmid	USOR
North End, West End,		Seiad Creek (Mt. View)	USCA
Spotted Fawn	USCA	September Morn	USCA
North Fork Chrome	USCA	Sexton Mountain	USOR
North Star	USOR	Shade Chromite	USOR
North Star (Red Mtn)	USCA	Shafer Lease	USCA
Norway	USOR	Shamrock	USCA
Oak Ridge	USCA	Shelly	USCA
Olive B.	USOR	Sheppard Mine	USCA
Olsen	USCA	Shotgun Creek	USCA
Onion Springs	USOR	Silver Lease	USOR
Oregon Chrome	USOR	Simmons	USCA
Oxford	USCA	Simon	USCA
P. U. P. (Zenith)	USCA	Sims	USCA
Paradise No. 1	USOR	Six-Mile	USOR
Paradise No. 2	USOR	Skyline Mine	USCA
Park's Ranch	USCA	Skyline No. 1	USCA
Parker	USCA	Skyline No. 2	USCA
Parkeson	USCA	Smith Geitsfield	USOR
Pearsoll Peak	USOR	Snakehead (Jumbo)	USCA
Peewan	USCA	Snowy Ridge	USCA
Peg Leg (Lambert)	USCA	Snowy Ridge	USOR
Pennington Butte	USOR	Snyder	USCA
Perconi Ranch	USCA	Sour Dough	USOR
Pillikin	USCA	Sousa Ranch	USCA
Pine Mountain Claim	USCA	Southern Pacific Property	USCA
Pines	USOR	Spot	USCA
Pleasant No. 1 & 2	USOR	Spring Hill	USCA
Poco Tiempo Quartz	USCA	St. Patrick (Camp 8)	USCA
Pony Shoe	USCA	Stafford	USCA
Poodle Dog	USCA	Stark Bee	USCA
Porter Property	USCA	State School	USCA
Powers	USOR	Stevens-Miller	USOR
Prater	USOR	Stewart	USCA
Pyramid	USCA	Stone & Haskins	USOR
Queen of May	USOR	Store Gulch	USOR
Quigg	USCA	Stray Dog	USOR
Rainbow	USOR	Sullivan and Kahl	USCA
Rainy Day	USOR	Sunnyslope	USCA
Rancherie	USOR	Sunrise	USCA
Randall	USCA	Sunset (Fresno Co.)	USCA
Rattlesnake Mountain	USCA	Sunset (Placer Co.)	USCA



Model 8a--Con.

Sunshine	USCA	Unknown Name	USOR
Sutro Mine	USCA	Valen Prospect	USOR
Suzy Bell (Lucky Strike)	USCA	Valenti	USCA
Swayne	USCA	Victory No. 3	USCA
Sweetwater	USCA	Violet	USOR
Tangle Blue Divide	USCA	Vogelgesang	USCA
Tennessee Chrome	USOR	Wait	USCA
Tennessee Pass	USOR	Waite	USCA
Thompson Gp.	USOR	Walker	USCA
Tomkin	USCA	War Bond	USCA
Toujours Gai	USCA	War Eagle-Miller	USCA
Trinidad	USCA	Ward	USOR
Twin Cedars	USOR	Ward and Lyons	USCA
Twin Valley	USOR	Washout	USCA
Unnamed	USCA	Welch Prospect	USCA
Uncle Sam	USOR	West Chrome	USCA
Unknown Name	USOR	Western Magnesite	USCA
Unknown Name	USOR	White Bear	USCA
Unknown Name	USOR	White Cedar	USCA
Unknown Name	USOR	White Feather	USCA
Unknown Name	USOR	White Pine Mine	USCA
Unknown Name	USOR	Wild Cat Claim	USOR
Unknown Name	USOR	Wilder (Fish Creek)	USCA
Unknown Name	USOR	Windy Point	USOR
Unknown Name	USOR	Wolf Creek	USCA
Unknown Name	USOR	Wolf Creek area	USCA
Unknown Name	USOR	Wonder	USOR
Unknown Name	USOR	Wonder Gp.	USOR
Unknown Name	USOR	Yellow Pine	USCA
Unknown Name	USOR	Young	USOR
Unknown Name	USOR	Young's Mine	USOR
Unknown Name	USOR	Zerfing Ranch	USCA
Unknown Name	USOR		

GRADE AND TONNAGE MODEL OF MAJOR PODIFORM CHROMITE

By Donald A. Singer, Norman J Page, and Bruce R. Lipin

DATA REFERENCES Page and others (1979), Page and others (1982b), Page and others (1984).

COMMENTS This model, number 8b, is provided as an alternative to the podiform chromite model, number 8a, based on California and Oregon deposits because of the significant difference in tonnage of the two groups. The two groups are geologically similar and share the same descriptive model. Rh, Ir, Ru, Pd, and Pt grades are based on reported analyses of samples from the deposits. Platinum grade is correlated with chromite grade ( $r = 0.76$ ,  $n = 12$ ) and iridium grade ( $r = 0.71$ ,  $n = 8$ ). Rhodium is correlated with iridium grade ( $r = 0.88$ ,  $n = 7$ ). See figs. 24-26.

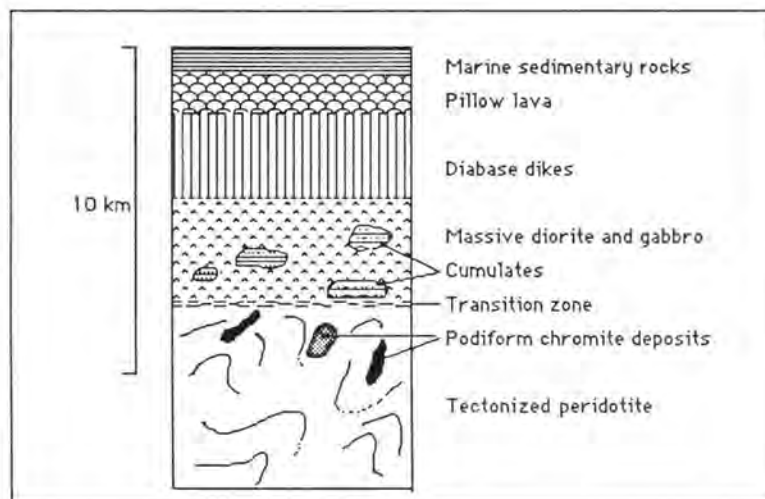
DEPOSITS

Name	Country	Name	Country
Abdasht	IRAN	Bagin	TRKY
Akarca	TRKY	Bagirsakdire	TRKY
Akcabuk	TRKY	Balcicakiri	TRKY
Akkoya	TRKY	Batikef	TRKY
Alice Louise	NCAL	Bati-N. Yarma	TRKY
Alpha	NCAL	Bati-Taban	TRKY
Altindag	TRKY	Bati- W. Yarma	TRKY
Amores	CUBA	Bellacoscia	NCAL
Andizlik	TRKY	Bellevue	NCAL
Anna Madeleine	NCAL	Bereket	TRKY
Asagi Zorkum	TRKY	Bezkere-Bulurlii	TRKY
Aventura	CUBA	Bicir-Cakir	TRKY
Avsar	TRKY	Bicir-Gul	TRKY

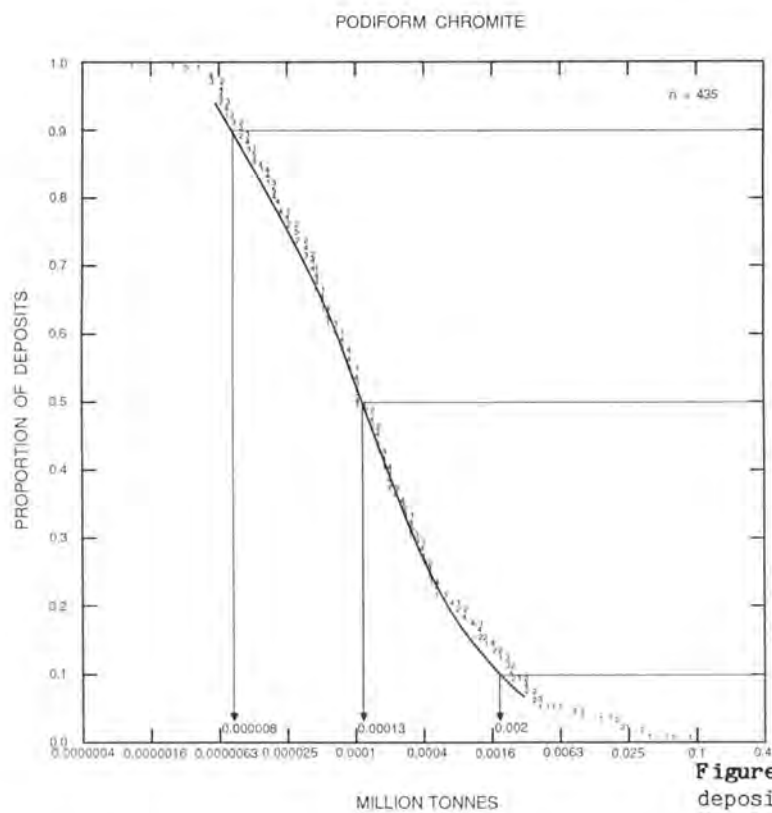
Bonsecours	NCAL	Karatas-Kumocak	TRKY
Bozkonus	TRKY	Kartalkoyu	TRKY
Bozotluk-No. 551	TRKY	Kavakcali	TRKY
Bugugan	TRKY	Kavakdere	TRKY
Buyiik Gurleyen	TRKY	Kazadere-Kandil	TRKY
Buyiik Karamanli	TRKY	Kefdag-East	TRKY
Caledonia	CUBA	Kemikli Inbasi	TRKY
Camaguey	CUBA	Kilic-Kafasi 1	TRKY
Catak	TRKY	Kilic-Kafasi 2	TRKY
Catak-Koraalan	TRKY	Kiranocak	TRKY
Catolsinir I	TRKY	Koca	TRKY
Catolsinir II	TRKY	Komek	TRKY
Cenger	TRKY	Koycegiz-Curukcu	TRKY
Cenger-Adatepe	TRKY	Koycegiz-Kurardi	TRKY
Cenger-Demirk	TRKY	Koycegiz-Orta	TRKY
Cenger-Domuza	TRKY	Kuldoden	TRKY
Cezni	TRKY	Kundikan-Keluskdere	TRKY
Chagrin	NCAL	Kundikan-Kelusktepe	TRKY
Child Harold	NCAL	Kurudere	TRKY
Consolation	NCAL	Kuyuluk Isletmesi	TRKY
Cosan	TRKY	Kuzkavak	TRKY
Coto	PLPN	La Caridid	CUBA
Cromita	CUBA	Lagonoy	PLPN
Dagardi	TRKY	La Victoria	CUBA
Dagkuplu	TRKY	Lolita	CUBA
Danacik	TRKY	Marais Kiki	NCAL
Dcev 7	NCAL	Meululter	TRKY
Delta	CUBA	Middle Ore Body	PLPN
Demirli	TRKY	Mirandag Koru	TRKY
Dinagat	PLPN	Mirandag Mevki	TRKY
Dogu Ezan	TRKY	Morrachini	NCAL
Dogu Kef	TRKY	Musa Danisman	TRKY
Domuzburnu II	TRKY	Narciso	CUBA
Dovis	IRAN	Ni Te Ocutes	CUBA
East Ore Body	PLPN	Ochanocagi	TRKY
El Cid	CUBA	Ofelia	CUBA
Eldirek	TRKY	Orta Ezan	TRKY
Ermenis	TRKY	Otmanlar-Harpuzlu	TRKY
Fanrouche	NCAL	Otmanlar-Mesebuku	TRKY
Findikli	TRKY	Panamana-An	PLPN
Findikli #301	TRKY	P. B.	NCAL
Findikli #306-#307	TRKY	Pergini	TRKY
Findikli #326	TRKY	Potosi	CUBA
General Gallieni	NCAL	Ruff Claim No. 32	PLPN
Gerdag	TRKY	Saka	TRKY
Golalan	TRKY	Salur	TRKY
Gorunur	TRKY	Sarialan	TRKY
Govniikbelen	TRKY	Sarikaya	TRKY
Gr2h	NCAL	Saysin	TRKY
Guillermina	CUBA	Sekioren	TRKY
Gunlet-Uckopur	TRKY	Shahin	IRAN
Gunliik Basi	TRKY	Sicankale	TRKY
Herpit Yayla	TRKY	Sirac	TRKY
Ikisulu-Cercek	TRKY	Sofulu	TRKY
Jose	CUBA	Sogham	IRAN
Kagit Octu	TRKY	Sta. Cruz	PLPN
Kandira	TRKY	Stephane	NCAL
Kapin	TRKY	Suluiyeh	IRAN
Karaculha	TRKY	Sulu	TRKY
Karageban	TRKY	Suluk	TRKY
Karani	TRKY	Sutpinar	TRKY
Karaninar	TRKY	Suzanne	NCAL
Karasivri	TRKY	Tekneli	TRKY

Model 8b--Con.

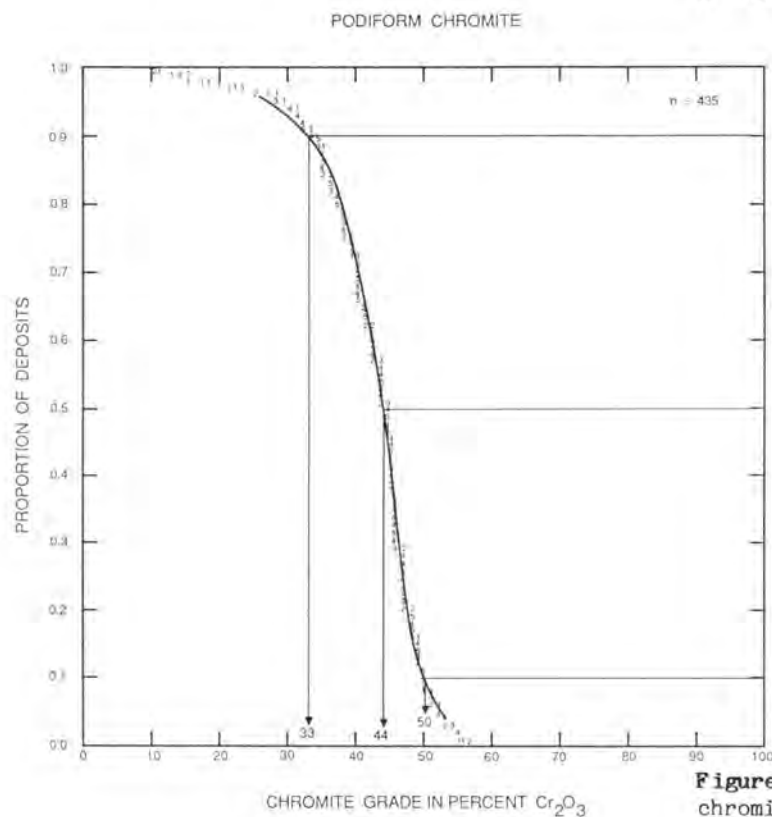
Tepebasi	TRKY	West Ore Body	PLPN
Terlik	TRKY	Yanikara	TRKY
Tiebaghi	NCAL	Yaprakli	TRKY
Tilkim-Karanlik	TRKY	Yayca Boyna	TRKY
Togobomar	PLPN	Yilmaz Ocagi	TRKY
Tosin	TRKY	Yukari Zorkum	TRKY
Toparlar-Alacik	TRKY	Yunus Yayla	TRKY
Tuzlakaya	TRKY	Yurtlak	TRKY
Uckopru	TRKY	Zambales Ch	PLPN
Vieille Montagne 1	NCAL	Zimparalik	TRKY
Vieille Montagne 2	NCAL		



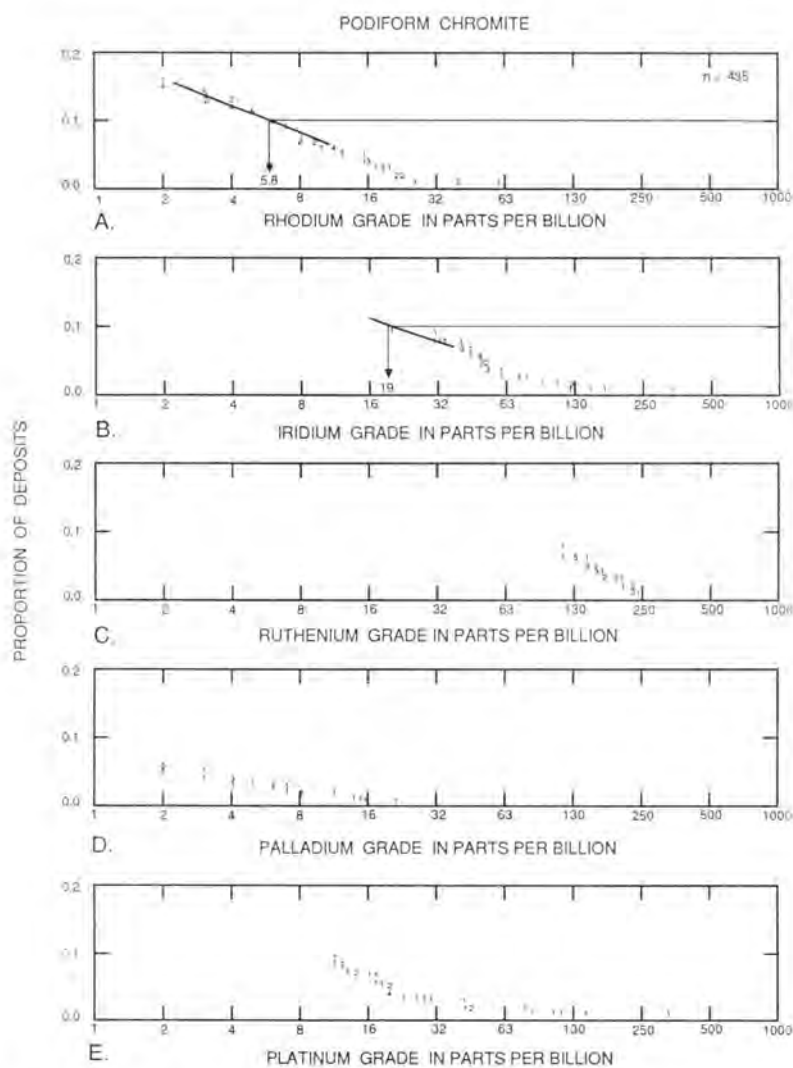
**Figure 20.** Cartoon cross section of a typical ophiolite sequence showing locations of podiform chromite deposits. From Dickey (1975).



**Figure 21.** Tonnages of podiform chromite deposits from California and Oregon, U.S.A. Individual digits represent number of deposits.

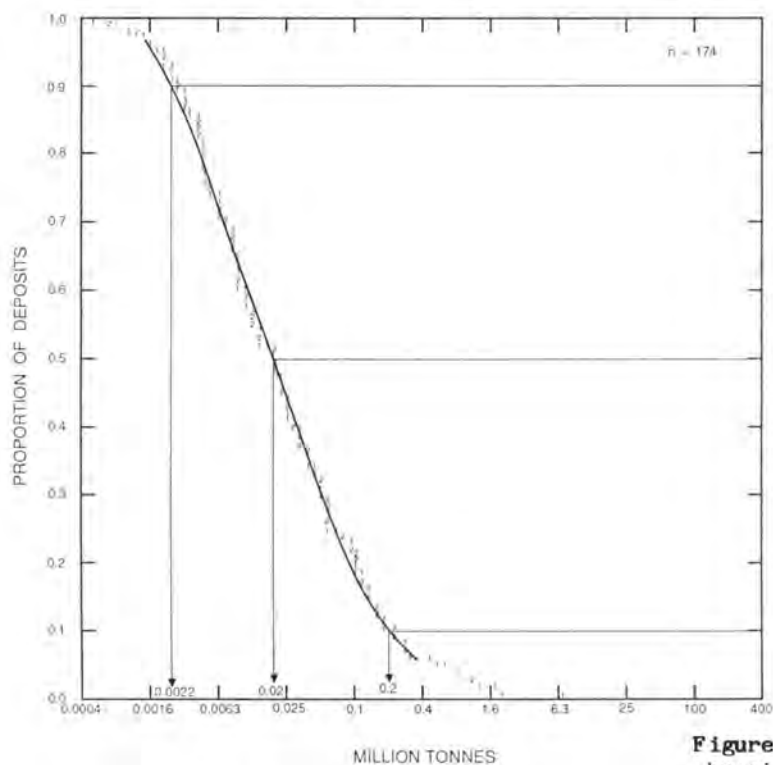


**Figure 22.** Chromite grades of podiform chromite deposits from California and Oregon, U.S.A. Individual digits represent number of deposits.



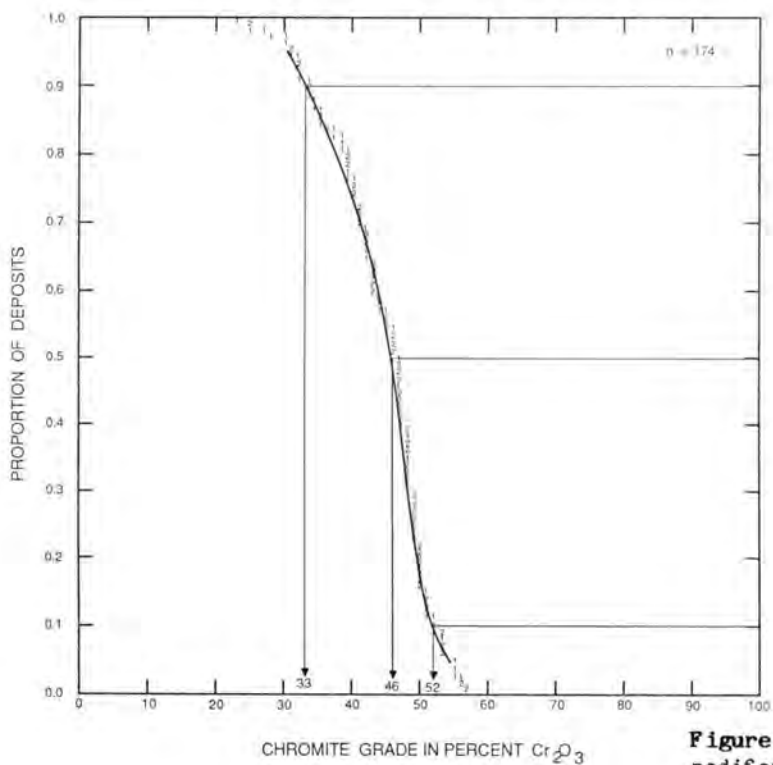
**Figure 23.** PGE grades of podiform chromite deposits from California and Oregon, U.S.A. A, Rhodium. B, Iridium. C, Ruthenium. D, Palladium. E, Platinum. Individual digits represent number of deposits.

## MAJOR PODIFORM CHROMITE



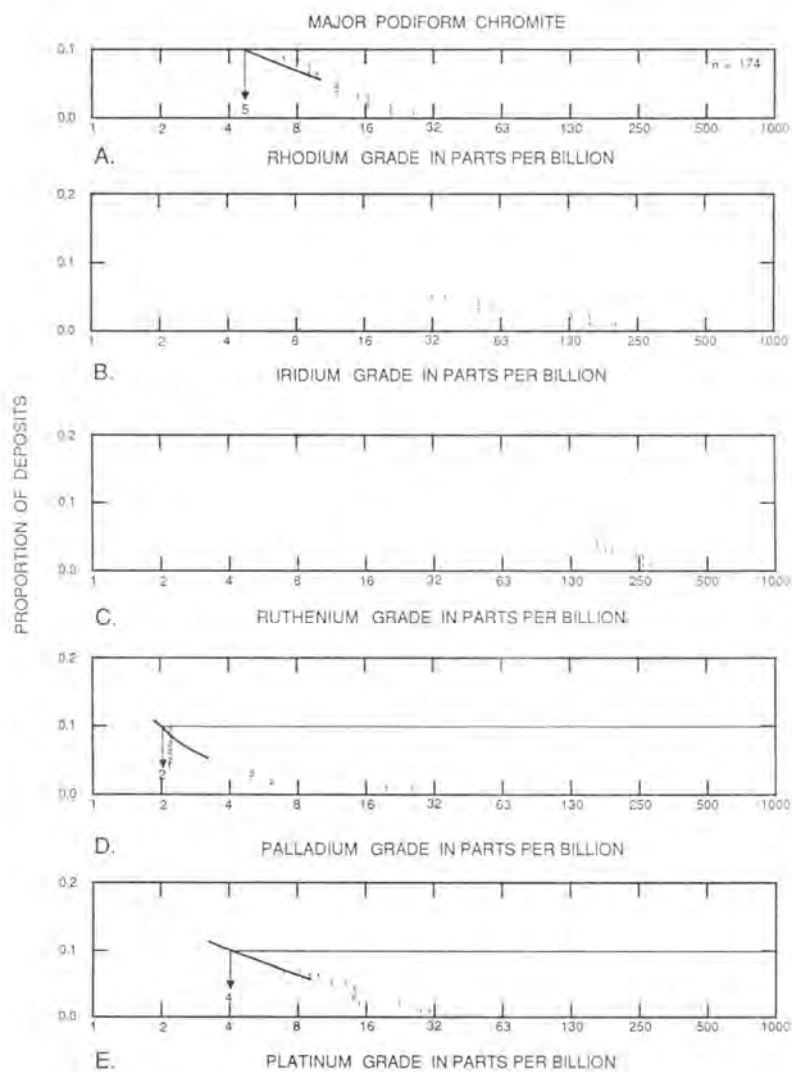
**Figure 24.** Tonnages of major podiform chromite deposits. Individual digits represent number of deposits.

## MAJOR PODIFORM CHROMITE



**Figure 25.** Chromite grades of major podiform chromite deposits. Individual digits represent number of deposits.





**Figure 26.** PGE grades of major podiform chromite deposits. A, Rhodium. B, Iridium. C, Ruthenium. D, Palladium. E, Platinum. Individual digits represent number of deposits.

## DESCRIPTIVE MODEL OF LIMASSOL FOREST Co-Ni

By Norman J Page

DESCRIPTION Irregular veins, pods and lenses associated with serpentinized peridotite and dunite or nearby country rocks.

GEOLOGICAL ENVIRONMENT

Rock Types Highly serpentinized dunite, harzburgite, pyroxenite; quartz-carbonate rocks.

Textures Sheared.

Age Range Paleozoic and Mesozoic.

Depositional Environment Faults, fractures associated with serpentinized ultramafic rocks of an ophiolite.

Tectonic Setting(s) Unstable, accreted terranes, near plate boundaries.

Associated Deposit Types Podiform chromite, Ni-laterite, Co-Ni-Cu ophiolite sulfide.

DEPOSIT DESCRIPTION

Mineralogy: Pyrrhotite + pyrite ± pentlandite ± chalcopyrite ± vallerite ± loellingite ± niccolite ± maucherite ± skutterudite ± gersdorffite ± cobaltite ± magnetite ± chromite ± mackinawite ± pararammelsbergite.

Texture/Structure Irregular vein and fracture fillings.

Alteration Serpentinization and quartz-carbonate.

Ore Controls Serpentinized ultramafic rock, possible external source of arsenic (see fig. 99).

Geochemical Signature As, Co, Ni

EXAMPLES

Bou Azzer, MRCO

(LeBlanc, 1981; LeBlanc and Bilaud, 1982)

Limassol Forest, CYPS

(Panayiotou, 1980)

## DESCRIPTIVE MODEL OF SERPENTINE-HOSTED ASBESTOS

By Norman J Page

APPROXIMATE SYNONYM Quebec Type (Shride, 1973).

DESCRIPTION Chrysotile asbestos developed in stockworks in serpentized ultramafic rocks.

### GEOLOGICAL ENVIRONMENT

Rock Types Serpentinites, dunite, harzburgite, pyroxenite.

Textures Highly fractured and veined, serpentized ultramafic rocks.

Age Range Paleozoic to Tertiary.

Depositional Environment Usually part of an ophiolite sequence. Later deformation and igneous intrusion may be important.

Tectonic Setting(s) Unstable accreted oceanic terranes.

Associated Deposit Types Podiform chromite.

### DEPOSIT DESCRIPTION

Mineralogy Chrysotile asbestos + magnetite + brucite + talc + tremolite-actinolite.

Texture/Structure Stockworks of veins in serpentized ultramafic rocks.

Alteration None associated with ore, but silica-carbonate, talc may be developed.

Ore Controls Two periods of serpentization, an earlier pervasive one and a later period near the end of intense deformation accompanied by hydrothermal activity perhaps as a function of intrusion of acidic, igneous rocks highly dependent upon major faulting, and fracture development.

Geochemical signature None.

### EXAMPLES:

Thetford-Black Lake, CNQU (Riordon, 1957)

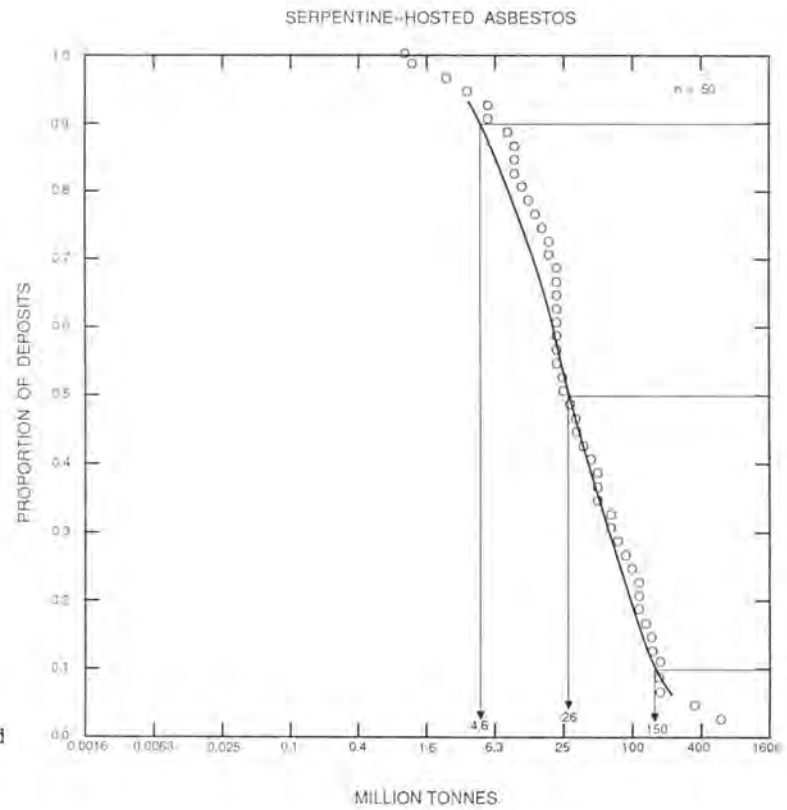
## GRADE AND TONNAGE MODEL OF SERPENTINE-HOSTED ASBESTOS

By Greta J. Orris

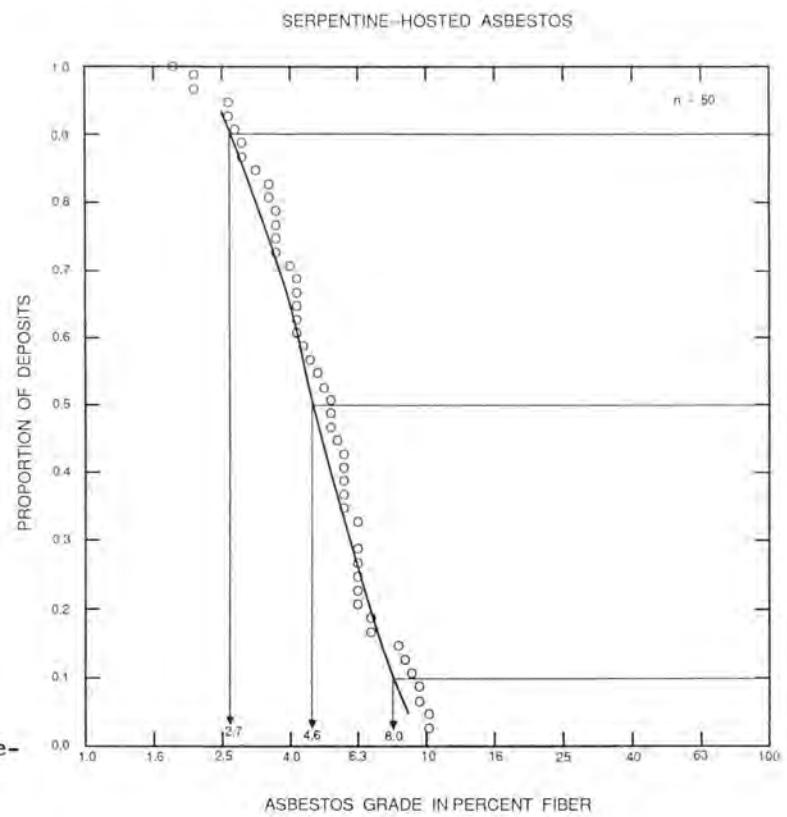
COMMENTS Long and short fibers are combined. Some literature did not specify if reported production was tons of fiber or tons of ore. In these cases, production was assumed to be tons of ore which may have led to underestimation of some deposit tonnages. See Figs. 27, 28.

DEPOSITS

<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Abitibi	CNQU	Lafayette	CNQU
Advocate	CNNF	Lake Asbestos	CNQU
Asbestos Hill	CNQU	Las Brisas	CLBA
Asbestos Island	CNQU	Lili	CNQU
Belvidere	USVT	McAdam	CNQU
Black Lake	CNQU	Midlothian	CNON
British Canadian	CNQU	Moladezhnoye	URRS
Caley	CNYT	Munro	CNON
Carey/East Broughton	CNQU	National	CNQU
Cana Brava	BRZL	Nicolet Asbestos	CNQU
Cassiar Mine	CNBC	Normandie/Penhale	CNQU
Clinton Creek	CNYT	Pontbriand	CNQU
Continental	CNQU	Qala-el-Nahl?	SUDN
Courvan Mine	CNQU	Reeves	CNON
Cranbourne	CNQU	Rex	CNYT
Daffodil	CNON	Roberge Lake	CNQU
Eagle	USAK	St. Adrien Mtn.	CNQU
Gilmont	CNQU	St. Cyr	CNQU
Golden Age	CNQU	Santiago Papalo	MXCO
Havelock Mine	SWAZ	Shihmien	CINA
Jefferson Lake	USCA	Steele Brook	CNQU
Jeffrey Lake	CNQU	Thetford Group	CNQU
Kinlock	SAFR	Windsor	CNQU
Kolubara-Azbest	YUGO	Woodsreef Mine	AUNS
Kudu Asbestos Mine	ZIMB	Zindani	GREC



**Figure 27.** Tonnages of serpentine-hosted asbestos deposits.



**Figure 28.** Asbestos grades of serpentine-hosted asbestos deposits.

## DESCRIPTIVE MODEL OF ALASKAN PGE

By Norman J Page and Floyd Gray

APPROXIMATE SYNONYMS Zoned ultramafic Cr-Pt; Kachkanar-type (Cabri and Naldrett, 1984).

DESCRIPTION Crosscutting ultramafic to felsic intrusive rocks with approximately concentric zoning of rock types containing chromite, platinum, and Ti-V-magnetite (see fig. 29).

GEOLOGICAL ENVIRONMENT

Rock Types Dunite, wehrlite, harzburgite, pyroxenite, magnetite-hornblende pyroxenite, two-pyroxene gabbros, hornblende gabbro, hornblende clinopyroxenite, hornblende-magnetite clinopyroxenite, olivine gabbro, norite. Post-orogenic tonalite and diorite are commonly spatially related. Orthopyroxene-bearing rocks absent in Klamath Mountains.

Textures Cumulus textures, poikilitic, mush flow textures, lineated fabrics, layered.

Age Range Precambrian to late Mesozoic, most Paleozoic and Mesozoic.

Depositional Environment Deposits occur in layered ultramafic and mafic rocks that intrude into granodiorite, island arc or ophiolite terranes. Evidence indicates shallow levels of emplacement.

Tectonic Setting(s) Unstable tectonic areas.

Associated Deposit Types PGE placer deposits.

DEPOSIT DESCRIPTION

Mineralogy Assemblage 1: chromite + Pt-Fe alloys + Os-Ir alloys + platinum-iridium ± pentlandite ± pyrrhotite ± native gold ± PGE arsenides. Assemblage 2: Ti-V magnetite ± Pt-Fe alloys ± Os-Ir alloys ± cooperite ± bornite ± chalcopyrite.

Texture/Structure Assemblage 1: clots, pods, schlieren, wisps of chromite in dunite, clinopyroxenite, harzburgite. Assemblage 2: magnetite segregations, layers in wehrlite, pyroxenite, gabbro (see fig. 29).

Alteration None: post-mineralization serpentinization.

Ore Controls Appear to be restricted to specific rock types by magmatic processes.

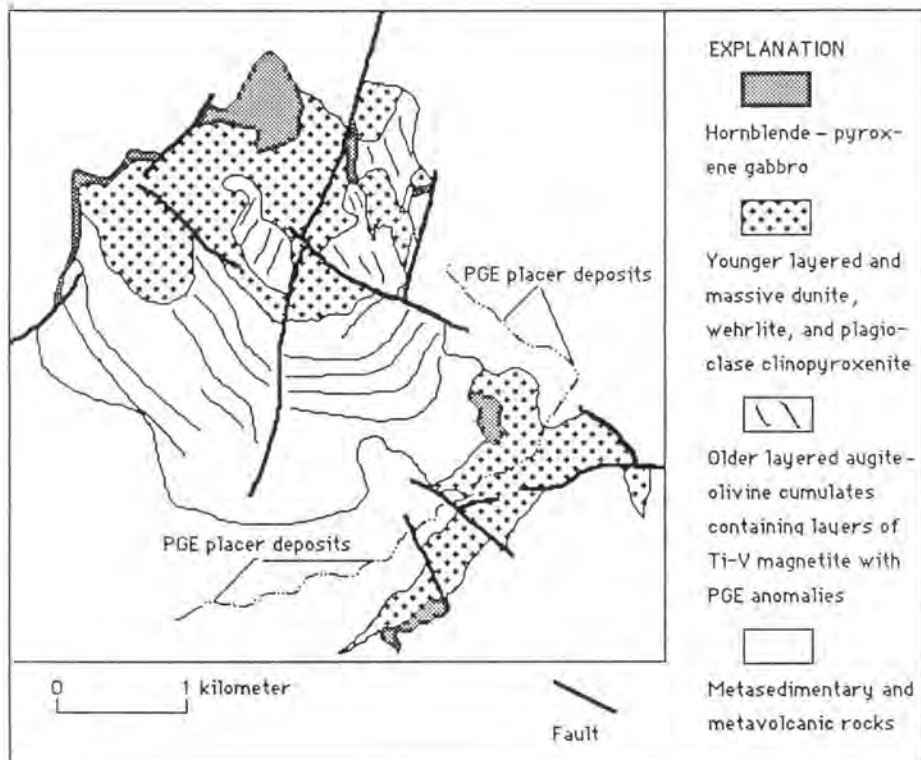
Weathering Mechanical weathering produces placers; chemical weathering could produce laterites.

Geochemical Signature Cr, PGE, Ti, V, Cu, Ni, S, As. Assemblage 2 ores in Klamath Mountains are low in Cr and Ni.

EXAMPLES

Urals, USSR	(Duparc and Tikonovitch, 1920)
Duke Island, USAK	(Irvine, 1974)
Guseva-Gora, USSR	(Razin, 1976)
Tin Cup Peak, USOR	(Page and others, 1982a)





**Figure 29.** Generalized geologic map of zoned ultramafic complex at Lower Coon Mountain, Calif. (from Gray and Page, 1985). V-rich magnetite layers and anomalous PGE concentrations typical of Alaskan Cr-Pt deposits are associated with plutons of this type.

## DESCRIPTIVE MODEL OF CARBONATITE DEPOSITS

By Donald A. Singer

APPROXIMATE SYNONYM Apatite-magnetite and rare earths in carbonatites.

DESCRIPTION Apatite-magnetite and rare-earth deposits and combinations of these in zoned complexes consisting of central plug of carbonatite or syenite breccia surrounded by ring dikes and cone sheets of alternating rock types.

GENERAL REFERENCE Tuttle and Gittins (1966).

### GEOLOGICAL ENVIRONMENT

Rock Types Apatite-magnetite deposits tend to be in sovite (calcitic carbonatite); RE types tend to occur in ankerite carbonatite; most deposits have both. In general pyroxenite, nepheline and feldspathic pyroxenite, carbonatite, fenite, ijolite, dunite, picrite-porphyrites, gneiss and alkalic fenitized gneiss, and locally alkaline volcanics rocks.

Textures Hypidiomorphic-granular, poikiloblastic. Breccias abundant. Carbonatites show intrusive relations. Wallrocks fenitized.

Age Range Almost all known carbonatite complexes are intrusive into Precambrian shields, however, the carbonatites themselves may be much younger.

Depositional Environment Multiple stages of igneous, deuteric and metasomatic crystallization in carbonatite magma.

Tectonic Setting(s) Continental shields. Spatially related to fault lineaments such as East African rift system. Locally related to alkaline volcanism.

Associated Deposit Types None.

### DEPOSIT DESCRIPTION

Mineralogy Apatite-magnetite-type: apatite, magnetite, pyrochlore ± columbite ± perovskite ± niocalite. RE-type: barite, strontianite ± siderite ± rhodochrosite ± ankerite ± bastnaesite ± chlorites ± parisite ± monagite ± breunnerite. General: calcite, dolomite, fluorite, pyrrhotite, ilmenite, molybdenite, chalcopryite, pyrite, sphalerite, pyroxene, biotite, phlogopite, amphibole, spinel, ± galena, ± hematite, ± quartz, ± forsterite, ± serpentine, ± zircon ± sphene, ± anatase, ± rutile, ± brookite, ± fersmite.

Texture/Structure Disseminated and banded.

Alteration Fenitization (widespread alkali metasomatism of quartzo-feldspathic rock; mostly alkalic feldspar with some aegerine and subordinate alkali-hornblende and accessory sphene and apatite) near contact of carbonatite intrusion. Locally, chloritization.

Ore Controls Commonly restricted to carbonatite dikes, sills, breccias, sheets, veins, and large masses, but may occur in other rocks associated with the complex rocks.

Weathering May result in goethite-rich soil enriched in P, Nb, and RE.

Geochemical Signature Radiometric anomalies, magnetic anomalies, high gravity anomalies, Th, U, Ti, Zn, Nb, Y, Ce, Mo, Cu, V, P, Mn, S, La, Sm, Pb, Zr, Ba, Eu. High values of Be, B, Li, Sn, Ta, Hf, and W are rare.

### EXAMPLES

Oka, CNQU	(Gold and others, 1966)
Iron Hill, USCO	(Temple and Grogan, 1965)
St. Honore, CNQU	(Dawson, 1974)
Gem Park, USCO	(Parker and Sharp, 1970)
Mountain Pass, USCA	(Olson and others, 1954)

## GRADE AND TONNAGE MODEL OF CARBONATITE DEPOSITS

By Donald A. Singer

COMMENTS Locally these carbonatite complexes may contain economically interesting grades of uranium, thorium, titanium, iron, copper, vermiculite, zirconium or phosphorus; frequently, these other commodities are in different zones than the niobium-rich parts of the complex. See figs. 30, 31.

DEPOSITS

<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Araxa	BRZL	Mountain Pass	USCA
Bingo	ZIRE	Mrima Hill	KNYA
Dominion Gulf	CNON	Nemogos (Lackner Lake)	CNON
Catalão	BRZL	Oka	CNQU
Iron Hill	USCO	Salitre	BRZL
James Bay	CNON	Serra Negra	BRZL
Lueshe	ZIRE	Søve	NRWY
Mbeya	TNZN	Sukulu	UGND
Martison Lake	CNON	St. Honore (Soquem)	CNQU
Manitou Island	CNON	Tapira	BRZL

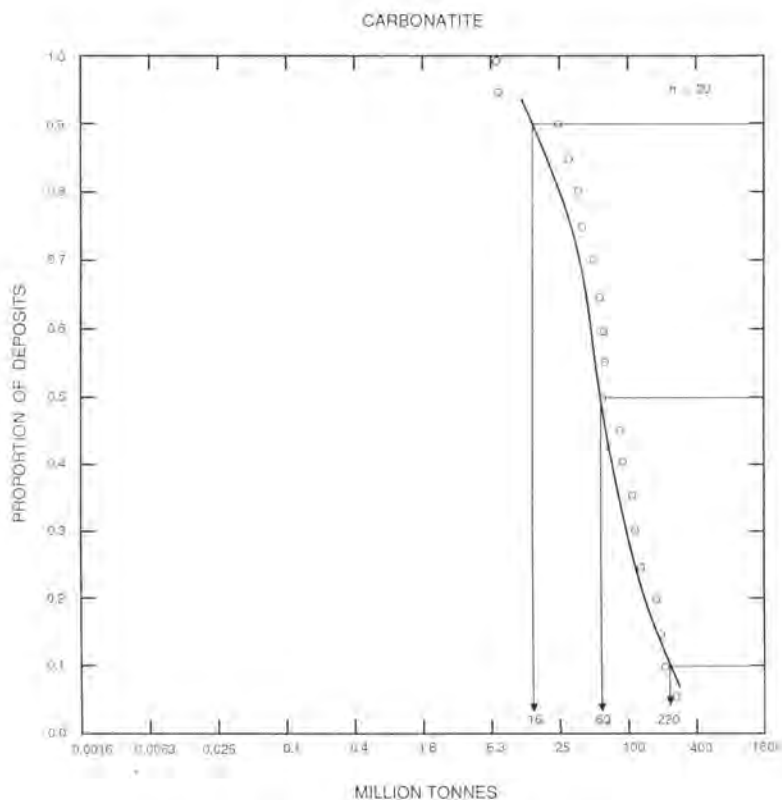
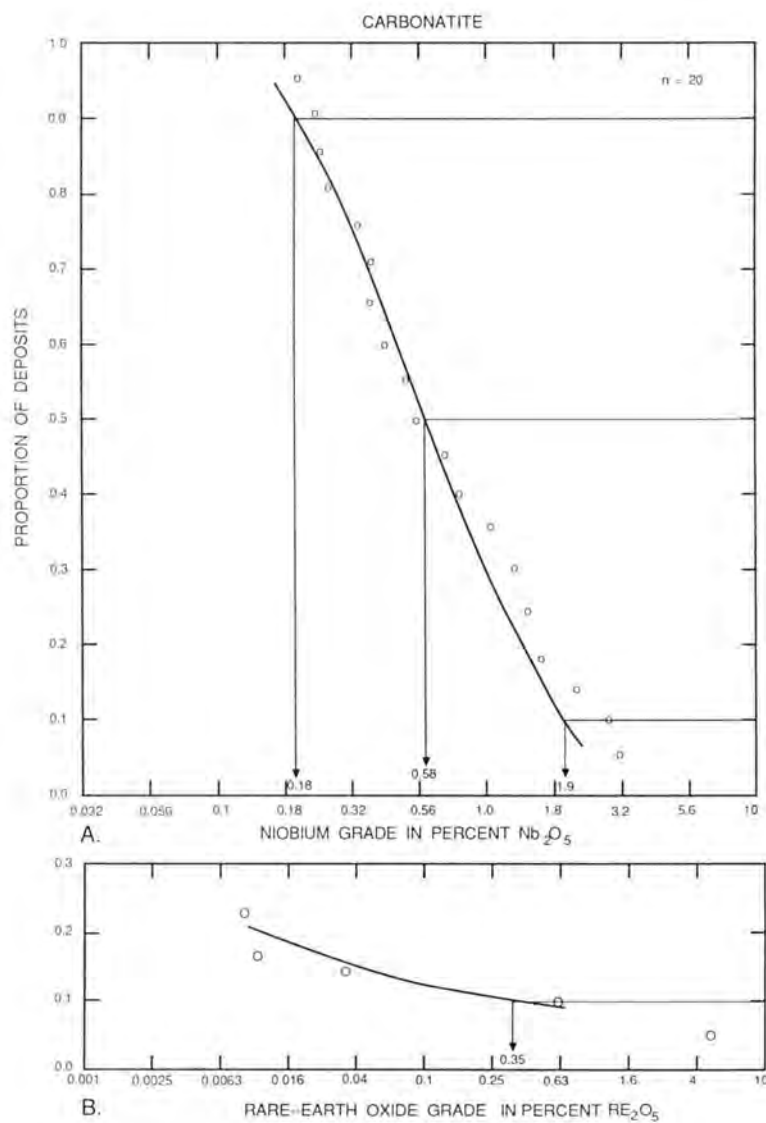


Figure 30. Tonnages of carbonatite deposits.



**Figure 31.** Grades of carbonatite deposits. A, Niobium. B, Rare-earth oxides.

## DESCRIPTIVE MODEL OF DIAMOND PIPES

By Dennis P. Cox

DESCRIPTION Diamonds in kimberlite diatremes and other alkaline mafic rocks.

GENERAL REFERENCE Orlov (1973), Dawson (1980), Gold (1984).

### GEOLOGICAL ENVIRONMENT

Rock Types Kimberlite diatremes. Olivine lamproite (K-rich Mg-lamprophyre) and leucite lamproite.

Textures Pipes: porphyritic igneous texture. Breccias with inclusions of many rocks from mantle, basement and overlying sequences. Lapilli tuff locally fills upper levels of diatreme.

Age Range Most productive pipes are 80-100, 250, and 1,000-1,100 m.y. in age.

Depositional Environment Pipes intruded from mantle source under high pressure but with rapid quenching.

Tectonic Setting(s) Most pipes intrude cratonic areas, stable since Early Proterozoic. Some intrude folded cover rocks that overlie deformed cratonic margins. Pipes are not correlated with orogenic events but occur in areas of epeirogenic warping or doming and along major basement fracture zones. Some pipes occur at intersections of regional zones of weakness visible in LANDSAT or SLAR.

Associated Deposit Types Diamond placers.

### DEPOSIT DESCRIPTION

Mineralogy Diamond, bort or carbonado (polycrystalline generally dark colored), ballas (spherulitic polycrystalline), and amorphous carbonado.

Texture/Structure Diamonds are sparsely disseminated as phenocrysts or xenocrysts in breccia. Mined kimberlites yield from 0.1 to 0.6 ppm diamond.

Alteration Serpentinization resulting in "blue clay" zones. Silicification and carbonate alteration of country rock near pipe; rarely, alkaline metasomatism forming K-feldspar and Na-amphiboles.

Ore Controls Diamond distribution is irregular and restricted to kimberlite or lamproite pipes and upward-flaring crater zones. Productive pipes are rare and, at present, can only be identified by their diamond content.

Weathering Pipes weather rapidly to form topographic depressions.

Geochemical Signature Cr, Ti, Mn, Ni, Co, PGE, Ba. Anomalous Ni, Nb, and heavy minerals pyrope, garnet, phlogopite, and Mg-ilmenite indicate nearby pipes. Lamproite pipes lack ilmenite.

### EXAMPLES

African deposits	(Sutherland, 1982)
Western Australia deposits	(Atkinson and others 1984)
Wyoming-Colorado	(Lincoln, 1983)

## DESCRIPTIVE MODEL OF W SKARN DEPOSITS

By Dennis P. Cox

DESCRIPTION Scheelite in calc-silicate contact metasomatic rocks.GENERAL REFERENCE Einaudi and Burt (1982), Einaudi and others (1981).GEOLOGICAL ENVIRONMENTRock Types Tonalite, granodiorite, quartz monzonite; limestone.Textures Granitic, granoblastic.Age Range Mainly Mesozoic, but may be any age.Depositional Environment Contacts and roof pendants of batholith and thermal aureoles of apical zones of stocks that intrude carbonate rocks.Tectonic Setting(s) Orogenic belts. Syn-late orogenic.Associated Deposit Types Sn-W skarns, Zn skarns.DEPOSIT DESCRIPTIONMineralogy Scheelite  $\pm$  molybdenite  $\pm$  pyrrhotite  $\pm$  sphalerite  $\pm$  chalcopyrite  $\pm$  bornite  $\pm$  arsenopyrite  $\pm$  pyrite  $\pm$  magnetite  $\pm$  traces of wolframite, fluorite, cassiterite, and native bismuth.Alteration Diopside-hedenbergite + grossular-andradite. Late stage spessartine + almandine. Outer barren wollastonite zone. Inner zone of massive quartz may be present.Ore Controls Carbonate rocks in thermal aureoles of intrusions.Geochemical Signature W, Mo, Zn, Cu, Sn, Bi, Be, As.EXAMPLES

Pine Creek, USCA	(Newberry, 1982)
MacTung, CNBC	(Dick and Hodgson, 1982)
Strawberry, USCA	(Nokleberg, 1981)

## GRADE AND TONNAGE MODEL OF W SKARN DEPOSITS

By W. David Menzie and Gail M. Jones

COMMENTS All mines associated with the contact zone of a particular intrusive with a favorable host rock were combined to form a single deposit. In the absence of detailed geologic information, mines within 10 km of each other were combined. See figs. 32, 33.DEPOSITS

<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Bailey	CNYT	Lost Creek	USMT
Brejui	BRZL	Lucky Mike	CNBC
Cab	CNYT	Mactung	CNNT
Calvert (Red Button)	USMT	Maykhura	URTD
Cantung	CNNT	Milford area	USUT
Dublin Gulch (GS2)	CNYT	Nevada-Massachusetts	USNV
Emerald-Dodger	CNBC	Nevada-Scheelite	USNV
Iron Mountain	USNM	Osgood Range	USNV
King Island	AUTS	Pine Creek	USCA



Model 14a--Con.

Quixaba	BRZL	Tyrny-Auz	URRS
Ray Gulch	CNYT	Uludag	TRKY
Sang Dong	SKOR	Victory	CNBC
Stormy Group	CNYT	Yellow Pine district	USID
Tem Piute district	USNV	Ysxjoberg	SWDN

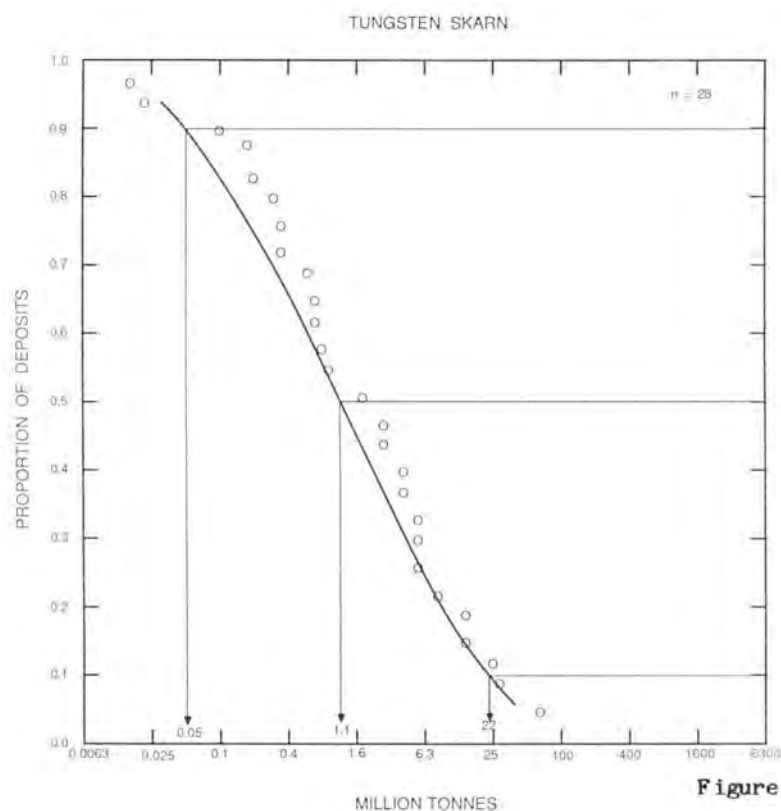


Figure 32. Tonnages of W skarn deposits.

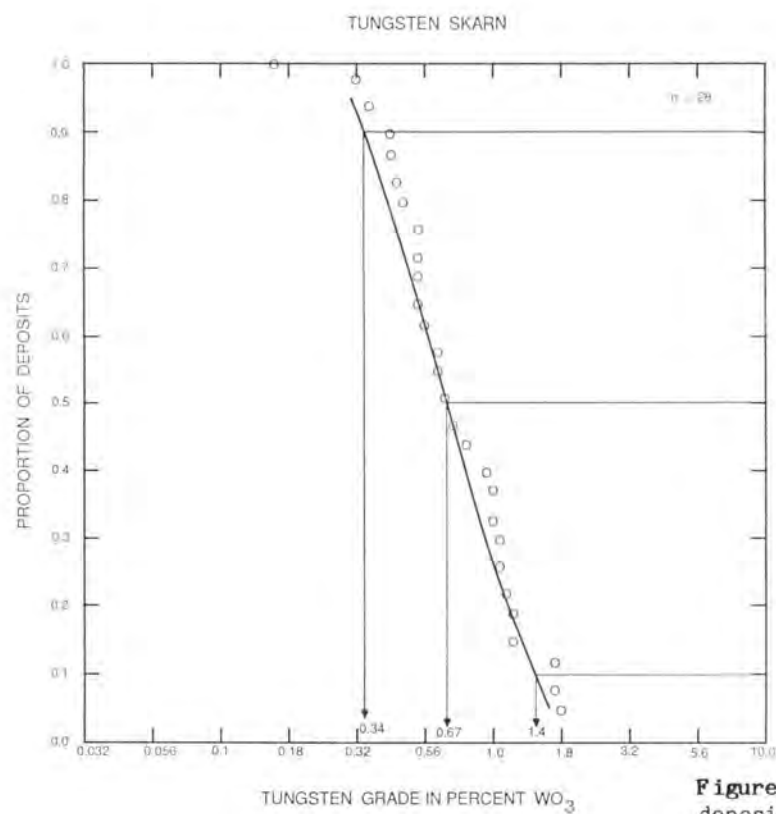


Figure 33. Tungsten grades of W skarn deposits.

## DESCRIPTIVE MODEL OF Sn SKARN DEPOSITS

By Bruce L. Reed and Dennis P. Cox

DESCRIPTION Tin, tungsten, beryllium minerals in skarns, veins, stockworks and greisens near granite-limestone contacts (see fig. 34).

GENERAL REFERENCE Einaudi and Burt (1982), Einaudi and others (1981), Scherba (1970).

### GEOLOGICAL ENVIRONMENT

Rock Types Leucocratic biotite and/or muscovite granite, specialized phase or end members common, felsic dikes, carbonate rocks.

Textures Plutonic textures most common (granitic, seriate, fine-grained granitic). Also porphyritic-aphanitic; skarn is granoblastic to hornfelsic, banded skarn common.

Age Range Mainly Mesozoic, but may be any age.

Depositional Environment Epizonal(?) intrusive complexes in carbonate terrane.

Tectonic Setting(s) Granite emplacement generally late (post orogenic).

Associated Deposit Types W skarn, Sn greisen, and quartz-cassiterite-sulfide veins; at increasing distances from intrusive-carbonate contact Sn replacement and fissure lodes may develop (as at Renison Bell).

### DEPOSIT DESCRIPTION

Mineralogy Cassiterite ± minor scheelite ± sphalerite ± chalcopyrite ± pyrrhotite ± magnetite ± pyrite ± arsenopyrite ± fluorite in skarn. Much Sn may be in silicate minerals and be metallurgically unavailable.

Texture/Structure Granoblastic skarn, wriggilite [chaotic laminar pattern of alternating light (fluorite) and dark (magnetite) lamellae], stockworks, breccia.

Alteration Greisenization (quartz-muscovite-topaz ± tourmaline, fluorite, cassiterite, sulfides) near granite margins and in cusps. Topaz tourmaline greisens. Idocrase + Mn-grossular-andradite ± Sn-andradite ± malayaite in skarn. Late-stage amphibole + mica + chlorite and mica + tourmaline + fluorite.

Ore Controls Mineralized skarns may or may not develop at intrusive contact with carbonate rocks; major skarn development up to 300 m from intrusion controlled by intrusion-related fractures; cross-cutting veins and felsic dikes.

Weathering Erosion of lodes may lead to deposition of tin placer deposits.

Geochemical Signature Sn, W, F, Be, Zn, Pb, Cu, Ag, Li, Rb, Cs, Re, B. Specialized granites characteristically have  $\text{SiO}_2 > 73$  percent,  $\text{K}_2\text{O} > 4$  percent and are depleted in CaO,  $\text{TiO}_2$ , MgO, and total Fe. They are enriched in Sn, F, Rb, Li, Be, W, Mo, Pb, B, Nb, Cs, U, Th, Hf, Ta, and most REE. They are depleted in Ni, Cu, Cr, Co, V, Sc, Sr, La, and Ba.

### EXAMPLES

Lost River, USAK	(Dobson, 1982)
Moina, AUTS	(Kwak and Askins, 1981)
	(Scherba, 1970)

## GRADE AND TONNAGE MODEL OF Sn SKARN DEPOSITS

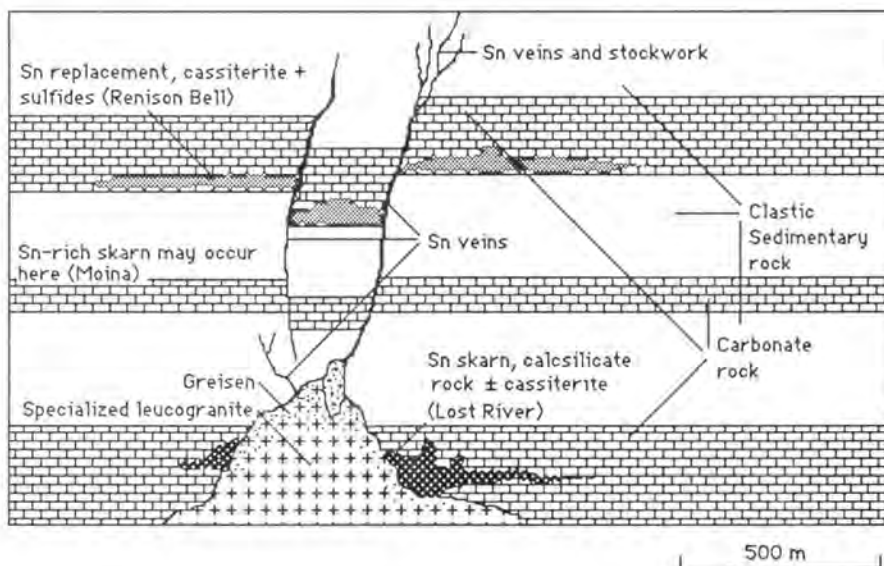
By W. David Menzie and Bruce L. Reed

COMMENTS Normally a grade-tonnage model would not be built with so few deposits. However, this model is presented because tin skarn deposits are significantly different than replacement deposits

in grades, tonnages, and other characteristics. Because of the small number of deposits plotted, the cumulative plot of discrete data points differs from the continuous lognormal curve. If the deposits had been plotted in descending order, the points would fall on the other side of the curve. Potential by-products from these deposits include tungsten, fluorite, beryllium, zinc, and gold. See figs. 35, 36.

#### DEPOSITS

Name	Country
Gilliam	AUQL
Lost River	USAK
Moina	AUTS
Pinnacles	AUQL



**Figure 34.** Cartoon cross section showing relation between Sn skarn, replacement Sn and Sn vein deposits, and granite intrusions.

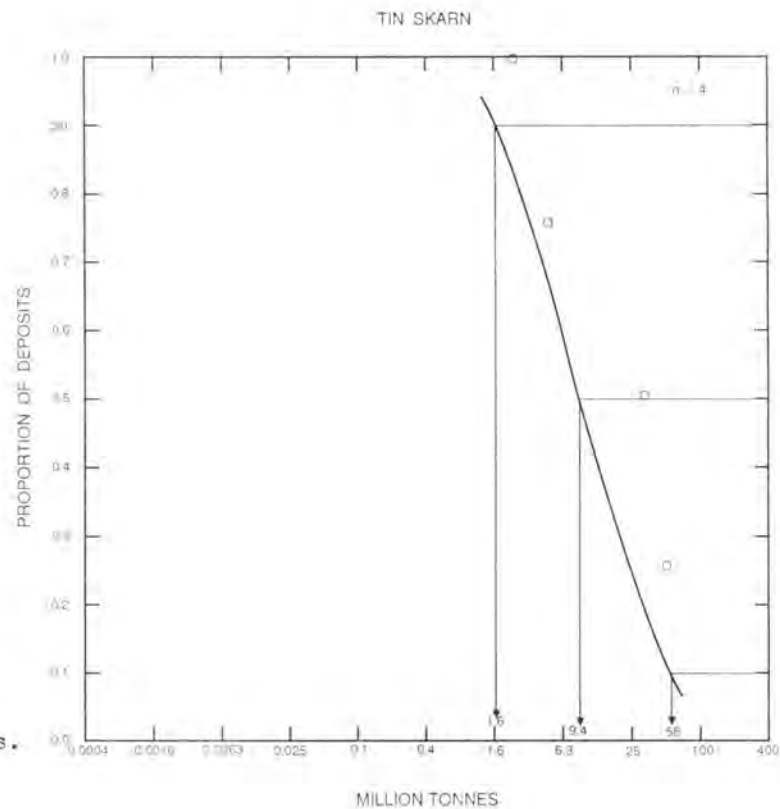


Figure 35. Tonnages of Sn skarn deposits.

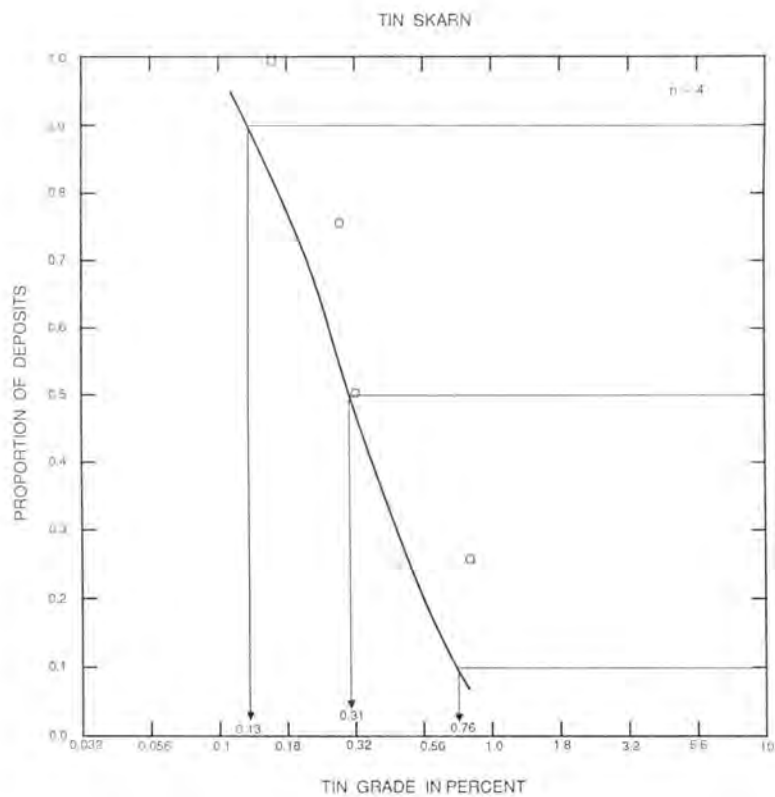


Figure 36. Tin grades of Sn skarn deposits.

## DESCRIPTIVE MODEL OF REPLACEMENT Sn

By Bruce L. Reed

APPROXIMATE SYNONYM Exhalative Sn (Plimer, 1980; Hutchinson, 1979).DESCRIPTION Stratabound cassiterite-sulfide (chiefly pyrrhotite) replacement of carbonate rocks and associated fissure lodes related to underlying granitoid complexes (see fig. 34).GENERAL REFERENCE Patterson and others (1981).GEOLOGICAL ENVIRONMENTRock Types Carbonate rocks (limestone or dolomite); granite, monzogranite, quartz porphyry dikes generally present; quartz-tourmaline rock; chert, pelitic and iron-rich sediments, and volcanic rocks may be present.Textures Plutonic (equigranular, seriate, porphyritic).Age Range Paleozoic and Mesozoic most common; other ages possible.Depositional Environment Epizonal granitic complexes in terranes containing carbonate rocks. Note: the epigenetic replacement classification for these deposits has been questioned and an alternative exhalative synsedimentary origin followed by postdepositional metamorphic reworking hypothesis proposed (Hutchinson, 1979, 1982; Plimer, 1980; Lehmann and Schneider, 1981).Tectonic Setting(s) Late orogenic to postorogenic passive emplacement of high-level granitoids in foldbelts containing carbonate rocks; alternatively, tin and associated metals were derived from submarine exhalative processes with subsequent reequilibration of sulfide and silicate minerals.Associated Deposit Types Greisen-style mineralization, quartz-tourmaline-cassiterite veins, Sn-W-Mo stockworks, Sn-W skarn deposits close to intrusions.DEPOSIT DESCRIPTIONMineralogy Pyrrhotite + arsenopyrite + cassiterite + chalcopyrite (may be major) + ilmenite + fluorite; minor: pyrite, sphalerite, galena, stannite, tetrahedrite, magnetite; late veins: sphalerite + galena + chalcopyrite + pyrite + fluorite.Texture/Structure Vein stockwork ores, and massive ores with laminations following bedding in host rock, locally cut by stockwork veins, pyrrhotite may be recrystallized.Alteration Greisenization ( $\pm$  cassiterite) near granite margins; sideritic alteration of dolomite near sulfide bodies; tourmalization of clastic sediments; proximity to intrusions may produce contact aureoles in host rocks.Ore Controls Replacement of favorable carbonate units; fault-controlled fissure lodes common. Isolated replacement orebodies may lie above granitoid cupolas; faults provide channels for mineralizing fluids.Geochemical Signature Sn, As, Cu, B, W, F, Li, Pb, Zn, Rb.EXAMPLES

Renison Bell, AUTS	(Patterson and others, 1981)
Cleveland, AUTS	(Collins, 1981)
Mt. Bischoff, AUTS	(Groves and others, 1972)
Changpo-Tongkeng, CINA	(Liang and others, 1984)



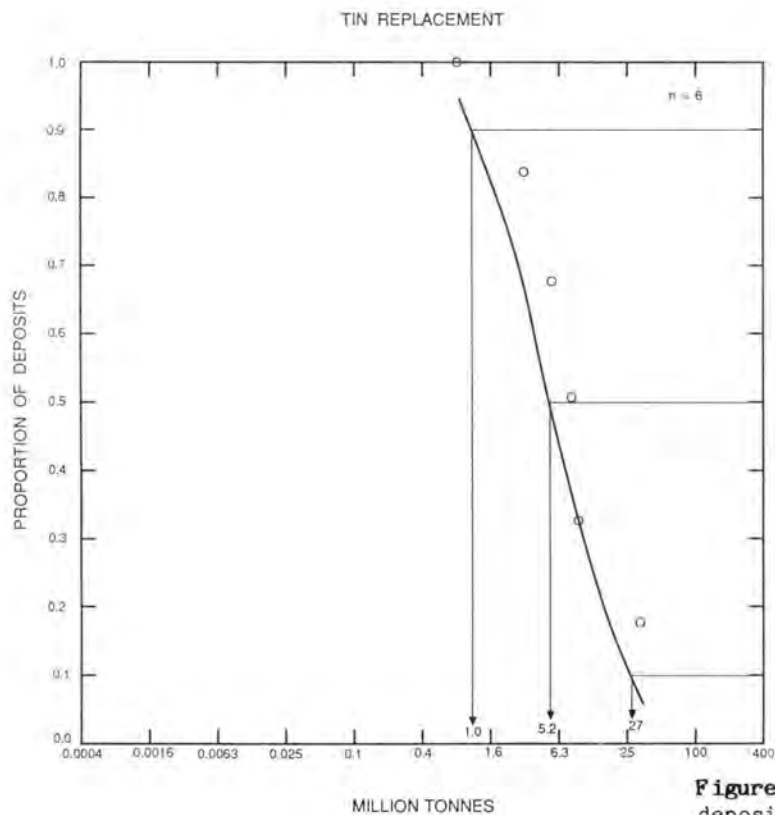
**GRADE AND TONNAGE MODEL OF REPLACEMENT Sn**

By W. David Menzie and Bruce L. Reed

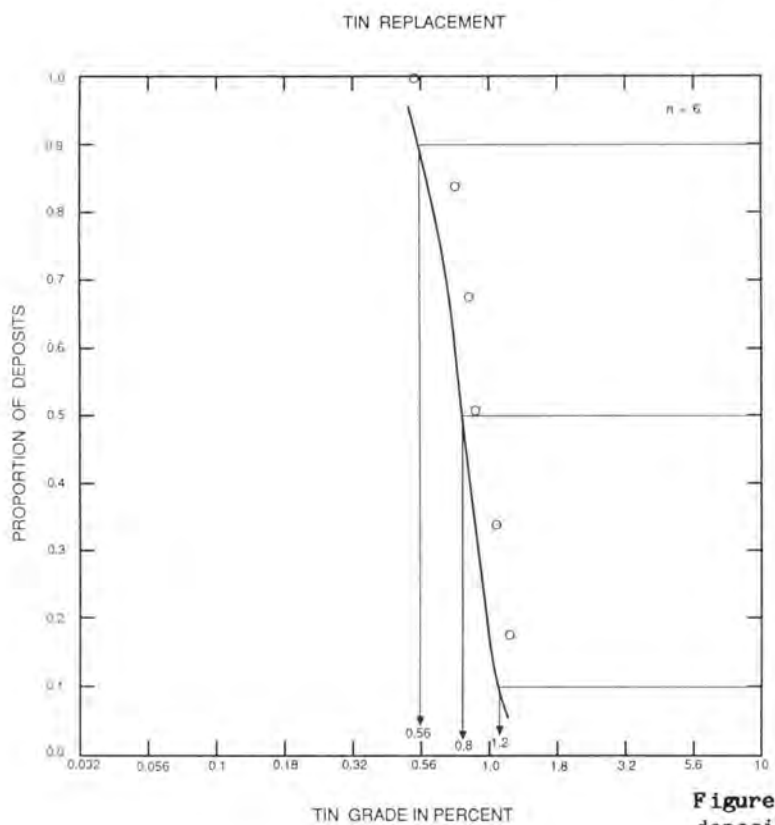
COMMENTS This model is built with deposits from Tasmania. Deposits of this type also occur in the Dachang and Geijui ore fields of the Peoples Republic of China. Potential by-products from this type of deposit include zinc, lead, and copper. See figs. 37, 38.

DEPOSITS

<u>Name</u>	<u>Country</u>
Cleveland	AUTS
Mount Bischoff	AUTS
Queen Hill	AUTS
Razorback	AUTS
Renison Bell	AUTS
St. Dizier	AUTS



**Figure 37.** Tonnages of Sn replacement deposits.



**Figure 38.** Tin grades of Sn replacement deposits.

## DESCRIPTIVE MODEL OF W VEINS

By Dennis P. Cox and William C. Bagby

APPROXIMATE SYNONYM Quartz-wolframite veins (Kelly and Rye, 1979).

DESCRIPTION Wolframite, molybdenite, and minor base-metal sulfides in quartz veins (see fig. 39).

### GEOLOGICAL ENVIRONMENT

Rock Types Monzogranite to granite stocks intruding sandstone, shale, and metamorphic equivalents.

Textures Phanerocrystalline igneous rocks, minor pegmatitic bodies, and porphyroaphanitic dikes.

Age Range Paleozoic to late Tertiary.

Depositional Environment Tensional fractures in epizonal granitic plutons and their wallrocks.

Tectonic Setting(s) Belts of granitic plutons derived from remelting of continental crust.  
Country rocks are metamorphosed to greenschist facies.

Associated Deposit Types Sn-W veins, pegmatites.

### DEPOSIT DESCRIPTION

Mineralogy Wolframite, molybdenite, bismuthinite, pyrite, pyrrhotite, arsenopyrite, bornite, chalcopryrite, scheelite, cassiterite, beryl, fluorite; also at Pasto Bueno, tetrahedrite-tennantite, sphalerite, galena, and minor enargite.

Texture/Structure Massive quartz veins with minor vugs, parallel walls, local breccia.

Alteration Deepest zones, pervasive albitization; higher pervasive to vein-selvage pink K-feldspar replacement with minor disseminated REE minerals; upper zones, vein selvages of dark-gray muscovite or zinnwaldite (greisen). Chloritization. Widespread tourmaline alteration at Isla de Pinos.

Ore Controls Swarms of parallel veins cutting granitic rocks or sedimentary rocks near igneous contacts.

Weathering Wolframite persists in soils and stream sediments. Stolzite and tungstite may be weathering products.

Geochemical Signature W, Mo, Sn, Bi, As, Cu, Pb, Zn, Be, F.

### EXAMPLES

Pasto Bueno, PERU	(Landis and Rye, 1974)
Xihuashan, CINA	(Hsu, 1943; Giuliani, 1985; and personal visit)
Isla de Pinos, CUBA	(Page and McAllister, 1944)
Hamme District, USNC	(Foote and others, 1980)
Round Mountain, USNV	(Shaw and others, 1984)
Chicote Grande, BLVA	(Personal visit)

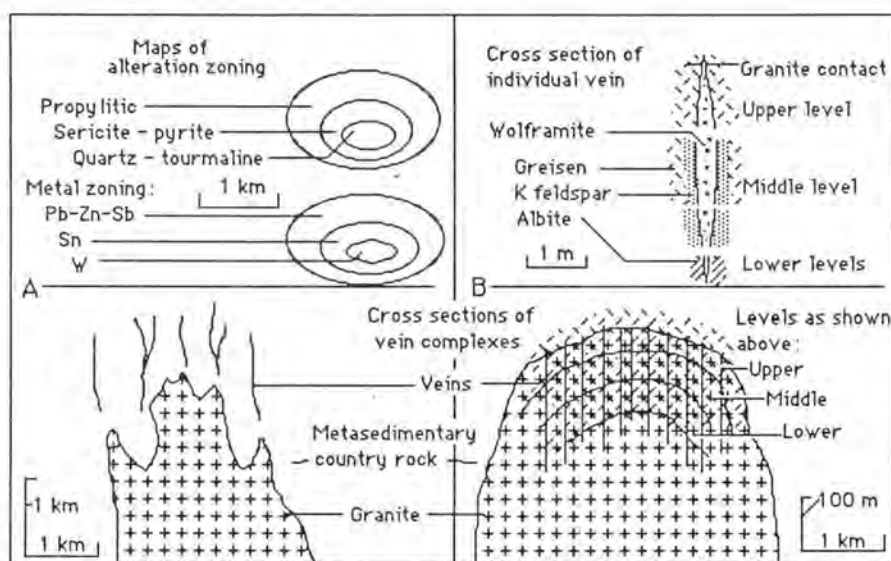
## GRADE AND TONNAGE MODEL OF W VEINS

By Gail M. Jones and W. David Menzie

**COMMENTS** Data are for vein systems rather than for individual veins or mines. Some data are based on past production only. Xihuashan is the sole deposit from the Peoples Republic of China. See figs. 40, 41.

DEPOSITS

<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Carrock Fell	GRBR	Montredon	FRNC
Chicote Grande	BLVA	Needle Hill	HONG
Grey River	CNNF	Oakleigh Creek	AUTS
Hamme District	USNC	Panasqueria	PORT
Isla de Pinos	CUBA	Pasto Bueno	PERU
Josefina	AGTN	San Martin	AGTN
Kami	BLVA	Storeys Creek	AUTS
Los Condores	AGTN	Xihuashan	CINA



**Figure 39.** Maps and sections of W vein deposits illustrating mineral and alteration zoning. A, Chicote Grande deposit, Bolivia. B, Xihuashan, China.

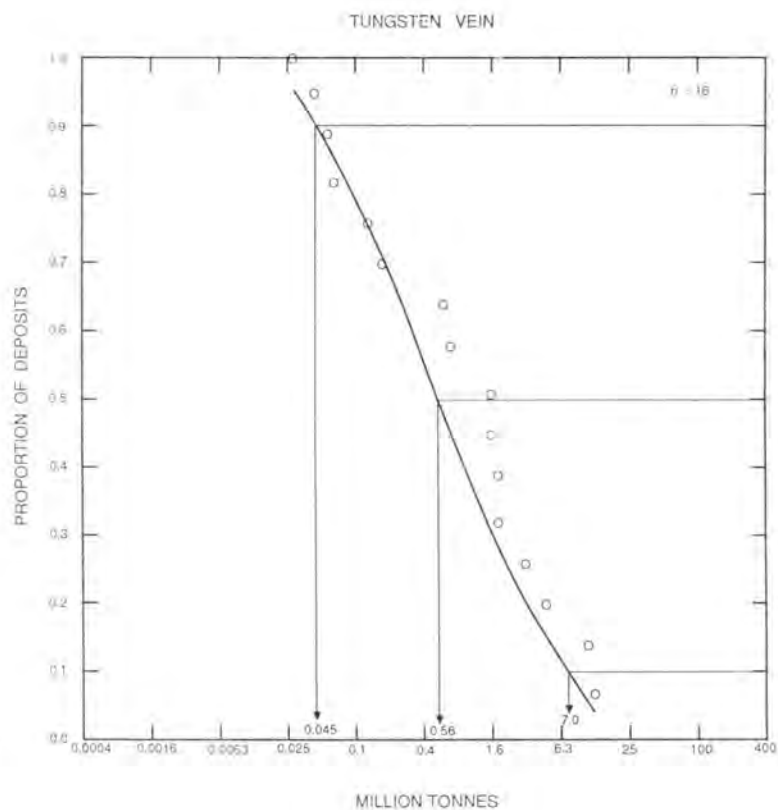


Figure 40. Tonngages of W vein deposits.

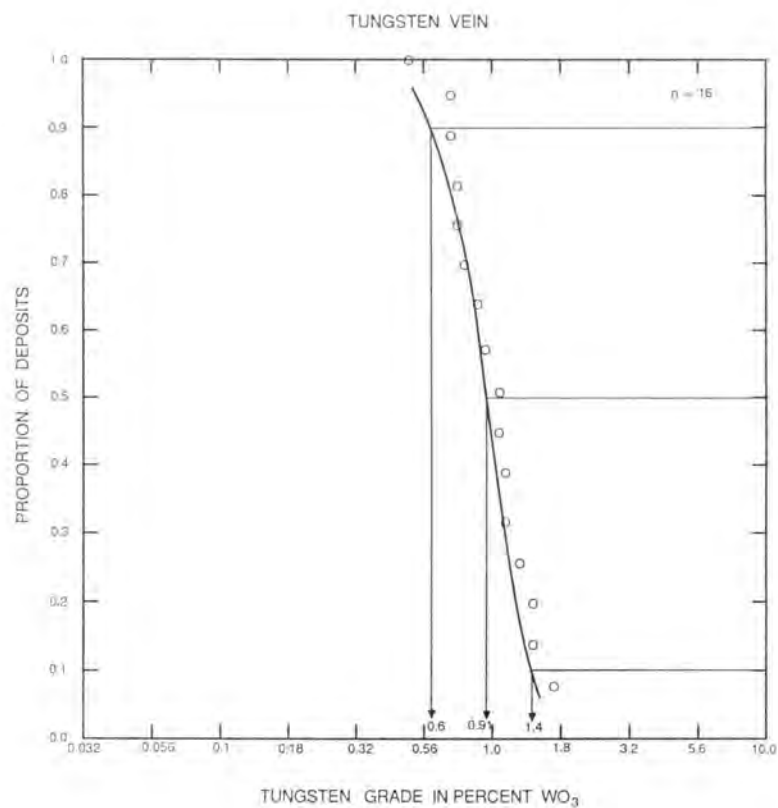


Figure 41. Tungsten grades of W vein deposits.

**DESCRIPTIVE MODEL OF Sn VEINS**

By Bruce L. Reed

APPROXIMATE SYNONYM Cornish type lodes.DESCRIPTION Simple to complex quartz-cassiterite  $\pm$  wolframite and base-metal sulfide fissure fillings or replacement lodes in ore near felsic plutonic rocks (see fig. 34).GENERAL REFERENCE Hosking (1974), Taylor (1979).GEOLOGICAL ENVIRONMENTRock Types Close spatial relation to multiphase granitoids; specialized biotite and(or) muscovite leucogranite common; pelitic sediments generally present.Textures Common plutonic textures.Age Range Paleozoic and Mesozoic most common; may be any age.Depositional Environment Mesozonal to hypabyssal plutons; extrusive rocks generally absent; dikes and dike swarms common.Tectonic Setting(s) Foldbelts and accreted margins with late orogenic to postorogenic granitoids which may, in part, be anatectic; regional fractures common.Associated Deposit Types Sn greisen, Sn skarn, and replacement Sn deposits.DEPOSIT DESCRIPTIONMineralogy Extremely varied; cassiterite  $\pm$  wolframite, arsenopyrite, molybdenite, hematite, scheelite, beryl, galena, chalcopryrite, sphalerite, stannite, bismuthinite; although variations and overlaps are ubiquitous, many deposits show an inner zone of cassiterite  $\pm$  wolframite fringed with Pb, Zn, Cu, and Ag sulfide minerals.Texture/Structure Variable; brecciated bands, filled fissures, replacement, open cavities.Alteration Sericitization (greisen development)  $\pm$  tourmalization common adjacent to veins and granite contacts; silicification, chloritization, hematization. An idealized zonal relation might consist of quartz-tourmaline-topaz, quartz-tourmaline-sericite, quartz-sericite-chlorite, quartz-chlorite, chlorite.Ore Controls Economic concentrations of tin tend to occur within or above the apices of granitic cusps and ridges; localized controls include variations in vein structure, lithologic and structural changes, vein intersections, dikes, and cross-faults.Weathering Cassiterite in stream gravels, placer tin deposits.Geochemical Signature Sn, As, W, B are good pathfinder elements; elements characteristic of specialized granites (F, Rb, Be, Nb, Cs, U, Mo, REE, see model 14b).EXAMPLES

Cornwall, GRBR	(Hosking, 1969)
Herberton, AUQL	(Blake, 1972)

**GRADE AND TONNAGE MODEL OF Sn VEINS**

By W. David Menzie and Bruce L. Reed

COMMENTS The grade-tonnage model for this deposit type is built with data from 43 deposits, or in some cases, districts. The imprecise definition of what constitutes a deposit has arisen here because many lodes were mined by a number of operators during the second half of the nineteenth century. Data for most deposits and districts consist of past production, although for some

deposits, especially those still operating, reserves are included. Of the 43 deposits in the model, 27 are from Australia. These include most of the small tonnage deposits. This is thought to be an artifact of data reporting. For example, if data were available for many of the small deposits in Cornwall, the deposits would undoubtedly fall within the low tonnage part of the curve. See figs. 42, 43.

#### DEPOSITS

<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Aberfoyle	AUTS	Kelapa Kampit	INDO
Adventure Creek	AUQL	Killifreth	GRBR
Bakerville	AUQL	Krupka	CZCL
Basset	GRBR	Levant	GRBR
Bloodwood Creek	AUQL	Maranboy	AUNT
Brownsville	AUQL	Mawchi	BRMA
Carn Brea-Tincroft	GRBR	Mount Nolan Dist.	AUQL
Carocoles	BLVA	Mount Paynter	AUNS
Conrad Lodes	AUNW	Mount Wellington	GRBR
Coolgarra Dist.	AUQL	Mowbray Creek	AUQL
Dargo Range Dist.	AUQL	Nount Wells	AUNS
Dulcoath	GRBR	Nymbool Dist.	AUQL
Emu Creek	AUQL	Ottery Lode	AUNS
Emu Dist.	AUQL	Pahang	MLYS
Geevor	GRBR	Royal George	AUTS
Gleneindale Dist.	AUQL	Silver Valley	AUQL
Grenville	GRBR	South Crofty	GRBR
Gundie	AUNW	Stannary Hills	AUQL
Gurrumba Dist.	AUQL	Watsonville	AUQL
Hales Siding	AUQL	Wheal Jane	GRBR
Herberton	AUQL	Wheal Kitty-Penhalls	GRGB
Irvine Bank	AUQL		



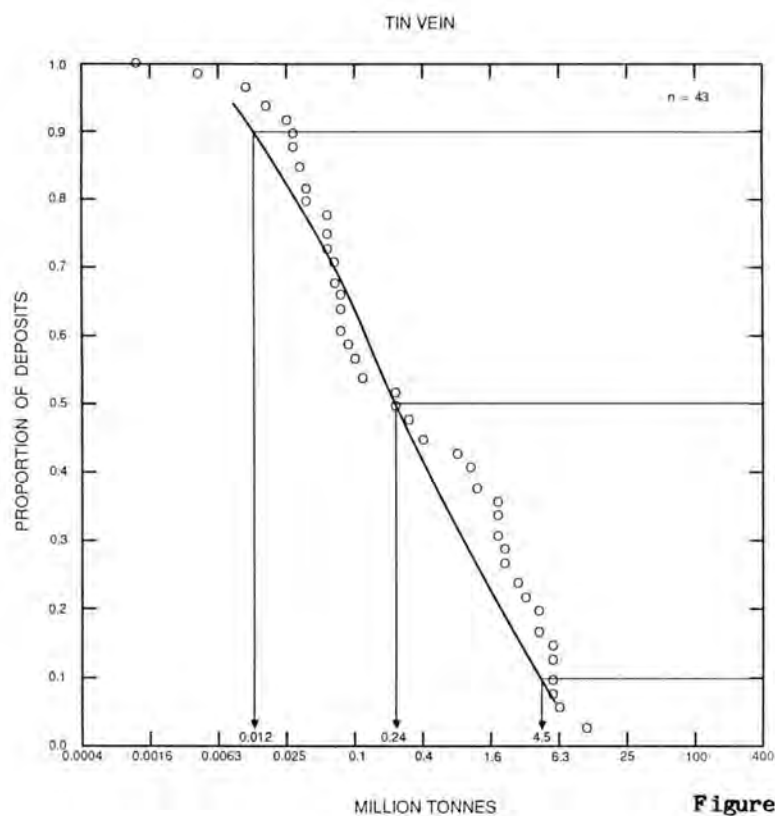


Figure 42. Tonnages of Sn vein deposits.

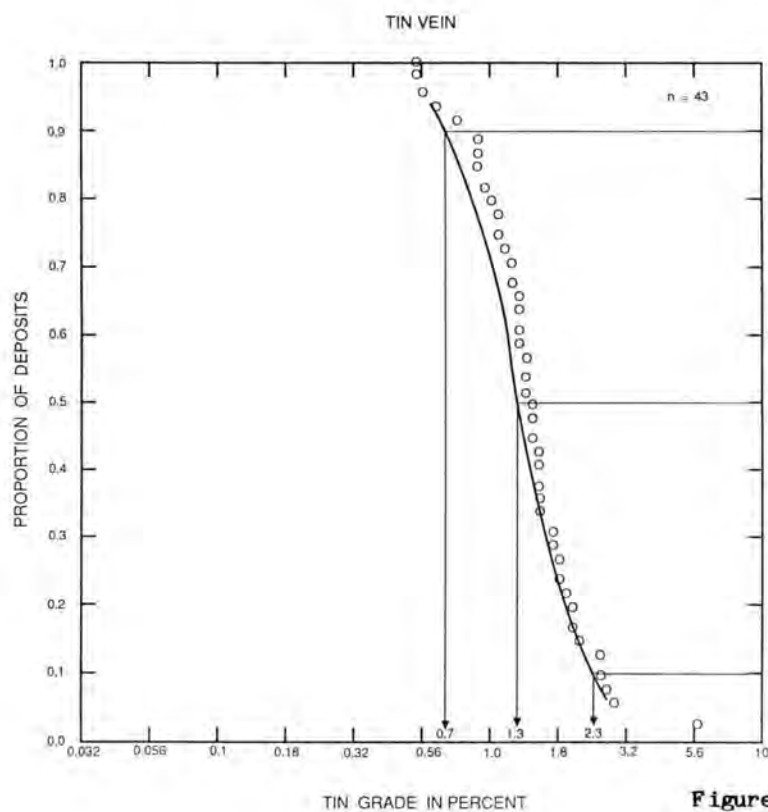


Figure 43. Tin grades of Sn vein deposits.

## DESCRIPTIVE MODEL OF Sn GREISEN DEPOSITS

By Bruce L. Reed

DESCRIPTION Disseminated cassiterite, and cassiterite-bearing veinlets, stockworks, lenses, pipes, and breccia in greisenized granite (see fig. 44).

GENERAL REFERENCE Scherba (1970), Taylor (1979), Reed (1982), Tischendorf (1977).

### GEOLOGICAL ENVIRONMENT

Rock Types Specialized biotite and(or) muscovite leucogranite (S-type); distinctive accessory minerals include topaz, fluorite, tourmaline, and beryl. Tin greisens are generally post-magmatic and associated with late fractionated melt.

Textures Common plutonic rock textures, miarolitic cavities may be common; generally nonfoliated; equigranular textures may be more evolved (Hudson and Arth, 1983); aplitic and porphyritic textures common.

Age Range May be any age; tin mineralization temporally related to later stages of granitoid emplacement.

Depositional Environment Mesozonal plutonic to deep volcanic environment.

Tectonic Setting(s) Foldbelts of thick sediments ± volcanic rocks deposited on stable cratonic shield; accreted margins; granitoids generally postdate major folding.

Associated Deposit Types Quartz-cassiterite sulfide lodes, quartz-cassiterite ± molybdenite stockworks, late complex tin-silver-sulfide veins.

### DEPOSIT DESCRIPTION

Mineralogy General zonal development of cassiterite + molybdenite, cassiterite + molybdenite + arsenopyrite + beryl, wolframite + beryl + arsenopyrite + bismuthinite, Cu-Pb-Zn sulfide minerals + sulphostannates, quartz veins ± fluorite, calcite, pyrite.

Texture/Structure Exceedingly varied, the most common being disseminated cassiterite in massive greisen, and quartz veinlets and stockworks (in cupolas or in overlying wallrocks); less common are pipes, lenses, and tectonic breccia.

Alteration Incipient greisen (granite): muscovite ± chlorite, tourmaline, and fluorite. Greisenized granite: quartz-muscovite-topaz-fluorite, ± tourmaline (original texture of granites retained). Massive greisen: quartz-muscovite-topaz ± fluorite ± tourmaline (typically no original texture preserved). Tourmaline can be ubiquitous as disseminations, concentrated or diffuse clots, or late fracture fillings. Greisen may form in any wallrock environment, typical assemblages developed in aluminosilicates.

Ore Controls Greisen lodes located in or near cupolas and ridges developed on the roof or along margins of granitoids; faults and fractures may be important ore controls.

Weathering Granite may be "reddened" close to greisen veins. Although massive greisen may not be economic as lodes, rich placer deposits form by weathering and erosion.

Geochemical Signature Cassiterite, topaz, and tourmaline in streams that drain exposed tin-rich greisens. Specialized granites may have high contents of SiO<sub>2</sub> (>73 percent) and K<sub>2</sub>O (>4 percent), and are depleted in CaO, TiO<sub>2</sub>, MgO, and total FeO. They are enriched in Sn, F, Rb, Li, Be, W, Mo, Pb, B, Nb, Cs, U, Th, Hf, Ta, and most REE, and impoverished in Ni, Cu, Cr, Co, V, Sc, Sr, La, and Ba.

### EXAMPLES

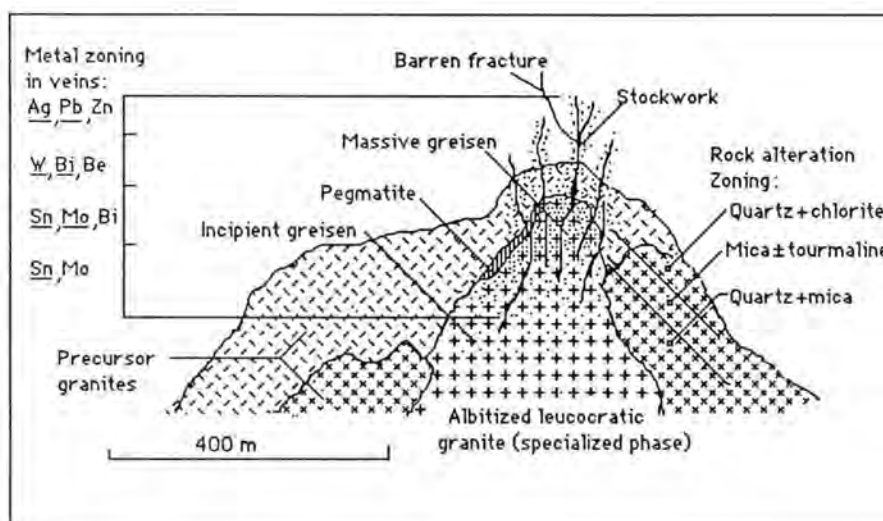
Lost River, USAK	(Dobson, 1982; Sainsbury, 1964)
Anchor Mine, AUTS	(Groves and Taylor, 1973)
Erzgebirge, CZCL	(Janecka and Stemprok, 1967)

## GRADE AND TONNAGE MODEL OF Sn GREISEN DEPOSITS

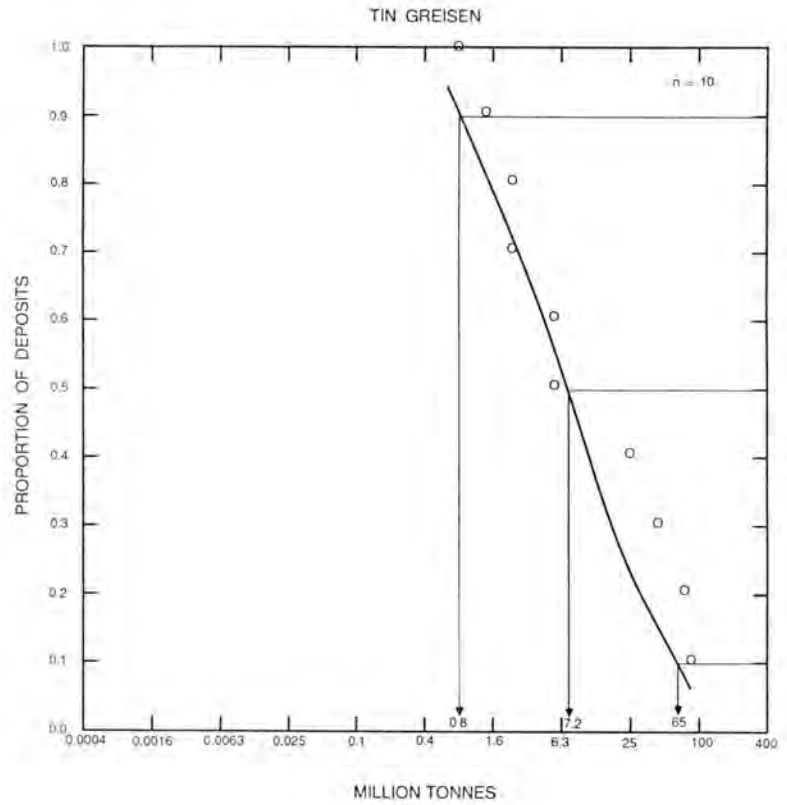
By W. David Menzie and Bruce L. Reed

COMMENTS See figs. 45, 46.DEPOSITS

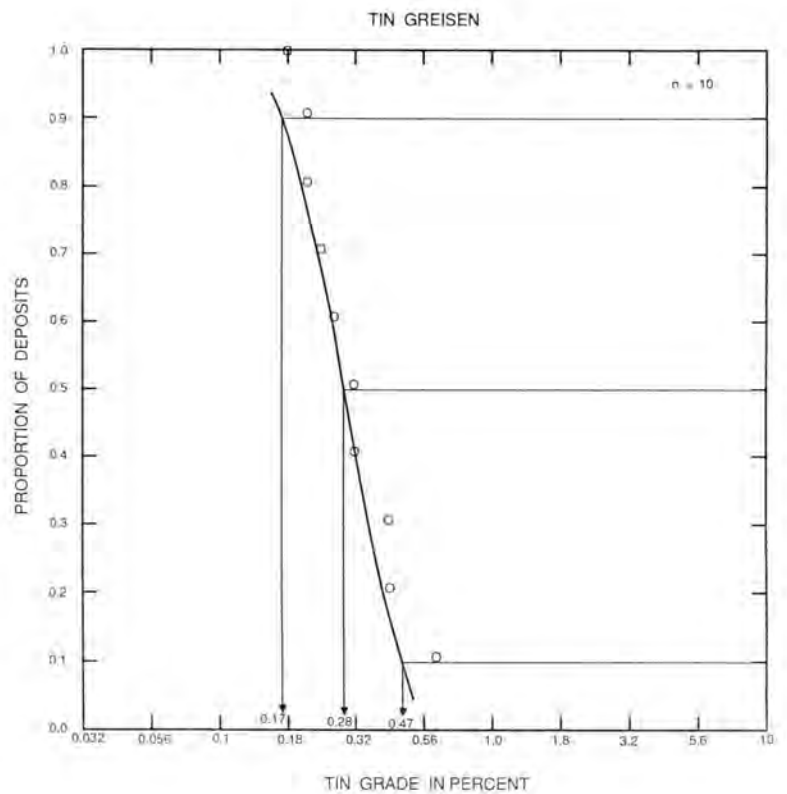
<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Altenberg	GRME	Coal Creek	USAK
Anchor	AUTS	E. Kempville	CNNS
Archer	AUTS	Hub	CZCL
Cinovec	CZCL	Potosi	BRZL
Cista	CZCL	Prebuz	CZCL

**Figure 44.** Cartoon cross section of a Sn greisen.

**Figure 45.** Tonnages of Sn greisen deposits.



**Figure 46.** Tin grades of Sn greisen deposits.



## DESCRIPTIVE MODEL OF CLIMAX Mo DEPOSITS

By Stephen D. Ludington

APPROXIMATE SYNONYM Granite molybdenite (Mutschler and others, 1981).

DESCRIPTION Stockwork of quartz and molybdenite associated with fluorite in granite porphyry (see fig. 47).

GENERAL REFERENCE White and others (1981).

### GEOLOGICAL ENVIRONMENT

Rock Types Granite-rhyolite with >75 percent SiO<sub>2</sub>. Rb, Y, Nb are high, Ba, Sr, Zr low. Stocks with radial dikes; small breccias common.

Textures Porphyry with fine- to medium-grained aplitic groundmass.

Age Range Examples are mainly mid-Tertiary.

Depositional Environment Multistage hypabyssal intrusions.

Tectonic Setting(s) Mainly extensional zones in cratons. May be related to subduction, but found far from continental margins in areas of thick crust, and late in the cycles.

Associated Deposit Types Ag-base-metal veins, fluorspar deposits. On the basis of similar geochemistry of associated rhyolite magmas, rhyolite-hosted Sn deposits may be a surface expression. Porphyry tungsten deposits, as at Mount Pleasant, Canada, may be W-rich Climax systems.

### DEPOSIT DESCRIPTION

Mineralogy: Molybdenite + quartz ± fluorite ± K-feldspar ± pyrite ± wolframite ± cassiterite ± topaz.

Texture/Structure Predominantly in veinlets and fractures; minor disseminations.

Alteration Intense quartz and quartz + K-feldspar veining in ore zone. Upper phyllic and propylitic zones. Halo of rhodochrosite, rhodonite, spessartine garnet. Minor greisen veins below ore body.

Ore Controls Stockwork ore zone draped over small, <1 km<sup>2</sup> stocks. Multiple phases of intrusion and mineralization are highly favorable.

Weathering Yellow ferrimolybdate stains.

Geochemical Signature Mo, Sn, W and Rb anomalies close above ore zones. Pb, Zn, F, and U anomalies in wall rocks up to a few kilometers distant. Cu anomaly external to Mount Emmons deposit. In panned concentrates, Sn, W, Mo, and F may be important.

### EXAMPLES

Redwell Basin, Winfield, Middle Mtn.	
Climax, Henderson,	
and Mt. Emmons, USCO	(White and others, 1981)
Pine Grove, USUT	(Abbott and Williams, 1981)
Mount Hope, USNV	(Westra, 1982b)
Big Ben, USMT	(Witkind, 1973)

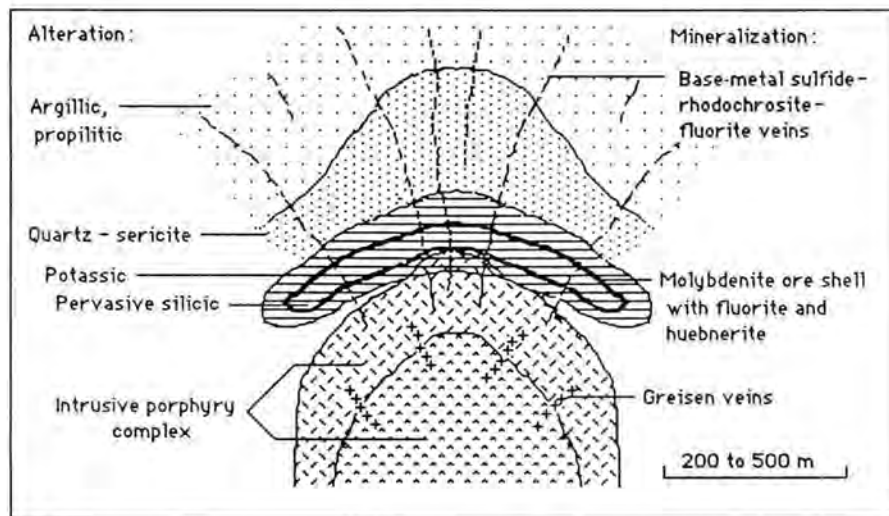
## GRADE AND TONNAGE MODEL OF CLIMAX Mo DEPOSITS

By Donald A. Singer, Ted G. Theodore, and Dan L. Mosier

COMMENTS See figs. 48, 49.

DEPOSITS

<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Big Ben	USMT	Mount Hope	USNV
Climax	USCO	Pine Grove	USUT
Henderson	USCO	Questa-Goat Hill	USNM
Malmbjerg	GRLD	Redwell	USCO
Mount Emmons	USCO		



**Figure 47.** Cartoon cross section of Climax Mo deposit showing relationship of ore and alteration zoning to porphyry intrusions from Mutschler and others (1981). Cartoon represents a region about 1 km wide.

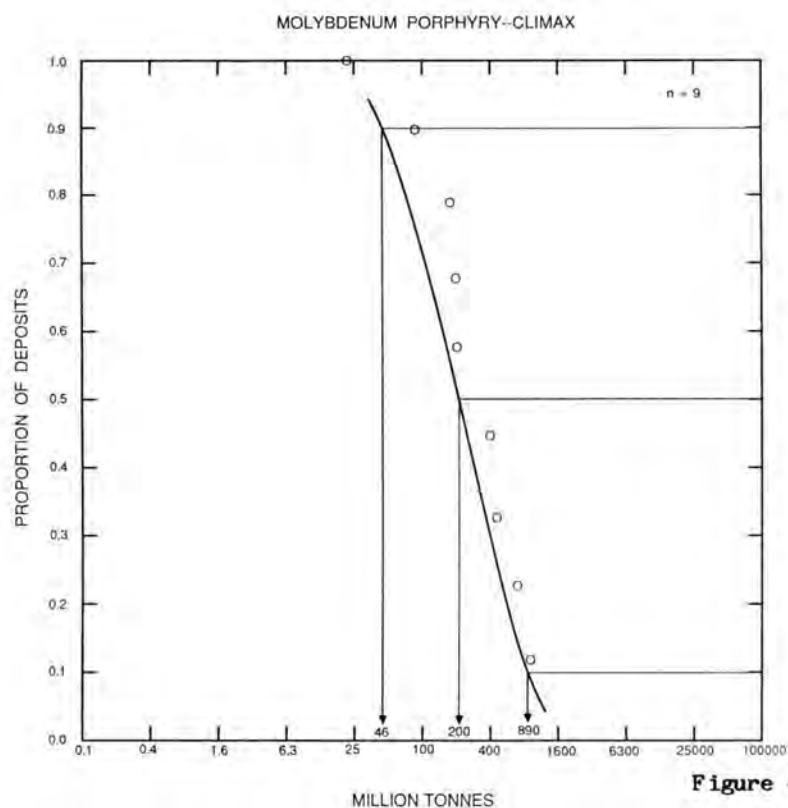


Figure 48. Tonnages of Climax Mo deposits.

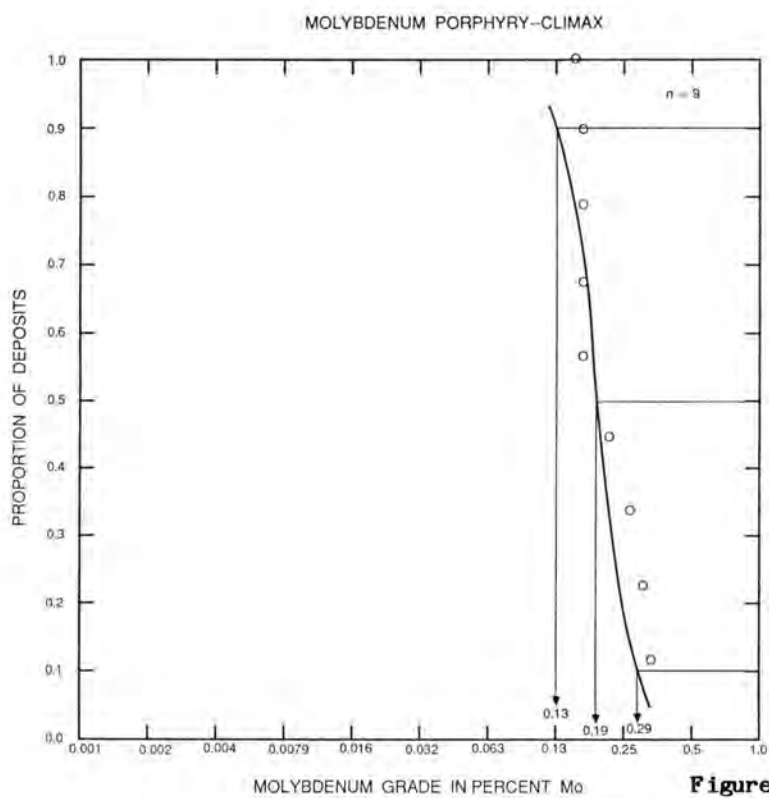


Figure 49. Molybdenum grades of Climax Mo deposits.



## DESCRIPTIVE MODEL OF PORPHYRY Cu

By Dennis P. Cox

DESCRIPTION This generalized model includes various subtypes all of which contain chalcopyrite in stockwork veinlets in hydrothermally altered porphyry and adjacent country rock (see fig. 50).

GENERAL REFERENCE Titley (1982).

### GEOLOGICAL ENVIRONMENT

Rock Types Tonalite to monzogranite or syenitic porphyry intruding granitic, volcanic, calcareous sedimentary, and other rocks.

Textures Porphyry has closely spaced phenocrysts and microaplitic quartz-feldspar groundmass.

Age Range Mainly Mesozoic and Cenozoic, but may be any age.

Depositional Environment High-level intrusive rocks contemporaneous with abundant dikes, breccia pipes, faults. Also cupolas of batholiths.

Tectonic Setting(s) Rift zones contemporaneous with Andean or island-arc volcanism along convergent plate boundaries. Uplift and erosion to expose subvolcanic rocks.

Associated Deposit Types Base-metal skarn, epithermal veins, polymetallic replacement, volcanic hosted massive replacement. See also: Porphyry Cu-skarn related, porphyry Cu-Mo, and porphyry Cu-Au.

### DEPOSIT DESCRIPTION

Mineralogy: Chalcopyrite + pyrite ± molybdenite; chalcopyrite + magnetite ± bornite ± Au; assemblages may be superposed. Quartz + K-feldspar + biotite + anhydrite; quartz + sericite + clay minerals. Late veins of enargite, tetrahedrite, galena, sphalerite, and barite in some deposits.

Texture/Structure Stockwork veinlets and disseminated sulfide grains.

Alteration From bottom, innermost zones outward: sodic-calcic, potassic, phyllic, and argillic to propylitic. High-alumina alteration in upper part of some deposits. See table 3. Propylitic or phyllic alteration may overprint early potassic assemblage.

Ore Controls Stockwork veins in porphyry, along porphyry contact, and in favorable country rocks such as carbonate rocks, mafic igneous rocks, and older granitic plutons.

Weathering Green and blue Cu carbonates and silicates in weathered outcrops, or where leaching is intense, barren outcrops remain after Cu is leached, transported downward, and deposited as secondary sulfides at water table or paleowater table. Fractures in leached outcrops are coated with hematitic limonite having bright red streak. Deposits of secondary sulfides contain chalcocite and other Cu<sub>2</sub>S minerals replacing pyrite and chalcopyrite. Residual soils overlying deposits may contain anomalous amounts of rutile.

Geochemical Signature: Cu + Mo + Au + Ag + W + B + Sr center, Pb, Zn, Au, As, Sb, Se, Te, Mn, Co, Ba, and Rb outer. Locally Bi and Sn form most distal anomalies. High S in all zones. Some deposits have weak U anomalies.

### EXAMPLES

Bingham, USUT	(Lanier and others, 1978)
San Manuel, USAZ	(Lowell and Guilbert, 1970)
El Salvador, CILE	(Gustafson and Hunt, 1975)

## GRADE AND TONNAGE MODEL OF PORPHYRY Cu

By Donald A. Singer, Dan L. Mosier, and Dennis P. Cox

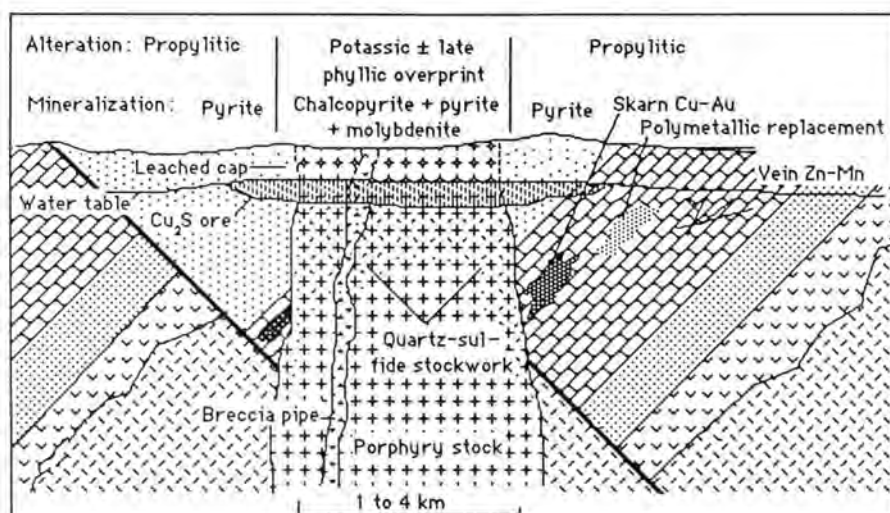
COMMENTS All porphyry copper deposits with available grades and tonnages were included in these plots in order to provide a model for cases where it is not possible to use the gold-rich or molybdenum-rich models. Parts of the porphyry copper deposits which could be considered skarn were included in these data. Gold grade is correlated with tonnage ( $r = -0.49$ ,  $n = 81$ ) and with molybdenum grade ( $r = -0.45$ ,  $n = 55$ ). See figs. 51-53.

DEPOSITS

<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Afton	CNBC	Copper Cities	USAZ
Ajax	CNBC	Copper Creek	USAZ
Ajo	USAZ	Copper Flat	USNM
Am	CNBC	Copper Mountain	CNBC
Amacan	PLPN	Cordon	PLPN
Andacolla	CILE	Cuajone	PERU
Ann	CNBC	Cubuagan	PLPN
Ann Mason	USNV	Dexing	CINA
Arie	PPNG	Dizon	PLPN
Atlas Carmen	PLPN	Dorothy	CNBC
Atlas Frank	PLPN	Dos Pobres	USAZ
Atlas Lutopan	PLPN	Eagle	CNBC
Axe	CNBC	El Abra	CILE
Aya Aya	PLPN	El Arco	MXCO
Bagdad	USAZ	El Pachon	AGTN
Basay	PLPN	El Salvador	CILE
Bear	USNV	El Soldado	CILE
Bell Copper	CNBC	El Teniente	CILE
Berg	CNBC	ElatSITE	BULG
Bethlehem	CNBC	Ely	USNV
Big Onion	CNBC	Escondida	CILE
Bingham	USUT	Esperanza	CILE
Bisbee	USAZ	Exotica	CILE
Bluebird	USAZ	Fish Lake	CNBC
Bond Creek	USAK	Florence	USAZ
Boneng Lobo	PLPN	Frieda River	PPNG
Bozshchaku	URRS	Galaxy	CNBC
Brenda	CNBC	Galore Creek	CNBC
Brenmac	USWA	Gambier Island	CNBC
Butilad	PLPN	Gaspé	CNQU
Butte	USMT	Gibraltar	CNBC
Campanamah	AGTN	Glacier Peak	USWA
Cananea	MXCO	Granisle	CNBC
Canariaco	PERU	Hale-Mayabo	PLPN
Cariboo Bell	CNBC	Heddleston	USMT
Carpenter	USAZ	Helvetia	USAZ
Cash	CNYT	Highmont	CNBC
Casino	CNYT	Hinobaan	PLPN
Castle Dome	USAZ	Huckleberry	CNBC
Catface	CNBC	Ingerbelle	CNBC
Catheart	USMN	Inguaran	MXCO
Cerro Blanco	CILE	Ino-Capaya	PLPN
Cerro Colorado	CILE	Inspiration	USAZ
Cerro Colorado	PANA	Iron Mask	CNBC
Cerro Verde	PERU	Island Copper	CNBC
Chaucha	ECDR	Ithaca Peak	USAZ
Chuquicamata	CILE	June	CNBC
Coalstoun	AUQL	Kadzharan	URAM
Copper Basin	USAZ	Kalamaton	PLPN

Model 17--Con.

Kalamazoo-San Manuel	USAZ	Petaquilla	PANA
Kalmakyr	URUZ	Philippine	PLPN
Kennon	PLPN	Pima-Mission	USAZ
King-King	PLPN	Plurhinaler	THLD
Kirwin	USWY	Poison Mountain	CNBC
Kounrad	URKZ	Potrerrillos	CILE
Krain	CNBC	Primer	CNBC
Kwanika	CNBC	Quebrada Blanca	CILE
La Alumbreira	AGTN	Quelleveco	PERU
La Caridad	MXCO	Ray	USAZ
La Florida	MXCO	Recsk	HUNG
La Verde	MXCO	Red Chris	CNBC
Lakeshore	USAZ	Red Mountain	USAZ
Lights Creek	USCA	Rio Blanco	CILE
Lornex	CNBC	Rio Vivi	PTRC
Lorraine	CNBC	Sacaton (E-W)	USAZ
Los Bronces	CILE	Safford (KCC)	USAZ
Los Pelambres	CILE	Saindak East	PKTN
Los Pilares	MXCO	Saindak North	PKTN
Lumbay	PLPN	Saindak South	PKTN
Luna-Bash	PLPN	Samar	PLPN
MacArthur	USNV	San Antonio	PLPN
Maggie	CNBC	San Fabian	PLPN
Majdanpek	YUGO	San Juan	USAZ
Mamut	MDGS	San Xavier	USAZ
Mantos Blancos	CILE	Sanchez	USAZ
Mapula	PLPN	Santa Rita	USNM
Marcopper	PLPN	Santo Nino	PLPN
Margaret	USWA	Santo Tomas	MXCO
Marian	PLPN	Santo Tomas	PLPN
Mazama	USWA	Sar Cheshmeh	IRAN
Metcalf	USAZ	Schaft Creek	CNBC
Michiquillay	PERU	Sierra Gorda	CILE
Middle Fork	USWA	Silver Bell	USAZ
Mineral Butte	USAZ	Sipalay	PLPN
Misty	CNBC	Star Mt.-Fubilan	PPNG
Mocha	CILE	Star Mt.-Futik	PPNG
Mocoa	CLBA	Star Mt.-Nong River	PPNG
Moniwa	BRMA	Star Mt.-Olgal	PPNG
Morenci	USAZ	Sugarloaf Hill	CNBC
Morococha	PERU	Tagpura	PLPN
Morrison	CNBC	Tanama	PTRC
Mountain Mines	PLPN	Tawi-Tawi	PLPN
Mount Canninda	AUQL	Taysan	PLPN
Namosi East	FIJI	Toledo	PLPN
Namosi West	FIJI	Toquepala	PERU
North Fork	USWA	Trojan	CNBC
Ok	CNBC	Twin Buttes	USAZ
Ok Tedi	PPNG	Tyrone	USNM
Orange Hill	USAK	Valley Copper	CNBC
Pampa Norte	CILE	Vekol	USAZ
Panguna	PPNG	Washington	MXCO
Paramillos	AGTN	Yandera	PPNG
Parks	AUNS	Yeoval	AUNS
Pashpap	PERU	Yerington	USNV

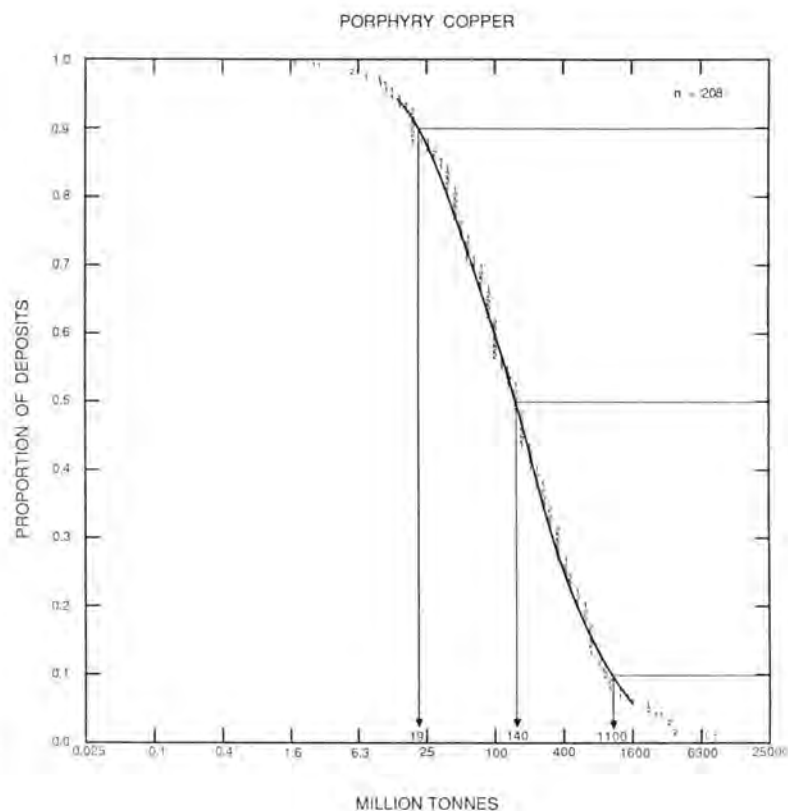


**Figure 50.** Cartoon cross section illustrating generalized model for porphyry Cu deposits showing relation of ore minerals, alteration zoning, supergene enrichment and associated skarn, replacement, and vein deposits.

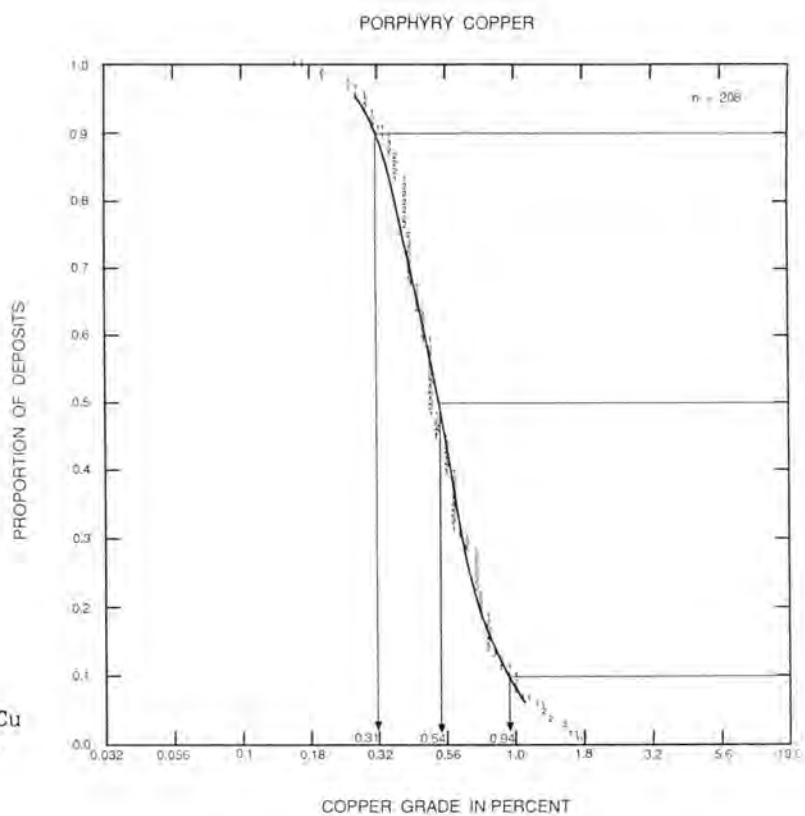
**Table 3.** Types of hydrothermal alteration characteristic of porphyry copper and other deposit models

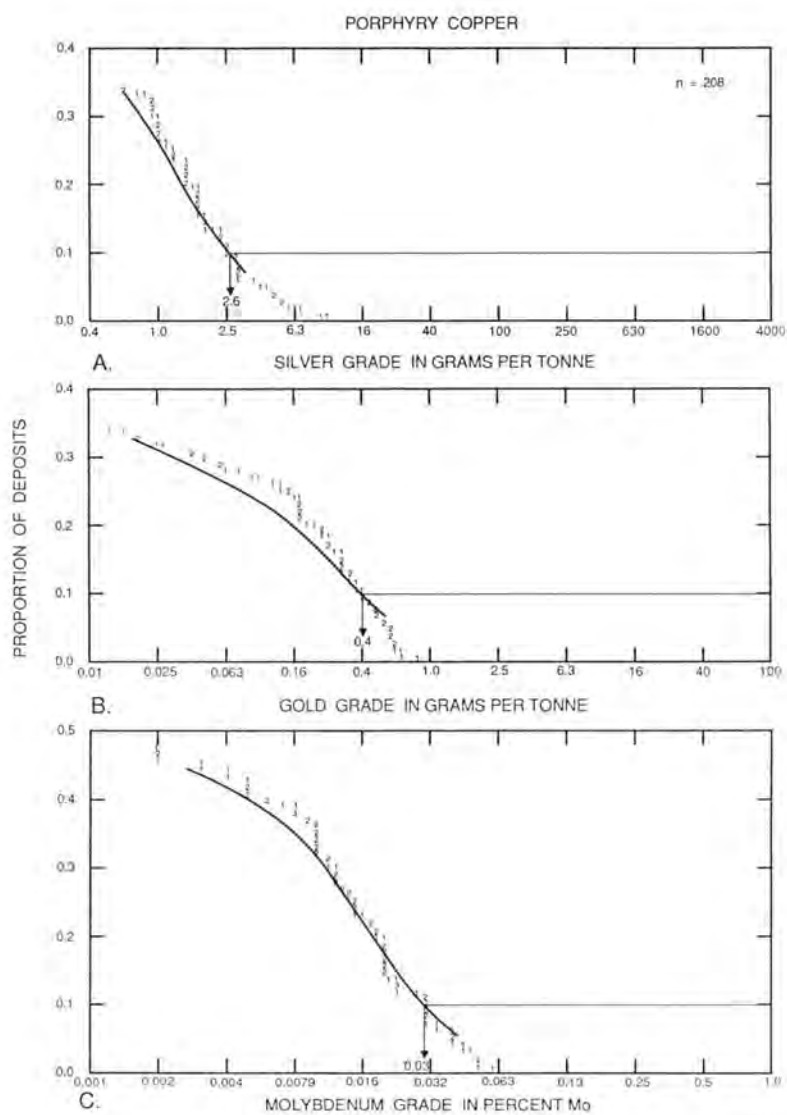
Type of alteration and synonyms	Original mineral	replaced by	Appearance
Potassic alteration (K-silicate)	plagioclase----- hornblende-----	K-feldspar fine-grained biotite + rutile + pyrite or magnetite. Anhydrite	Rocks look fresh but may have pinkish K-feldspar veinlets and black biotite veinlets and clusters of fine biotite after mafic phenocrysts.
Sodic-calcic alteration (albitic)	K-feldspar----- biotite-----	oligoclase or albite actinolite + sphene	Rocks are hard and dull white. Biotite is absent. Veinlets of actinolite, epidote, and hematite have hard, white alteration haloes.
Phyllic alteration (quartz-sericite)	plagioclase----- hornblende and biotite-----	sericite sericite + chlorite + rutile + pyrite	Rocks are soft and dull to lustrous white. Pyrite veinlets have distinct, soft translucent gray, sericite haloes. Tourmaline rosettes may be present.
Propylitic alteration	plagioclase-----  hornblende and biotite-----	albite or oligoclase + epidote or calcite  chlorite + rutile + magnetite or pyrite	Rocks are hard and dull greenish gray. Veinlets of pyrite or chlorite and epidote lack prominent alteration haloes.
Argillic alteration	plagioclase----- mafic minerals----	clay + sericite clay + sericite + chlorite + pyrite	Rocks are soft and white. Tongue will stick to clay-altered minerals.
High alumina (albic, advanced argillic)	All original and earlier hydrothermal minerals converted to pyrophyllite, alunite, andalusite, corundum, and diasporite with variable amounts of clay and sericite.		Rocks are light-colored and moderately soft.

**Figure 51.** Tonnages of porphyry Cu deposits. Individual digits represent number of deposits.



**Figure 52.** Copper grades of porphyry Cu deposits. Individual digits represent number of deposits.





**Figure 53.** By-product grades of porphyry Cu deposits. A, Silver. B, Gold. C, Molybdenum. Individual digits represent number of deposits.

## DESCRIPTIVE MODEL OF PORPHYRY Cu, SKARN-RELATED DEPOSITS

By Dennis P. Cox

DESCRIPTION Chalcopyrite in stockwork veinlets in hydrothermally altered intrusives and in skarn with extensive retrograde alteration (see fig. 50).

GENERAL REFERENCE Einaudi and others (1981), p. 341-354.

### GEOLOGICAL ENVIRONMENT

Rock Types Tonalite to monzogranite intruding carbonate rocks or calcareous clastic rocks.

Textures Porphyry has microaplitic groundmass.

Age Range Mainly Mesozoic and Tertiary, but may be any age.

Depositional Environment Epizonal intrusion of granitic stocks into carbonate rocks. Intense fracturing.

Tectonic Setting(s) Andean-type volcanism and intrusion superimposed on older continental shelf carbonate terrane.

Associated Deposit Types Skarn copper, replacement Pb-Zn-Ag.

### DEPOSIT DESCRIPTION

Mineralogy Chalcopyrite + pyrite + magnetite in inner garnet pyroxene zone; bornite + chalcopyrite + sphalerite + tennantite in outer wollastonite zone. Scheelite and traces of molybdenite and galena may be present. Hematite or pyrrhotite may be predominant.

Texture/Structure Fine granular calc-silicates and quartz sulfide veinlets.

Alteration Potassic alteration in pluton is associated with andradite and diopside in calcareous rocks. Farther from contact are zones of wollastonite or tremolite with minor garnet, idocrase, and clinopyroxene. These grade outward to marble. Phyllic alteration in pluton is associated with retrograde actinolite, chlorite, and clay in skarn.

Ore Controls Intense stockwork veining in igneous and skarn rocks contains most of the copper minerals. Cu commonly accompanies retrograde alteration.

Weathering Cu carbonates, silicates, Fe-rich gossan.

Geochemical Signature Cu, Mo, Pb, Zn, Au, Ag, W, Bi, Sn, As, Sb.

### EXAMPLES

Ruth, (Ely), USNV	(Westra, 1982a)
Gaspe, CNQU	(Allcock, 1982)
Christmas, USAZ	(Koski and Cook, 1982)
Silver Bell, USAZ	(Graybeal, 1982)

## GRADE AND TONNAGE MODEL OF PORPHYRY Cu, SKARN-RELATED DEPOSITS

By Donald A. Singer

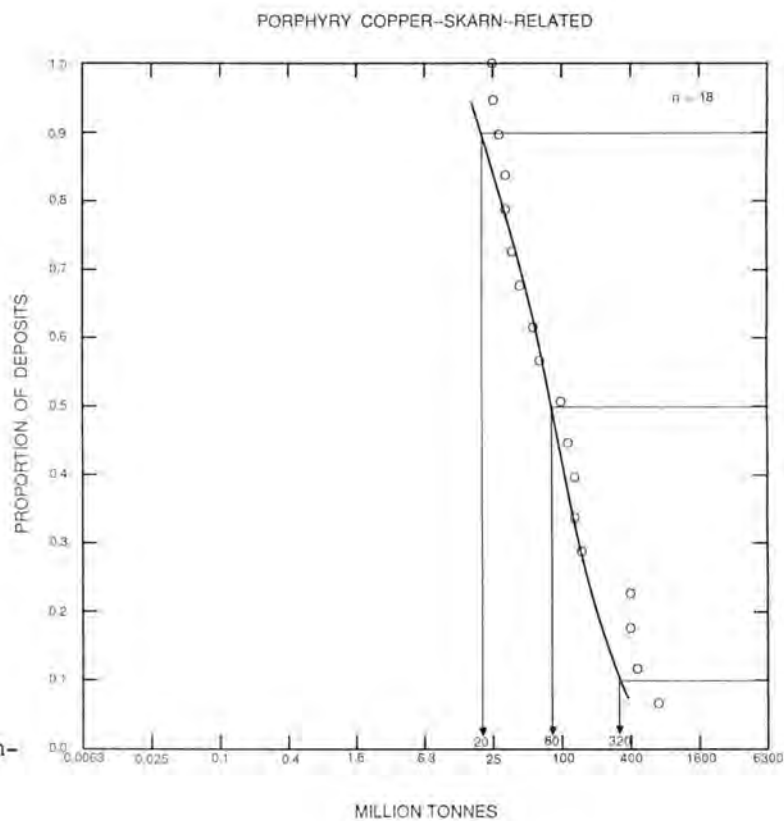
DATA REFERENCES Einaudi and others (1981), Einaudi (1981).

COMMENTS Skarn copper deposits associated with porphyry copper deposits are included in this model. Tonnages and grades attributable to skarn were estimated for some deposits from estimated proportions of skarn provided by Einaudi and others (1981) and Einaudi (1981). See figs. 54-56.

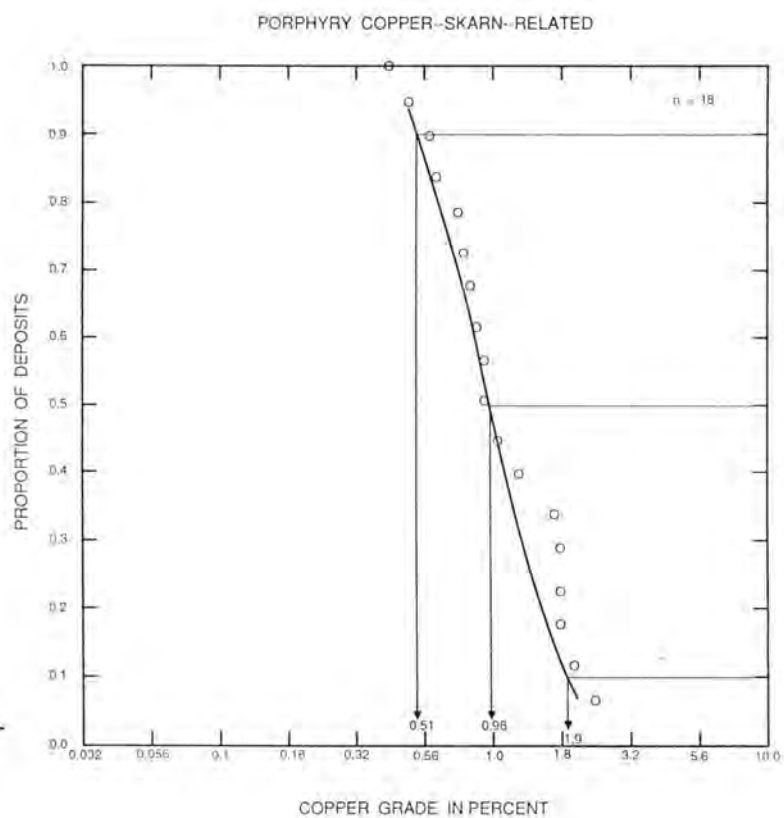


DEPOSITS

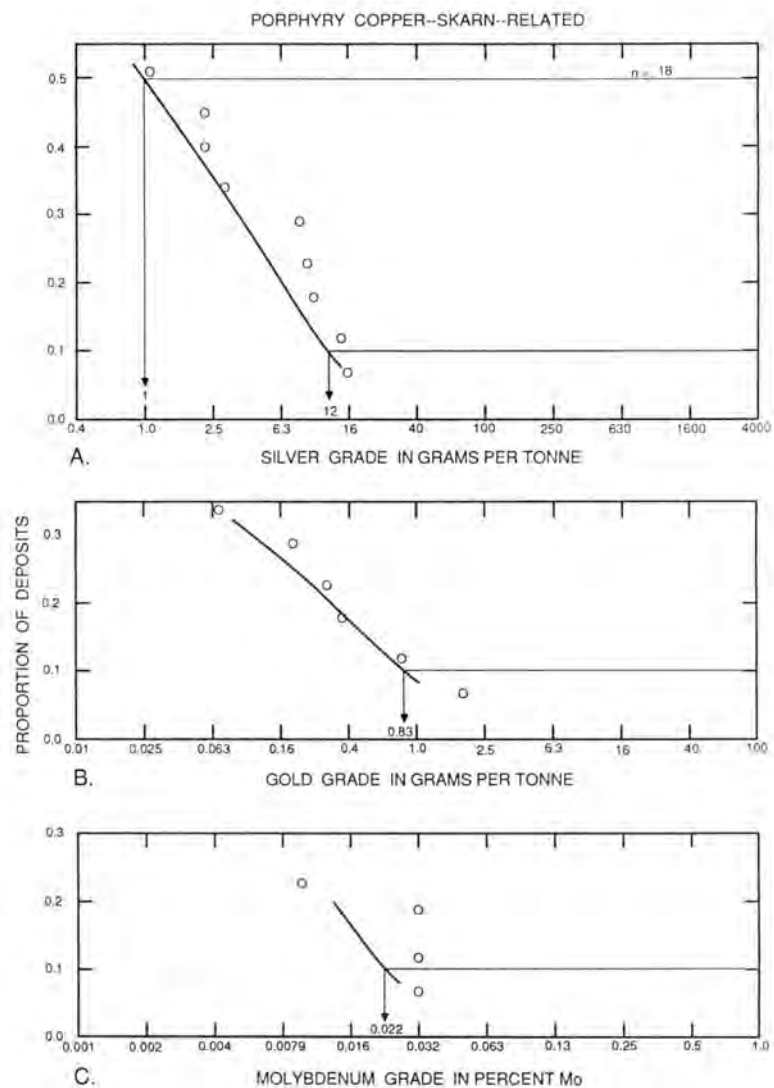
<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Cananea (Capote)	MXCO	Gold Coast	PPNG
Carr Fork	USUT	Lakeshore	USAZ
Christmas	USAZ	Lyon	USNV
Continental	USNM	Pima-Mission	USAZ
Copper Basin (Battle Mt. D.)	USNV	Potrerrillos	CILE
Copper Canyon	USNV	Recsk	HUNG
Craigmont	CNBC	Santa Rita	USNM
Ely	USNV	Silver Bell	USAZ
Gaspe (Needle Mountain)	CNQU	Twin Buttes	USAZ



**Figure 54.** Tonnages of porphyry Cu-skarn-related deposits.



**Figure 55.** Copper grades of porphyry Cu-skarn-related deposits.



**Figure 56.** By-product grades of porphyry Cu-skarn-related deposits. A, Silver. B, Gold. C, Molybdenum.

## DESCRIPTIVE MODEL OF Cu SKARN DEPOSITS

By Dennis P. Cox and Ted G. Theodore

DESCRIPTION Chalcopyrite in calc-silicate contact metasomatic rocks (see fig. 57).

GENERAL REFERENCES Einaudi and Burt (1982), Einaudi and others (1981).

### GEOLOGICAL ENVIRONMENT

Rock Types Tonalite to monzogranite intruding carbonate rocks or calcareous clastic rocks.

Textures Granitic texture, porphyry, granoblastic to hornfelsic in sedimentary rocks.

Age Range Mainly Mesozoic, but may be any age.

Depositional Environment Miogeosynclinal sequences intruded by felsic plutons.

Tectonic Setting(s) Continental margin late orogenic magmatism.

Associated Deposit Types Porphyry Cu, zinc skarn, polymetallic replacement, Fe skarn.

### DEPOSIT DESCRIPTION

Mineralogy Chalcopyrite + pyrite ± hematite ± magnetite ± bornite ± pyrrhotite. Also molybdenite, bismuthinite, sphalerite, galena, cosalite, arsenopyrite, enargite, tennantite, loellingite, cobaltite, and tetrahedrite may be present. Au and Ag may be important products.

Texture/Structure Coarse granoblastic with interstitial sulfides. Bladed pyroxenes are common.

Alteration Diopside + andradite center; wollastonite + tremolite outer zone; marble peripheral zone. Igneous rocks may be altered to epidote + pyroxene + garnet (endoskarn). Retrograde alteration to actinolite, chlorite, and clays may be present.

Ore Controls Irregular or tabular ore bodies in carbonate rocks and calcareous rocks near igneous contacts or in xenoliths in igneous stocks. Breccia pipe, cutting skarn at Victoria, is host for ore. Associated igneous rocks are commonly barren.

Weathering Cu carbonates, silicates, Fe-rich gossan. Calc-silicate minerals in stream pebbles are a good guide to covered deposits.

Geochemical Signature Rock analyses may show Cu-Au-Ag-rich inner zones grading outward to Au-Ag zones with high Au:Ag ratio and outer Pb-Zn-Ag zone. Co-As-Sb-Bi may form anomalies in some skarn deposits. Magnetic anomalies.

### EXAMPLES

Mason Valley, USNV	(Harris and Einaudi, 1982)
Victoria, USNV	(Atkinson and others, 1982)
Copper Canyon, USNV	(Blake and others, 1979)
Carr Fork, USUT	(Atkinson and Einaudi, 1978)

## GRADE AND TONNAGE MODEL OF Cu SKARN DEPOSITS

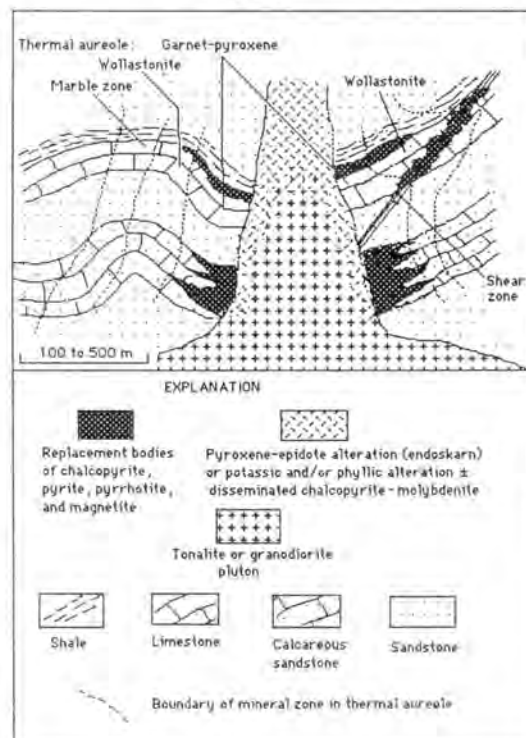
By Gail M. Jones and W. David Menzie

COMMENTS Data used in this model were restricted to copper skarns associated with barren stocks as recommended by Einaudi and others (1981). Some of the data are from districts. See figs. 58-60

DEPOSITS

<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Agordo-Brosso	ITLY	Loei-Chiengkarn	THLD
Arctic Chief	CNYT	Ludwig	USNV
B. C.	CNBC	Mackey	USID
Benson Lake	CNBC	Malko Trnova	BULG
Best Chance	CNYT	Marble Bay	CNBC
Black Cub	CNYT	Mason Valley-Malachite	USNV
Blue Grouse	CNBC	McConnell	USNV
Bluestone	USNV	Meme	HATI
Caledonia	CNBC	Mina El Sapo	CLBA
Cassius	HATI	Mina Vieja	CLBA
Casting	USNV	Mother Lode-Sunset	CNBC
Cerro de Cobre	CLBA	Obira	JAPN
Chalcobamba	PERU	Oregon	CNBC
Coast Copper	CNBC	Oro Denoro (Ema)	CNBC
Cobriza	PERU	Phoenix	CNBC
Concepcion Del Oro	MXCO	Queen Victoria (Swift)	CNBC
Copper Queen	CNBC	Rosita	NCRG
Cornell	CNBC	San Pedro	USNM
Cowley Creek	CNYT	Sasca Montana	RMNA
Douglas Hill	USNV	Sasagatani	JAPN
Gem	CNYT	Snowshoe	USNM
Hiragane	JAPN	Strandzha	BULG
Hope	CNBC	Tasu-Wesfrob	CNBC
Iide	JAPN	Tintaya	PERU
Indian Chief	CNBC	Traversella	ITLY
Kamaishi	JAPN	Tsumo	JAPN
Kedbeg Copper	URRS	Vananda	CNBC
Keewenaw	CNYT	War Eagle	CNYT
Kodiak Cub	CNYT	Western Nevada	USNV
Lily (Ikeno)	CNBC	Wexford	CNBC
Little Chief	CNYT	Yreka	CNBC
Lucky Four	CNBC	Zip	CNBC

**Figure 57.** Cartoon cross section of Cu skarn deposit showing relationship between contact metamorphic zones, ore bodies, and igneous intrusion.



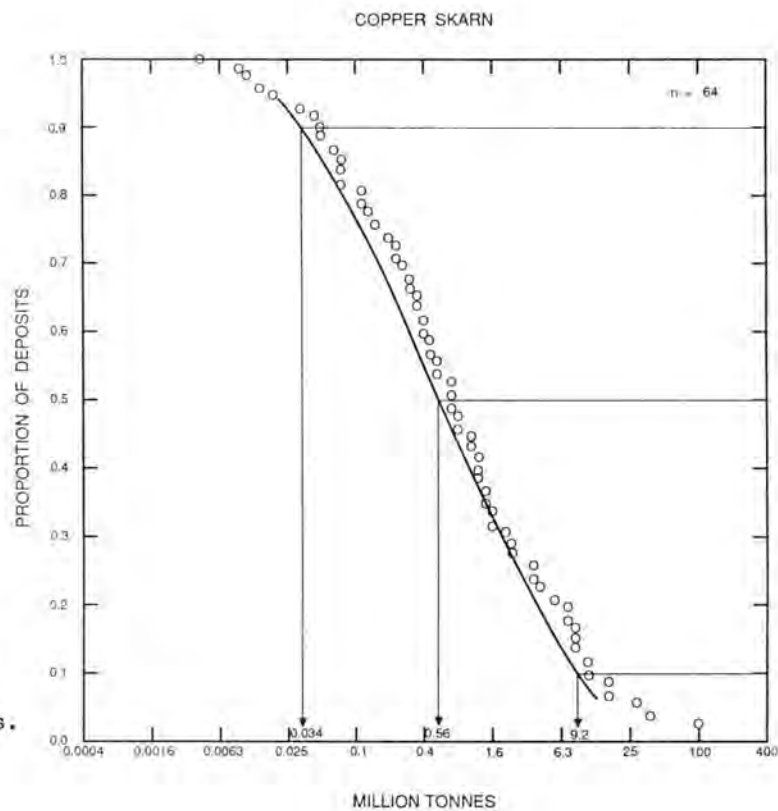


Figure 58. Tonnages of Cu skarn deposits.

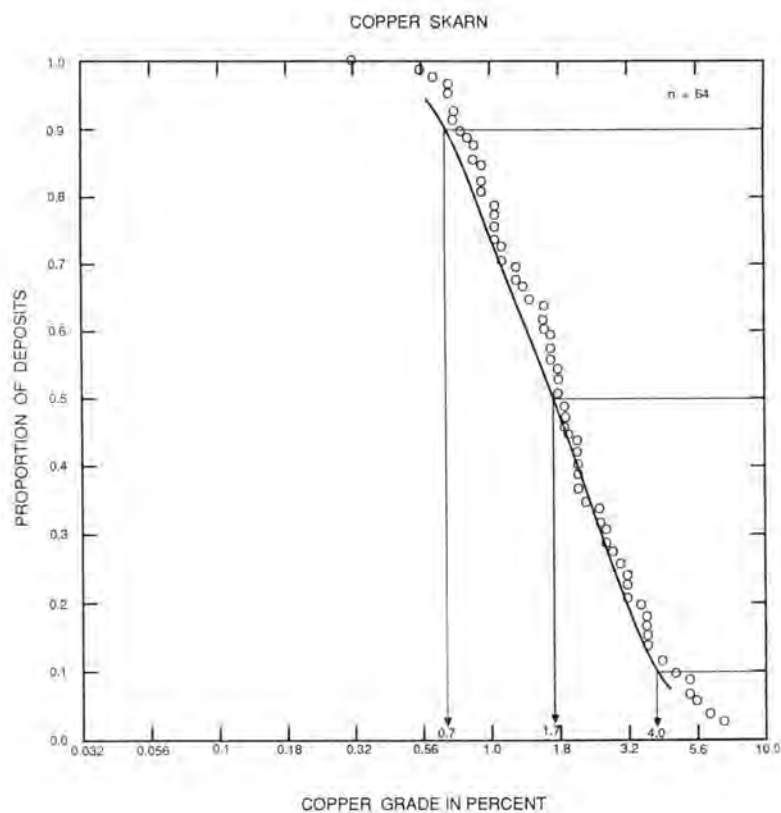
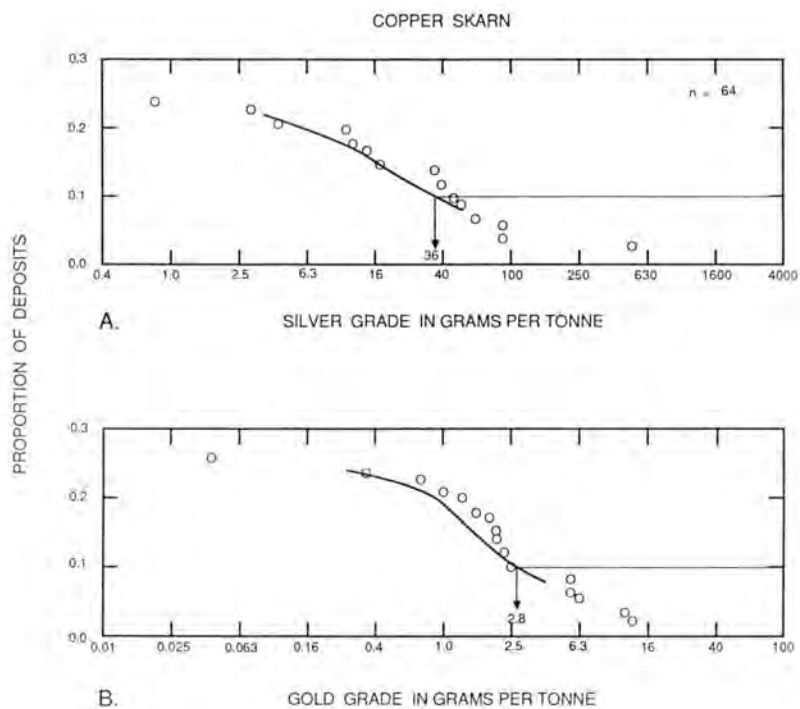


Figure 59. Copper grades of Cu skarn deposits.



**Figure 60.** Precious-metal grades of Cu skarn deposits. A, Silver. B, Gold.



# DESCRIPTIVE MODEL OF Zn-Pb SKARN DEPOSITS

By Dennis P. Cox

DESCRIPTION Sphalerite and galena in calc-silicate rocks.

GENERAL REFERENCES Einaudi and Burt (1982); Einaudi and others (1981).

## GEOLOGICAL ENVIRONMENT

Rock Types Granodiorite to granite, diorite to syenite. Carbonate rocks, calcareous clastic rocks.

Textures Granitic to porphyritic; granoblastic to Hornfelsic.

Age Range Mainly Mesozoic, but may be any age.

Depositional Environment Miogeoclinal sequences intruded by generally small bodies of igneous rock.

Tectonic Setting(s) Continental margin, late-orogenic magmatism.

Associated Deposit Types Copper skarn.

## DEPOSIT DESCRIPTION

Mineralogy Sphalerite + galena ± pyrrhotite ± pyrite ± magnetite ± chalcopyrite ± bornite ± arsenopyrite ± scheelite ± bismuthinite ± stannite ± fluorite. Gold and silver do not form minerals.

Texture/Structure Granoblastic, sulfides massive to interstitial.

Alteration Mn-hedenbergite ± andradite ± grossular ± spessartine ± bustamite ± rhodonite. Late stage Mn-actinolite ± ilvaite ± chlorite ± dannemorite ± rhodochrosite.

Ore Controls Carbonate rocks especially at shale-limestone contacts. Deposit may be hundreds of meters from intrusive.

Weathering Gossan with strong Mn oxide stains.

Geochemical Signature Zn, Pb, Mn, Cu, Co, Au, Ag, As, W, Sn, F, possibly Be.  
Magnetic anomalies.

## EXAMPLES

Ban Ban, AUQU (Ashley, 1980)  
Hanover-Fierro district, USNM (Hernon and Jones, 1968)

# GRADE AND TONNAGE MODEL OF Zn-Pb SKARN DEPOSITS

By Dan L. Mosier

COMMENTS Zinc grade is correlated with lead grade ( $r = 0.66$ ,  $n = 30$ ) and with copper ( $r = 0.61$ ,  $n = 17$ ). See figs. 61-65.

## DEPOSITS

<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Aguilar	AGTN	El Mochito	HNDR
Ammeberg	SWDN	Falun	SWDN
Aravaipa	USAZ	Garpenberg Norra	SWDN
Black Hawk	USNM	Garpenberg Odal	SWDN
Dolores	MXCO	Groundhog	USNM

Kalvbacken	SWDN	Shuikoushan	CINA
Kennecott	USNM	Stollberg	SWDN
Langban	SWDN	Svardsio	SWDN
McDame Belle	CNBC	Tetyukhe	URRS
Meat Cove	CNNS	Tienpaoshan	CINA
Mount Hundere	CNYT	Uchucchacua	PERU
Nyseter	NRWY	Ulchin	SKOR
Parroquio-Magistral	MXCO	Washington Camp	USAZ
Rajabasa	INDS	Yanchiachangtze	CINA
Ryllshyttan	SWDN	Yeonhwa I	SKOR
Sala	SWDN	Yeonhwa II	SKOR
Saxberget	SWDN	Zip	CNBC

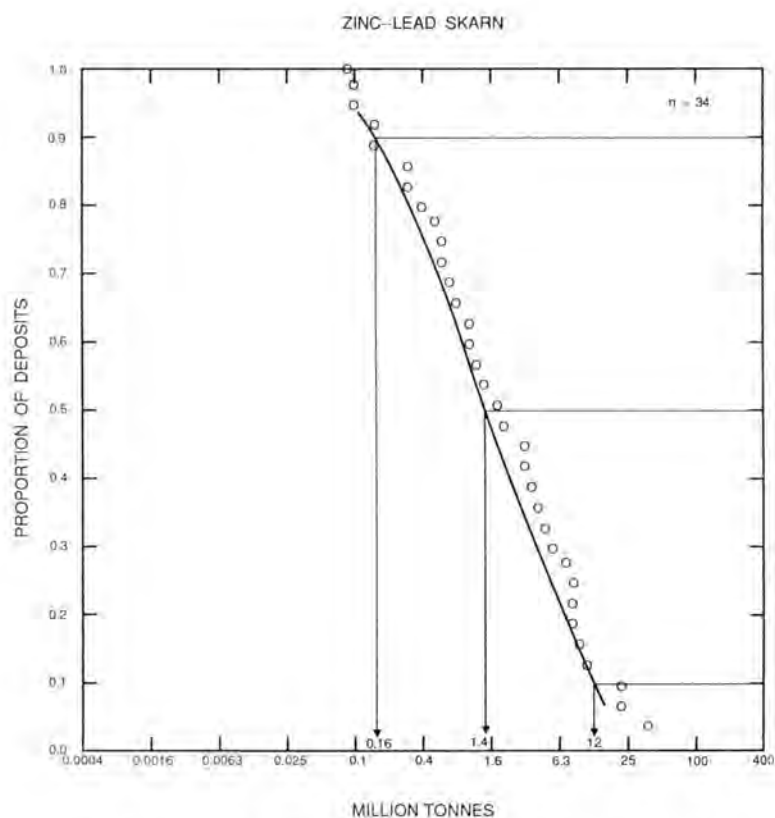


Figure 61. Tonnages of Zn-Pb skarn deposits.

Figure 62. Zinc grades of Zn-Pb skarn deposits.

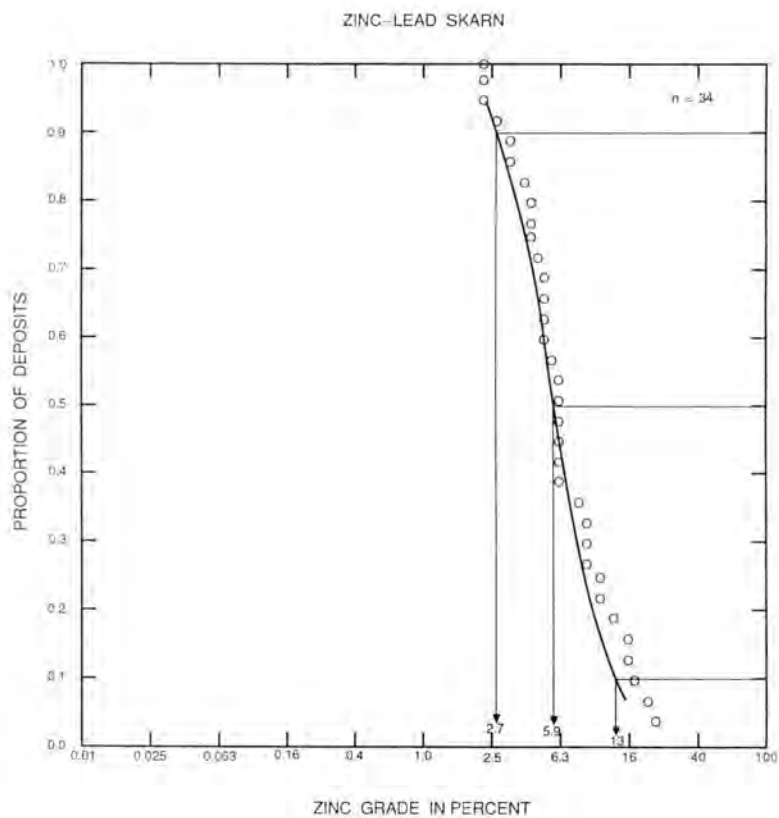
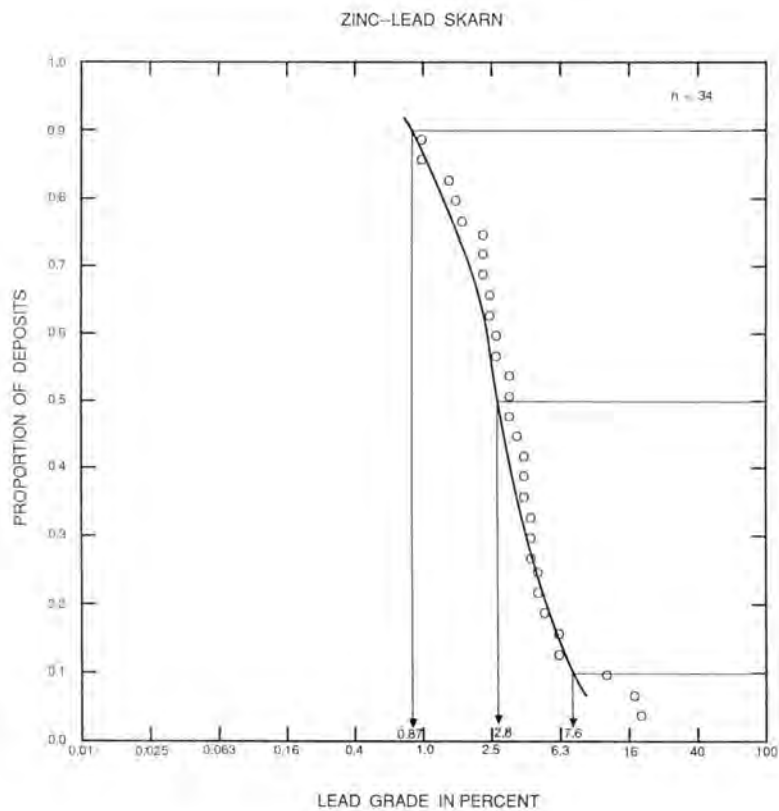
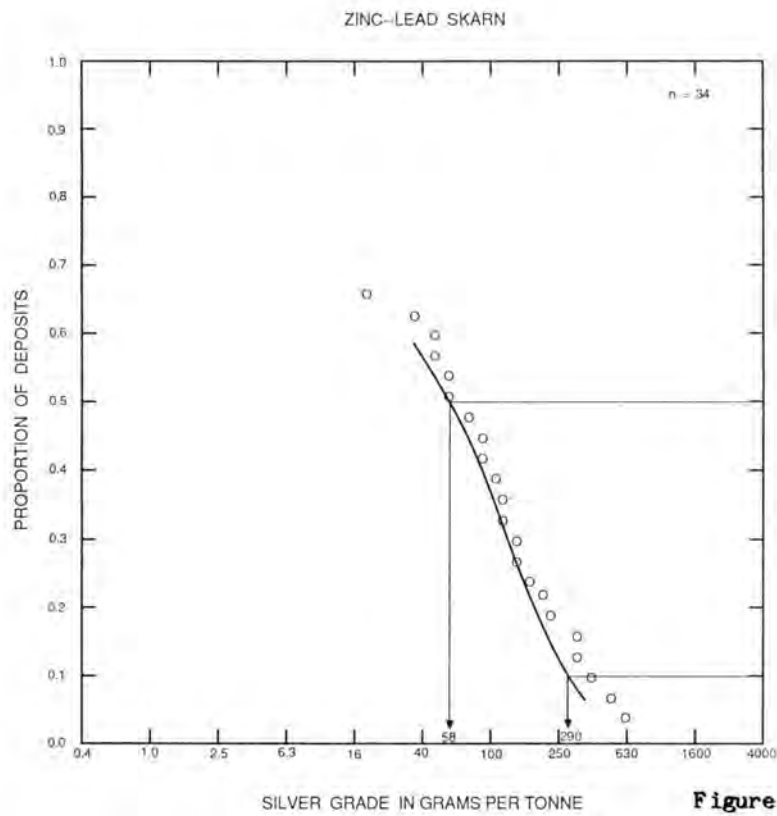
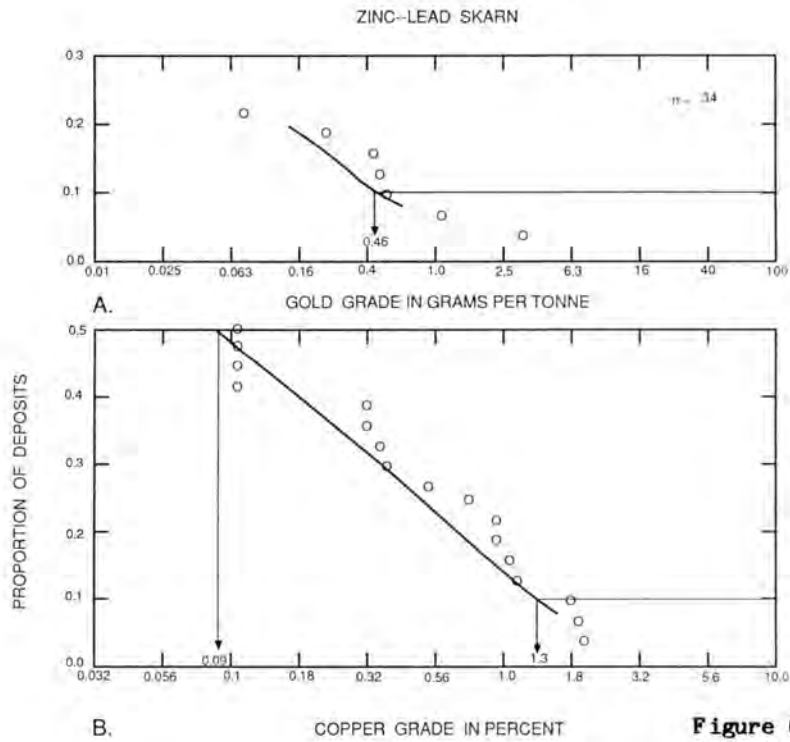


Figure 63. Lead grades of Zn-Pb skarn deposits.





**Figure 64.** Silver grades of Zn-Pb skarn deposits.



**Figure 65.** Metal grades of Zn-Pb skarn deposits. A, Gold. B, Copper.

## DESCRIPTIVE MODEL OF Fe SKARN DEPOSITS

By Dennis P. Cox

DESCRIPTION Magnetite in calc-silicate contact metasomatic rocks.

GENERAL REFERENCES Einaudi and Burt (1982), Einaudi and others (1981).

### GEOLOGICAL ENVIRONMENT

Rock Types Gabbro, diorite, diabase, syenite, tonalite, granodiorite, granite, and coeval volcanic rocks. Limestone and calcareous sedimentary rocks.

Textures Granitic texture in intrusive rocks; granoblastic to hornfelsic textures in sedimentary rocks.

Age Range Mainly Mesozoic and Tertiary, but may be any age.

Depositional Environment Contacts of intrusion and carbonate rocks or calcareous clastic rocks.

Tectonic Setting(s) Miogeosynclinal sequences intruded by felsic to mafic plutons. Oceanic island arc, Andean volcanic arc, and rifted continental margin.

### DEPOSIT DESCRIPTION

Mineralogy Magnetite  $\pm$  chalcopyrite  $\pm$  Co-pyrite  $\pm$  pyrite  $\pm$  pyrrhotite. Rarely cassiterite in Fe skarns in Sn-granite terranes.

Texture/Structure Granoblastic with interstitial ore minerals.

Alteration Diopside-hedenbergite + grossular-andradite + epidote. Late stage amphibole  $\pm$  chlorite  $\pm$  ilvaite.

Ore Controls Carbonate rocks, calcareous rocks, igneous contacts and fracture zones near contacts. Fe skarn ores can also form in gabbroic host rocks near felsic plutons.

Weathering Magnetite generally crops out or forms abundant float.

Geochemical and Geophysical Signature Fe, Cu, Co, Au, possibly Sn. Strong magnetic anomaly.

### EXAMPLES

Shinyama, JAPN	(Uchida and Iiyama, 1982)
Cornwall, USPA	(Lapham, 1968)
Iron Springs, USUT	(Mackin, 1968)

## GRADE AND TONNAGE MODEL OF Fe SKARN DEPOSITS

By Dan L. Mosier and W. David Menzie

COMMENTS Some of the data represent districts. See figs. 66-67.

### DEPOSITS

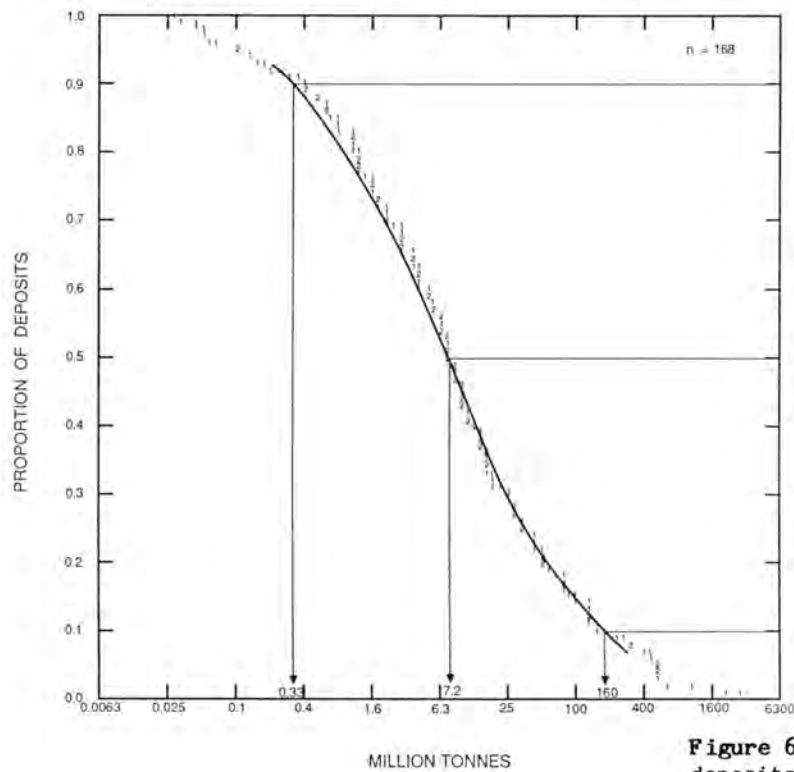
<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Adaevka central	URRS	Alagada	PORT
Adaevka north	URRS	Aleshinka	URRS
Adaevka south	URRS	Argonaut	CNBC
Agalteca	HNDR	Asvan	TRKY
Ain Mokra	ALGR	Auerbach	URUR
Ain Qudrer	ALGR	Ayazmant	TRKY
Akatani	JAPN	Baghain	IRAN

Baisoara	RMNA	Kambaikhin east	URRS
Beck	USCA	Kambaikhin north	URRS
Beni Douala	ALGR	Karamadazi	TRKY
Benkala	URRS	Kaunisvaara-Masugnsbyn	SWDN
Bessemer	CNON	Kesikkopru	TRKY
Bizmisen-Akusagi	TRKY	Kozyrevka	URRS
Blairton	CNON	Kroumovo	URRS
Bolsherechensk	URRS	Kruglogorsk	URRS
Bulacan	PLPN	Kurzunkul	URRS
Brynor	CNBC	La Carmen	MXCO
Calabogie	CNON	La Laguna	DMRP
Camiglia	ITLY	La Paloma	MXCO
Capacmarca	PERU	La Piedra Iman	MXCO
Capitan	USNM	Las Animas Cerro Prieto	MXCO
Carmen	CILE	Las Truchas	MXCO
Cave Canyon	USCA	Larap-Calambayungan	PLPN
Cehegin	SPAN	Lava Bed	USCA
Chichibu	JAPN	Lebyazhka	URRS
Childs Mine	CNON	Livitaca-Velille	PERU
Colquemarca	PERU	Lomonosov	URRS
Copper Flat	USNM	Maanshan	HONG
Cuchillo-Negro	USNM	Mac	CNBC
Daiquiri	CUBA	Marbella	SPAN
Dammer Nissar	PKTN	Marmoraton	CNON
Dannemora	SWDN	Martinovo	BULG
Dayton	USNV	Maslovo	URRS
Divrigi	TRKY	Mati	PLPN
Dungun	MDGS	Mogpog	PLPN
Dzama	URRS	Monte Carmelo	NCRG
Eagle Mountain	USCA	Munesada	JAPN
El Pedroso	SPAN	Nimpkish	CNBC
El Sol y La Luna	MXCO	Novo Maslovo	URRS
El Volcan-Piedra Iman	MXCO	Novo Peschansk	URRS
Eltay	URRS	Oena de Fier	RMNA
Estyunin	URRS	Old Dad Mountains	USCA
Fierro-Hannover	USNM	Orogrande	USNM
Gallinas	USNM	Osokino-Aleksandrovsk	URRS
Giresun	TRKY	Pambuhan Sur	PLPN
Gora Magnitnaya	URRS	Pampachiri	PERU
Gora Vysokaya	URRS	Paracale	PLPN
Hatillo	DMRP	Pena Colorada	MXCO
Hierro Indio	AGTN	Perda Niedda	ITLY
Huacravilca	PERU	Persberg	SWDN
Hualpai	CNBC	Peschansk	URRS
Huancabamba	PERU	Picila	MXCO
Hull	CNQU	Piddig	PLPN
Imancasa	PERU	Plagia	GREC
Ino	JAPN	Pokrovsk	URRS
Iron Duke	CNBC	Rankin	CNON
Iron Hat	USCA	Recibimiento	MXCO
Iron Mike	CNBC	Rondoni	PERU
Iron Mountain (Colfax Co.)	USNM	Rose	CNBC
Iron Mountain (Sierra Co.)	USNM	Rudna Glava	YUGO
Iron Springs	USUT	Sabana Grande	DMRP
Jedway	CNBC	Samli	TRKY
Jerez de los Caballeros	SPAN	San Carlos	MXCO
Jib	CNBC	San Juan de Chacna	PERU
Jicarilla	USNM	San Leone	ITLY
Jones Camp	USNM	Sankyo	JAPN
Juncos	CNBC	Santa Lucia	PERU
Kachar	URRS	Santa Rita	USNM
Kalkan	TRKY	Sarbay	URRS
Kambaikhin central	URRS	Senor de Huarquisa	PERU

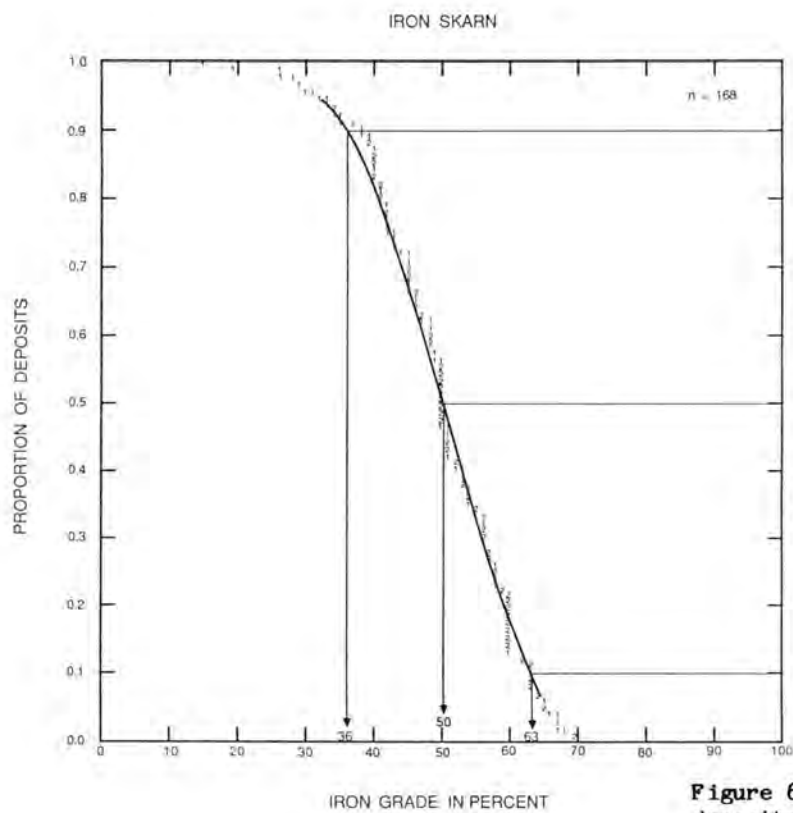
Model 18d--Con.

Severnoe I	URRS	Tepustete	MXCO
Severnoe II	URRS	Texada	CNBC
Severnoe III	URRS	Tovarnica	YUGO
Shagyrkul	URRS	Tsaitsukou	CINA
Shasta-California	USCA	Val Di Peio	ITLY
Shinyama	JAPN	Valuev	URRS
Silver Lakes	USCA	Vorontsovka	URRS
Sorka	URRS	Vulcan	USCA
Sosva	URRS	Vyhne	CZCL
South Sarbay	URRS	Wagasennin	JAPN
Takanokura	JAPN	Yellow Jacket	USNM
Tapairihua	PERU	Zanitza	MXCO
Techa	URRS	Zarikan	IRAN
Tecolote	USNM	Zeballos	CNBC





**Figure 66.** Tonnages of Fe skarn deposits. Individual digits represent number of deposits.



**Figure 67.** Iron grades of Fe skarn deposits. Individual digits represent number of deposits.

## DESCRIPTIVE MODEL OF CARBONATE-HOSTED ASBESTOS

By Chester T. Wrucke and Andrew F. Shride

APPROXIMATE SYNONYM Arizona type (Shride, 1973).

DESCRIPTION Long-staple chrysotile asbestos in veins developed in tabular layers of serpentine that replaced silicated limestone adjacent to diabase sheets, sills, and dikes.

GENERAL REFERENCE Shride (1969).

### GEOLOGIC ENVIRONMENT

Rock Types Serpentine, diabase, silicated limestone, cherty dolomite.

Textures Original bedding details of cherty dolomite preserved in fine-grained metamorphic limestone that includes nodular silicate masses partly to wholly replaced by serpentine.

Age Range Middle Proterozoic in Arizona, but may be of any age.

Depositional Environment Contact metamorphic aureole associated with injection of diabase magma into cherty dolomite.

Tectonic Setting Probably rifted or partly rifted continental terrane, as suggested by regionally voluminous alkalic olivine tholeiite diabase in nearshore marine and terrestrial strata.

Associated Deposit Types Contact-metamorphic magnetite. Talc deposits exist widely in similar physical settings.

### DEPOSIT DESCRIPTION

Mineralogy Chrysotile asbestos, dense serpentine, magnetite, and calcite.

Texture/Structure Sharp-walled gash fracture and ribbon veins of cross-fiber chrysotile and calcite with occasional veins of dense chrysotile in massive serpentine. Veins mostly less than 0.3 cm wide but commonly 2-8 and rarely up to 25 cm.

Alteration Tremolite, diopside, and talc formed during prograde metamorphism were largely replaced by massive serpentine during retrograde metamorphism. Vein minerals were emplaced during late hydrothermal stage.

Ore Controls Favorable stratigraphic zones proximate (within 10 m) to diabase. Open folds formed on emplacement of the diabase were favorable sites for small-scale bedding and thrust faults which were repeatedly opened during metamorphism and mineralization.

### EXAMPLES

Gila County, USAZ, Cuddappah district, INDA  
southwestern USMT, Barberton-Caroline District, SAFR  
Hopeh Province, CINA, near Kanye, BOTS (Sinclair, 1955)

## DESCRIPTIVE MODEL OF POLYMETALLIC REPLACEMENT DEPOSITS

By Hal T. Morris

APPROXIMATE SYNONYM Manto deposits, many authors.DESCRIPTION Hydrothermal, epigenetic, Ag, Pb, Zn, Cu minerals in massive lenses, pipes and veins in limestone, dolomite, or other soluble rock near igneous intrusions (see fig. 68).GENERAL REFERENCE Jensen and Bateman (1981), p. 134-146.GEOLOGICAL ENVIRONMENTRock Types Sedimentary rocks, chiefly limestone, dolomite, and shale, commonly overlain by volcanic rocks and intruded by porphyritic, calc-alkaline plutons.Textures The textures of the replaced sedimentary rocks are not important; associated plutons typically are porphyritic.Age Range Not important, but many are late Mesozoic to early Cenozoic.Depositional Environment Carbonate host rocks that commonly occur in broad sedimentary basins, such as epicratonic miogeosynclines. Replacement by solutions emanating from volcanic centers and epizonal plutons. Calderas may be favorable.Tectonic Setting(s) Most deposits occur in mobile belts that have undergone moderate deformation and have been intruded by small plutons.Associated Deposit Types Base metal skarns, and porphyry copper deposits.DEPOSIT DESCRIPTIONMineralogy Zonal sequence outward: enargite + sphalerite + argentite + tetrahedrite + digenite ± chalcopryite, rare bismuthinite; galena + sphalerite + argentite ± tetrahedrite ± proustite ± pyrrargyrite, rare jamesonite, jordanite, bournonite, stephanite, and polybasite; outermost sphalerite + rhodochrosite (see fig. 68). Widespread quartz, pyrite, marcasite, barite. Locally, rare gold, sylvanite, and calaverite.Texture/Structure Ranges from massive to highly vuggy and porous.Alteration Limestone wallrocks are dolomitized and silicified (to form jasperoid); shale and igneous rocks are chloritized and commonly are argillized; where syngenetic iron oxide minerals are present, rocks are pyritized. Jasperoid near ore is coarser grained and contains traces of barite and pyrite.Ore Controls Tabular, podlike and pipelike ore bodies are localized by faults or vertical beds; ribbonlike or blanketlike ore bodies are localized by bedding-plane faults, by susceptible beds, or by preexisting solution channels, caverns, or cave rubble.Weathering Commonly oxidized to ochreous masses containing cerrusite, anglesite, hemimorphite, and cerargyrite.Geochemical Signature On a district-wide basis ore deposits commonly are zoned outward from a copper-rich central area through a wide lead-silver zone, to a zinc- and manganese-rich fringe. Locally Au, As, Sb, and Bi. Jasperoid related to ore can often be recognized by high Ba and trace Ag content.Examples

East Tintic district, USUT	(Morris and Lovering, 1979)
Eureka district, USNV	(Nolan, 1962)
Manto deposit, MXCO	(Prescott, 1926)

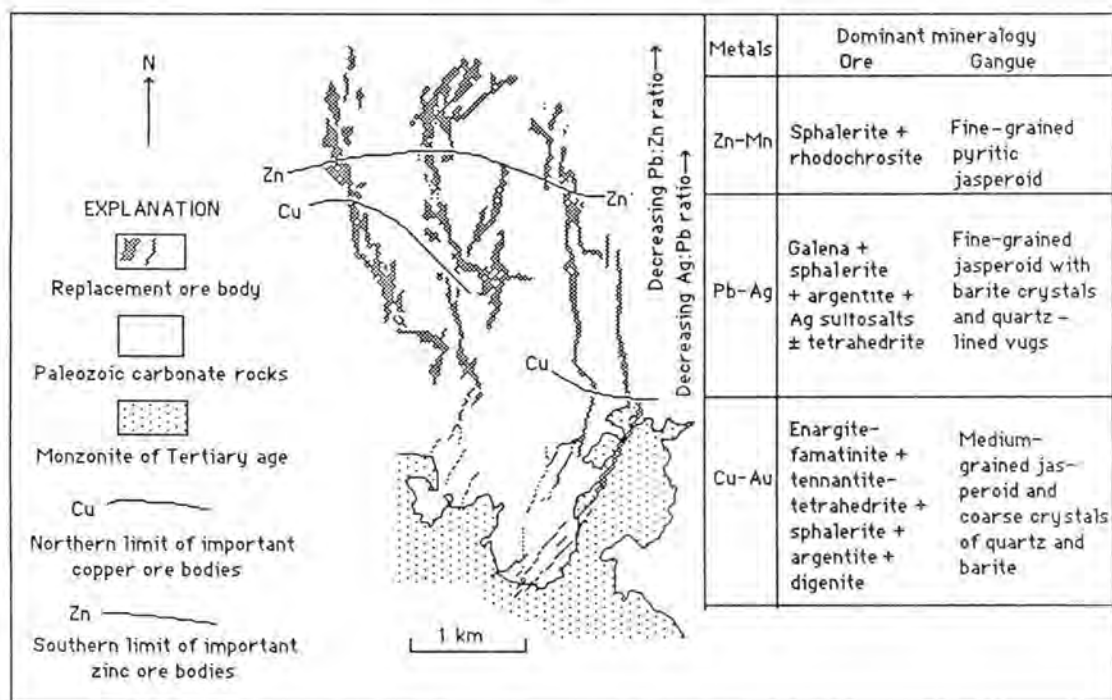


Figure 68. Generalized map showing metal and mineral zoning in polymetallic replacement deposits in the Main Tintic district, Utah. Modified from Morris (1968).

## GRADE AND TONNAGE MODEL OF POLYMETALLIC REPLACEMENT DEPOSITS

By Dan L. Mosier, Hal T. Morris, and Donald A. Singer

COMMENTS Carbonate-hosted replacement and transitional vein and other replacement deposits are included. Only districts with combined production and reserves of at least 100,000 tonnes are used. Tonnages for many districts, particularly in the U.S. are biased because only production data were available. The break in slope in the zinc grade plot at about 1 percent may be related to early difficulties of processing zinc oxides, and the consequent underreporting of zinc grades where estimates were based on production. Lead grade is correlated with silver ( $r = 0.55$ ,  $n = 45$ ). See figs. 69-74.

DEPOSITS

<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
American Fork	USUT	Nakatatsu	JAPN
Atacocha	PERU	Mitate	JAPN
Bell	USNV	Naica	MXCO
Big Cottonwood-L.C.	USUT	New Calumet	CNQU
Blue Bell	CNBC	Olympias Chalkidiki	GREC
Bolkardag	TRKY	Ophir	USUT
Bristol (Jack Rabbit)	USNV	Park City	USUT
Cerro Gordo	USCA	Plomosas	MXCO
Chalchihuites	MXCO	Rush Valley	USUT
Charcas	MXCO	San Francisco	USUT
Cortez	USNV	Santa Eulalia	MXCO
Darwin	USCA	Santander	PERU
Drina	YUGO	Saua-Toranica	YUGO
East Tintic	USUT	Silva-Aysen	CILE
El Porvenir (Milpo)	PERU	Sombrerete	MXCO
Eureka	USNV	Spruce Mountain	USNV
Hunnan	CINA	Star	USUT
La Encantada	MXCO	Sumadisa	YUGO
La Reforma	MXCO	Tecopa	USCA
Lampazos	MXCO	Tintic	USUT
Laurium	GREC	Tombstone	USAZ
Liaoning	CINA	Trepca-Kopaonik	YUGO
Lone Mountain	USNV	Velardepa	MXCO
Magdalena	USNM	White Pine	USNV
Maria Christina	CILE	Yellow Pine	USNV
Mazapil	MXCO	Zimapan	MXCO

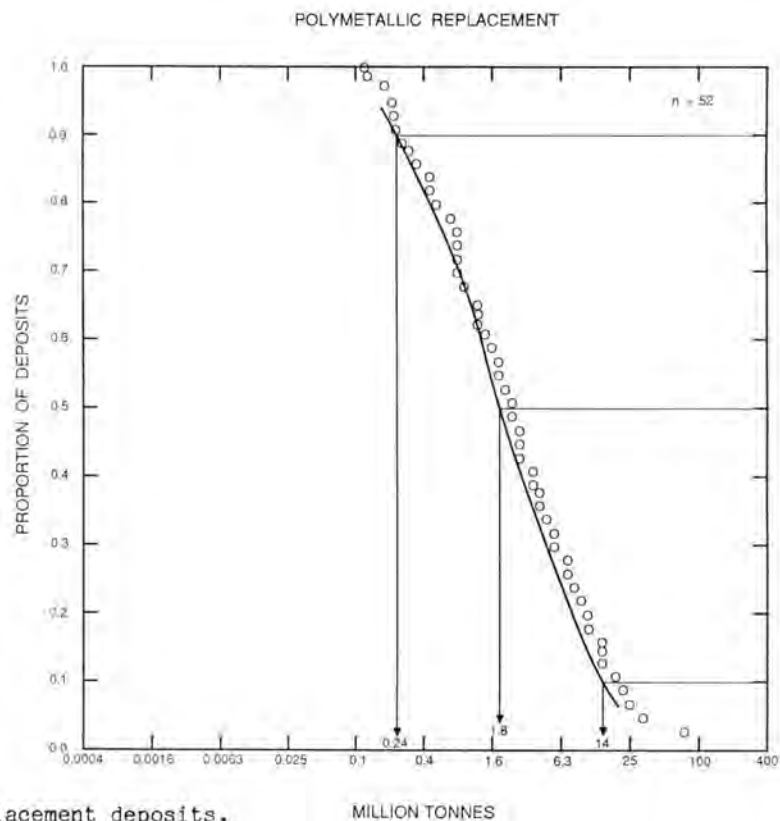


Figure 69. Tonnages of polymetallic replacement deposits.

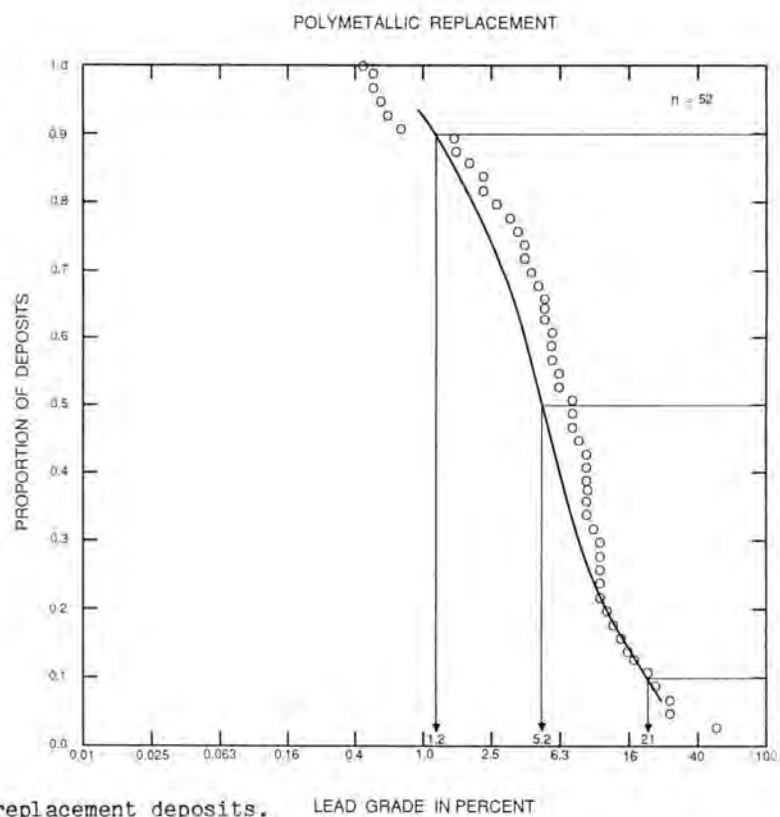
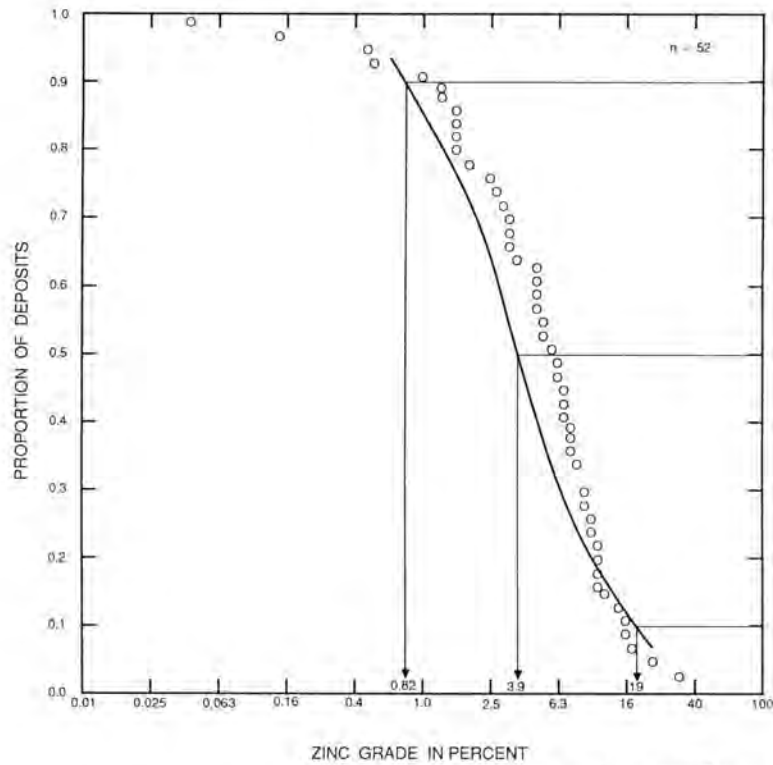
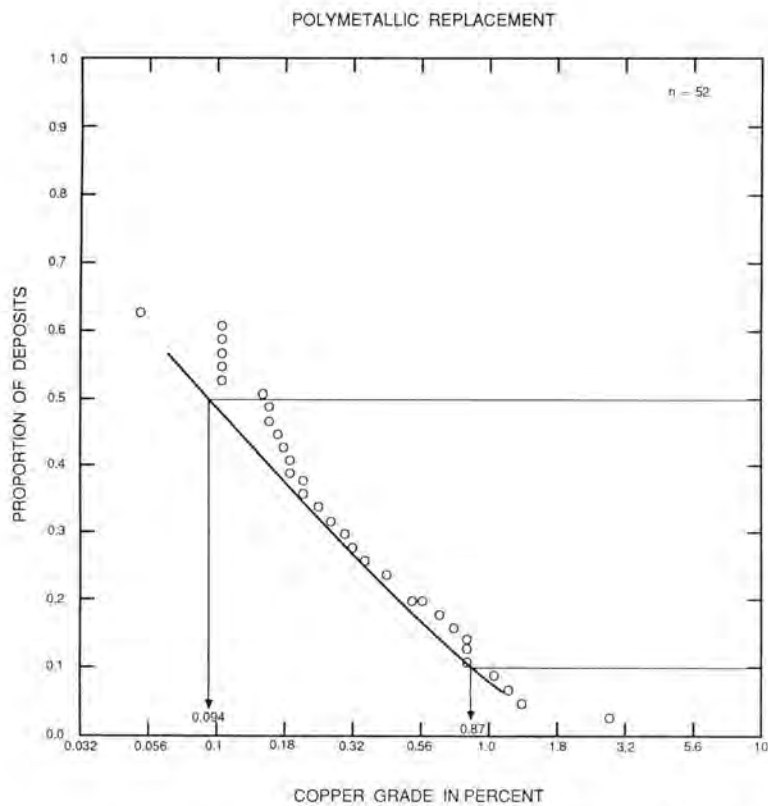


Figure 70. Lead grades of polymetallic replacement deposits.



**Figure 71.** Zinc grades of polymetallic replacement deposits.



**Figure 72.** Copper grades of polymetallic replacement deposits.



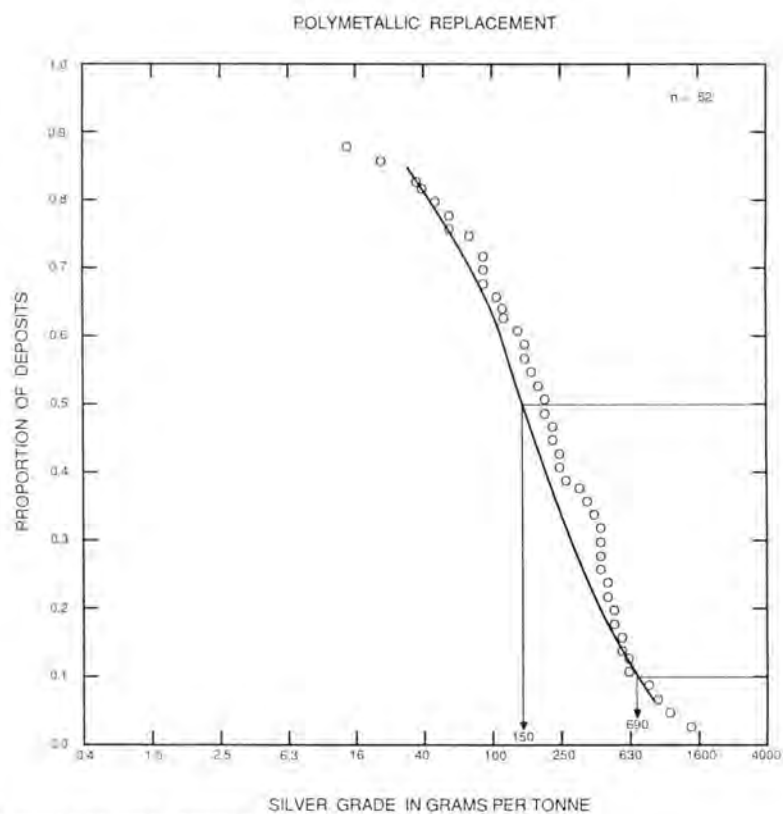


Figure 73. Silver grades of polymetallic replacement deposits.

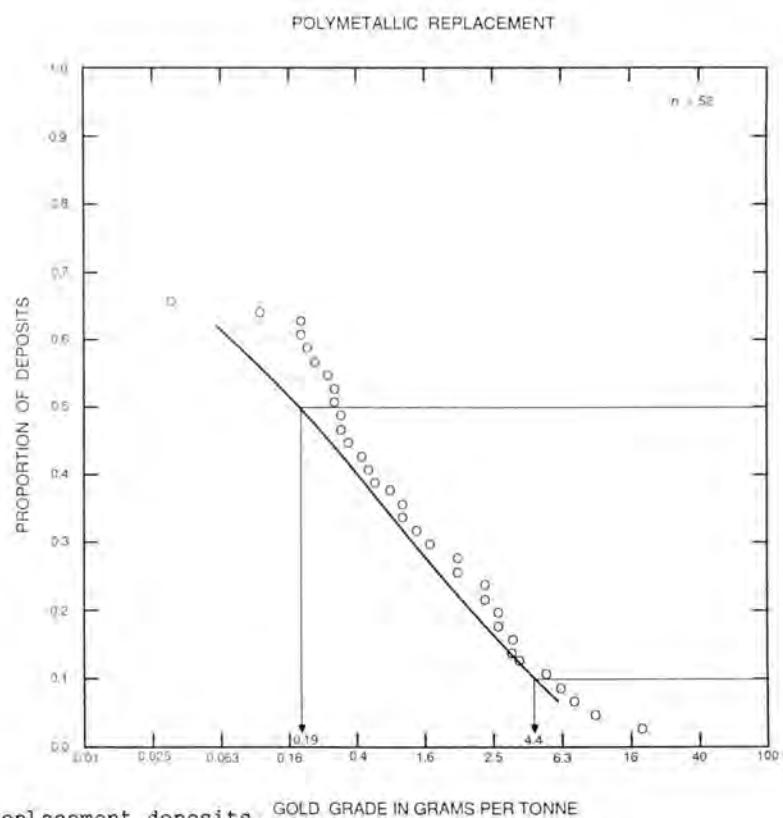


Figure 74. Gold grades of polymetallic replacement deposits.

## DESCRIPTIVE MODEL OF REPLACEMENT Mn

By Dan L. Mosier

DESCRIPTION Manganese oxide minerals occur in epigenetic veins or cavity fillings in limestone, dolomite, or marble, which may be associated with intrusive complexes.

GEOLOGICAL ENVIRONMENT

Rock Types Limestone, dolomite, marble, and associated sedimentary rocks; granite and granodiorite plutons.

Age Range Mainly Paleozoic to Tertiary, but may be any age.

Depositional Environment Miogeosynclinal sequences intruded by small plutons.

Tectonic Setting(s) Orogenic belts, late orogenic magmatism.

Associated Deposit Types Polymetallic vein, polymetallic replacement, skarn Cu, skarn Zn, porphyry copper.

DEPOSIT DESCRIPTION

Mineralogy Rhodochrosite ± rhodonite + calcite + quartz ± barite ± fluorite ± jasper ± manganocalcite ± pyrite ± chalcopyrite ± galena ± sphalerite.

Texture/Structure Tabular veins, irregular open space fillings, lenticular pods, pipes, chimneys.

Ore Controls Fracture permeability in carbonate rocks. May be near intrusive contact.

Weathering Mn oxide minerals: psilomelane, pyrolusite, and wad form in the weathered zone and make up the richest parts of most deposits. Limonite and kaolinite.

Geochemical Signature Mn, Fe, P, Cu, Ag, Au, Pb, Zn.

EXAMPLES

Lake Valley, USNM	(Farnham, 1961)
Philipsburg, USMT	(Prinz, 1963)
Lammereck, ASTR	(Lechner and Ploehinger, 1956)

## GRADE AND TONNAGE MODEL OF REPLACEMENT Mn

By Dan L. Mosier

COMMENTS Copper grades are only available for some of the low tonnage deposits. See figs. 75-76.

DEPOSITS

<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Atlas	USAZ	Golden Gate	USAZ
Bear Mountain	USNM	Hendricks-Twilight	USAZ
Birchfield	USNM	Kahal de Brezina	ALGR
Blinman	AUSA	Kingston	USNM
Brachy	FRNC	Lake Valley	USNM
Chloride Flat	USNM	Lammereck	ASTR
Crown King	USAZ	Las Ambollas	FRNC
Cynthia	GREC	Las Cabesses	FRNC
Danville-Hanchette	USAZ	Lone Mountain	USNM
Detroit	USUT	Los Volcanes	MXCO
Dinamita	MXCO	Mammoth	USAZ
Djebel El Aziza	TUNS	Mercedes	CUBA
Essex and Steptoe	USNV	Philipsburg	USMT

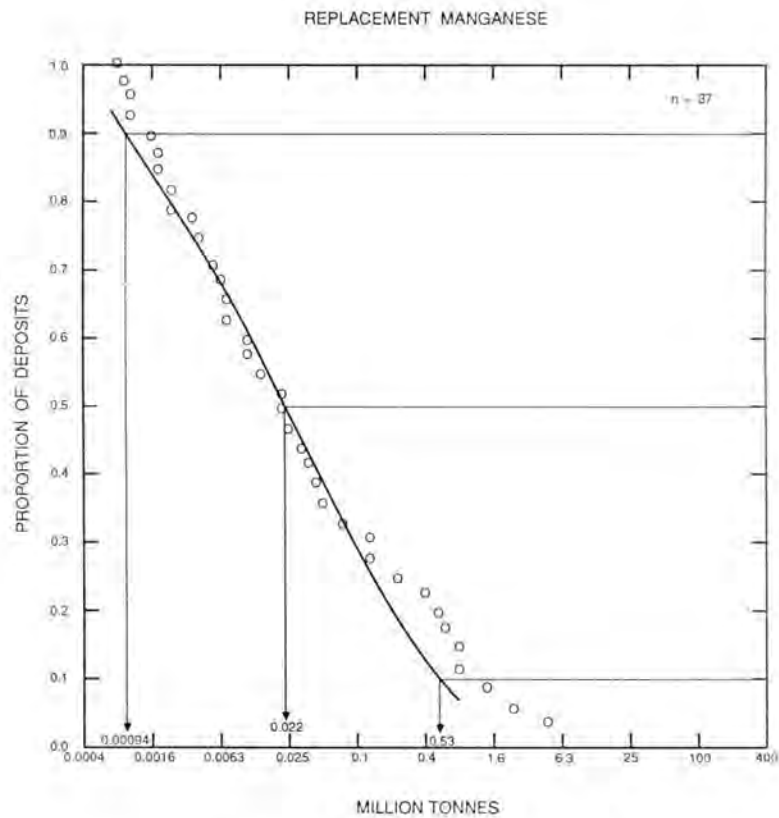
Model 19b--Con.

Poludnig-Hermagor  
Oregon  
Saligny  
San Carlos  
Sattelberges  
Summit-No. 4

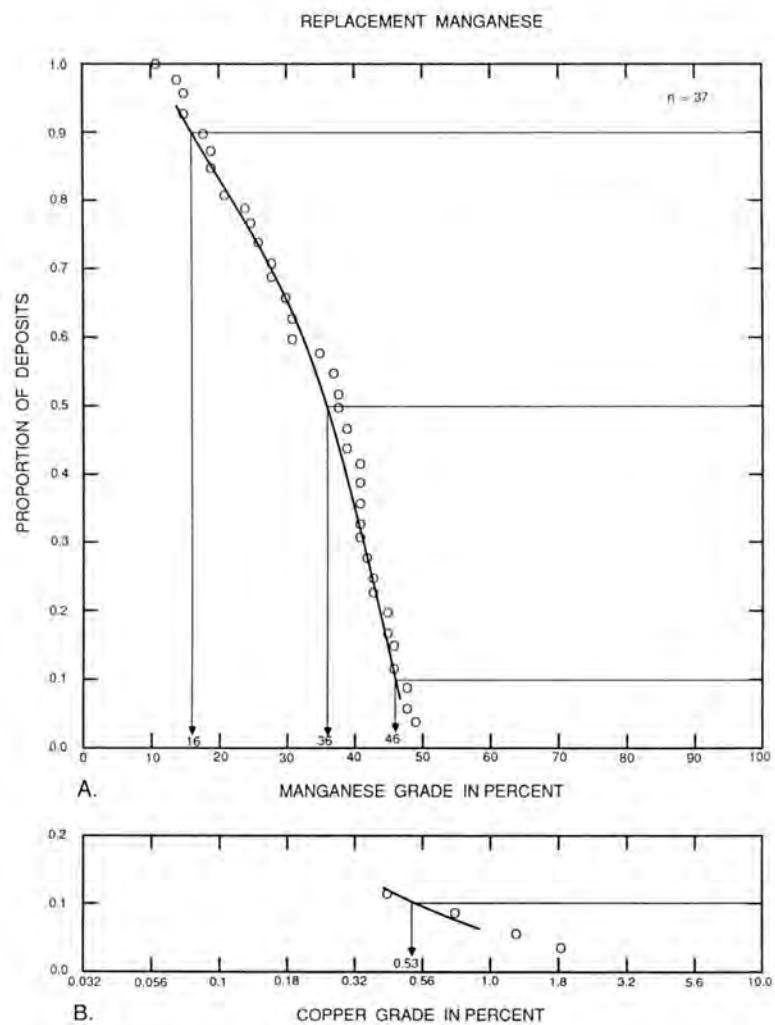
ASTR  
USAZ  
FRNC  
MXCO  
ASTR  
USAZ

Thuburnie  
Ulukoy  
Veitsch  
Vorderen Strubberges  
Waterloo

TUNS  
TRKY  
ASTR  
ASTR  
USAZ



**Figure 75.** Tonnages of replacement Mn deposits.



**Figure 76.** Manganese and copper grades of replacement Mn deposits.

## DESCRIPTIVE MODEL OF PORPHYRY Sn

By Bruce L. Reed

APPROXIMATE SYNONYM Subvolcanic tin (Grant and others, 1977).

DESCRIPTION Subvolcanic intrusive complexes containing disseminated, veinlet- and breccia-controlled fine-grained cassiterite in quartz porphyry and adjacent rocks.

GENERAL REFERENCE Grant and others (1980).

### GEOLOGICAL ENVIRONMENT

Rock Types Intermediate to acid quartz porphyry stocks (quartz-latite, dacite, rhyodacite) and cogenetic calc-alkaline pyroclastics and lavas (quartz-latite to rhyodacite).

Textures Intrusions most closely associated with mineralization are strongly altered and brecciated quartz porphyry.

Age Range May be any age. Classic Bolivian porphyry tin deposits are Miocene. Subvolcanic W-Mo-Sn deposits at Mount Pleasant, New Brunswick, are late Carboniferous.

Depositional Environment Subvolcanic stocks emplaced 1 to 3 km beneath or within vents of terrestrial strato-volcanoes.

Tectonic Setting(s) Paleozoic foldbelt cut by subduction-generated high-level stocks and cogenetic volcanic rocks.

Associated Deposit Types Sn veins and Sn polymetallic veins.

### DEPOSIT DESCRIPTION

Mineralogy Cassiterite and quartz accompanied by sulfide minerals (chiefly pyrite) but including pyrrhotite, stannite, chalcopyrite, sphalerite, and arsenopyrite; late veins commonly carry complex sulfostannates and Ag minerals.

Texture/Structure Disseminations, veinlets, and fractures in igneous breccia and adjacent wallrock; stocks commonly funnel-shaped and 1-2 km<sup>2</sup>.

Alteration Pervasive alteration and porphyry tin mineralization predates tin-silver veins; concentric zoning grades from a central quartz-tourmaline core (minor disseminated cassiterite), outward to sericite-tourmaline, sericite (closely related to disseminated cassiterite), and propylitic alteration; argillic alteration present in upper parts of some systems.

Ore Controls Porphyry mineralization is breccia controlled and centered on stocks emplaced in the inner, deeper regions of volcanoes; close relation between disseminated cassiterite and sericitic alteration; late fracture-controlled quartz-cassiterite and quartz-cassiterite-sulfide veins occur within or near the margins of intrusive centers.

Weathering Surface iron staining variable (pyrite); supergene enrichment unlikely; cassiterite may be concentrated in nearby placer deposits.

Geochemical Signature: Sn + B center; Sn, Ag, Pb, Zn, As, Sb, Cu, Ba in outer zone.

### EXAMPLES

Chorolque, BLVA	(Grant and others, 1980)
Catavi (Salvadora stock,	
Llallagua), BLVA	(Sillitoe and others, 1975)

## DESCRIPTIVE MODEL OF Sn-POLYMETALLIC VEINS

by Yukio Togashi (Geological Survey of Japan)

APPROXIMATE SYNONYMS Polymetallic xenothermal (Imai and others, 1978), Bolivian subvolcanic multistage.

DESCRIPTION Multistage Cu-Zn-Sn-Ag-bearing veins associated with felsic ignimbrites and subvolcanic intrusions.

GENERAL REFERENCES Nakamura and Hunahashi (1970), Grant and others (1977).

### GEOLOGICAL ENVIRONMENT

Rock Types Rhyolitic tuff, welded tuff and tuff breccia. Rhyolitic to basaltic dikes. Sandstone, slate, chert, and basic tuff.

Textures Welded and airfall tuff. Porphyritic-aphanitic intrusives.

Age Range Late Cretaceous to Miocene in Japan, Miocene in Bolivia, but may be any age.

Depositional Environment Fissures in and around felsic ignimbrite.

Tectonic Setting(s) Continental margin. Syn-late orogenic.

Associated Deposit Types Polymetallic replacement, epithermal Ag veins, porphyry Sn.

### DEPOSIT DESCRIPTION

Mineralogy Cassiterite, chalcopyrite, sphalerite, pyrrhotite, pyrite, galena, scheelite, wolframite, arsenopyrite, native bismuth, bismuthinite, argentite, native gold, magnetite, molybdenite, and complex sulfosalt minerals including teallite, frankeite, cylindrite, and stannite.

Texture/Structure Multistage composite veins with Sn, Cu, Zn, and Ag minerals occurring in the same vein.

Alteration Minor quartz-chlorite-sericite alteration close to veins. Tourmaline, fluorite, or siderite may be present.

Ore Controls Veins, breccia veins, and breccia pipes. Metal zoning sequence is Sn + W to Cu + Sn, Cu + Zn, Pb + Zn, Pb + Ag, Au + Ag from center to periphery, or from depths to shallow levels. Zones are commonly superimposed or "telescoped" to produce complex veins.

Weathering Limonitization. Cassiterite in soils and gossans.

Geochemical Signature Cu, Zn, Sn, Pb, W, Au, Ag, Bi, As.

### EXAMPLES

Ashio, Akenobe, Ikuno, Kishu, JAPAN	(Nakamura, 1970)
Potosi, BLVA	(Turneure, 1971)

## DESCRIPTIVE MODEL OF PORPHYRY Cu-Au

By Dennis P. Cox

DESCRIPTION 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 (see fig. 77).

GENERAL REFERENCES Sillitoe (1979), Cox and Singer (in press).

### GEOLOGICAL ENVIRONMENT

Rock Types Tonalite to monzogranite; dacite, andesite flows and tuffs coeval with intrusive rocks. Also syenite, monzonite, and coeval high-K, low-Ti volcanic rocks (shoshonites).

Textures Intrusive rocks are porphyritic with fine- to medium-grained aplitic groundmass.

Age Range Cretaceous to Quaternary.

Depositional Environment In porphyry intruding coeval volcanic rocks. Both involved and in large-scale breccia. Porphyry bodies may be dikes. Evidence for volcanic center; 1-2 km depth of emplacement.

Tectonic Setting(s) Island-arc volcanic setting, especially waning stage of volcanic cycle. Also continental margin rift-related volcanism.

Associated Deposit Types Porphyry Cu-Mo; gold placers.

### DEPOSIT DESCRIPTION

Mineralogy Chalcopyrite ± bornite; traces of native gold, electrum, sylvanite, and hessite. Quartz + K-feldspar + biotite + magnetite + chlorite + actinolite + anhydrite. Pyrite + sericite + clay minerals + calcite may occur in late-stage veinlets.

Texture/Structure Veinlets and disseminations.

Alteration Quartz ± magnetite ± biotite (chlorite) ± K-feldspar ± actinolite, ± anhydrite in interior of system. Outer propylitic zone. Late quartz + pyrite + white mica ± clay may overprint early feldspar-stable alteration.

Ore Controls Veinlets and fractures of quartz, sulfides, K-feldspar magnetite, biotite, or chlorite are closely spaced. Ore zone has a bell shape centered on the volcanic-intrusive center. Highest grade ore is commonly at the level at which the stock divides into branches.

Weathering Surface iron staining may be weak or absent if pyrite content is low in protore. Copper silicates and carbonates. Residual soils contain anomalous amounts of rutile.

Geochemical Signature Central Cu, Au, Ag; peripheral Mo. Peripheral Pb, Zn, Mn anomalies may be present if late sericite pyrite alteration is strong. Au (ppm):Mo (percent) 30 in ore zone. Au enriched in residual soil over ore body. System may have magnetic high over intrusion surrounded by magnetic low over pyrite halo.

### EXAMPLES

Dos Pobres, USAZ	(Langton and Williams, 1982)
Copper Mountain, CNBC	(Fahrni and others, 1976)
Tanama, PTRC	(Cox, 1985)

## GRADE AND TONNAGE MODEL OF PORPHYRY Cu-Au

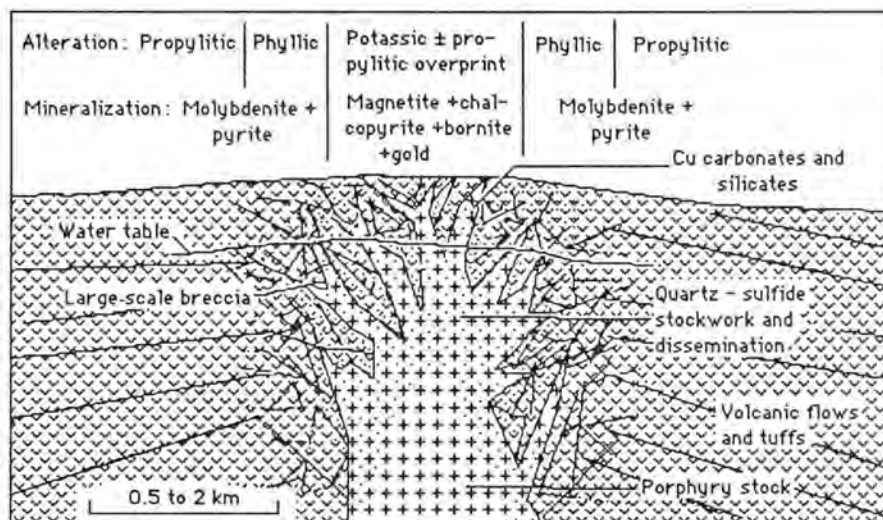
By Donald A. Singer and Dennis P. Cox

COMMENTS See figs. 78-81.

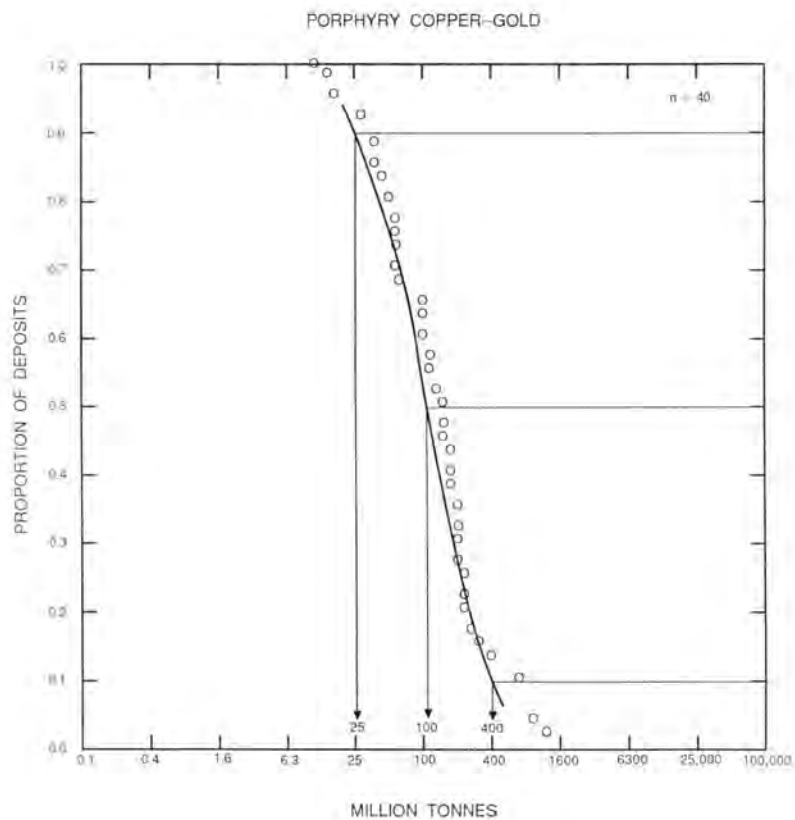


DEPOSITS

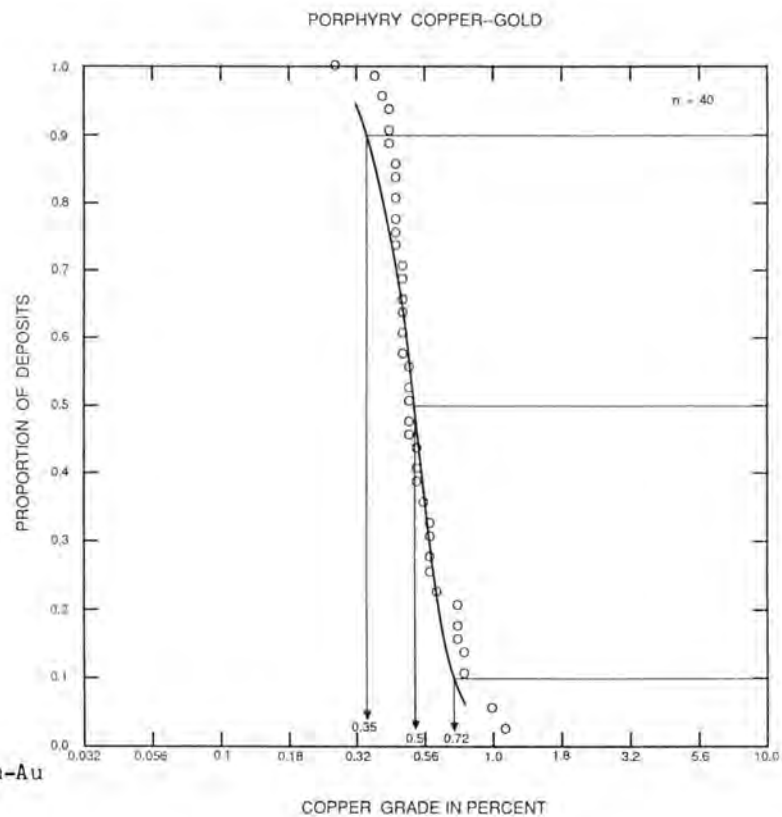
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Afton	CNBC	Mamut	MDGS
Amacan	PLPN	Mapula	PLPN
Atlas Lutopan	PLPN	Marcopper	PLPN
Basay	PLPN	Marian	PLPN
Bell Copper	CNBC	Mountain Mines	PLPN
Boneng Lobo	PLPN	Ok Tedi	PPNG
Cariboo Bell	CNBC	Panguana	PPNG
Copper Mountain	CNBC	Red Chris	CNBC
Cubuagan	PLPN	Rio Vivi	PTRC
Dizon	PLPN	Saindak South	PKTN
Dos Pobres	USAZ	San Antonio	PLPN
Fish Lake	CNBC	San Fabian	PLPN
Frieda River	PPNG	Santo Nino	PLPN
Galore Creek	CNBC	Santo Tomas	PLPN
Hinobaan	PLPN	Star Mt.-Fubilan	PPNG
Ingerbelle	CNBC	Star Mt.-Futik	PPNG
Kennon	PLPN	Tanama	PTRC
La Alumbraera	ACTN	Tawi-Tawi	PLPN
Lorraine	CNBC	Taysan	PLPN
Lumbay	PLPN	Toledo	PLPN



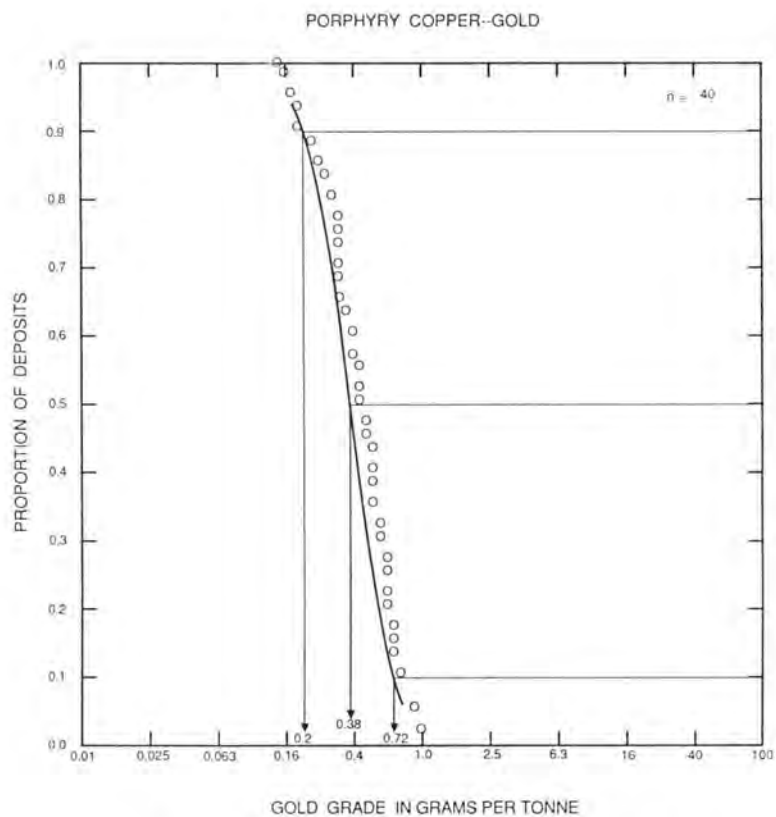
**Figure 77.** Cartoon cross section of porphyry Cu-Au deposit. Modified from Langton and Williams (1982).



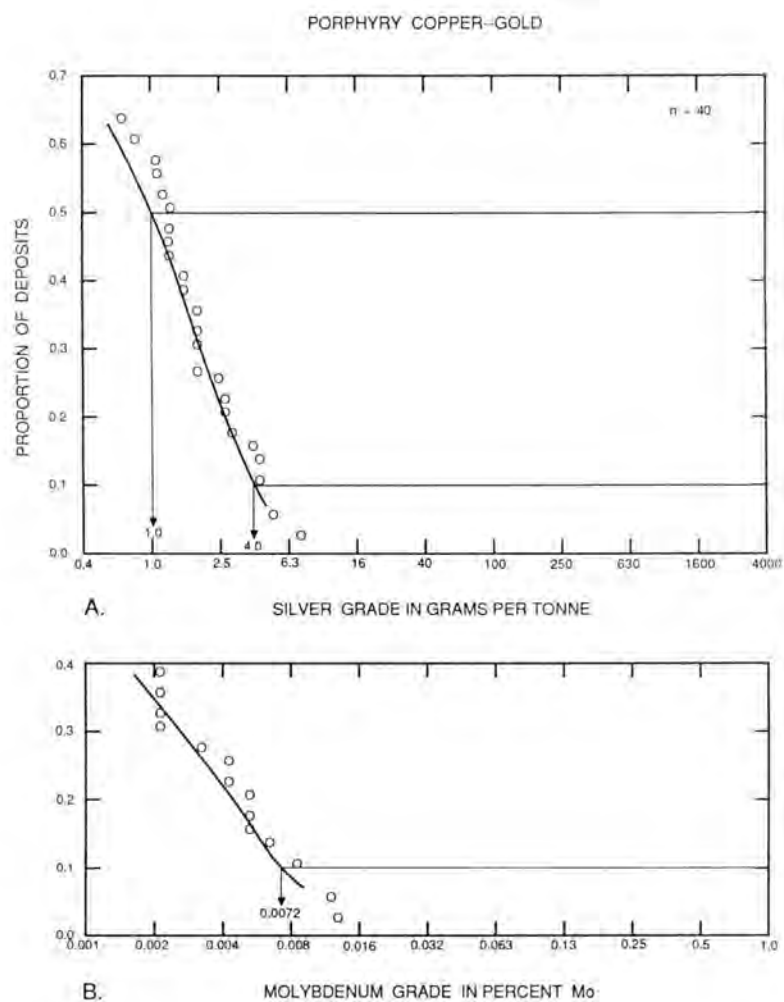
**Figure 78.** Tonnages of porphyry Cu-Au deposits.



**Figure 79.** Copper grades of porphyry Cu-Au deposits.



**Figure 80.** Gold grades of porphyry Cu-Au deposits.



**Figure 81.** By-product grades of porphyry Cu-Au deposits. A, Silver. B, Molybdenum.

## DESCRIPTIVE MODEL OF PORPHYRY Cu-Mo

By Dennis P. Cox

DESCRIPTION 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 (See fig. 82).

GENERAL REFERENCE Titley (1982).

GEOLOGICAL ENVIRONMENT

Rock Types Tonalite to monzogranite stocks and breccia pipes intrusive into batholithic, volcanic, or sedimentary rocks.

Textures Intrusions contemporaneous with ore commonly are porphyries with fine- to medium-grained aplitic groundmass. Porphyry texture may be restricted to small dikes in some deposits (Brenda).

Age Range Mainly Mesozoic to Tertiary, but can be any age.

Depositional Environment High-level intrusive porphyry contemporaneous with abundant dikes, faults, and breccia pipes. Cupolas of batholiths.

Tectonic Setting(s) Numerous faults in subduction-related volcanic plutonic arcs. Mainly along continental margins but also in oceanic convergent plate boundaries.

Associated Deposit Types Cu, Zn, or Fe skarns may be rich in gold, gold + base-metal sulfosalts in veins, gold placers. Volcanic-hosted massive replacement and polymetallic replacement.

DEPOSIT DESCRIPTION

Mineralogy Chalcopyrite + pyrite + molybdenite. Peripheral vein or replacement deposits with chalcopyrite + sphalerite + galena ± gold. Outermost zone may have veins of Cu-Ag-Sb-sulfides, barite, and gold.

Texture/Structure Veinlets and disseminations or massive replacement of favorable country rocks.

Alteration Quartz + K-feldspar + biotite (chlorite) ± anhydrite (potassic alteration) grading outward to propylitic. Late white mica + clay (phyllitic) alteration may form capping or outer zone or may affect the entire deposit. High-alumina alteration assemblages may be present in upper levels of the system (see table 3).

Ore Controls Ore grade is, in general, positively correlated with spacing of veinlets and mineralized fractures. Country rocks favorable for mineralization are calcareous sediments; diabase, tonalite, or diorite.

Weathering Intense leaching of surface; wide areas of iron oxide stain. Fractures coated with hematitic limonite. Supergene copper as chalcocite may form blanket below leached zone. Residual soils may contain anomalous amounts of rutile.

Geochemical Signature Cu + Mo + Ag ± W + B + Sr center; Pb, Zn, Au, As, Sb, Se, Te, Mn, Co, Ba, and Rb in outer zone. Locally Bi and Sn form distal anomalies. High S in all zones. Ratio of Au (ppm): Mo (percent) < 3. Magnetic low.

EXAMPLES

Brenda, CNBC	(Soregaroli and Whitford, 1976)
Sierrita Esperanza, USAZ	(West and Aiken, 1982)

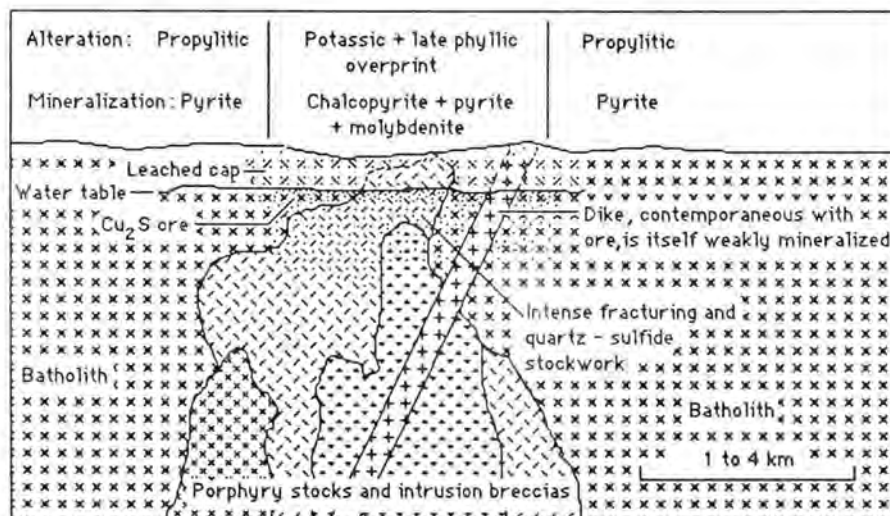
## GRADE AND TONNAGE MODEL OF PORPHYRY Cu-Mo

By Donald A. Singer, Dennis P. Cox, and Dan L. Mosier

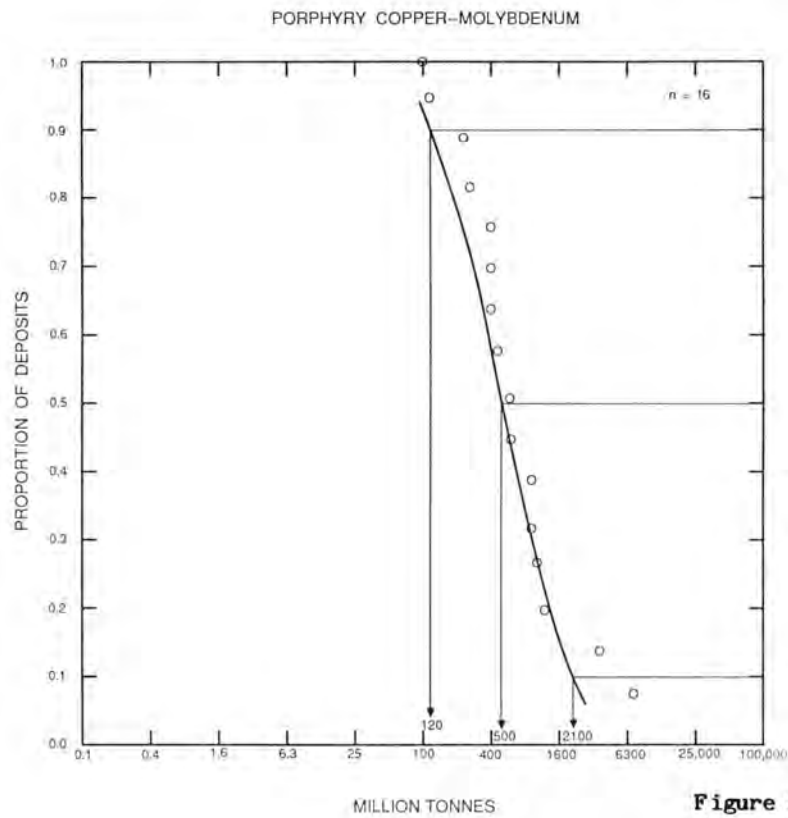
COMMENTS These deposits are a subset of porphyry Cu-Mo deposits for which a Cu, Mo and Au grade were available. See figs. 83-87.

DEPOSITS

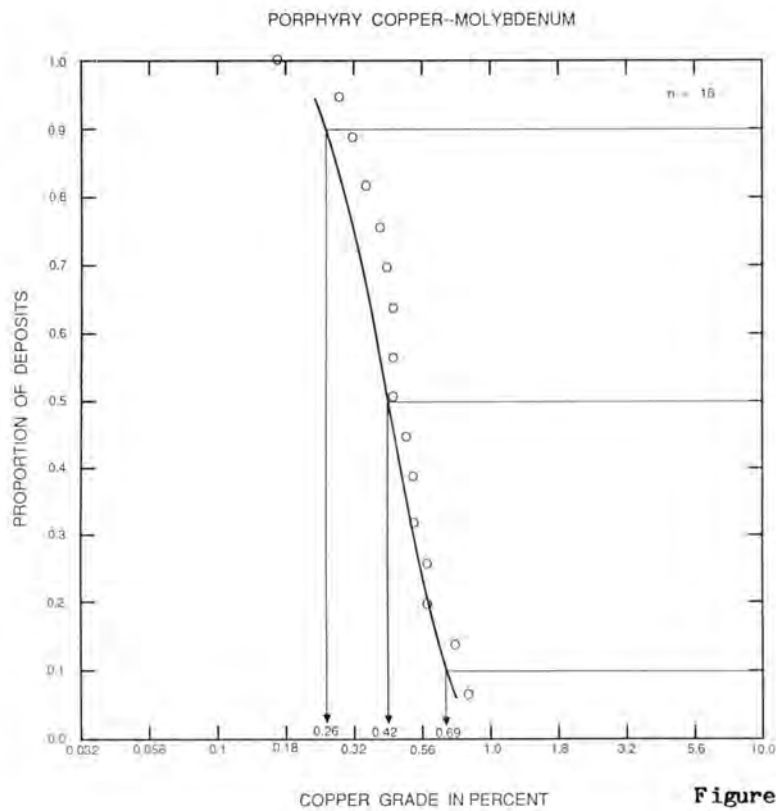
<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Berg	CNBC	Inspiration	USNM
Bethlehem	CNBC	Lornex	CNBC
Brenda	CNBC	Morenci	USAZ
Gambier Island	CNBC	Ray	USAZ
Gaspe	CNQU	Sierrita-Esperanza	USAZ
Gibraltar	CNBC	Tyrone	USNM
Highmont	CNBC	Twin Buttes	USAZ
Huckleberry	CNBC	Valley Copper	CNBC



**Figure 82.** Cartoon cross section of porphyry Cu-Mo deposit showing relationship between mineral- and alteration-zoning and igneous intrusion.

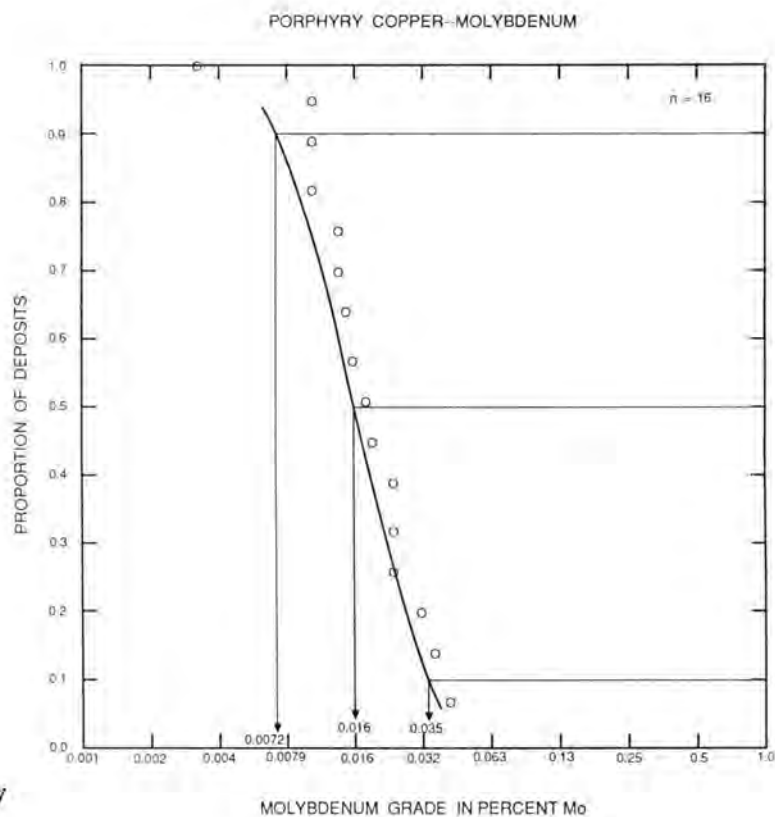


**Figure 83.** Tonnages of porphyry Cu-Mo deposits.

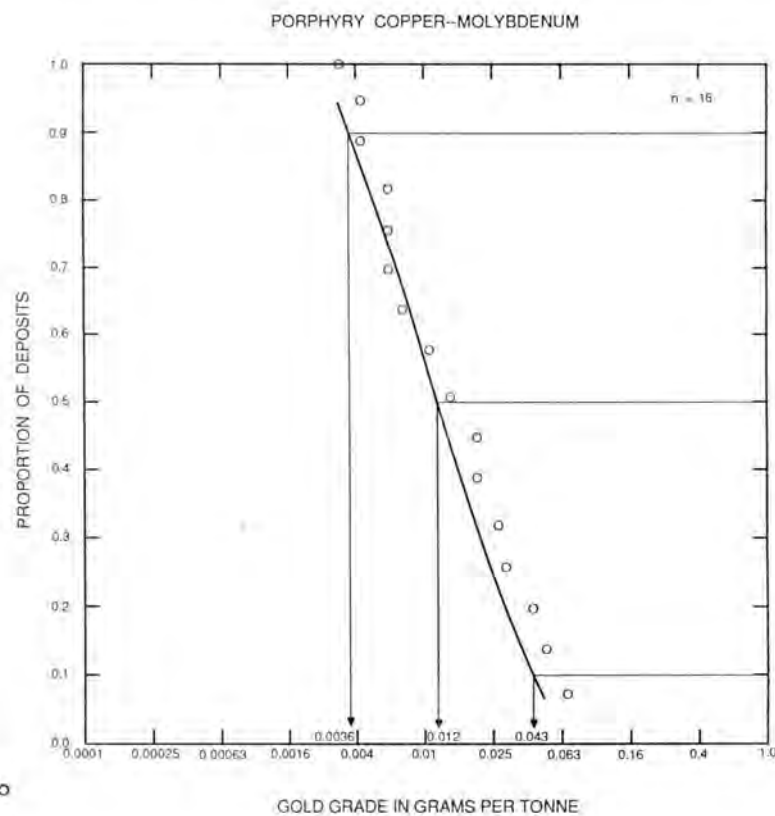


**Figure 84.** Copper grades of porphyry Cu-Mo deposits.

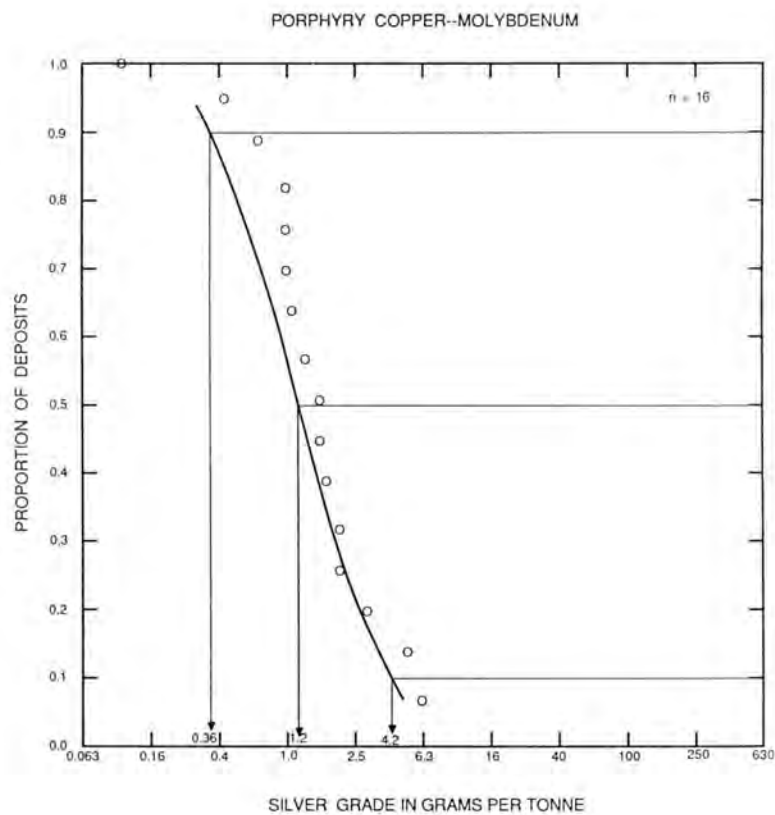




**Figure 85.** Molybdenum grades of porphyry Cu-Mo deposits.



**Figure 86.** Gold grades of porphyry Cu-Mo deposits.



**Figure 87.** Silver grades of porphyry Cu-Mo deposits.

## DESCRIPTIVE MODEL OF PORPHYRY Mo, LOW-F

By Ted G. Theodore

APPROXIMATE SYNONYM Calc-alkaline Mo stockwork (Westra and Keith, 1981).DESCRIPTION Stockwork of quartz-molybdenite veinlets in felsic porphyry and in its nearby country rock.GENERAL REFERENCE Westra and Keith (1981).GEOLOGICAL ENVIRONMENTRock Types Tonalite, granodiorite, and monzogranite.Textures Porphyry, fine aplitic groundmass.Age Range Mesozoic and Tertiary.Depositional Environment Orogenic belt with calcalkaline intrusive rocks.Tectonic Setting(s) Numerous faults.Associated Deposit Types Porphyry Cu-Mo, Cu skarn, volcanic hosted Cu-As-Sb.DEPOSIT DESCRIPTIONMineralogy Molybdenite + pyrite + scheelite + chalcopyrite + argentian tetrahedrite. Quartz + K-feldspar + biotite + calcite + white mica and clays.Texture/Structure Disseminated and in veinlets and fractures.Alteration Potassic outward to propylitic. Phyllic and argillic overprint (see table 3).Ore Controls Stockwork in felsic porphyry and in surrounding country rock.Weathering Yellow ferrimolybdate after molybdenite. Secondary copper enrichment may form copper ores in some deposits.Geochemical Signature Zoning outward and upward from Mo + Cu ± W to Cu + Au to Zn + Pb, + Au, + Ag. F may be present but in amounts less than 1,000 ppm.EXAMPLES

Buckingham, USNV	(Blake and others, 1979)
USSR deposits	(Pavlova and Rundquist, 1980)

## GRADE AND TONNAGE MODEL OF PORPHYRY Mo, LOW-F

By W. David Menzie and Ted G. Theodore

COMMENTS See figs. 88, 89.DATA REFERENCE Theodore and Menzie (1983).DEPOSITS

<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Anduramba	AUQL	Boss Mountain	CNBC
Adanac (Ruby Creek)	CNBC	Boswell River	CNYT
Ajax (Dak River)	CNBC	Buckingham	USNV
B. C. Moly	CNBC	Cannivan Gulch	USMT
Bell Molybdenum	CNBC	Carmi	CNBC

Creston	MXCO	Pitman (JB)	CNBC
Endako	CNBC	Quartz Hill	USAK
Gem	CNBC	Red Bird	CNBC
Glacier Gulch	CNBC	Red Mountain	CNYT
Hall	USNV	Serb Creek	CNBC
Haskin Mountain	CNBC	Setting Net Lake	CNON
Karen	CNBC	Storie	CNBC
Lucky Ship	CNBC	Sunshine Creek	CNBC
Machkatica	YUGO	Thompson Creek	USID
Mount Thomlinson	CNBC	Trout Lake	CNBC
Mount Tolman	USWA	UV Industries	USNV
Pine Nut	USNV		

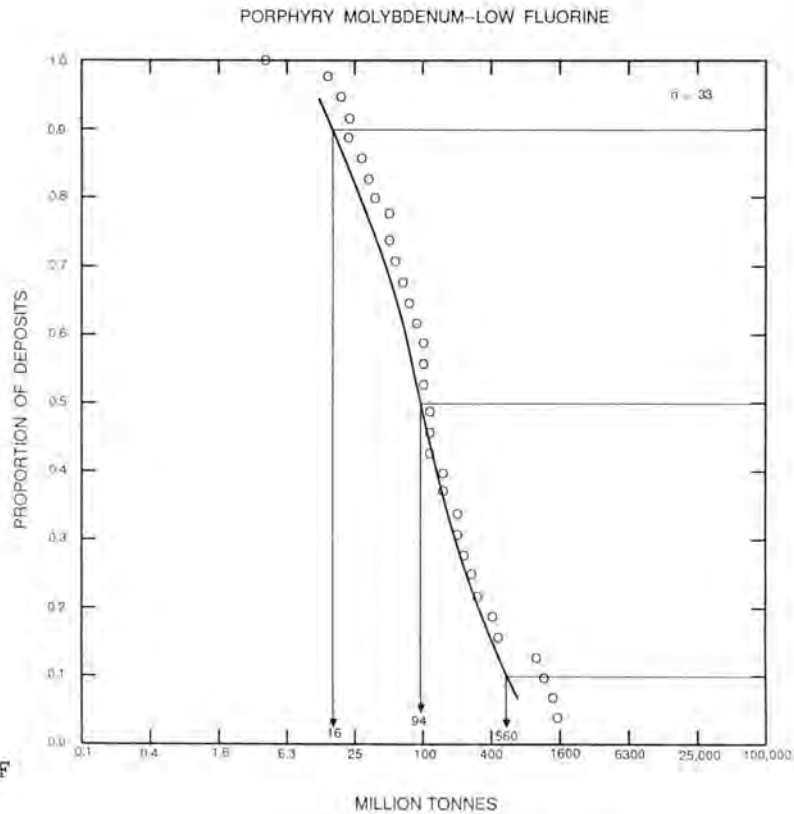


Figure 88. Tonnages of porphyry Mo-low F deposits.

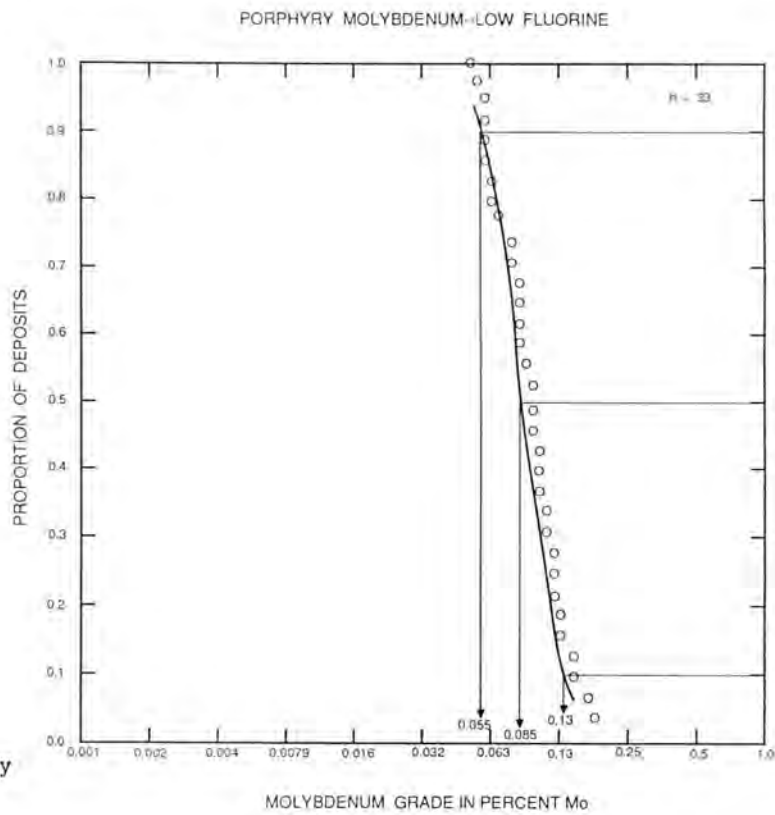


Figure 89. Molybdenum grades of porphyry Mo-low F deposits.

## DESCRIPTIVE MODEL OF VOLCANIC-HOSTED Cu-As-Sb

By Dennis P. Cox

APPROXIMATE SYNONYM Enargite massive sulfide (Sillitoe, 1983)DESCRIPTION Stratabound to pipelike massive copper sulfosalt deposits in volcanic flows, breccias, and tuffs near porphyry systems.GENERAL REFERENCES Sillitoe (1983), Ashley (1982).GEOLOGICAL ENVIRONMENTRock Types Andesite, dacite, flows, breccias, and tuffs.Textures Fine grained, porphyritic, brecciated.Age Range Mainly Tertiary.Depositional Environment Volcanic terrane, uppermost levels of intrusive systems.Tectonic Setting(s) Continental margins and island arcs.Associated Deposit Types Porphyry Cu-Mo, porphyry Mo low-F.DEPOSIT DESCRIPTIONMineralogy All contain pyrite. In addition, enargite + luzonite + tennantite (Lepanto), enargite + covellite + chalcocite + bornite + chalcopyrite (Bor), enargite + luzonite + tetrahedrite (Resck), tetrahedrite + sphalerite + chalcopyrite + arsenopyrite (Sam Goosly). Most contain a few parts per million Au; Sam Goosly is Ag-rich.Texture/Structure Massive ore, breccia filling, replacement of clasts by sulfides.Alteration Chalcedony plus high-alumina assemblages containing alunite, pyrophyllite, diaspore, dickite, andalusite. Dumortierite, tourmaline, barite, and scorzalite may be present.Ore Controls Tuff-breccias or breccia pipes are the channelways for ore solutions originating from younger porphyry copper systems. Known deposits are separated from typical porphyry type mineralization by 500 to 700 m.Geochemical Signature As, Sb, Cu, Zn, Ag, Au,  $\pm$  minor Sn (Lepanto), and W (Sam Goosly).EXAMPLES

Lepanto, PLPN	(Gonzales, 1956)
Resck, HUNG; Bor, YUGO	(Sillitoe, 1983)
Sam Goosly (Equity Silver), CNBC	(Cyr and others, 1984)

## DESCRIPTIVE MODEL OF Au-Ag-Te VEINS

By Dennis P. Cox and William C. Bagby

DESCRIPTION Gold telluride minerals and fluorite in veins and breccia bodies related to hypabyssal or extrusive alkalic rocks.

### GEOLOGICAL ENVIRONMENT

Rock Types Syenite, monzonite, or diorite; phonolite, monchiquite, and vogesite. Silica-undersaturated low-Ti basalts (shoshonites).

Textures Porphyro-aphanitic. Volcanic breccias and lapilli tuff.

Age Range Mainly Cretaceous and Tertiary, but could be any age.

Depositional Environment Volcanic centers, caldera rims, and caldera-fill breccias.

Tectonic Setting(s) Disrupted Precambrian craton with thin Phanerozoic cover. Also late shoshonitic stage of volcanism in island arcs.

Associated Deposit Types Polymetallic veins, polymetallic replacement deposits.

### DEPOSIT DESCRIPTION

Mineralogy Calaverite, sylvanite, hessite, coloradoite, fine-grained pyrite, galena, sphalerite, tetrahedrite, and stibnite in veins of smokey quartz, calcite, purple fluorite, barite, celestite, roscoelite (V-mica), and adularia. Fluorite absent in Fiji deposit.

Texture/Structure Veins mainly carbonates and quartz. Ore minerals in clusters and locally in vug linings. Breccia-filling textures in some deposits.

Alteration Propylitic, dominated by carbonates (particularly dolomite) and pyrite. Sericite introduced in wallrocks. Silicification is rare.

Ore Controls Rich breccia ores in central zone of caldera. Veins on steep radial fractures and on faults gently inclined toward caldera. Veins may follow porphyry dikes. Replacement ore bodies may form where veins cut limestone, organic-rich argillaceous limestone being especially favorable.

Weathering Tellurides easily destroyed by weathering. Resulting "flour" gold may not be retained in placer deposits. Some tellurium redeposited as green oxides (emmonsite). Supergene enrichment, depositing native Au, occurs in some deposits.

Geochemical Signature Au, Ag, Te, Cu, Pb, Zn, Sb, Hg, F, Ba, PGE.

### EXAMPLES

Cripple Creek, USCO

Gold Hill, USCO

LaPlata district, USCO

Zortman-Landusky (Little Rockies district), USMT

North Mocassin-Warm Springs district), USMT

Emperor mine, Tavua, FIJI

(Loughlin and Koschman, 1935;

Lindgren and Ransome, 1906)

(Kelly and Goddard, 1969)

(Eckel, 1949)

(Corry, 1933)

(Blixt, 1933)

(Colley, 1976)

## DESCRIPTIVE MODEL OF POLYMETALLIC VEINS

By Dennis P. Cox

APPROXIMATE SYNONYM Felsic intrusion-associated Ag-Pb-Zn veins (Sangster, 1984).

DESCRIPTION Quartz-carbonate veins with Au and Ag associated with base metal sulfides related to hypabyssal intrusions in sedimentary and metamorphic terranes.

### GEOLOGICAL ENVIRONMENT

Rock Types Calcalkaline to alkaline, diorite to granodiorite, monzonite to monzogranite in small intrusions and dike swarms in sedimentary and metamorphic rocks. Subvolcanic intrusions, necks, dikes, plugs of andesite to rhyolite composition.

Textures Fine- to medium-grained equigranular, and porphyroaphanitic.

Age Range Most are Mesozoic and Cenozoic, but may be any age.

Depositional Environment Near-surface fractures and breccias within thermal aureol of clusters of small intrusions. In some cases peripheral to porphyry systems.

Tectonic Setting(s) Continental margin and island arc volcanic-plutonic belts. Especially zones of local domal uplift.

Associated Deposit Types Porphyry Cu-Mo, porphyry Mo low-F, polymetallic replacement. Placer Au.

### DEPOSIT DESCRIPTION

Mineralogy Native Au and electrum with pyrite + sphalerite ± chalcopyrite ± galena ± arsenopyrite ± tetrahedrite-tennantite ± Ag sulfosalts ± argentite ± hematite in veins of quartz + chlorite + calcite ± dolomite ± ankerite ± siderite ± rhodochrosite ± barite ± fluorite ± chalcedony ± adularia.

Texture/Structure Complex, multiphase veins with comb structure, crustification, and colloform textures. Textures may vary from vuggy to compact within mineralized system.

Alteration Generally wide propylitic zones and narrow sericitic and argillic zones. Silicification of carbonate rocks to form jasperoid.

Ore Controls Areas of high permeability: intrusive contacts, fault intersections, and breccia veins and pipes. Replacement ore bodies may form where structures intersect carbonate rocks.

Weathering Minor gossans and Mn-oxide stains. Zn and Pb carbonates and Pb sulfate. Abundant quartz chips in soil. Placer gold concentrations in soils and stream sediments. Supergene enrichment produces high-grade native and horn silver ores in veins where calcite is not abundant.

Geochemical Signature Zn, Cu, Pb, As, Au, Ag, Mn, Ba. Anomalies zoned from Cu-Au outward to Zn-Pb-Ag to Mn at periphery.

### EXAMPLES

St. Anthony (Mammoth), USAZ	(Creasey, 1950)
Wallapai District, USAZ	(Thomas, 1949)
Marysville District, USMT	(Knopf, 1913)
Misima I., PPNG	(Williamson and Rogerson, 1983)
Slocan District, CNBC	(Cairnes, 1934)

## GRADE AND TONNAGE MODEL OF POLYMETALLIC VEINS

By James D. Bliss and Dennis P. Cox

COMMENTS The data used to generate grade and tonnage models for polymetallic veins reflect considerable complexity in the geology and economic conditions under which deposits are produced or evaluated. This model represents a first attempt to resolve these complexities. Four important



factors may affect the adequacy of this model.

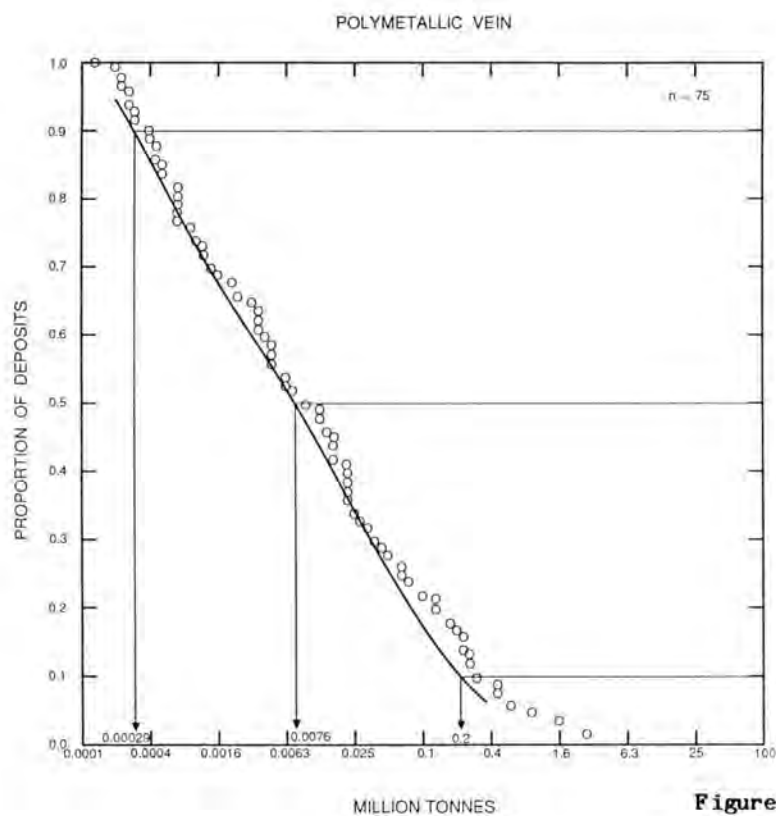
1. Zinc grades are subject to considerable uncertainty because smelters have in the past penalized producers for ore containing zinc which in turn caused mine operators to avoid zinc-bearing ore in their mining and milling. Zinc grades are likely underestimated. Irregular behavior in the zinc-grade model may be due to these factors.

2. Polymetallic veins of two types appear to exist--a base-metal polymetallic vein worked primarily for a base metal or metals and silver and a gold-silver polymetallic vein with copper, lead, and zinc production likely in less than half the deposits. Grade and tonnage models are presented for the base-metal polymetallic veins. Grade and tonnage models are not presented for the gold-silver polymetallic veins because preliminary data are inadequate. In our data, districts in which both types occur generally have six times as many base-metal polymetallic veins as gold-silver polymetallic veins.

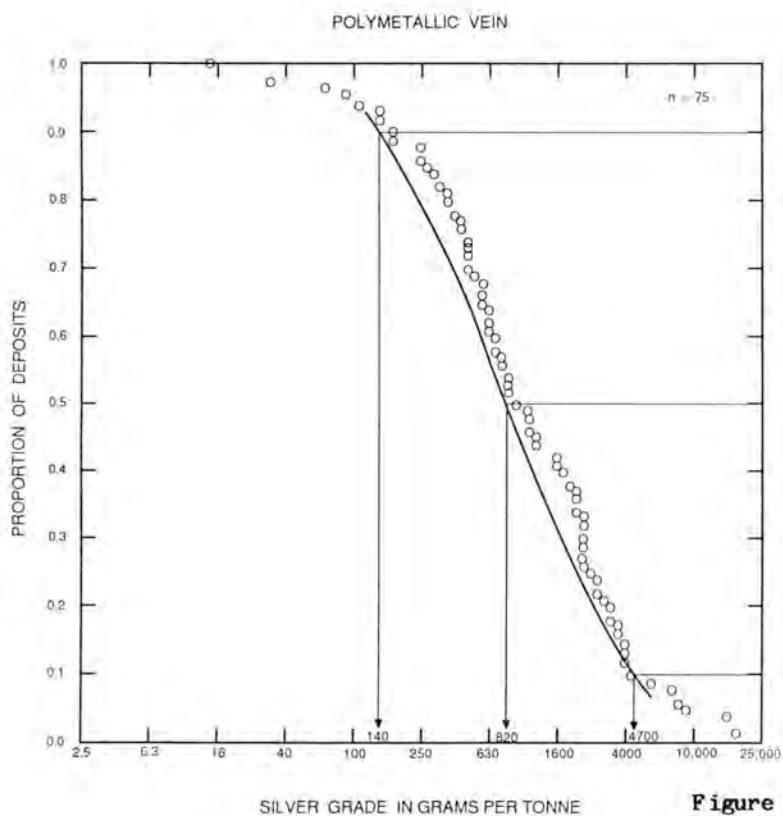
3. The Slocan Mining District, British Columbia, Canada, contributed nearly 60 percent of the deposit data for the base-metal polymetallic veins, and this may bias the models in ways not identified.

4. Deposits are defined as all workings within 1 km of each other and having a minimum of 100 tonnes of ore. A few deposits are for districts with workings of unknown spacing. See figs. 90-94.

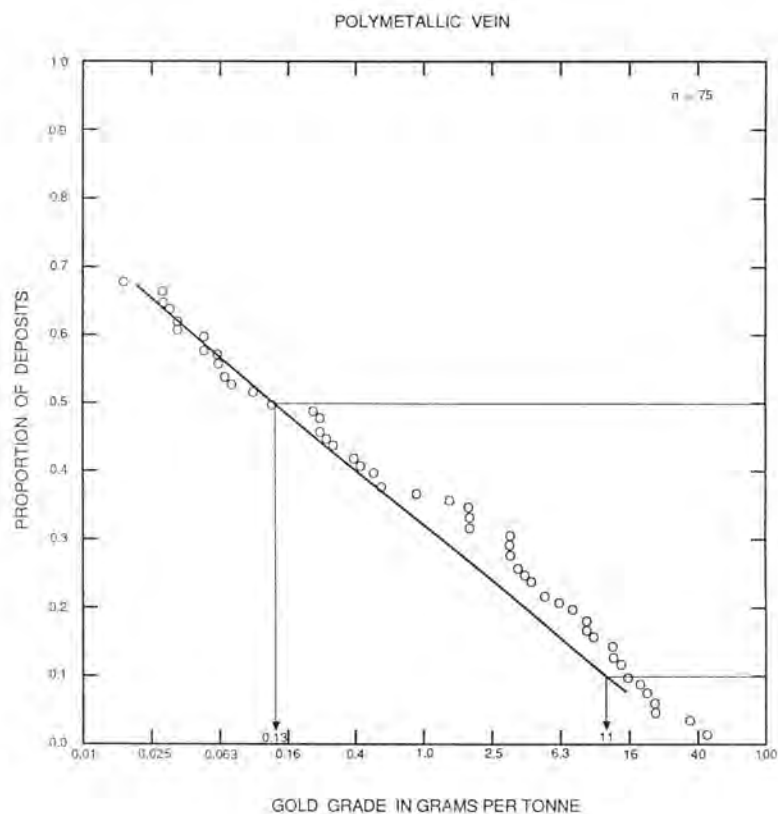
<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Albert Lea Group	USAZ	Mammoth-St. Anthony	USAZ
Altoona-Elkhor-Mercury	CNBC	Marietta	USMT
Amazon	USMT	Mineral Park	USAZ
Antoine	CNBC	Minniehaha	CNBC
Arlington	CNBC	Molly Gibson	CNBC
Badger	USAZ	Monitor	CNBC
Baltic and Revenue	USCO	Montezuma	CNBC
Baltimore	USMT	Mountain Chief and vicinity	CNBC
Bell	CNBC	Mountain Con	CNBC
Bell and California	USCO	Noonday	CNBC
Bell Boy-Niles-Towsley	USMT	North Cerbat (Golconda)	USAZ
Big Four	USMT	Northern Bell-Jackson	CNBC
Bosum	CNBC	Payne Group	CNBC
Bullion	USCO	Pennsylvania	USCO
C.O.D.	USAZ	Queen Bess and vicinity	CNBC
California-Hartney-Marion	CNBC	Rambler-Cariboo	CNBC
Carnation-Jennie Lind	CNBC	Rio	CNBC
Central Cerbat District	USAZ	Robert Emmet	USMT
Champion-New London	USAZ	Santiago-Commonwealth-	
Chlorite District	USAZ	Centennial	USCO
Comstock	CNBC	Scranton-Pontiac-Sunset	CNBC
Cork-Province	CNBC	Silversmith-Richmond-	
Dardanelles	CNBC	Ruth-Hope	CNBC
Defiance	USAZ	Slocan-Sovereign	CNBC
Eva May	USMT	Soho	CNBC
Fisher Maiden Group	CNBC	Standard and vicinity	CNBC
Flint-Martin	CNBC	Stockton	USAZ
Galena Farm and vicinity	CNBC	Sunshine-Corinth	CNBC
Gray Eagle	USMT	Surprise-Noble Five and	
Idaho-Alamo Group	CNBC	vicinity	CNBC
Idaho-Alamo-Silver Bell	CNBC	Treasure Hill	USAZ
Ivanhoe-Canadian	CNBC	Tybo	USNV
Keno Hill-Galena Hill	CNYT	Union	USNV
King Solomon	USMT	Utica	CNBC
Leadsmith	CNBC	Vancouver Group	CNBC
Legal Tender	USMT	Von Roi-Hewitt-A.U.	CNBC
Little Nell	USMT	Wellington	CNBC
Liverpool	USMT	Wintrop	CNBC
Majestic-Sapphire	CNBC	Wonderful-Elkhorn	CNBC



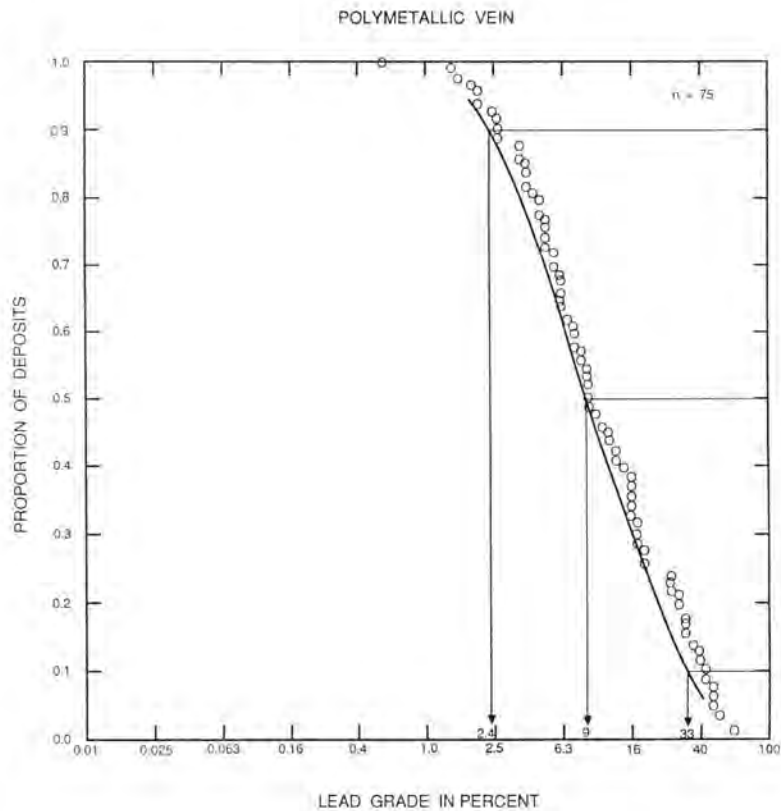
**Figure 90.** Tonnages of polymetallic vein deposits.



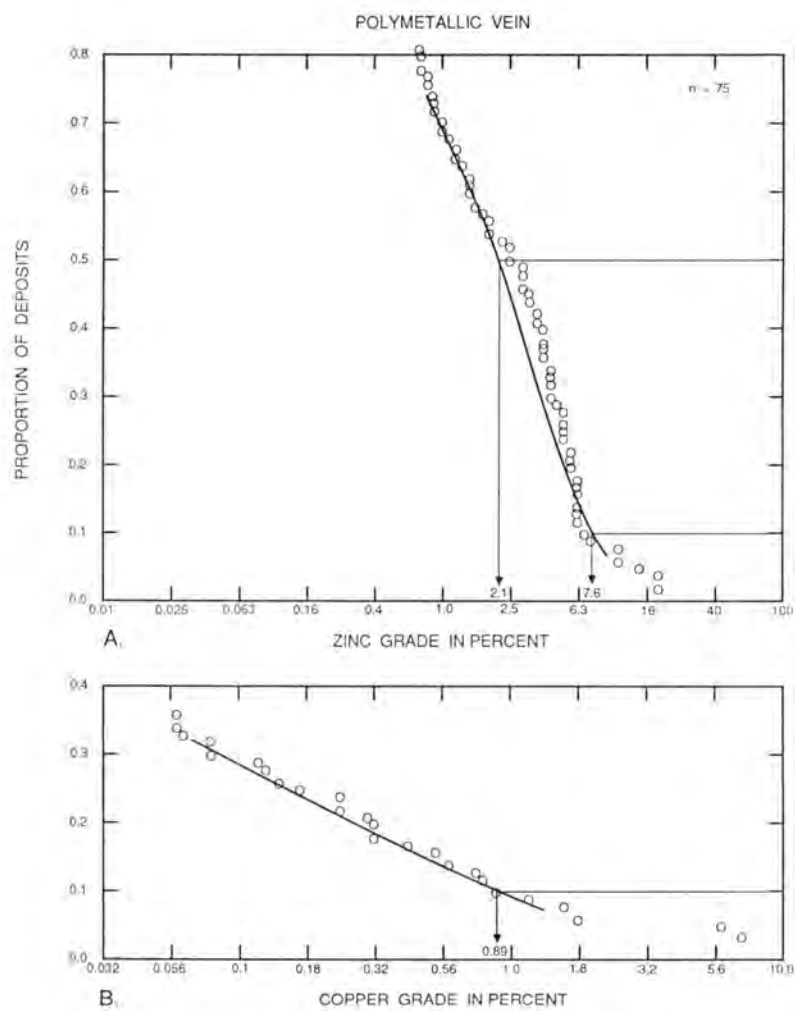
**Figure 91.** Silver grades of polymetallic vein deposits.



**Figure 92.** Gold grades of polymetallic vein deposits.



**Figure 93.** Lead grades of polymetallic vein deposits.



**Figure 94.** Zinc and copper grades of polymetallic vein deposits. A, Zinc. B, Copper.

## DESCRIPTIVE MODEL OF BASALTIC Cu

By Dennis P. Cox

APPROXIMATE SYNONYM Volcanic redbed Cu (Kirkham, 1984).

DESCRIPTION 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.

GENERAL REFERENCE Kirkham (1984).

### GEOLOGICAL ENVIRONMENT

Rock Types Subaerial to shallow marine basalt flows, breccias and tuffs, red-bed sandstone, tuffaceous sandstone, conglomerate. Younger tidal facies limestone and black shale.

Textures Amygdules, flow-top breccias in lava. Laminated algal carbonate rocks. Sediments with high original porosity.

Age Range Proterozoic, Triassic and Jurassic, and Tertiary deposits known.

Depositional Environment Copper-rich (100-200 ppm) basalt interlayered with red clastic beds and overlain by mixed shallow marine and continental deposits formed near paleo-equator.

Tectonic Setting(s) Intracontinental rift, continental margin rift. Regional low-grade metamorphism may mobilize copper in some districts. Deposits are characteristic of the Triassic part of Wrangellia terrane in Alaska.

Associated Deposit Types Sediment-hosted copper. Volcanogenic Mn at Boleo, Mexico.

### DEPOSIT DESCRIPTION

Mineralogy Native copper, native silver in flows and coarse clastic beds. Chalcocite and other  $Cu_2S$  minerals and locally bornite and chalcopyrite are concentrated in overlying shale and carbonate rocks. Fine-grained pyrite is common but not abundant with copper sulfide minerals.

Texture/Structure Flow-top breccia and amygdule fillings in basalt. Fine grains in matrix and along shaley parting in clastics. Massive replacement of carbonates at Kennicott. Finely varved chalcopyrite sediment at Denali.

Alteration Calcite-zeolite + epidote + K-feldspar. Red coloration due to fine hematite.

Ore Controls Flow-top breccias, amygdules, fractures in basalt; organic shale, limestone in overlying sequence. Limestone is tidal, algal, with stromatolite fossils. Synsedimentary faulting may be important.

Weathering Widely dispersed copper nuggets in streams draining basalts.

Geochemical Signature Cu-Ag-Zn-Cd. Co at Boleo, Mexico. Cu:Zn ratio is very high. Au anomalously low.

### EXAMPLES

Keweenaw, USMI	(White, 1968)
Calumet, USMI	(Ensign and others, 1968)
Kennicott, USAK	(Bateman and McLaughlin, 1920)
Denali, USAK	(Seraphim, 1975)
Boleo, MXCO	(Wilson, 1955)
Buena Esperanza, CILE	(Ruiz, 1965)
Redstone, CNNT	(Ruelle, 1982)
Sustut, CNBC	(Harper, 1977)

## DESCRIPTIVE MODEL OF CYPRUS MASSIVE SULFIDE

By Donald A. Singer

APPROXIMATE SYNONYM Cupreous pyrite.

DESCRIPTION Massive pyrite, chalcopyrite, and sphalerite in pillow basalts (see figs. 95, 96).

GENERAL REFERENCE Franklin, and others (1981).

### GEOLOGICAL ENVIRONMENT

Rock Types Ophiolite assemblage: tectonized dunite and harzburgite, gabbro, sheeted diabase dikes, pillow basalts, and fine-grained metasedimentary rocks such as chert and phyllite (fig. 95).

Textures Diabase dikes, pillow basalts, and in some cases brecciated basalt.

Age Range Archean(?) to Tertiary--majority are Ordovician or Cretaceous.

Depositional Environment Submarine hot spring along axial grabens in oceanic or back-arc spreading ridges. Hot springs related to submarine volcanoes producing seamounts (fig. 96).

Tectonic Setting(s) Ophiolites. May be adjacent to steep normal faults.

Associated Deposit Types Mn and Fe-rich cherts regionally.

### DEPOSIT DESCRIPTION

Mineralogy Massive: pyrite + chalcopyrite + sphalerite + marcasite + pyrrhotite. Stringer (stockwork): pyrite + pyrrhotite, minor chalcopyrite and sphalerite (cobalt, gold, and silver present in minor amounts).

Texture/Structure Massive sulfides (>60 percent sulfides) with underlying sulfide stockwork or stringer zone. Sulfides brecciated and recemented. Rarely preserved fossil worm tubes.

Alteration Stringer zone--feldspar destruction, abundant quartz and chalcedony, abundant chlorite, some illite and calcite. Some deposits overlain by ochre (Mn-poor, Fe-rich bedded sediment containing goethite, maghemite, and quartz).

Ore Controls Pillow basalt or mafic volcanic breccia, diabase dikes below; ores rarely localized in sediments above pillows. May be local faulting.

Weathering Massive limonite gossans. Gold in stream sediments.

Geochemical Signature General loss of Ca and Na and introduction and redistribution of Mn and Fe in the stringer zone.

### EXAMPLES

Cyprus deposits, CYPS	(Constantinou and Govett, 1973)
Oxec, GUAT	(Petersen and Zantop, 1980)
York Harbour, CNNE	(Duke and Hutchinson, 1974)
Turner-Albright, USOR	(Koski and Derkey, 1981)

## GRADE AND TONNAGE MODEL OF CYPRUS MASSIVE SULFIDE

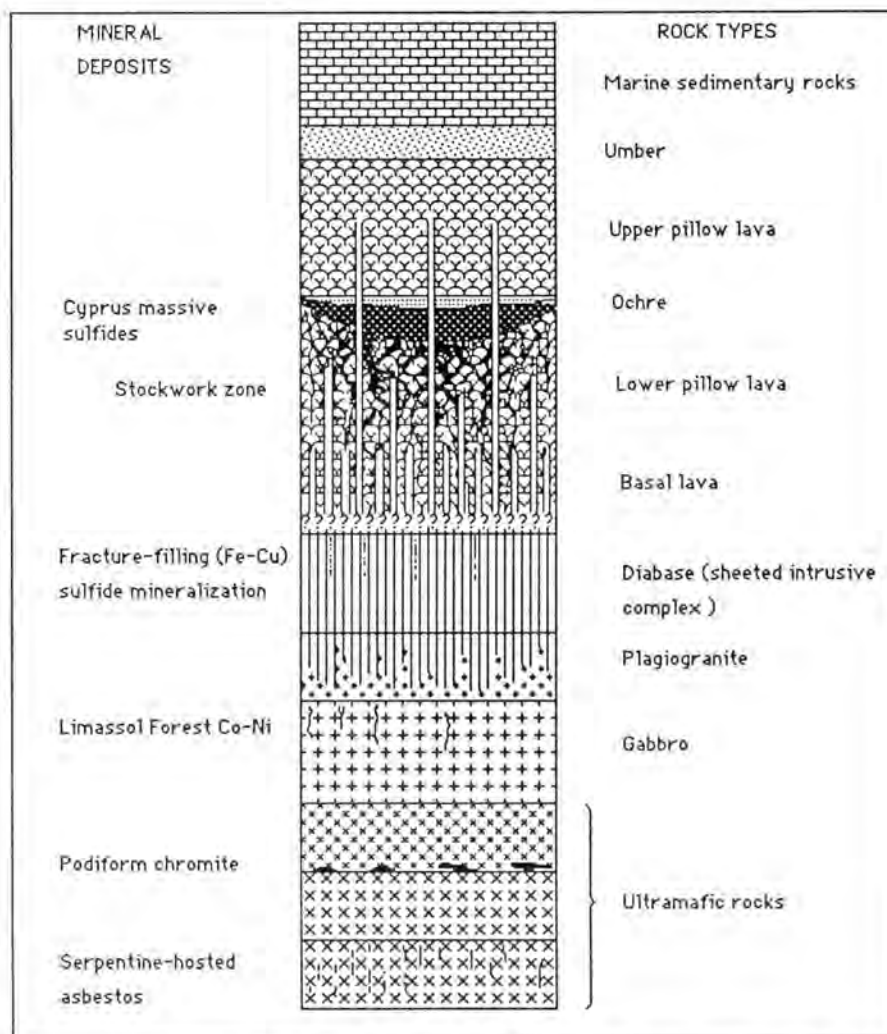
By Donald A. Singer and Dan L. Mosier

DATA REFERENCE Mosier and others (1983).

COMMENTS Massive sulfide deposits from Mosier and others (1983) which had only mafic or ultramafic rocks immediately above through 500 m below, and had either pillow basalt or diabase dikes in the sequence were included in these plots. See figs. 97-99.

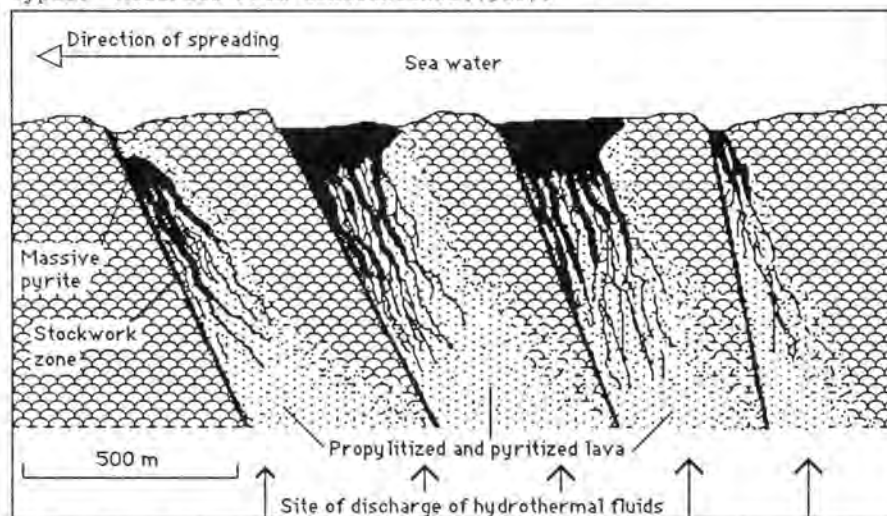
DEPOSITS

<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Aarja	OMAN	Lasail	OMAN
Agrokipia	CYPS	Limni	CYPS
Ambelikou	CYPS	Little Bay	CNNF
Ana Yatak-Ergani	TRKY	Lokken	NRWY
Apliki	CYPS	Lorraine	PLPN
Arinteiro	SPAN	Mathiati North	CYPS
Bama	SPAN	Mavrovouni	CYPS
Barlo	PLPN	Mousoulos-Kalavasos	CYPS
Bayda	OMAN	Ny Sulitjelma	NRWY
Betts Cove	CNNF	Oxec	GUAT
Big Mike	USNV	Peravasa	CYPS
Bonanza	CNBC	Platies	CYPS
Bongbongan	PLPN	Rendall-Jackson	CNNF
Carawison	PLPN	Rua Cove	USAK
Carmel	PLPN	Sha	CYPS
Colchester	CNNF	Siirt Madenkoy	TRKY
Fornas	SPAN	Skorovass	NRWY
Hand Camp	CNNF	Skouriotissa	CYPS
Huntingdon	CNQU	Svano	NRWY
Kapedhes	CYPS	Tilt Cove	CNNF
Kokkinoyia	CYPS	Troulli	CYPS
Kokkinopezoula	CYPS	Turner-Albright	USOR
Kure (Asikoy)	TRKY	Whalesback-Little Deer	CNNF
Kure (Bakibaba)	TRKY	York Harbour	CNNF
Kynousa	CYPS		



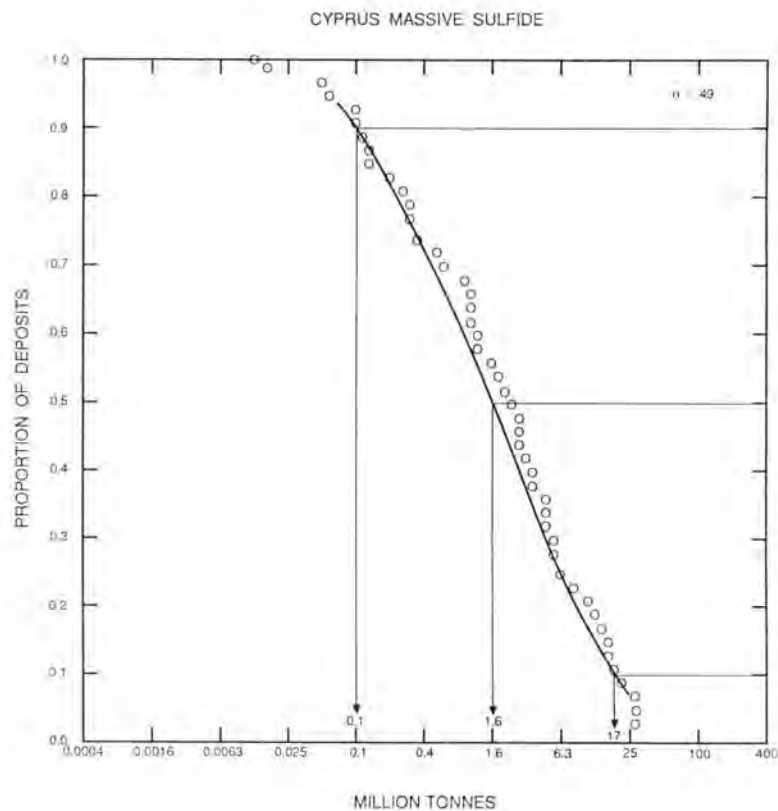
Model 24a--Con.

**Figure 95.** Generalized stratigraphic column through the Troodos ophiolite showing Cyprus massive sulfides and other deposit types and their associated rock types. Modified from Constantinou(1980).

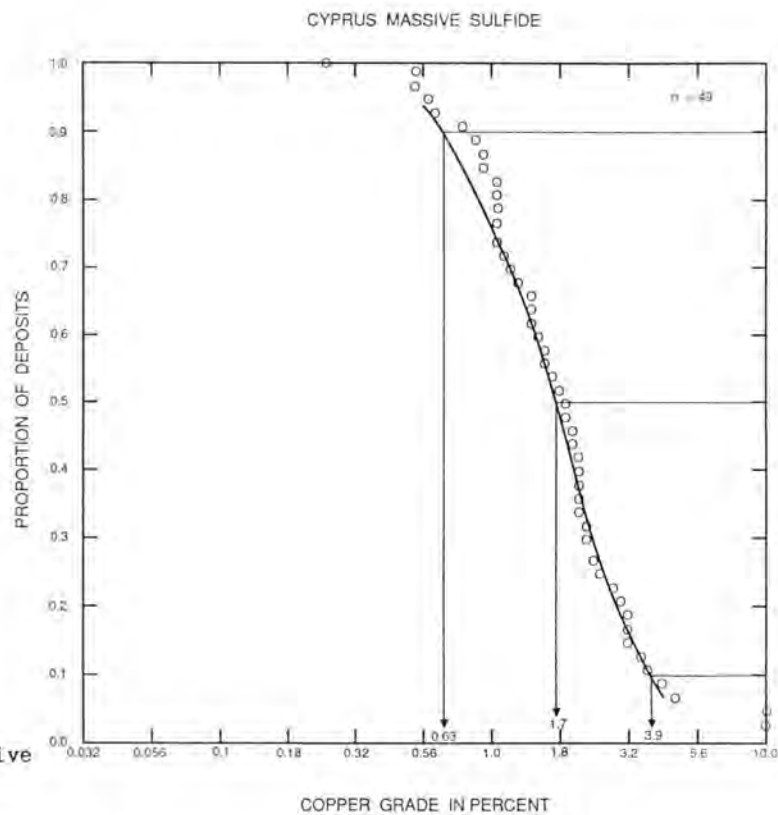


**Figure 96.** Cross section through the Kalavos district, Cyprus, showing relationship of massive sulfide deposits to faults and alteration zones. Section is drawn normal to the spreading axis and represents a time period prior to deposition of a thick sequence of pillow lavas and sedimentary rocks. Modified from Adamides (1980).

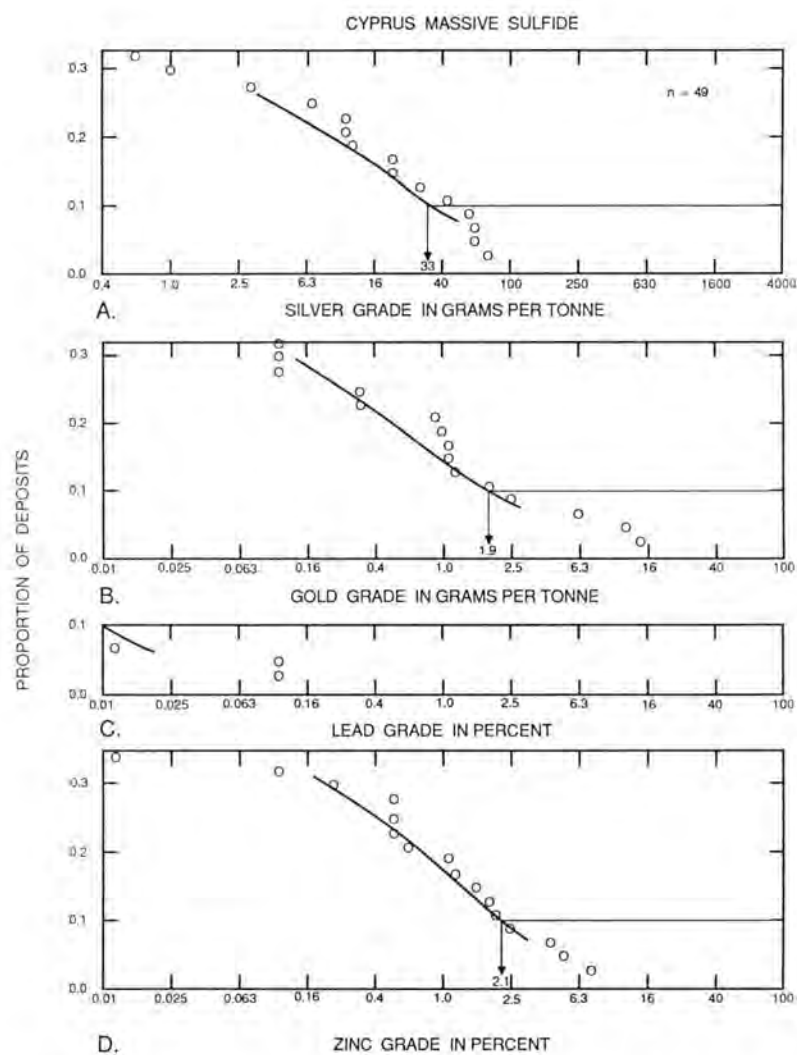




**Figure 97.** Tonnages of Cyprus massive sulfide deposits.



**Figure 98.** Copper grades of Cyprus massive sulfide deposits.



**Figure 99.** By-product grades of Cyprus massive sulfide deposits.  
A, Silver. B, Gold. C, Lead. D, Zinc.

## DESCRIPTIVE MODEL OF BESSHI MASSIVE SULFIDE

By Dennis P. Cox

APPROXIMATE SYNONYM Besshi type, Kieslager.

DESCRIPTION Thin, sheetlike bodies of massive to well-laminated pyrite, pyrrhotite, and chalcopyrite within thinly laminated clastic sediments and mafic tuffs.

GENERAL REFERENCES Klau and Large (1980), Fox (1984).

### GEOLOGICAL ENVIRONMENT

Rock Types Clastic terrigenous sedimentary rocks and tholeiitic to andesitic tuff and breccia. Locally, black shale, oxide-facies iron formation, and red chert.

Textures Thinly laminated clastic rocks. All known examples are in strongly deformed metamorphic terrane. Rocks are quartzose and mafic schist.

Age Range Mainly Paleozoic and Mesozoic.

Depositional Environment Uncertain. Possibly deposition by submarine hot springs related to basaltic volcanism. Ores may be localized within permeable sediments and fractured volcanic rocks in anoxic marine basins.

Tectonic Setting(s) Uncertain. Possibly rifted basin in island arc or back arc. Possibly spreading ridge underlying terrigenous sediment at continental slope.

Associated Deposit Types None known.

### DEPOSIT DESCRIPTION

Mineralogy Pyrite + pyrrhotite + chalcopyrite + sphalerite ± magnetite ± valleriite ± galena ± bornite ± tetrahedrite ± cobaltite ± cubanite ± stannite ± molybdenite. Quartz, carbonate, albite, white mica, chlorite, amphibole, and tourmaline.

Texture/Structure Fine-grained, massive to thinly laminated ore with colloform and framboidal pyrite. Breccia or stringer ore. Cross-cutting veins contain chalcopyrite, pyrite, calcite or galena, sphalerite, calcite.

Alteration Difficult to recognize because of metamorphism. Chloritization of adjacent rocks is noted in some deposits.

Ore Controls Uncertain. Deposits are thin, but laterally extensive and tend to cluster in en echelon pattern.

Weathering Gossan.

Geochemical Signature Cu, Zn, Co, Ag, Ni, Cr, Co/Ni >1.0, Au up to 4 ppm, Ag up to 60 ppm.

### EXAMPLES

Besshi, JAPN	(Kanehira and Tatsumi, 1970)
Motoyasu, JAPN	(Yui, 1983)
Kieslager, ASTR	(Derkman and Klemm, 1977)
Raul, PERU	(Ripley and Ohmoto, 1977)

## GRADE AND TONNAGE MODEL OF BESSHI MASSIVE SULFIDE

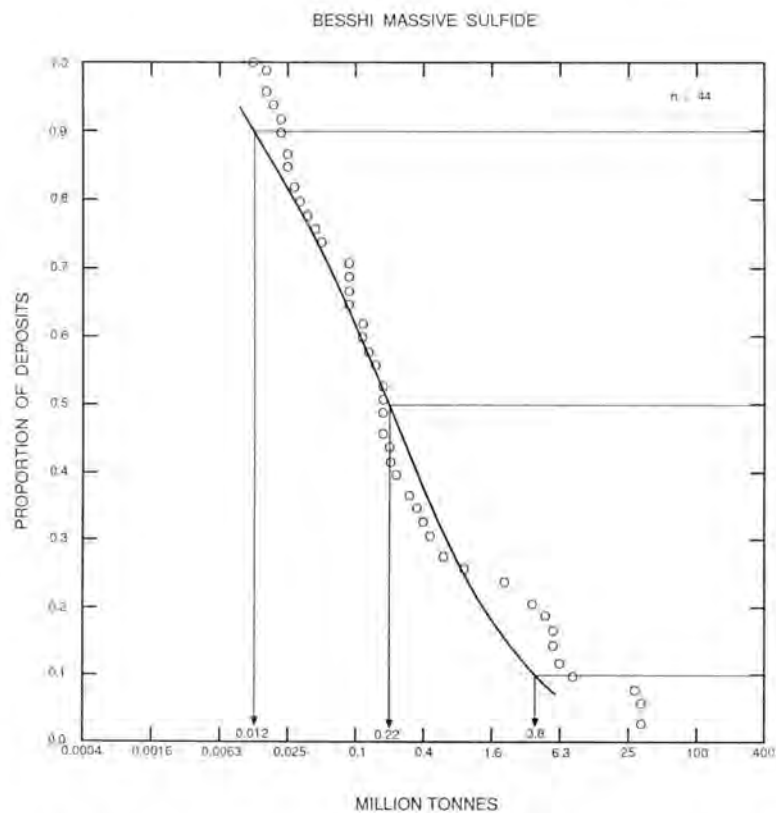
By Donald A. Singer

DATA REFERENCE Yamada and others (1980).

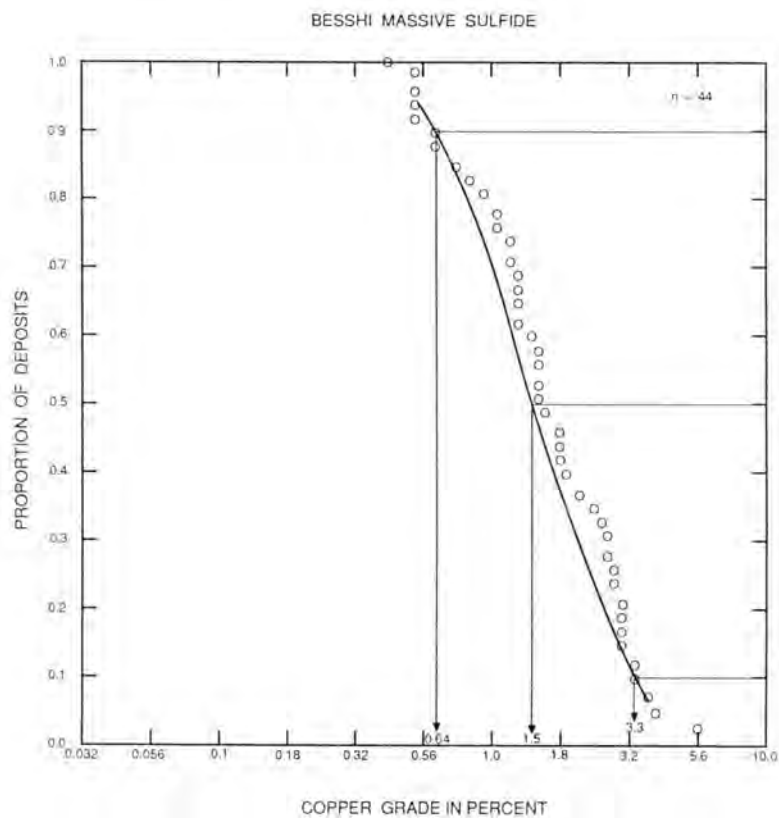
COMMENTS Only deposits from Japan containing more than 10,000 tonnes are included. See figs. 100-102.

DEPOSITS

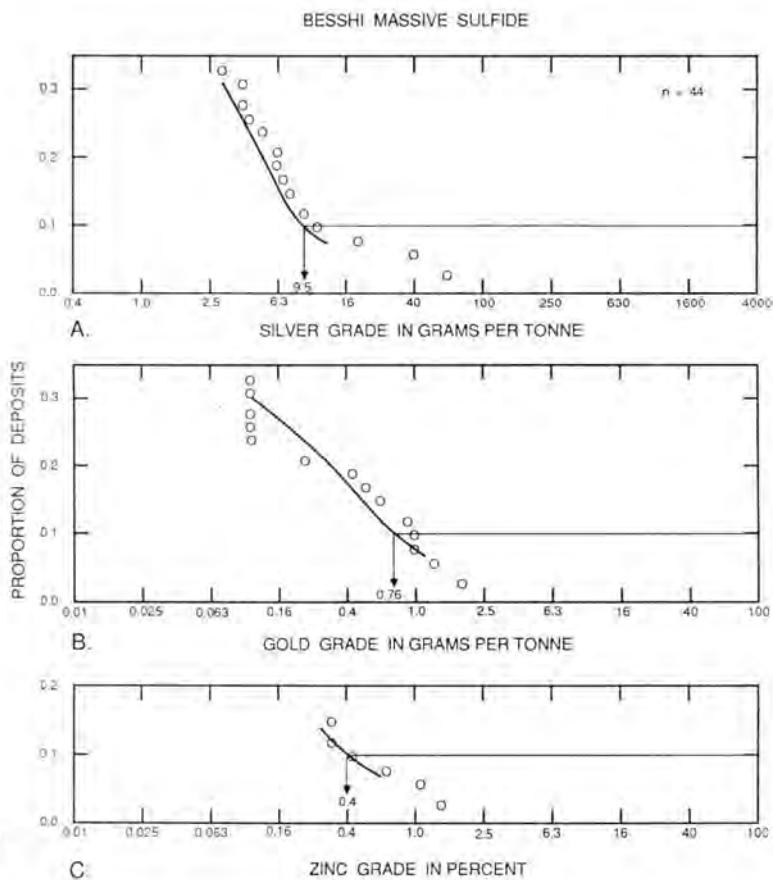
<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Akinokawa (Onishi)	JAPN	Motoyasu	JAPN
Asakawa	JAPN	Nakayama	JAPN
Besshi	JAPN	Nanogawa	JAPN
Choja	JAPN	Naruyasu	JAPN
Chushiro	JAPN	Nii	JAPN
Ehime	JAPN	Nishinokawa	JAPN
Higashiyame	JAPN	Noji	JAPN
Hirabaya	JAPN	Nonowaki	JAPN
Hirota	JAPN	Okuki	JAPN
Hitachi	JAPN	Omine	JAPN
Imade & Ouchi	JAPN	Ryuo	JAPN
Imori	JAPN	Sazare	JAPN
Iyo	JAPN	Shiiba, Takaragi	JAPN
Izushi	JAPN	Shimokawa	JAPN
Kamegamori	JAPN	Shimokawa (Kouchi)	JAPN
Kanayama	JAPN	Shinga	JAPN
Kotsu	JAPN	Shirataki	JAPN
Kune	JAPN	Takaura	JAPN
Machimi	JAPN	Terano	JAPN
Makimine, Hibira	JAPN	Yanahara	JAPN
Minawa	JAPN	Yoshimoto	JAPN
Miyawa	JAPN	Yuryo	JAPN

**Figure 100.** Tonnages of Besshi massive sulfide deposits.

**Figure 101.** Copper grades of Besshi massive sulfide deposits.



**Figure 102.** By-product grades of Besshi massive sulfide deposits. A, Silver. B, Gold. C, Zinc.



**DESCRIPTIVE MODEL OF VOLCANOGENIC Mn**

By Randolph A. Koski

APPROXIMATE SYNONYM Volcanogenic-sedimentary (Roy, 1981)DESCRIPTION Lenses and stratiform bodies of manganese oxide, carbonate, and silicate in volcanic-sedimentary sequences. Genesis related to volcanic (volcanogenic) processes.GENERAL REFERENCE Roy (1981).GEOLOGICAL ENVIRONMENTRock Types Chert, shale, graywacke, tuff, basalt; chert, jasper, basalt (ophiolite); basalt, andesite, rhyolite (island-arc); basalt, limestone; conglomerate, sandstone, tuff, gypsum.Age Range Cambrian to Pliocene.Depositional Environment Sea-floor hot spring, generally deep water; some shallow water marine; some may be enclosed basin.Tectonic Setting(s) Oceanic ridge, marginal basin, island arc, young rifted basin; all can be considered eugeosynclinal.Associated Deposit Types Kuroko massive sulfide deposits.DEPOSIT DESCRIPTIONMineralogy Rhodochrosite, Mn-calcite, braunite, hausmannite, bementite, neotocite, alleghenyite, spessartine, rhodonite, Mn-opal, manganite, pyrolusite, coronadite, cryptomelane, hollandite, todorokite, amorphous MnO<sub>2</sub>.Texture/Structure Fine-grained massive crystalline aggregates, botryoidal, colloform in bedded and lensoid masses.Alteration Spilitic or greenschist-facies alteration of associated mafic lavas, silicification, hematitization.Ore Controls Sufficient structure and porosity to permit subsea-floor hydrothermal circulation and sea-floor venting; redox boundary at seafloor-seawater interface around hot spring; supergene enrichment to upgrade Mn content.Weathering Strong development of secondary Mn oxides (todorokite, birnessite, pyrolusite, amorphous MnO<sub>2</sub>) at the surface and along fractures.Geochemical Signature Although Mn is only moderately mobile and relatively abundant in most rocks, Mn minerals may incorporate many other trace elements such as Zn, Pb, Cu, and Ba.Examples

Olympic Peninsula, USWA	(Park, 1942, 1946; Sorem and Gunn, 1967)
Franciscan type, USCA, USOR	(Taliaferro and Hudson, 1943; Crerar and others, 1982; Snyder 1978; Kuypers and Denyer, 1979)

**GRADE AND TONNAGE MODEL OF VOLCANOGENIC Mn**

By Dan L. Mosier

COMMENTS Tonnage is correlated with manganese grade ( $r = -0.32$ ) and with phosphorus grade ( $r = -0.94$ ,  $n = 8$ ). See figs. 103-104.

DEPOSITS

<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Abuhemsin (Abiulya)	TRKY	Korucular	TRKY
Abundancia	TRKY	La Calanesa	SPAN
Akoakilise Topkirazlar	TRKY	Ladd	USCA
Akoluuk	TRKY	Lagnokaha	UVOL
Akseki Gokceovacik	TRKY	Lasbela	PKTN
Antonio	CUBA	La Unica	CUBA
Augusto Luis and others	CUBA	Laverton-Mt. Lucky	AUWA
Avispa	CUBA	Liberty	USCA
Black Diablo	USNV	Lucia (Generosa)	CUBA
Blue Jay	USCA	Lucifer	MXCO
Boston Group	CUBA	Magdalena	CUBA
Briseida Group and others	CUBA	Manacas Group	CUBA
Buckeye	USCA	Manuel	CUBA
Bueycito	CUBA	Montenegro-Adriana	CUBA
Buritirama	BRZL	Mrima	KNYA
Cadiz	CUBA	Pirki	TRKY
Castillode Palanco	SPAN	Piskala	TRKY
Cavdarli-Komurluk	TRKY	Ponupo	CUBA
Cayirli Koy	TRKY	Ponupo de Manacal	CUBA
Charco Redondo-Casualidad	CUBA	Pozo Prieto	CUBA
Crescent	USWA	Progreso	CUBA
Cubenas	CUBA	Quarzazate	MRCO
Cubuklu Koyu	TRKY	Quinto	CUBA
Cummings	USCA	Raymond	NCAL
Curial-Playa Real-Pavones	CORI	Rhiw	GRBH
Danishment	TRKY	Sabanilla	CUBA
Dassoumble	IVCO	Santa Rosa	CUBA
Djebel Guettara	ALGR	Sapalskoe	URRS
Durnovskoe	URRS	Sereno	BRZL
El Cuervo	SPAN	Sigua	CUBA
Esperancita	CUBA	Soloviejo	SPAN
Estrella-Sopresa	CUBA	South Thomas	USCA
Fabian	USCA	Taratana	CUBA
Faucogney	FRNC	Taritipan	INDS
Foster Mountain	USCA	Thatcher Creek	USCA
Glib en Nam	MRCO	Thomas	USCA
Gloria-Elvira-Polaris	CUBA	Tiere	UVOL
Gocek Koyu	TRKY	Tiouine	MRCO
Gran Piedra	CUBA	Tokoro	JAPN
Guanaba Group	CUBA	Topkirozlar	TRKY
Gunbasi (Akcakese)	TRKY	Toscana (Cerchiara)	ITLY
Hyatt No. 1	PANA	Tutunculer	TRKY
Idikel	MRCO	Valle de Maganeso	CUBA
Jo7	NCAL	Welch	USCA
Jutinicu	CUBA	Woody Woody	AUWA
Komurluk Koyunun	TRKY	Yeya	CUBA

## VOLCANOGENIC MANGANESE

Model 24c--Con.

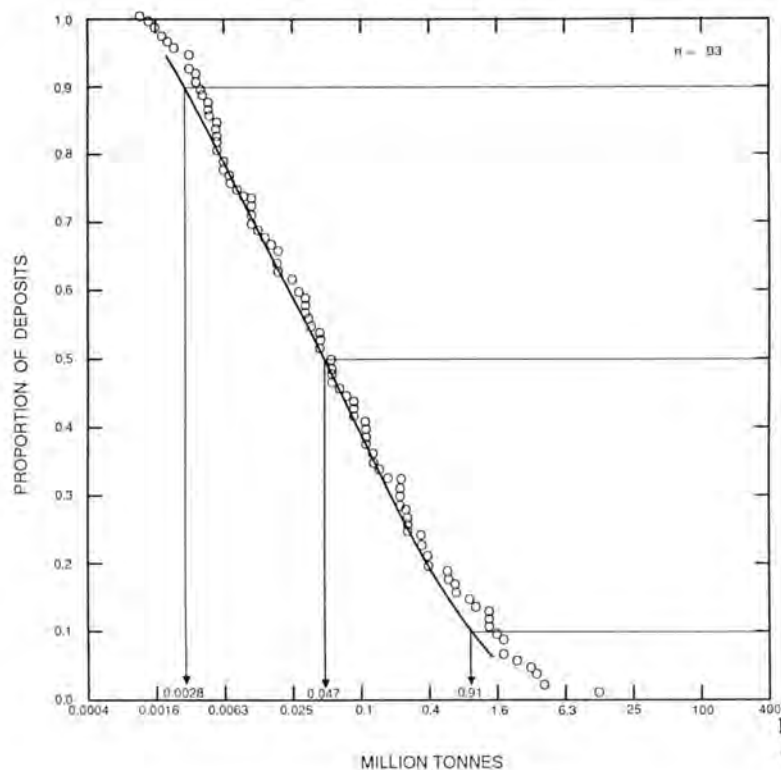
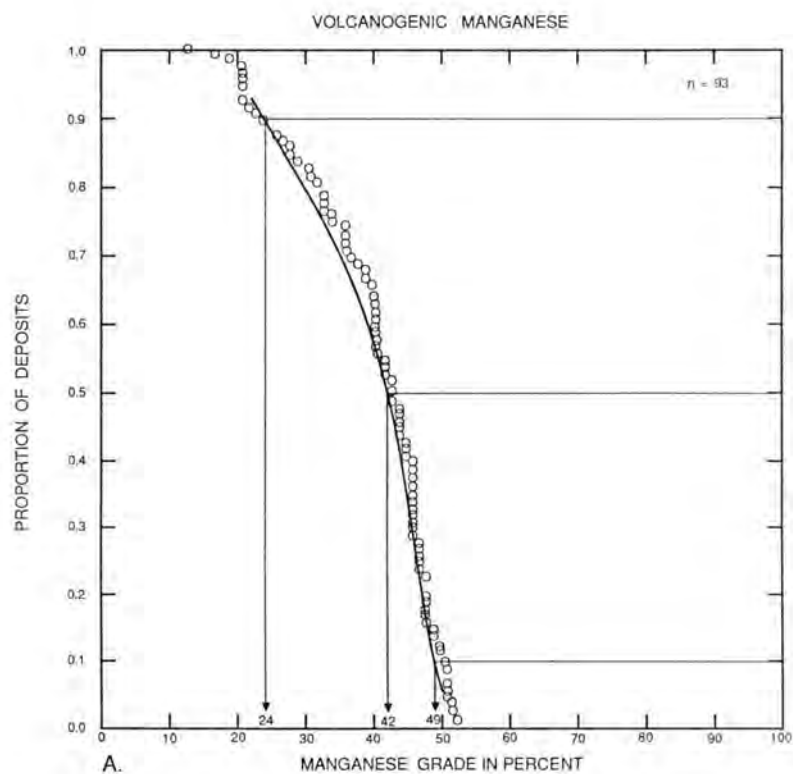
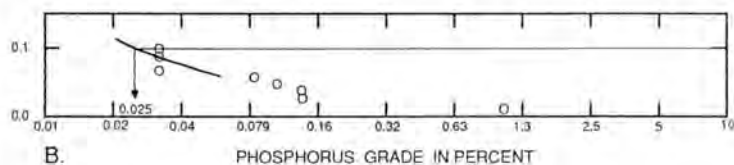


Figure 103. Tonnages of volcanogenic Mn deposits.



A.



B.

Figure 104. Metal grades of volcanogenic Mn deposits. A, Manganese. B, Phosphorus.



## DESCRIPTIVE MODEL OF BLACKBIRD Co-Cu

By Robert L. Earhart

DESCRIPTION Massive and disseminated pyrite, pyrrhotite, arsenopyrite, cobaltite, chalcopyrite, and magnetite in stratabound lenses, stringers, and in quartz-tourmaline breccia pipes.

GENERAL REFERENCES Bennett (1977), Hughes (1983).

### GEOLOGICAL ENVIRONMENT

Rock Types Fine-grained metasedimentary rocks (argillite, siltite, and quartzite), mafic metatuff, and magnetite-pyrite iron formation. Metasedimentary rocks may have large volcanic rock component.

Textures Fine-grained, thin-bedded turbidite sequences, graded beds, mafic dikes.

Age Range The Blackbird example is Proterozoic, but deposits could be of any age.

Depositional Environment Marine turbidite deposition with basaltic pyroclastic activity and submarine hot springs.

Tectonic Setting(s) Failed rift along continental margin.

Similar or Associated Deposit Types Besshi-type massive sulfide (?).

### DEPOSIT DESCRIPTION

Mineralogy Cobaltite, chalcopyrite, pyrite, pyrrhotite, arsenopyrite, and magnetite. Gold and silver are locally present in tourmaline breccia pipes. Breccias contain pyrite-arsenopyrite-pyrrhotite and minor chalcopyrite-cobaltite.

Texture/Structure Fine to fairly coarse sulfides and sulfarsenides in lenses and stringers, locally with cataclastic texture along shear zones. Pyrite locally has colloform structure.

Alteration Silicification and intense chloritization.

Ore Controls Ore commonly occupies disrupted beds, regional distribution of ore closely follows distribution of mafic tuff and (or) iron-formation. Lenses may form at several stratigraphic horizons separated by barren metasedimentary rocks. Relationship between stratabound and breccia pipe mineralization is not understood.

Weathering Forms prominent gossans where sulfide and sulfarsenide-rich rocks crop out.

Geochemical Signature Enriched in Fe, As, B, Co, Cu, Au, Ag, Mn. May be depleted in Ca, Na. Rare-earth and trace-element distribution poorly known.

EXAMPLES Blackbird, USID (Bennett, 1977)

# DESCRIPTIVE MODEL OF HOT-SPRING Au-Ag

By Byron R. Berger

DESCRIPTION Fine-grained silica and quartz in silicified breccia with gold, pyrite, and Sb and As sulfides (see fig. 105).

GENERAL REFERENCE Berger (1985).

## GEOLOGICAL ENVIRONMENT

Rock Types Rhyolite.

Textures Porphyritic, brecciated.

Age Range Mainly Tertiary and Quaternary.

Depositional Environment Subaerial rhyolitic volcanic centers, rhyolite domes, and shallow parts of related geothermal systems.

Tectonic Setting(s) Through-going fracture systems related to volcanism above subduction zones, rifted continental margins. Leaky transform faults.

Associated Deposit Types Epithermal quartz veins, hot-spring Hg, placer Au.

## DEPOSIT DESCRIPTION

Mineralogy Native gold + pyrite + stibnite + realgar; or arsenopyrite ± sphalerite ± chalcopryite ± fluorite; or native gold + Ag-selenide or tellurides + pyrite.

Texture/Structure Crustified banded veins, stockworks, breccias (cemented with silica or uncemented). Sulfides may be very fine grained and disseminated in silicified rock.

Alteration Top of bottom of system: chalcedonic sinter, massive silicification, stockworks and veins of quartz + adularia and breccia cemented with quartz, quartz + chlorite. Veins generally chalcedonic, some opal. Some deposits have alunite and pyrophyllite. Ammonium feldspar (buddingtonite) may be present.

Ore Controls Through-going fracture systems, brecciated cores of intrusive domes; cemented breccias important carrier of ore.

Weathering Bleached country rock, yellow limonites with jarosite and fine-grained alunite, hematite, goethite.

Geochemical Signature Au + As + Sb + Hg + Tl higher in system, increasing Ag with depth, decreasing As + Sb + Tl + Hg with depth. Locally, NH<sub>4</sub>, W.

## EXAMPLES

McLaughlin, USCA

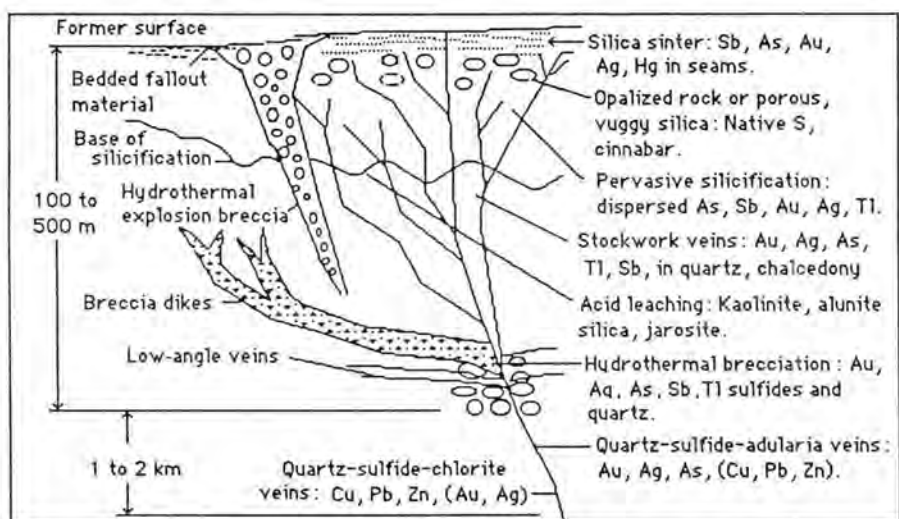
Round Mountain, USNV

Delamar, USID

(Averitt, 1945 and Becker, 1888)

(Tingley and Berger, 1985)

(Lindgren, 1900)



**Figure 105.** Cartoon cross section of hot-spring Au-Ag deposit.

# DESCRIPTIVE MODEL OF CREEDE EPITHERMAL VEINS

By Dan L. Mosier, Takeo Sato, Norman J. Page, Donald A. Singer,  
and Byron R. Berger

APPROXIMATE SYNONYM Epithermal gold (quartz-adularia) alkali-chloride-type, polymetallic veins (see fig. 106).

DESCRIPTION Galena, sphalerite, chalcopryrite, sulfosalts,  $\pm$  tellurides  $\pm$  gold in quartz-carbonate veins hosted by felsic to intermediate volcanics. Older miogeosynclinal evaporites or rocks with trapped seawater are associated with these deposits.

GENERAL REFERENCES Buchanan (1980), Boyle (1979).

## GEOLOGICAL ENVIRONMENT

Rock Types Host rocks are andesite, dacite, quartz latite, rhyodacite, rhyolite, and associated sedimentary rocks. Mineralization related to calc-alkaline or bimodal volcanism.

Textures Porphyritic.

Age Range Mainly Tertiary (most are 29-4 m.y.).

Depositional Environment Bimodal and calc-alkaline volcanism. Deposits related to sources of saline fluids in prevolcanic basement such as evaporites or rocks with entrapped seawater.

Tectonic Setting(s) Through-going fractures systems; major normal faults, fractures related to doming, ring fracture zones, joints associated with calderas. Underlying or nearby older rocks of continental shelf with evaporite basins, or island arcs that are rapidly uplifted.

Associated Deposit Types Placer gold, epithermal quartz alunite Au, polymetallic replacement.

## DEPOSIT DESCRIPTION

Mineralogy Galena + sphalerite + chalcopryrite + copper sulfosalts + silver sulfosalts  $\pm$  gold  $\pm$  tellurides  $\pm$  bornite  $\pm$  arsenopyrite. Gangue minerals are quartz + chlorite  $\pm$  calcite + pyrite + rhodochrosite + barite  $\pm$  fluorite  $\pm$  siderite  $\pm$  ankerite  $\pm$  sericite  $\pm$  adularia  $\pm$  kaolinite. Specularite and alunite may be present.

Texture/Structure Banded veins, open space filling, lamellar quartz, stockworks, colloform textures.

Alteration Top to bottom: quartz  $\pm$  kaolinite + montmorillonite  $\pm$  zeolites  $\pm$  barite  $\pm$  calcite; quartz + illite; quartz + adularia  $\pm$  illite; quartz + chlorite; presence of adularia is variable.

Ore Controls Through-going or anastomosing fracture systems. High-grade shoots where vein changes strike or dip and at intersections of veins. Hanging-wall fractures are particularly favorable.

Weathering Bleached country rock, goethite, jarosite, alunite--supergene processes often important factor in increasing grade of deposit.

Geochemical Signature Higher in system Au + As + Sb + Hg; Au + Ag + Pb + Zn + Cu; Ag + Pb + Zn, Cu + Pb + Zn. Base metals generally higher grade in deposits with silver. W + Bi may be present.

## EXAMPLES

Creede, USCO	(Steven and Eaton, 1975; Barton and others, 1977)
Pachuca, MXCO	(Geyne and others, 1963)
Toyoha, JAPN	(Yajima and Ohta, 1979)

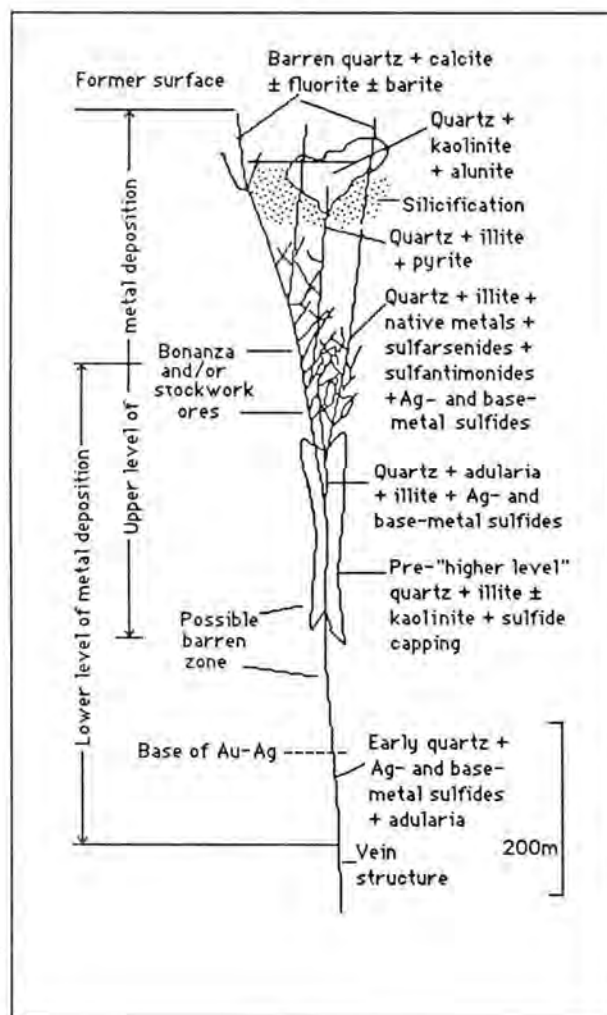
# GRADE AND TONNAGE MODEL OF CREEDE EPITHERMAL VEINS

By Dan L. Mosier, Takeo Sato, and Donald A. Singer

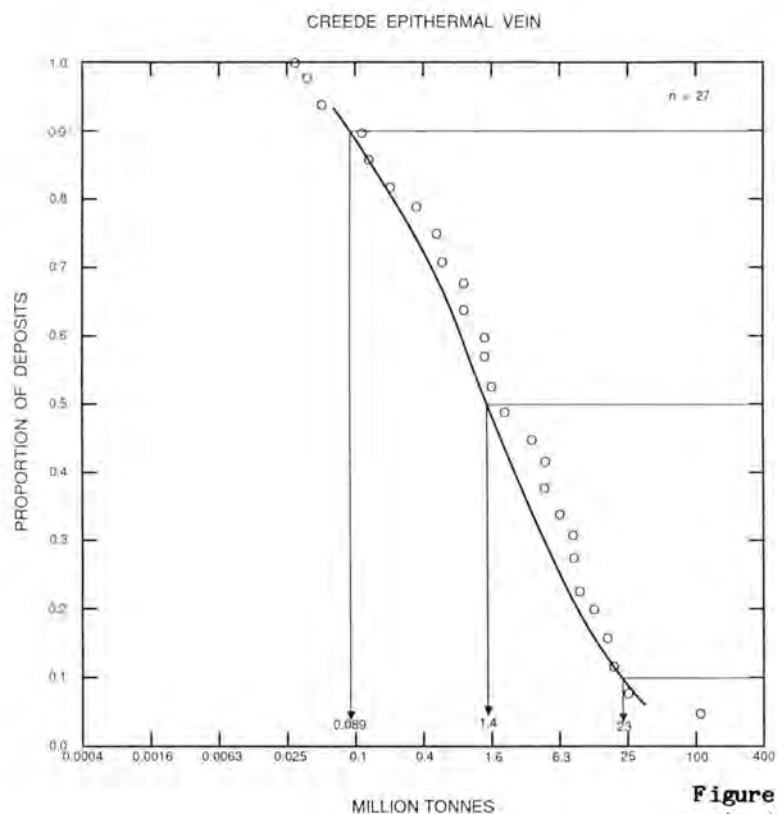
COMMENTS Gold grade is correlated with zinc grade ( $r = -0.52$ ,  $n = 22$ ). See figs. 107-112.

## DEPOSITS

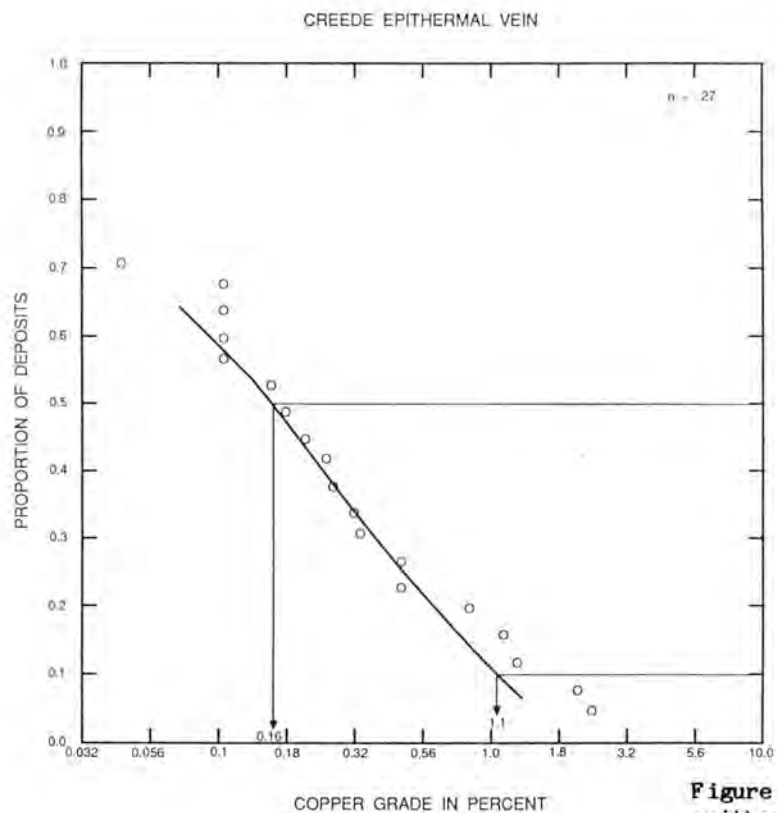
<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Animas	USCO	Nogal	USNM
Bonanza	USCO	Oe	JAPN
Casapalca	PERU	Ogane	JAPN
Chavin	PERU	Ophir	USCO
Coco Mina	NCGA	Pachuca-Real del Monte	MXCO
Colqui	PERU	Red Mountain	USCO
Creede	USCO	Rio Pallanga	PERU
El Tigre	MXCO	Sai	JAPN
Eureka	USCO	Sneffels	USCO
Hosokura	JAPN	Telluride	USCO
Kata	PERU	Toyoha	JAPN
Lake City	USCO	Uruachic	MXCO
Los Mantiales	AGTN	Yatani	JAPN
Madrigal	PERU		



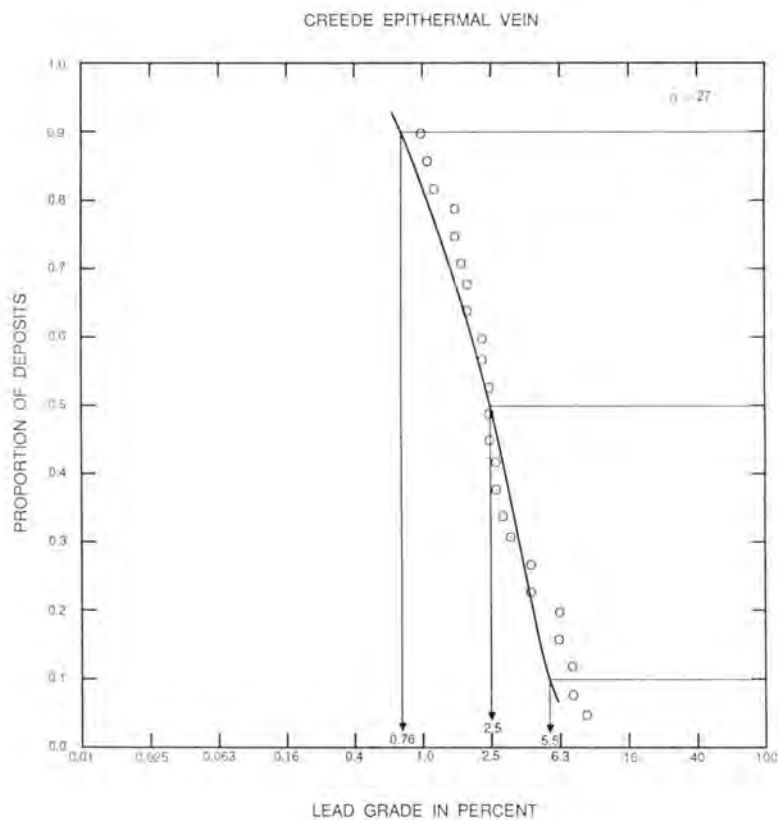
**Figure 106.** Cartoon cross section of typical Creede-type epithermal vein deposit.



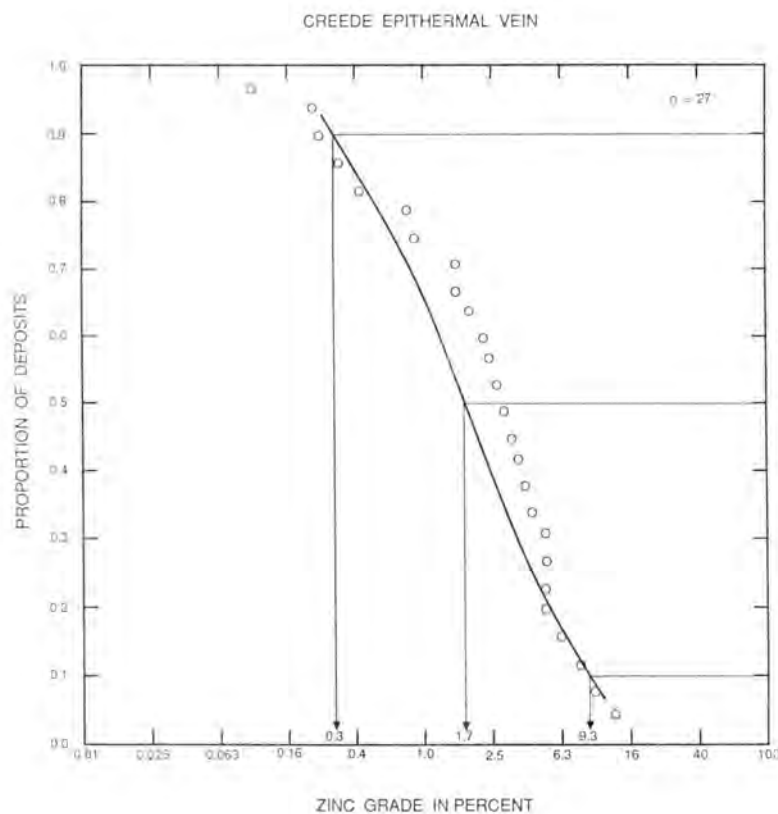
**Figure 107.** Tonnages of Creede epithermal vein deposits.



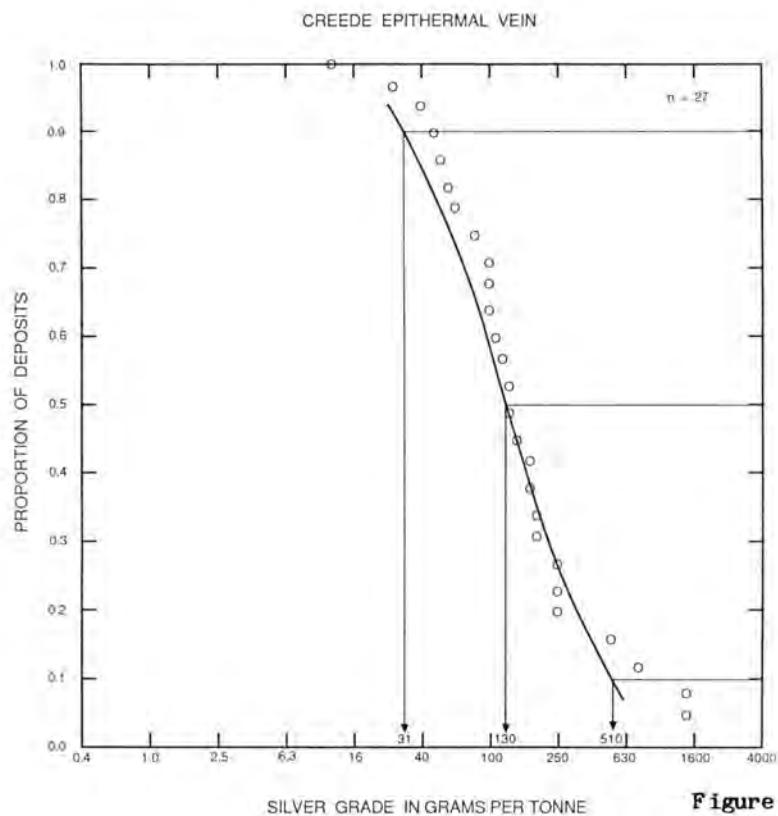
**Figure 108.** Copper grades of Creede epithermal vein deposits.



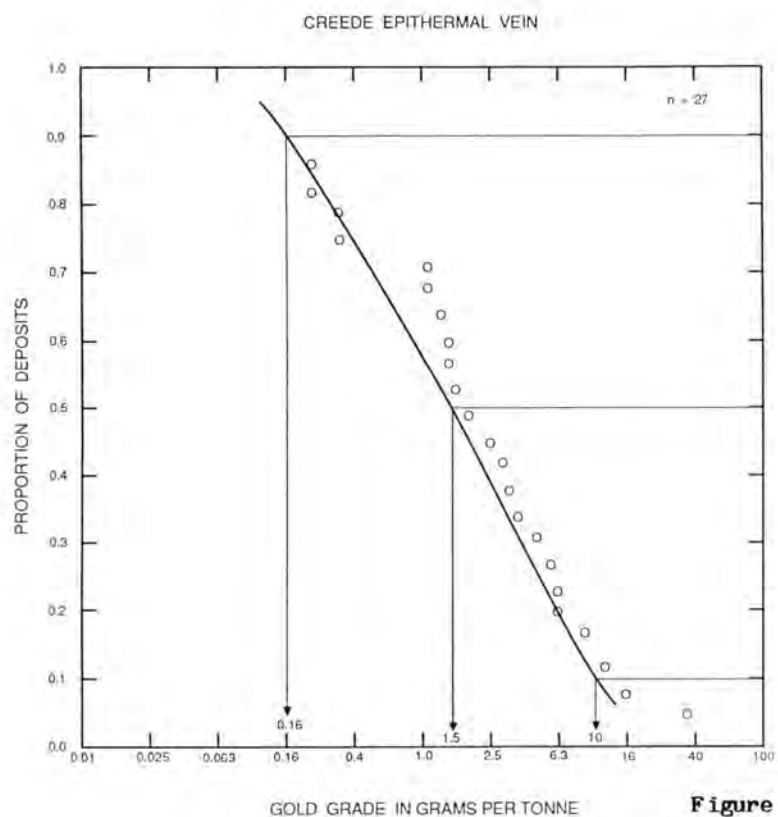
**Figure 109.** Lead grades of Creede epithermal vein deposits.



**Figure 110.** Zinc grades of Creede epithermal vein deposits.



**Figure 111.** Silver grades of Creede epithermal vein deposits.



**Figure 112.** Gold grades of Creede epithermal vein deposits.



## DESCRIPTIVE MODEL OF COMSTOCK EPITHERMAL VEINS

By Dan L. Mosier, Donald A. Singer, and Byron R. Berger

APPROXIMATE SYNONYM Epithermal gold (quartz-adularia) alkali-chloride type.

DESCRIPTION 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 (see fig. 106).

GENERAL REFERENCES Buchanan (1980), Boyle (1979).

### GEOLOGICAL ENVIRONMENT

Rock Types Host rocks are andesite, dacite, quartz latite, rhyodacite, rhyolite; and associated sedimentary rocks. Mineralization related to calc-alkaline or bimodal volcanism.

Textures Porphyritic.

Age Range Mainly Tertiary (most are 40-3.7 m.y.).

Depositional Environment Calc-alkaline and bimodal volcanism and associated intrusive activity over basement rocks composed of clastic sedimentary rocks and their metamorphic equivalents. Volcanic-related geothermal systems lack access to saline fluids from basement sources.

Tectonic Setting(s) Through-going fracture systems, major normal faults, fractures related to doming, ring fracture zones, joints.

Associated Deposit Types Placer gold and epithermal quartz-alunite Au.

### DEPOSIT DESCRIPTION

Mineralogy Argentite + gold or electrum ± silver sulfosalts ± naumannite. Galena, sphalerite, chalcopryite, tellurides, hematite, and arsenopyrite are moderate to sparse. Gangue minerals are quartz + pyrite ± adularia ± calcite ± sericite ± chlorite. Barite, fluorite, rhodochrosite, kaolinite, and montmorillonite are moderate to sparse. Ore minerals constitute only a few percent of vein.

Texture/Structure Banded veins, open space filling, lamellar quartz, stockwork.

Alteration From top to bottom of system: quartz + kaolinite + montmorillonite ± zeolite ± barite ± calcite; quartz + illite; quartz + adularia ± illite; quartz + chlorite; presence of adularia is variable.

Ore Controls Through-going anastomosing fracture systems, centers of intrusive activity. Hanging wall more favorable.

Weathering Bleached country rock, limonite, jarosite, goethite, alunite, hematite, argillization with kaolinite.

Geochemical Signature Higher in system Au + As + Sb + Hg or Au + As + Cu; Au + Ag + Pb + Cu; also Te and W.

### EXAMPLES

Comstock, USNV  
Guanajuato, MXCO

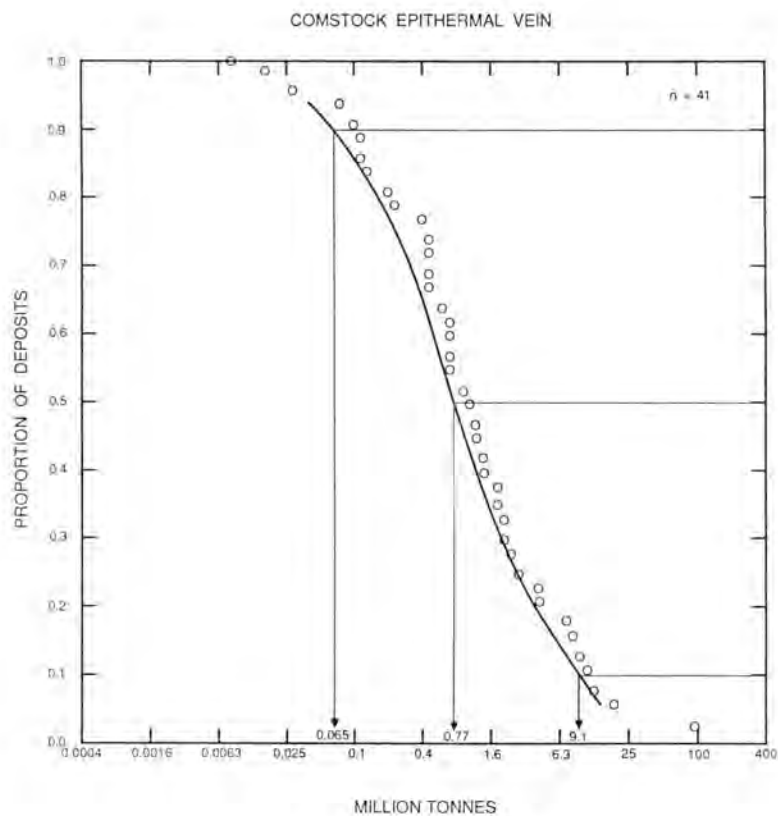
(Becker, 1882)  
(Buchanan, 1980;  
Wandke and Martinez, 1928)

## GRADE AND TONNAGE MODEL OF COMSTOCK EPITHERMAL VEINS

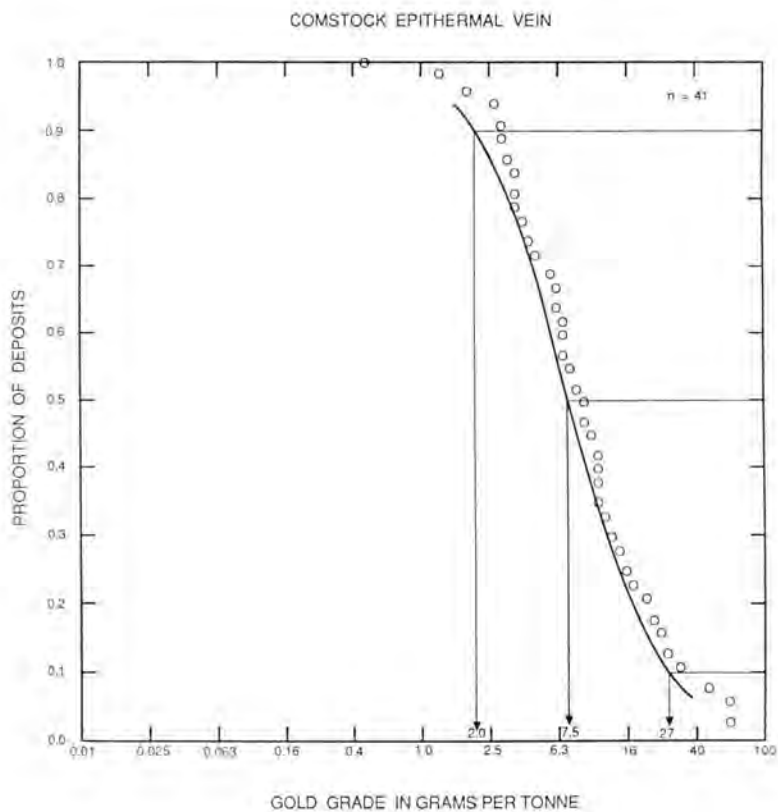
By Dan L. Mosier, Donald A. Singer, and Byron R. Berger

COMMENTS See figs. 113-116.DEPOSITS

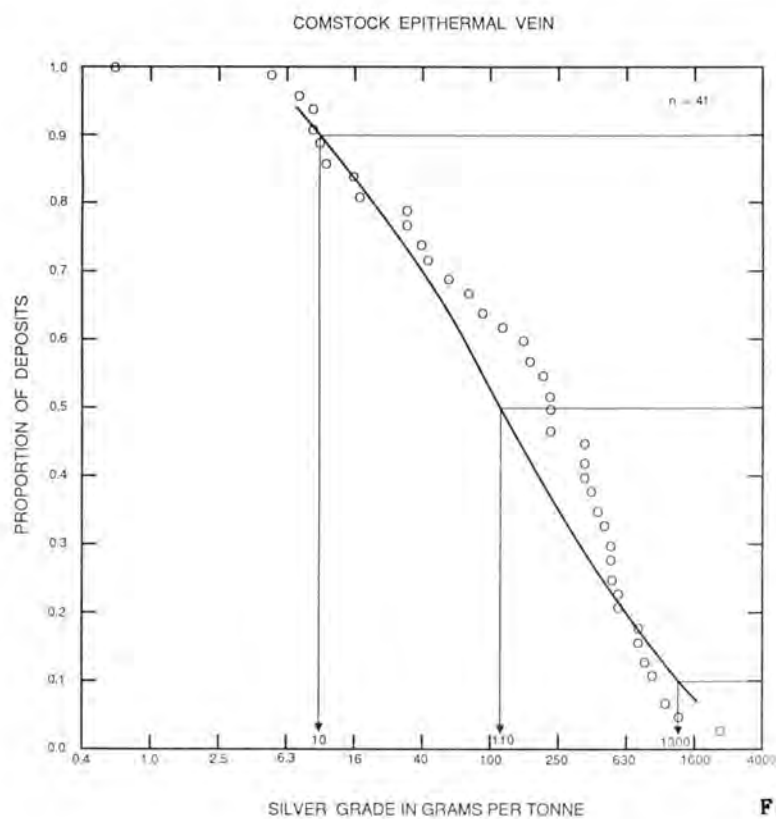
<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Aurora	USNV	Ohguchi	JAPN
Bodie	USCA	Ohito	JAPN
Bovard	USNV	Olinghouse	USNV
Calico	USCA	Orient	USWA
Calistoga	USCA	Patterson	USCA
Comstock	USNV	Republic	USWA
Divide	USNV	Rosario	HNDR
Dolores	MXCO	Sand Springs	USNV
El Rincon	MXCO	Searchlight	USNV
Fairview	USNV	Seikoshi	JAPN
Fuke	JAPN	Seven Trough	USNV
Gold Mountain	USUT	Sheep Tank	USAZ
Guanacevi	MXCO	Silver City	USNV
Guana juato	MXCO	Taio	JAPN
Hostotipaquilla	MXCO	Tayoltita	MXCO
Katherine	USAZ	Toi	JAPN
Kushikino-Arakawa	JAPN	Tonopah	USNV
Mochikoshi	JAPN	Tuscarora	USAZ
Mogollon	USNM	Weaver	USAZ
Nawaji	JAPN	Yugashima	JAPN
Oatman	USAZ		



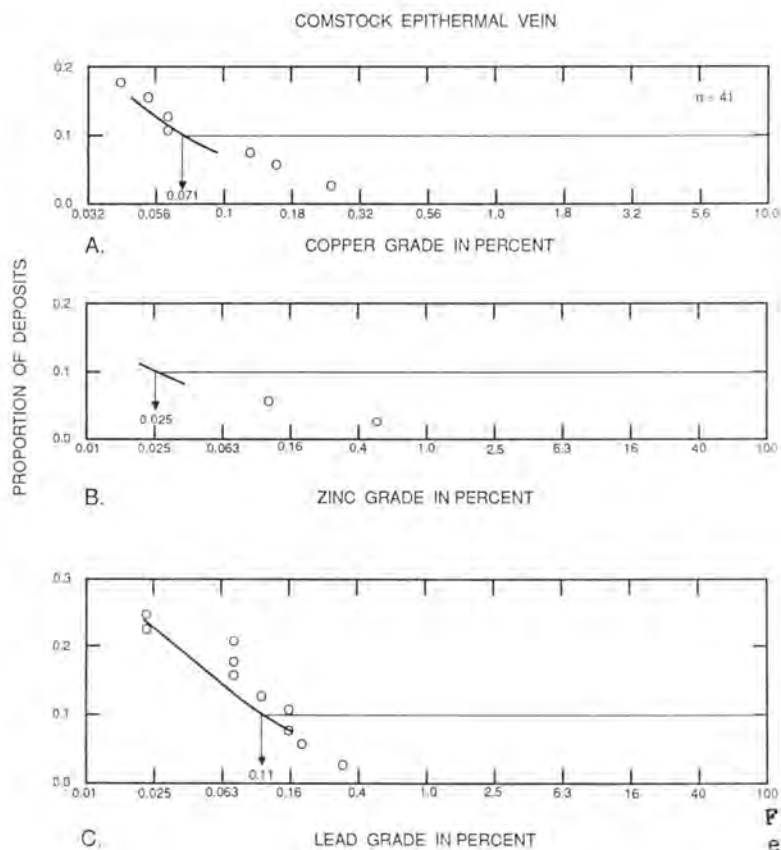
**Figure 113.** Tonnages of Comstock epithermal vein deposits.



**Figure 114.** Gold grades of Comstock epithermal vein deposits.



**Figure 115.** Silver grades of Comstock epithermal vein deposits.



**Figure 116.** By-product grades of Comstock epithermal vein deposits. A, Copper. B, Zinc. C, Lead.

## DESCRIPTIVE MODEL OF SADO EPITHERMAL VEINS

By Dan L. Mosier, Bruce R. Berger, and Donald A. Singer

DESCRIPTION Gold, chalcopyrite, sulfosalts, and argentite in vuggy veins hosted by felsic to intermediate volcanic rocks that overlie older volcanic sequences or igneous intrusions (see fig. 106).

GENERAL REFERENCE Boyle (1979).

### GEOLOGICAL ENVIRONMENT

Rock Types Host rocks are andesite, dacite, quartz latite, rhyodacite, rhyolite, and associated sedimentary rocks. Mineralization related to calc-alkaline or bimodal volcanism.

Textures Porphyritic.

Age Range Mainly Tertiary (most are 38-5 m.y.).

Depositional Environment Calc-alkaline and bimodal volcanism and associated intrusive activity over basement rocks composed of thick, older volcanic sequences or igneous intrusives (batholiths). Volcanic-related geothermal systems lack access to saline fluids from basement sources.

Tectonic Setting(s) Through-going fracture systems, major normal faults, fractures related to doming, ring fracture zones, joints.

Associated Deposit Types Placer gold and quartz-alunite Au.

### DEPOSIT DESCRIPTION

Mineralogy Gold ± argentite + electrum + chalcopyrite. Sulfosalts and tellurides are moderate, galena and sphalerite are sparse. Gangue minerals are quartz ± pyrite ± adularia ± calcite. Chalcedony, adularia, kaolinite, rhodochrosite, chlorite, sericite, and barite are moderate to sparse.

Texture/Structure Banded veins, open space filling, lamellar quartz, stockwork, breccia pipes.

Alteration Silicification zoned by quartz + kaolinite + montmorillonite ± alunite; may have pervasive propylitic alteration of chlorite + calcite.

Ore Controls Through-going fracture systems; major normal faults, fractures related to doming, ring fractures, joints.

Weathering Bleached country rock, limonite, hematite, goethite, jarosite, alunite; argillization with kaolinite.

Geochemical Signature: Au + Ag; Au + Ag + Cu.

### EXAMPLES

Takeno, JAPAN

(Soeda and Watanabe, 1981)

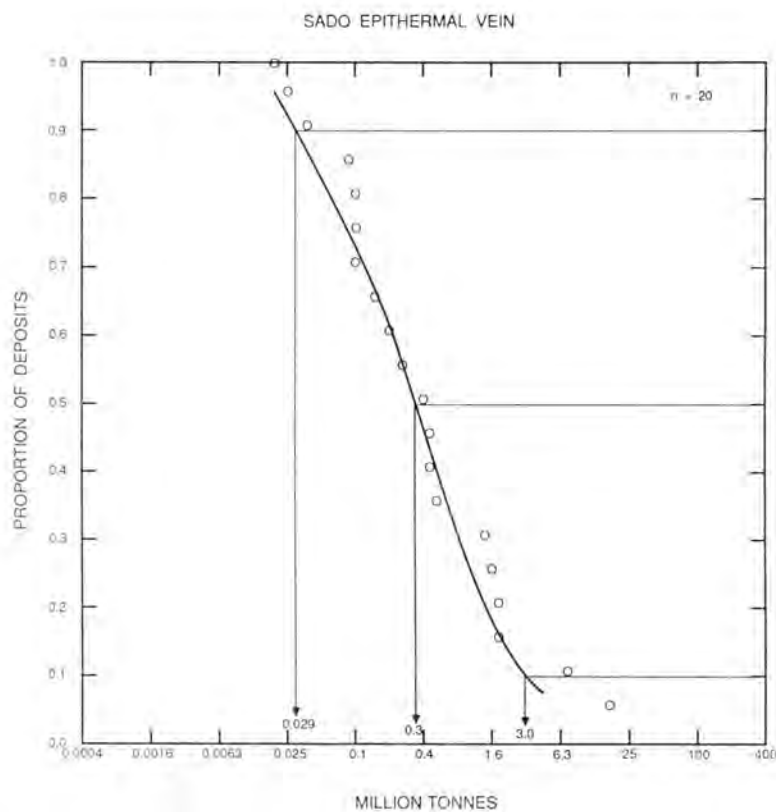
## GRADE AND TONNAGE MODEL OF SADO EPITHERMAL VEINS

By Dan L. Mosier and Takeo Sato

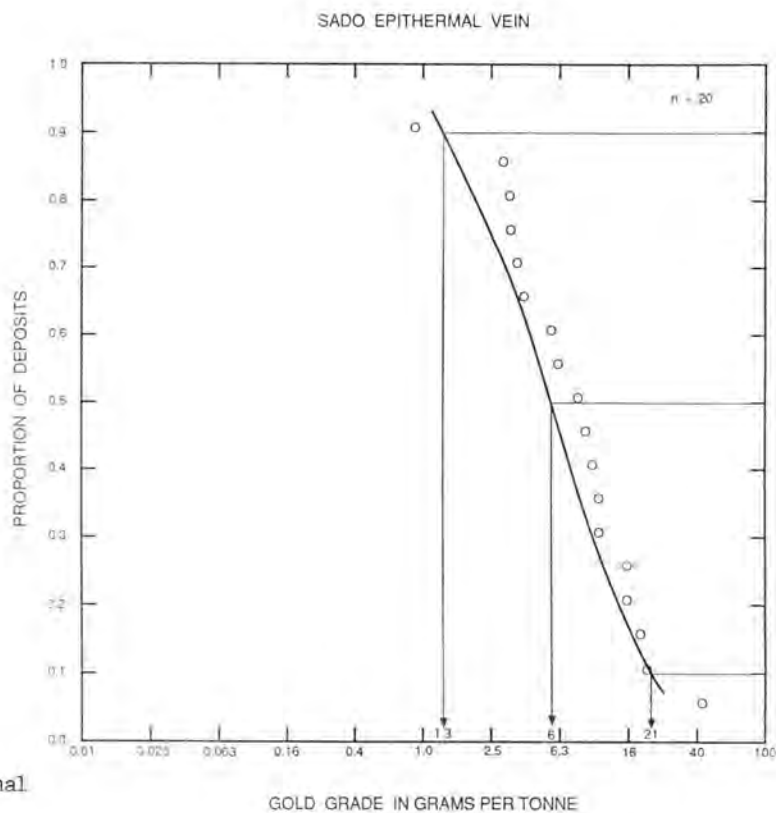
COMMENTS The two lowest gold grades were not plotted because it is suspected that their reported grades are in error. See figs. 117-119.

DEPOSITS

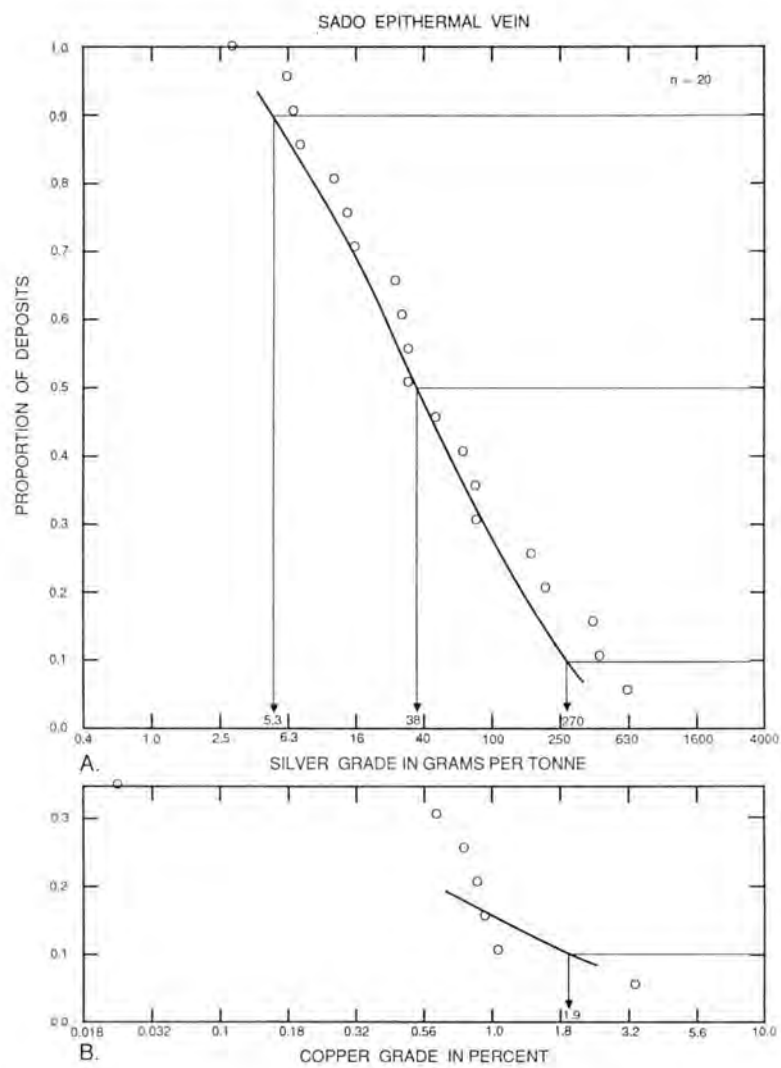
<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Bajo	JAPN	La Libertad	MXCO
Benten	JAPN	Mamuro	JAPN
Bruner	USNV	Mizobe	JAPN
Chitose	JAPN	Nagamatsu	JAPN
Guadalupe and Calvo	MXCO	Sado	JAPN
Hayden Hill	USCA	Sanei	JAPN
High Grade	USCA	Takahata	JAPN
Innai	JAPN	Takatama	JAPN
Kawasaki	JAPN	Takeno	JAPN
Koyama	JAPN	Winters	USCA



**Figure 117.** Tonnages of Sado epithermal vein deposits.



**Figure 118.** Gold grades of Sado epithermal vein deposits.



**Figure 119.** By-product grades of Sado epithermal vein deposits. A, Silver. B, Copper.



## DESCRIPTIVE MODEL OF EPITHERMAL QUARTZ-ALUNITE Au

By Byron R. Berger

APPROXIMATE SYNONYM Acid-sulfate, or enargite gold (Ashley, 1982).

DESCRIPTION Gold, pyrite, and enargite in vuggy veins and breccias in zones of high-alumina alteration related to felsic volcanism.

GENERAL REFERENCE Ashley (1982).

### GEOLOGICAL ENVIRONMENT

Rock Types Volcanic: dacite, quartz latite, rhyodacite, rhyolite. Hypabyssal intrusions or domes.

Textures Porphyritic.

Age Range Generally Tertiary, but can be any age.

Depositional Environment Within the volcanic edifice, ring fracture zones of calderas, or areas of igneous activity with sedimentary evaporites in basement.

Tectonic Setting(s) Through-going fracture systems: keystone graben structures, ring fracture zones, normal faults, fractures related to doming, joint sets.

Associated Deposit Types Porphyry copper, polymetallic replacement, volcanic hosted Cu-As-Sb. Pyrophyllite, hydrothermal clay, and alunite deposits.

### DEPOSIT DESCRIPTION

Mineralogy Native gold + enargite + pyrite + silver-bearing sulfosalts ± chalcopyrite ± bornite ± precious-metal tellurides ± galena ± sphalerite ± huebnerite. May have hypogene oxidation phase with chalcocite + covellite ± luzonite with late-stage native sulfur.

Texture/Structure Veins, breccia pipes, pods, dikes; replacement veins often porous, and vuggy, with comb structure, and crustified banding.

Alteration Highest temperature assemblage: quartz + alunite + pyrophyllite may be early stage with pervasive alteration of host rock and veins of these minerals; this zone may contain corundum, diaspore, andalusite, or zunyite. Zoned around quartz-alunite is quartz + alunite + kaolinite + montmorillonite; pervasive propylitic alteration (chlorite + calcite) depends on extent of early alunite. Ammonium-bearing clays may be present.

Ore Controls Through-going fractures, centers of intrusive activity. Upper and peripheral parts of porphyry copper systems.

Weathering Abundant yellow limonite, jarosite, goethite, white argillization with kaolinite, fine-grained white alunite veins, hematite.

Geochemical Signature Higher in system: Au + As + Cu; increasing base metals at depth. Also Te and (at El Indio) W.

### EXAMPLES

Goldfield, USNV  
Kasuga mine, JAPAN  
El Indio, CILE  
Summitville, USCO  
Iwato, JAPAN

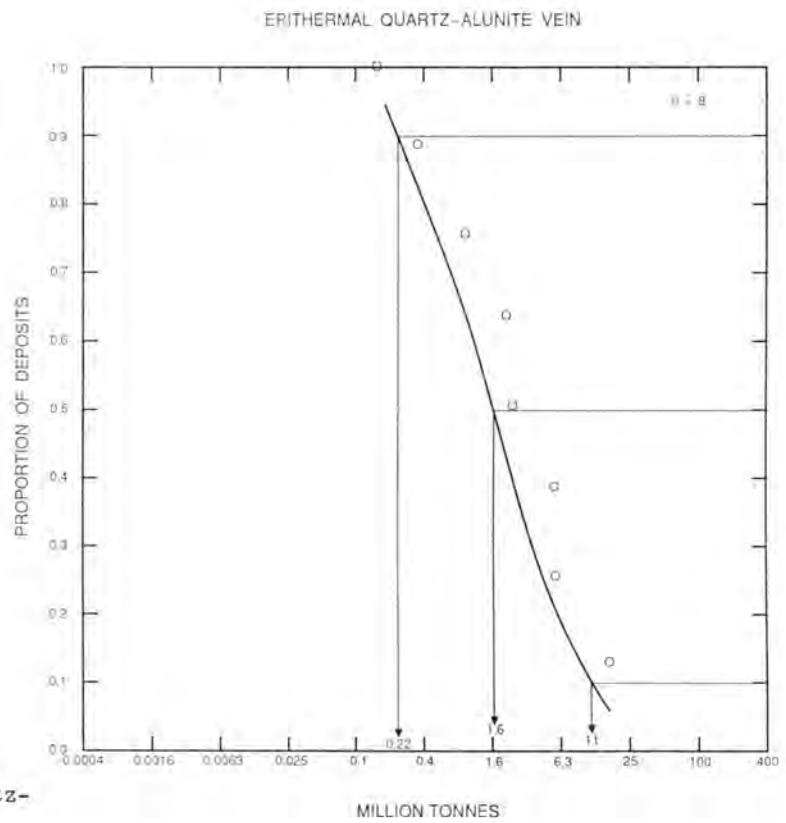
(Ransome, 1909)  
(Taneda and Mukaiyama, 1970)  
(Walthier and others, 1982)  
(Perkins and Nieman, 1983)  
(Saito and Sato, 1978)

## GRADE AND TONNAGE MODEL OF EPITHERMAL QUARTZ-ALUNITE Au

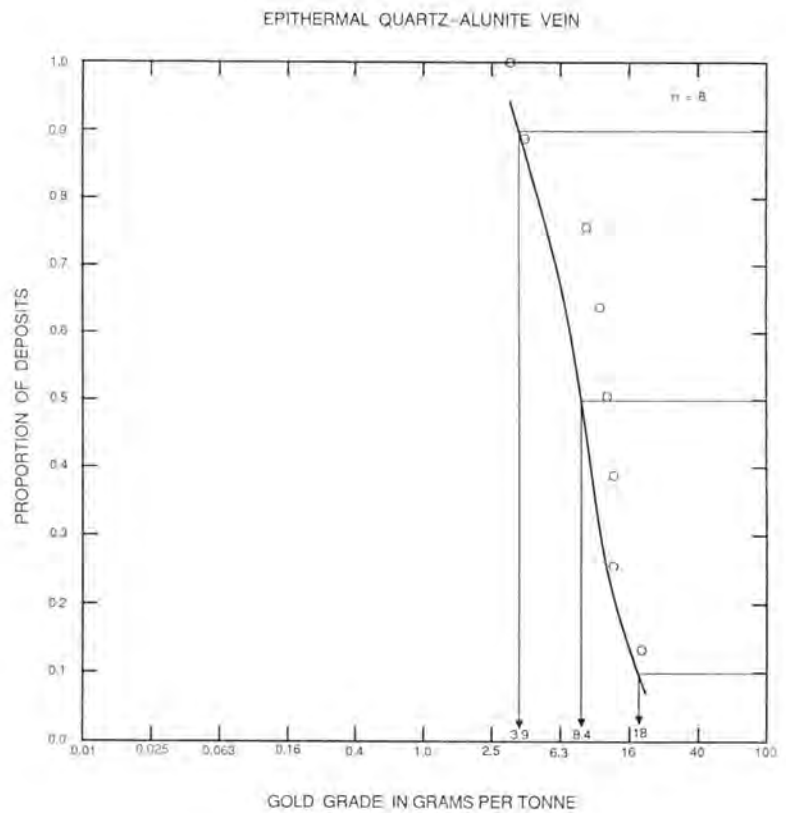
By Dan L. Mosier and W. David Menzie

COMMENTS See figs. 120-123.DEPOSITS

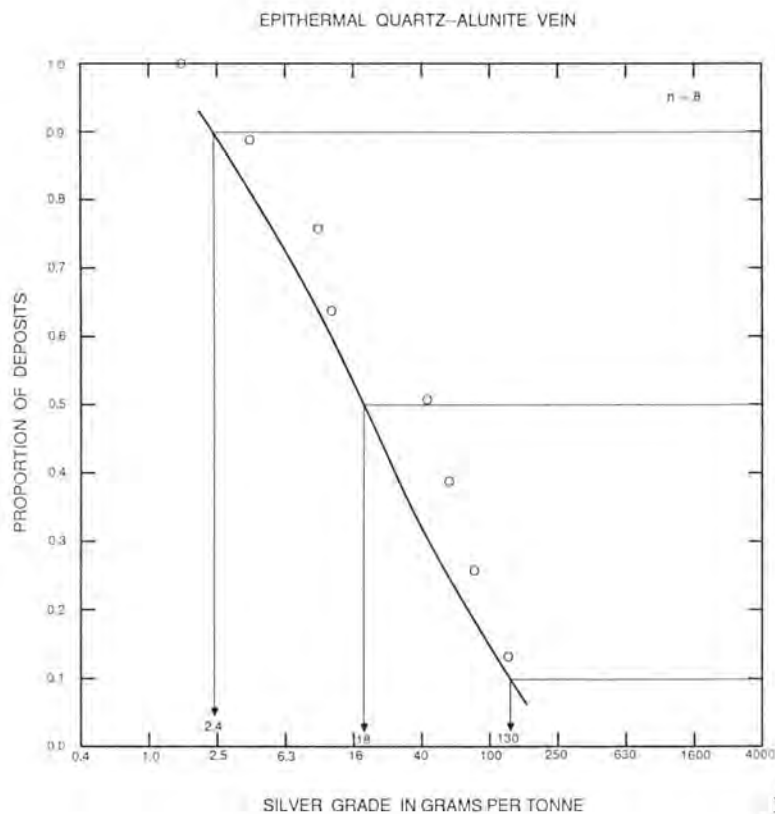
<u>Name</u>	<u>Country</u>
Chinkuashih	TIWN
El Indio	CILE
Goldfield	USNV
Iwato	JAPN
Kasuga	JAPN
Masonic	USCA
Mohave	USCA
Stedman	USCA



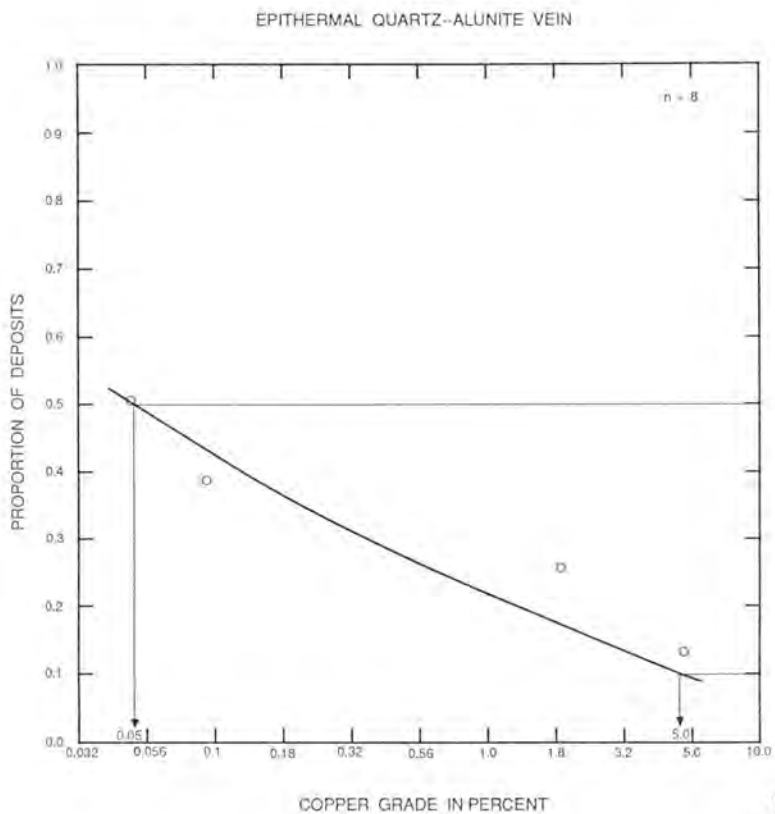
**Figure 120.** Tonnages of epithermal quartz-alunite vein deposits.



**Figure 121.** Gold grades of epithermal quartz-alunite vein deposits.



**Figure 122.** Silver grades of epithermal quartz-alunite vein deposits.



**Figure 123.** Copper grades of epithermal quartz-alunite vein deposits.

## DESCRIPTIVE MODEL OF VOLCANOGENIC U

By William C. Bagby

DESCRIPTION Uranium mineralization in epithermal veins composed of quartz, fluorite, and iron, arsenic, and molybdenum sulfides.

GENERAL REFERENCE Nash (1981).

### GEOLOGICAL ENVIRONMENT

Rock Types High-silica alkali rhyolite and potash trachytes. Peralkaline and peraluminous rhyolite host ore.

Textures Porphyritic to aphyric vesicular flows and shallow intrusive rocks.

Age Range Precambrian to Tertiary.

Depositional Environment Subaerial to subaqueous volcanic complexes. Near-surface environment, association with shallow intrusive rocks is important.

Tectonic Setting(s) Continental rifts and associated calderas.

Associated Deposit Types Roll-front uranium in volcanoclastic sediments. Fluorite deposits.

### DEPOSIT DESCRIPTION

Mineralogy Coffinite, uraninite, brannerite are most common uranium minerals. Other minerals include pyrite, realgar/orpiment, leucocoxene, molybdenite, fluorite, quartz, adularia, and barite. Gold is present in some deposits. Deposits associated with alkaline complexes may contain bastnaesite.

Texture/Structure Open-space filling in breccias. Uraninite commonly encapsulated in silica.

Alteration Kaolinite, montmorillonite, and alunite are common. Silicification, accompanied by adularia, affects wallrocks spatially most closely associated with ore.

Ore Controls Through-going fractures and breccias formed along the margins of shallow intrusives. Vugs in surface flows are of minor importance.

Weathering Near-surface oxidation produces jordisite and a variety of secondary uranium minerals. Supergene uranium enrichment is generally not important.

Geochemical Signature Li and Hg are zoned away from the ore. High anomalous As, Sb, F, Mo  $\pm$  W occur near and with the ore. Mo is deep, Hg is shallow. REE may be highly anomalous. Anomalously radioactive.

### EXAMPLES

Marysville, USUT	(Kerr and others, 1957)
Aurora prospect, USOR	(Roper and Wallace, 1981)
Rexspar, CNBC	(Joubin and James, 1956)

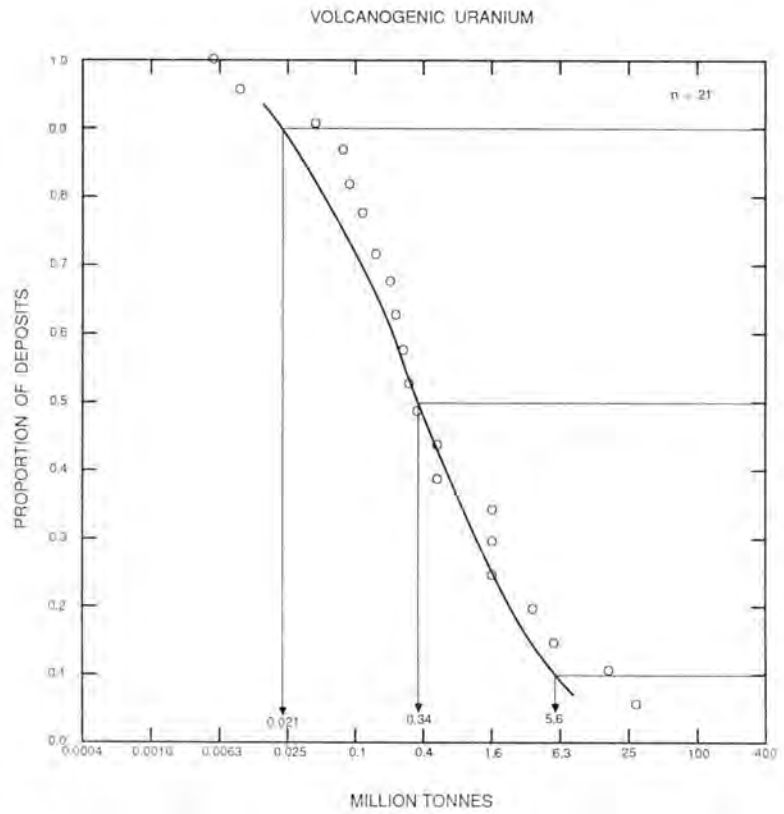
## GRADE AND TONNAGE MODEL OF VOLCANOGENIC U

By Dan L. Mosier

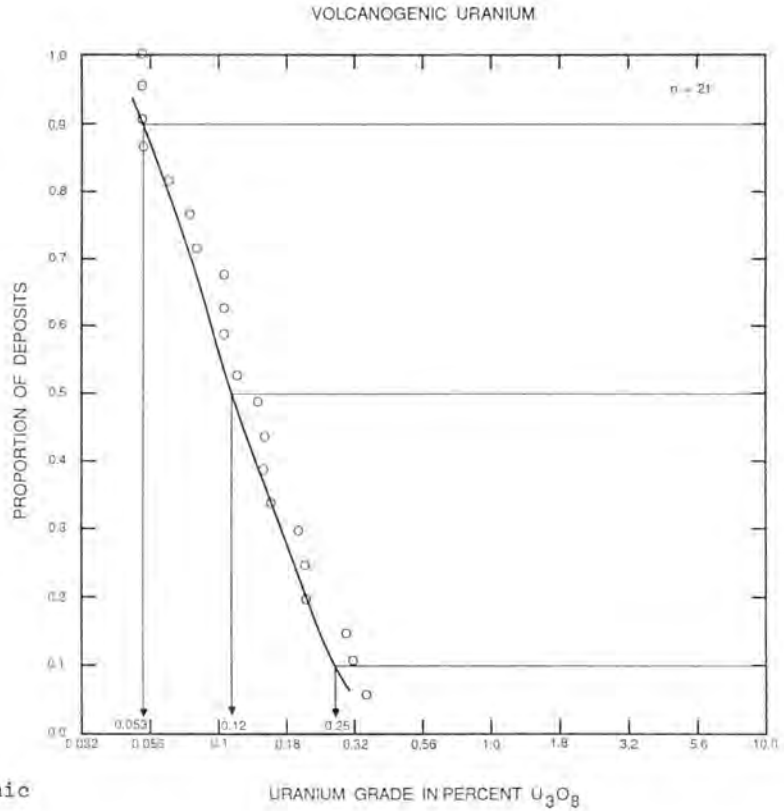
COMMENTS Only deposits with reported sizes greater than 1,000 tonnes are included. See figs. 124, 125.

DEPOSITS

<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Aurora	USOR	Los Puertos	MXCO
Ben Lomond	AUQL	Lucky Lass	USOR
Bretz	USOR	Macusani	PERU
Buckhorn	USNV	Moonlight	USNV
Coteje	BLVA	Nopal III	MXCO
El Mezquite	MXCO	Novazza	ITLY
El Nopal (Nopal I)	MXCO	Osamu Utsumi	BRZL
Henry district	USUT	Petersen Mtn.	USCA
La Bajada	USNM	Rexspar	CNBC
Laguna Colorado	AGTN	White King	USOR
Laguna del Cuervo	MXCO		



**Figure 124.** Tonnages of volcanogenic U deposits.



**Figure 125.** Uranium grades of volcanogenic U deposits.

## DESCRIPTIVE MODEL OF EPITHERMAL Mn

By Dan L. Mosier

DESCRIPTION Manganese mineralization in epithermal veins filling faults and fractures in subaerial volcanic rocks.

GEOLOGICAL ENVIRONMENT

Rock Types Flows, tuffs, breccias, and agglomerates of rhyolitic, dacitic, andesitic or basaltic composition.

Age Range Tertiary.

Depositional Environment Volcanic centers.

Tectonic Setting(s) Through-going fracture systems.

Associated Deposit Types Epithermal gold-silver.

DEPOSIT DESCRIPTION

Mineralogy Rhodochrosite, manganocalcite, calcite, quartz, chalcedony, barite, zeolites.

Texture/Structure Veins, bunches, stringers, nodular masses, disseminations.

Alteration Kaolinitization.

Ore Controls Through-going faults and fractures; brecciated volcanic rocks.

Weathering Oxidization zone contains abundant manganese oxides, psilomelane, pyrolusite, braunite, wad, manganite, cryptomelane, hollandite, coronadite, and Fe oxides.

Geochemical Signature Mn, Fe, P(Pb, Ag, Au, Cu). At Talamantes W is important.

EXAMPLES

Talamantes, MXCO  
Gloryana, USNM  
Sardegna, ITALY

(Rocha and Wilson, 1948)  
(Farnham, 1961)  
(Burckhardt and Falini, 1956)

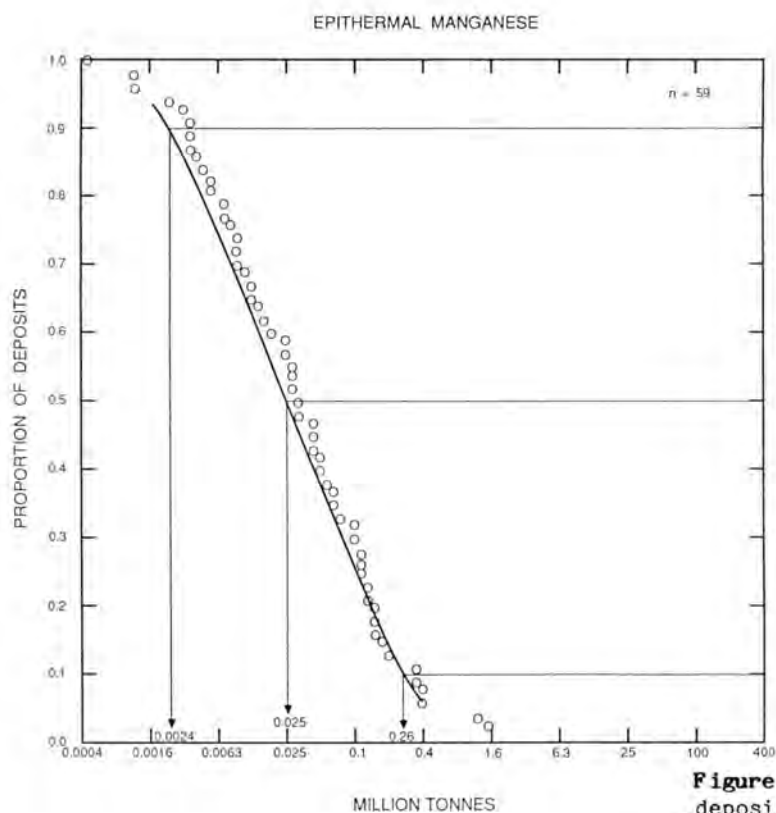


## GRADE AND TONNAGE MODEL OF EPITHERMAL Mn

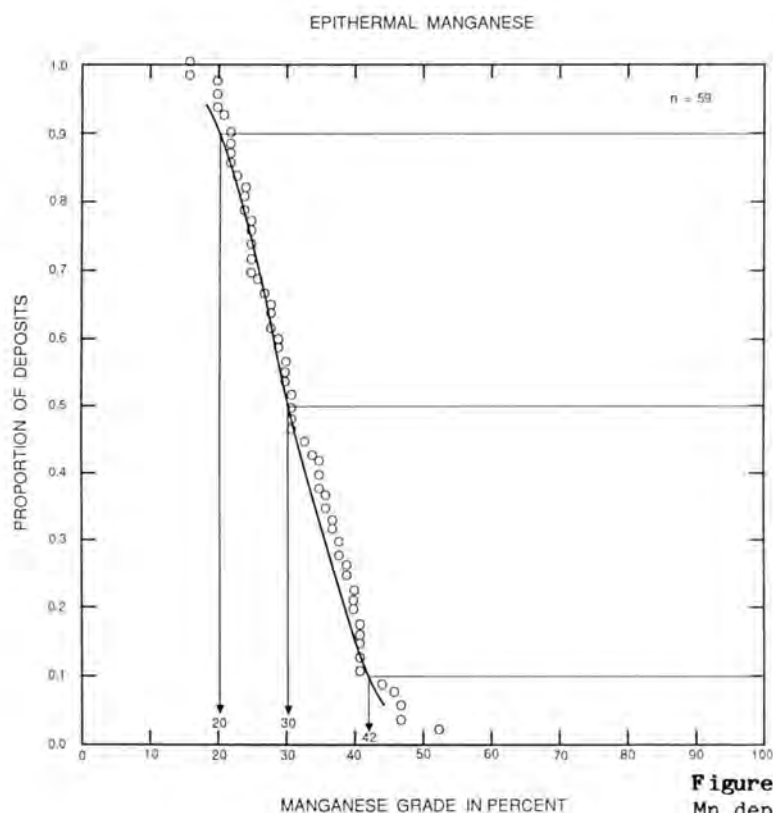
By Dan L. Mosier

COMMENTS See figs. 126-127.DEPOSITS

<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Abra Negra	MXCO	Murguia	MXCO
Armour Group	USAZ	Nacozari	MXCO
Atenguillo	MXCO	Niggerhead	USNM
Black Crow-San Juan	USNM	Oviachic 1&2	MXCO
California Group	USAZ	Phillips Lease	USNM
Casa de Janos	MXCO	Pito Real	MXCO
Casas Grandes	MXCO	Red Hill-Red Hill Ext.	USNM
Ciudad Obregon	MXCO	St. Pietro	ITLY
Cliff Roy	USNM	San Bernardo	MXCO
Estacion Llanos	MXCO	San Miguel El Alto	MXCO
Gloryana	USNM	Santa Ana	MXCO
Griffith	USNM	Sardegna	ITLY
Hatton	USAZ	Satevo	MXCO
J.M. Meadows Group	USAZ	Selimiye	TRKY
JVB Claim	USNM	Shag Rock	CNBC
Karangnunggal	INDS	Sierra de El Alto	MXCO
Karatas	TRKY	Sierra de Enmedio	MXCO
Kliripan	INDS	Sierra Los Organos	MXCO
Lajas	MXCO	Soto	MXCO
La Leona	MXCO	Talamantes	MXCO
La Noria	MXCO	Terrenates	MXCO
Las Varas-La Vaca	MXCO	Thurston & Hardy	USAZ
Los Borregos	MXCO	Topock	USAZ
Los Volcanes	MXCO	Turfullar	TRKY
M and M Group	USNM	U.S. Group	USAZ
Manganese Chief	USNM	Viterbo-Roma	ITLY
Manganese Development	USAZ	West Niggerhead	USNM
Matamoros	MXCO	Yahualica	MXCO
Mezcala	MXCO	Zacate-Cerro Chino	MXCO
Montosa	MXCO		



**Figure 126.** Tonnages of epithermal Mn deposits.



**Figure 127.** Manganese grades of epithermal Mn deposits.

## DESCRIPTIVE MODEL OF RHYOLITE-HOSTED Sn

By Bruce L. Reed, Wendell Duffield, Stephen D. Ludington, Charles H. Maxwell,  
and Donald H. Richter

APPROXIMATE SYNONYM Mexican-type.

DESCRIPTION Cassiterite and wood tin in discontinuous veinlets in rhyolite flow-dome complexes and derivative placers (see fig. 128).

GENERAL REFERENCES Lee-Moreno (1980), Huspeni and others (1984).

### GEOLOGICAL ENVIRONMENT

Rock Types Alkali-feldspar rhyolite with  $\text{SiO}_2$  >75 percent; includes topaz rhyolites of Burt and others (1982) and Christiansen and others (1983). Distinctive accessory minerals may include topaz, fluorite, bixbyite, pseudobrookite, and beryl. Petrochemical signature similar to Climax Mo.

Textures Crystal-poor (5 percent) to crystal-rich (50 percent) rhyolite with quartz and sanidine phenocrysts; rare fayalite, biotite, or hornblende may be present.

Age Range Tertiary; chiefly Oligocene and Miocene.

Depositional Environment Rhyolite flow-dome complexes and related pyroclastic and epiclastic rocks.

Tectonic Setting(s) Silicic volcanic fields, generally in areas of thick continental crust.

Associated Deposit Types None are known, but based on geochemical similarity of associated magmas, these may be a surface expression of Climax Mo.

### DEPOSIT DESCRIPTION

Mineralogy Cassiterite (including wood tin) plus hematite (characteristically specularite)  $\pm$  cristobalite, fluorite, tridymite, opal, chalcedony, beudantite, mimetite, adularia, durangite, and zeolite minerals.

Texture/Structure Most commonly as 0.1- to 10-cm-wide discontinuous veins and veinlets whose other dimensions seldom exceed 75 m. These veins and veinlets may be clustered in zones of somewhat greater dimension. Cassiterite also occurs as disseminations in the matrix of rhyolite flows or fault breccias. These two types of deposits are part of a continuum.

Alteration May be absent; tin may or may not occur in large areas of vapor-phase alteration (tridymite, sanidine, hematite,  $\pm$  pseudobrookite); alteration directly associated with mineralization may include cristobalite, fluorite, smectite, kaolinite, and other clay minerals.

Ore Controls Deposits are generally in the fractured and brecciated outer parts of flow-dome complexes where permeability is high.

Weathering Weathering is generally minor, but a translucent red-orange clay mineral (smectite) is present in most deposits.

Geochemical Signature Dispersion of associated elements (Sn, Fe, Be, Li, F, As, Sb, Pb, Zn, Bi, REE) in rock is minimal. Best exploration guide is presence of high concentrations of tin (>1,000 ppm) in pan concentrate samples. Cassiterite in stream sediments is usually restricted to within 2-3 km of tin deposits.

### Examples

Black Range, USNM  
Mexico deposits

(Fries, 1940; Lufkin, 1972)  
(Foshag and Fries, 1942; Smith and others,  
1950; Ypma and Simons, 1969; Pan, 1974;  
Lee-Moreno, 1980)

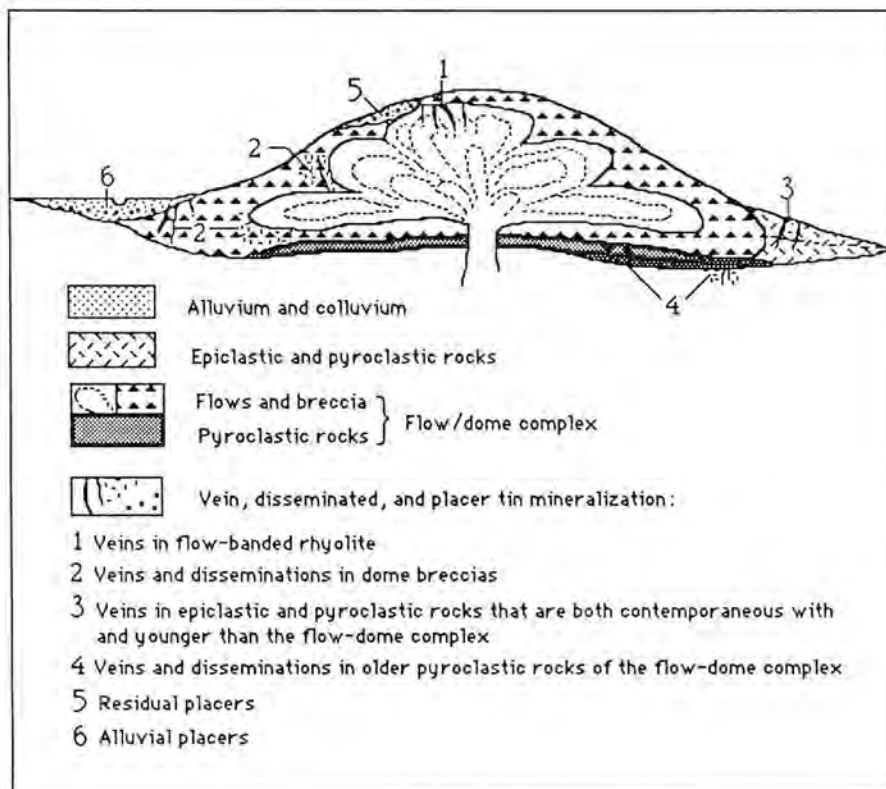
## GRADE AND TONNAGE MODEL OF RHYOLITE-HOSTED Sn

By Donald A. Singer and Dan L. Mosier

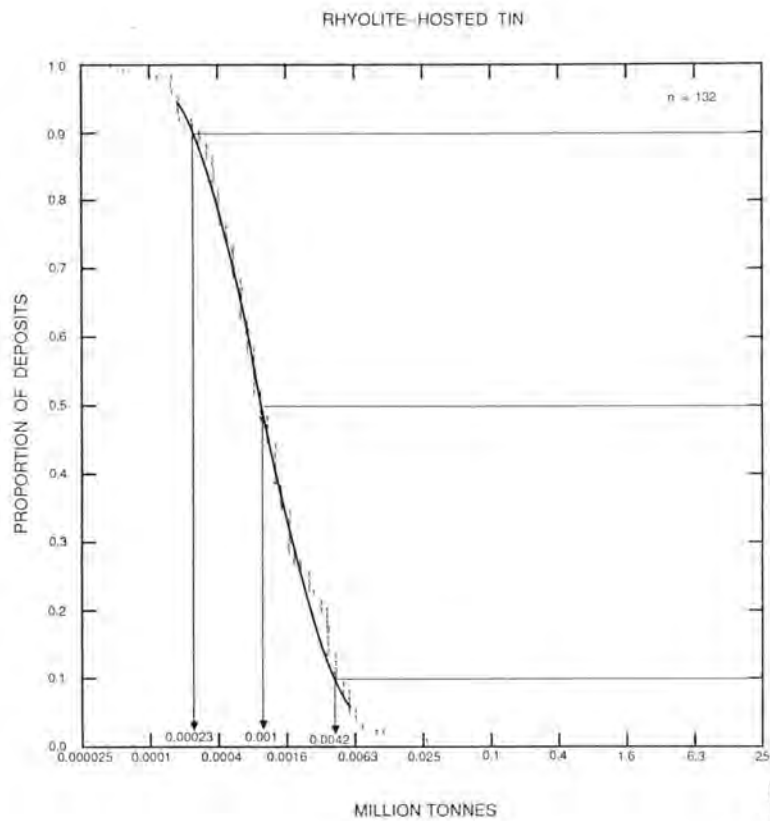
COMMENTS See figs. 129-130.DATA REFERENCES Bracho (1960, 1961).COMMENTS Grade and tonnage estimates were based on reserves. Tonnage is significantly correlated with tin grades ( $r = 0.36$ ).DEPOSITS

<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Arguilillas	MXCO	El Picacho	MXCO
Amigos	MXCO	El Pleito	MXCO
Arrieros #2	MXCO	El Polvillo	MXCO
Arrieros #3	MXCO	El Profesor	MXCO
Arrieros #4	MXCO	El Romadizo	MXCO
Arroyo Durango	MXCO	El Santo Nino	MXCO
Castrita	MXCO	El Socavon #4	MXCO
Catas de las Vacas	MXCO	El Socavon #5	MXCO
Catas el Durango	MXCO	El Socavon #6	MXCO
Cerro Blanco	MXCO	El Socavon #7	MXCO
Cerro Grande	MXCO	El Socavon #8	MXCO
Cerro Prieto,		El Tarango	MXCO
La Quemada, La		El Venado	MXCO
Colocion	MXCO	El Zanzon	MXCO
Chavarria	MXCO	Galvan	MXCO
Cordon Estaneros	MXCO	Gavilancillos	MXCO
Don Teodoro	MXCO	Grupos 1 & 2-Vendo W	MXCO
El Abra	MXCO	Grupos 3 & 4	MXCO
El Atascadero	MXCO	Guadalupe	MXCO
El Baluarte	MXCO	Hierbaniz	MXCO
El Barroso	MXCO	La Chapeteada	MXCO
El Borrego #1	MXCO	La Chililla	MXCO
El Borrego #2	MXCO	La Chinche	MXCO
El Calabrote	MXCO	La Chorrera	MXCO
El Capulin	MXCO	La Cinta Corrida	MXCO
El Coloradillo	MXCO	La Cocona	MXCO
El Corral	MXCO	La Desparramada	MXCO
El Cristal	MXCO	La Escondida	MXCO
El Dorado	MXCO	La Esperanza (El Aguila)	MXCO
El Duraznillo	MXCO	La Esperanza (La Ochoa)	MXCO
El Durazno (El		La Esperanza (Los Angeles)	MXCO
Aguila)	MXCO	La Estrella	MXCO
El Durazno (Juan Aldama)	MXCO	La Guera	MXCO
El Encino	MXCO	La Hormiga	MXCO
El Gotera	MXCO	La Huacalona	MXCO
El Huacal	MXCO	La Leona	MXCO
El Indio, El		La Loba	MXCO
Plieto, Tadeo,		La Liendre	MXCO
San Antonio	MXCO	La Mula	MXCO
El Ladrillo	MXCO	La Polvosa	MXCO
El Mamey	MXCO	La Puntilla	MXCO
El Naranjo, Buena		Las Aguilas	MXCO
Suerte	MXCO	Las Amarillas	MXCO
El Noladero	MXCO	Las Calaveras	MXCO
El Nopal (Juan Aldama)	MXCO	Las Flores	MXCO
El Nopal (La Ochoa)	MXCO	Las Fundiciones	MXCO
El Penasco	MXCO	Las Marias	MXCO
El Perdido	MXCO	Las Pegazones	MXCO

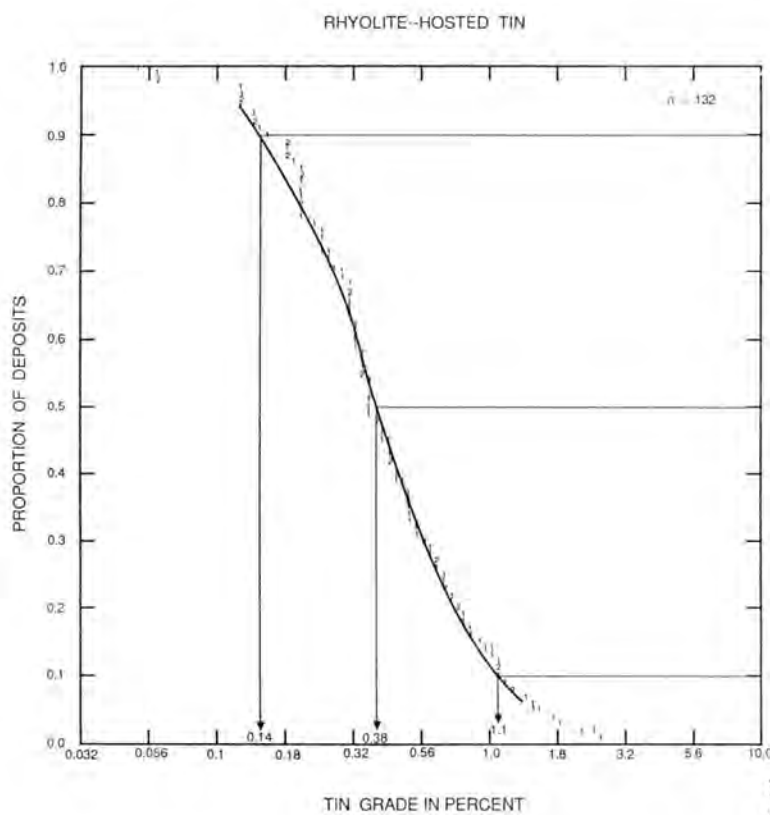
Las Perlititas	MXCO	Mina del Aire	MXCO
Las Tablas	MXCO	Mina Dura	MXCO
La Triste	MXCO	Palo Colorado	MXCO
La Venadita	MXCO	Panchillo	MXCO
La Vibora	MXCO	Plan de Tecolotes	MXCO
La Victoria	MXCO	Potrero del Molino	MXCO
La Vieja-El Agua	MXCO	San Francisco	MXCO
Leoncitos	MXCO	San Humberto	MXCO
Loreto	MXCO	San Juanera	MXCO
Los Angeles	MXCO	San Rafael	MXCO
Los Arrieros	MXCO	San Ruperto	MXCO
Los Caballos	MXCO	Santa Efigenia	MXCO
Los Campamentos #1	MXCO	Santa Gertrudis	MXCO
Los Campamentos #2	MXCO	Santa Leonor	MXCO
Los Campamentos #3	MXCO	Santa Lucia	MXCO
Los Cuatillos	MXCO	Socorro-Guadalupe	MXCO
Los Garcia	MXCO	Sombreretillo	MXCO
Los Lobos	MXCO	Soto	MXCO
Los Pinacates	MXCO	Tecolotes	MXCO
Manga de Lopez	MXCO	Tolano	MXCO
Manzanillas	MXCO	Veta Blanca	MXCO
Metal Negro	MXCO		



**Figure 128.** Cartoon cross section of rhyolite-hosted Sn deposit showing relationship of cassiterite concentrations to rhyolite dome.



**Figure 129.** Tonnages of rhyolite-hosted Sn deposits. Individual digits represent number of deposits.



**Figure 130.** Tin grades of rhyolite-hosted Sn deposits. Individual digits represent number of deposits.

## DESCRIPTIVE MODEL OF VOLCANIC-HOSTED MAGNETITE

By Dennis P. Cox

APPROXIMATE SYNONYM Porphyrite iron, Kiruna iron.DESCRIPTION Massive concordant and discordant magnetite ore bodies in intermediate to alkalic volcanic rocks with actinolite or diopside alteration.GEOLOGICAL ENVIRONMENTRock Types Andesitic to trachytic flows and subvolcanic intrusions, also at Kiruna, quartz porphyry, syenite porphyry, monzonite, and diorite.Textures Porphyroaphanitic to fine- to medium-grained equigranular. Flows may be amygdaloidal.Age Range Mesozoic to Holocene in circum-Pacific area. In Sweden and Missouri, 1,300-1,500 m.y.Depositional Environment Continental volcanic rocks and clastic sediments intruded by subvolcanic intermediate plutons.Tectonic Setting(s) Continental margin, subduction-related volcanic terrane. Especially with high-K volcanic rocks, possibly related to waning stages of volcanism.Associated Deposit Types Sedimentary Fe in associated clastic rocks, apatite-magnetite deposits, hematite in quartz-sericite alteration, possible disseminated Au.DEPOSIT DESCRIPTIONMineralogy Magnetite + apatite. Rarely pyrite, chalcopyrite, chalcocite, and covellite. Ti is in sphene.Texture/Structure Fine, granoblastic, skarn type textures.Alteration Actinolite or diopside, andradite, biotite, quartz, albite, andesine, K-feldspar, sodic scapolite, epidote; carbonates, and locally, tourmaline, sphene, chlorite, barite, fluorite, kaolin, or sericite.Ore Controls Magnetite in massive replacement, breccia filling and stockwork veins. Orebodies may be stratabound, concordant to intrusive contacts or in cross-cutting veins. Possibly related to cupolas of deeper plutons.Geochemical and Geophysical Signature Fe, P, V, and minor Ba, F, Bi, Cu, Co; strong magnetic anomalies.EXAMPLES

Kirunavaara, Sweden	(Frietsch 1982, 1978)
El Romeral, Chile	(Bookstrom, 1977)
Middle-Lower Yangtze Valley,	(Research Group of
CINA	Porphyrite Iron Ore, 1977)

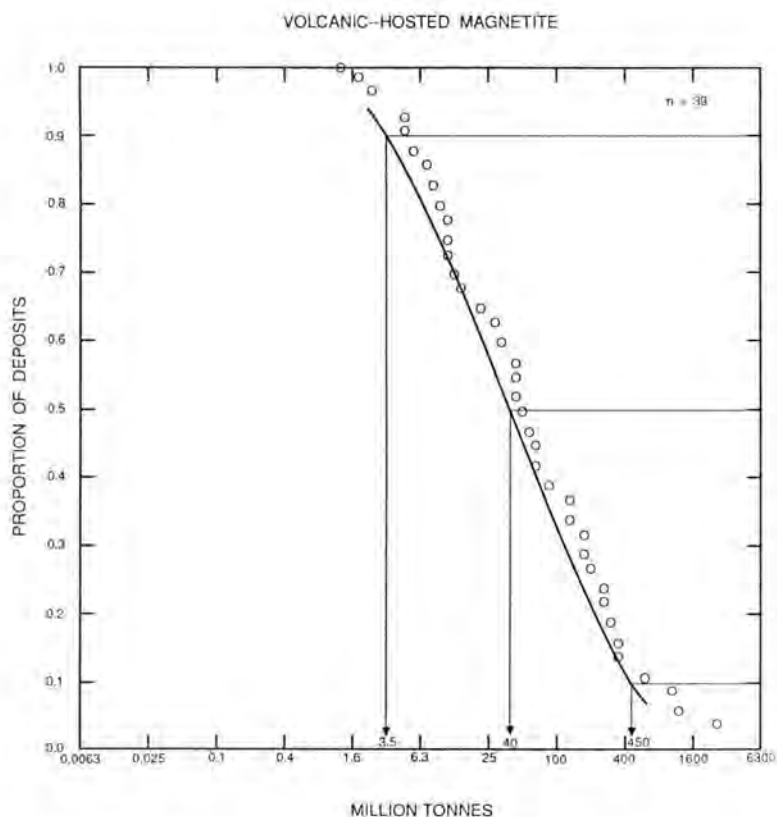
## GRADE AND TONNAGE MODEL OF VOLCANIC-HOSTED MAGNETITE

By Dan L. Mosier

COMMENTS Only deposits with abundant apatite are included. See figs. 131-133.DEPOSITS

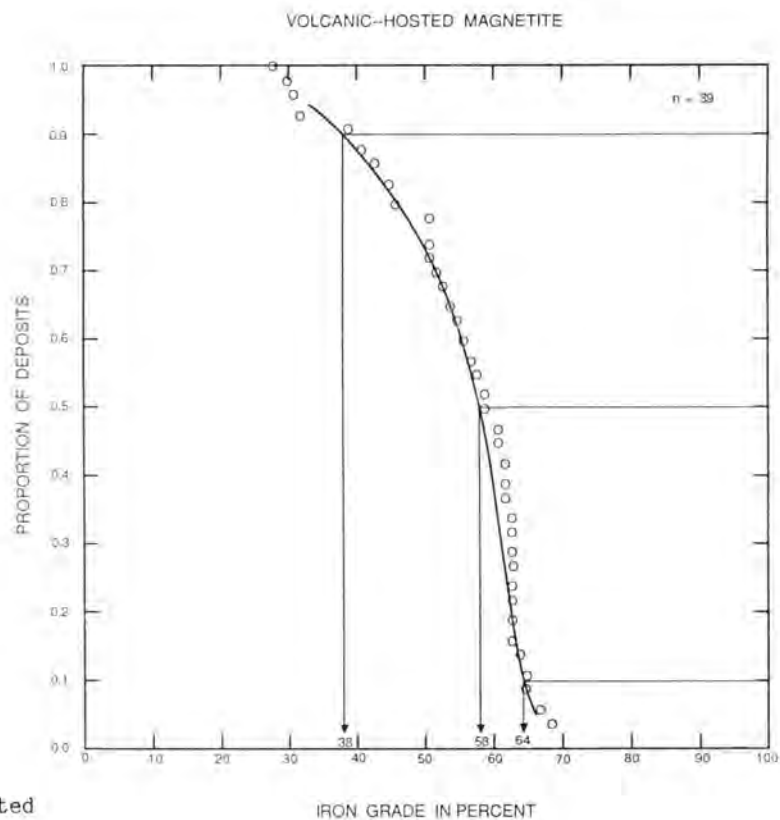
<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Arnold Hill	USNY	Cerro de Mercado	MXCO
Benson	USNY	Chador-Malu	IRAN

Chahehgaz	IRAN	Los Vasitos	MXCO
Choghart	IRAN	Luossauaara	SWDN
Ekstromberg	SWDN	Malmberget	SWDN
El Algarrobo	CILE	Minarets	USCA
El Dorado	CILE	Mineville-Port Henry	USNY
El Encino	MXCO	Modarelli	USNV
EL Romeral	CILE	Nakerivaara	SWDN
Grangesberg	SWDN	Northern Anomaly	IRAN
Gruvberget	SWDN	Painirova	SWDN
Guadalupe & Solis	MXCO	Pea Ridge	USMO
Hercules	MXCO	Ringwood	USNJ
Idkerberget	SWDN	Saghand	IRAN
Infiernillo	CILE	Savage River	AUTS
Joinville	BRZL	Se Chakhum	IRAN
Kiirunavaara	SWDN	Sterling Lake	USNY
La Grulla	MXCO	Tjarrojakka	SWDN
La Perla-La Negra	MXCO	Unnamed	MXCO
Leveaniemi	SWDN		

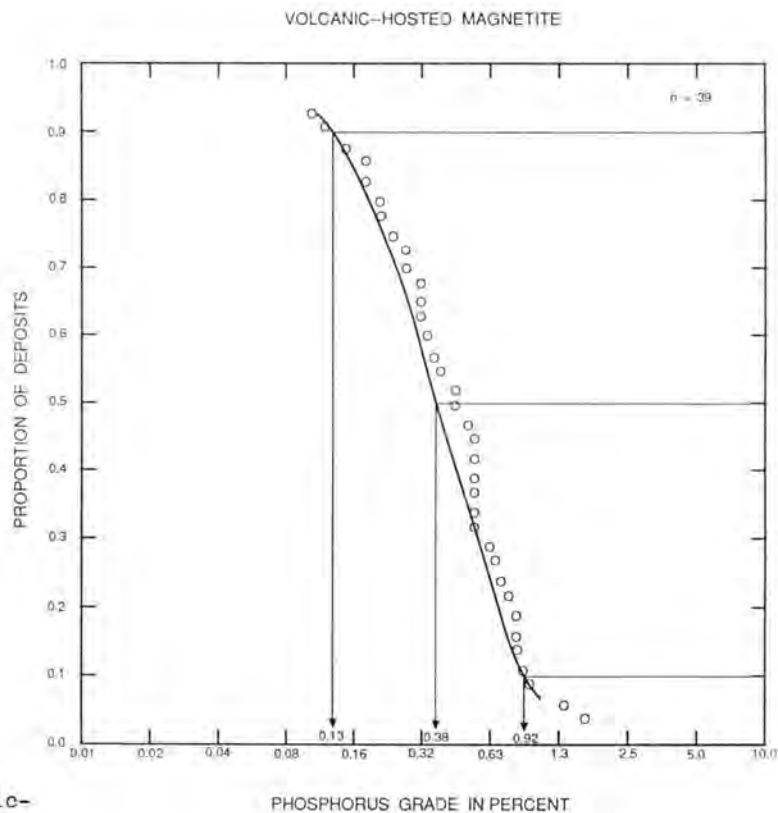


**Figure 131.** Tonnages of volcanic-hosted magnetite deposits.





**Figure 132.** Iron grades of volcanic-hosted magnetite deposits.



**Figure 133.** Phosphorus grades of volcanic-hosted magnetite deposits.

**DESCRIPTIVE MODEL OF CARBONATE-HOSTED Au-Ag**

By Byron R. Berger

APPROXIMATE SYNONYM Carlin-type or invisible gold.DESCRIPTION Very fine grained gold and sulfides disseminated in carbonaceous calcareous rocks and associated jasperoids.GENERAL REFERENCE Tooker (1985).GEOLOGICAL ENVIRONMENTRock Types Host rocks: thin-bedded silty or argillaceous carbonaceous limestone or dolomite, commonly with carbonaceous shale. Intrusive rocks: felsic dikes.Textures Dikes are generally porphyritic.Age Range Mainly Tertiary, but can be any age.Depositional Environment Best host rocks formed as carbonate turbidites in somewhat anoxic environments. Deposits formed where these are intruded by igneous rocks under nonmarine conditions.Tectonic Setting(s) High-angle normal fault zones related to continental margin rifting.Associated Deposit Types W-Mo skarn, porphyry Mo, placer Au, stibnite-barite veins.DEPOSIT DESCRIPTIONMineralogy Native gold (very fine grained) + pyrite + realgar + orpiment ± arsenopyrite ± cinnabar ± fluorite ± barite ± stibnite. Quartz, calcite, carbonaceous matter.Texture/Structure Silica replacement of carbonate. Generally less than 1 percent fine-grained sulfides.Alteration Unoxidized ore: jasperoid + quartz + illite + kaolinite + calcite. Abundant amorphous carbon locally appears to be introduced. Hypogene oxidized ore: kaolinite + montmorillonite + illite + jarosite + alunite. Ammonium clays may be present.Ore Controls Selective replacement of carbonaceous carbonate rocks adjacent to and along high-angle faults, or regional thrust faults or bedding.Weathering Light-red, gray, and (or) tan oxides, light-brown to reddish-brown iron-oxide-stained jasperoid.Geochemical Signature: Au + As + Hg + W ± Mo; As + Hg + Sb + Tl ± F (this stage superimposed on preceding); NH<sub>3</sub> important in some deposits.EXAMPLES

Carlin, USNV	(Radtke and others, 1980)
Getchell, USNV	(Joralemon, 1951)
Mercur, USUT	(Gilluly, 1932)

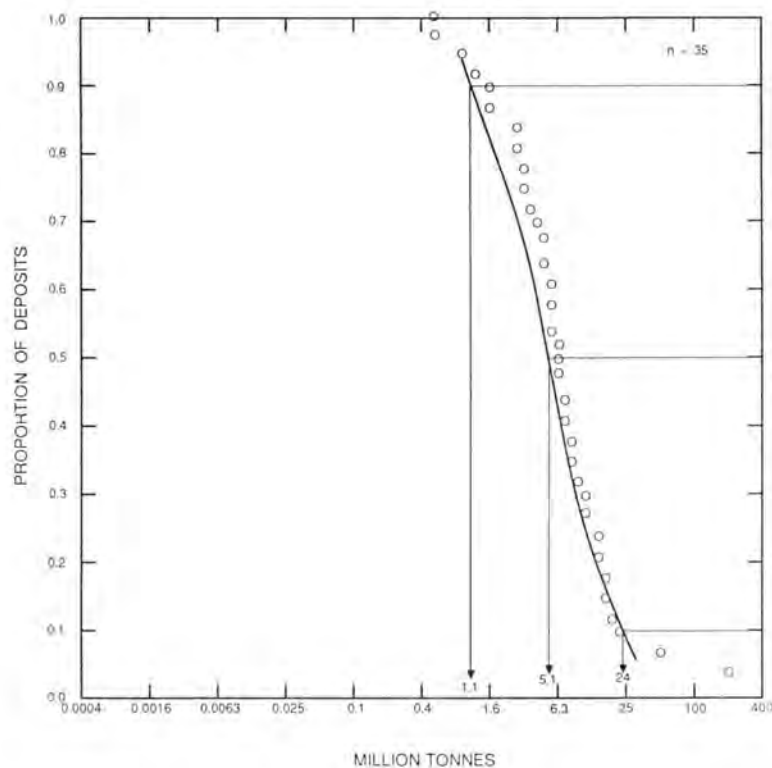
**GRADE AND TONNAGE MODEL OF CARBONATE-HOSTED Au-Ag**

By William C. Bagby, W. David Menzie, Dan L. Mosier, and Donald A. Singer

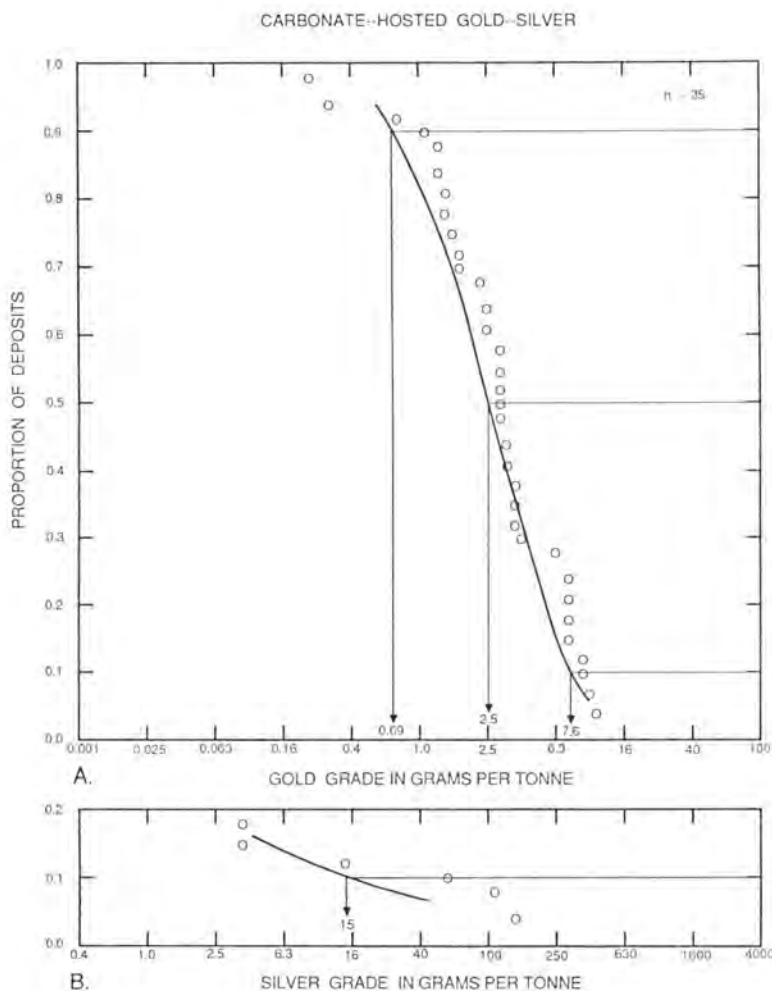
COMMENTS See figs. 134-135

DEPOSITS

<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Alligator Ridge	USNV	Jerritt Canyon	USNV
Atlanta	USNV	Maggie Creek	USNV
Blue Star	USNV	Mercur	USUT
Carlin	USNV	Northumberland	USNV
Cortez	USNV	Pinson	USNV
Dee	USNV	Preble	USNV
Emigrant Springs #1	USNV	Rain	USNV
Emigrant Springs #2	USNV	Relief Canyon	USNV
Florida Canyon	USNV	Roberts Mtns. Dist.	USNV
Getchell	USNV	Santa Fe	USNV
Giltedge	USMT	Standard	USNV
Gold Bar	USNV	Toiyabe	USNV
Gold Acres	USNV	Tolman	USID
Gold Quarry	USNV	Tonkin Springs	USNV
Horse Canyon	USNV	Windfall	USNV



**Figure 134.** Tonnages of carbonate-hosted Au-Ag deposits.



**Figure 135.** Precious-metal grades of carbonate-hosted Au-Ag deposits. A, Gold. B, Silver.

## DESCRIPTIVE MODEL OF HOT-SPRING Hg

By James J. Rytuba

APPROXIMATE SYNONYM Sulphur Bank type of White (1981) or sulfurous type of Bailey and Phoenix (1944).

DESCRIPTION Cinnabar and pyrite disseminated in siliceous sinter superjacent to graywacke, shale, andesite, and basalt flows and diabase dikes.

GEOLOGICAL ENVIRONMENT

Rock Types Siliceous sinter, andesite-basalt flows, diabase dikes, andesitic tuffs, and tuff breccia.

Age Range Tertiary.

Depositional Environment Near paleo ground-water table in areas of fossil hot-spring system.

Tectonic Setting(s) Continental margin rifting associated with small volume mafic to intermediate volcanism.

Associated Deposit Types Hot-spring Au.

DEPOSIT DESCRIPTION

Mineralogy Cinnabar + native Hg + minor marcasite.

Texture/Structure Disseminated and coatings on fractures in hot-spring sinter.

Alteration Above paleo ground-water table, kaolinite-alunite-Fe oxides, native sulfur; below paleo ground-water table, pyrite, zeolites, potassium feldspar, chlorite, and quartz. Opal deposited at the paleo water table.

Ore Controls Paleo ground-water table within hot-spring systems developed along high-angle faults.

Geochemical Signature Hg + As + Sb + Au.

EXAMPLES

Sulfur bank, USCA (White and Roberson, 1962)

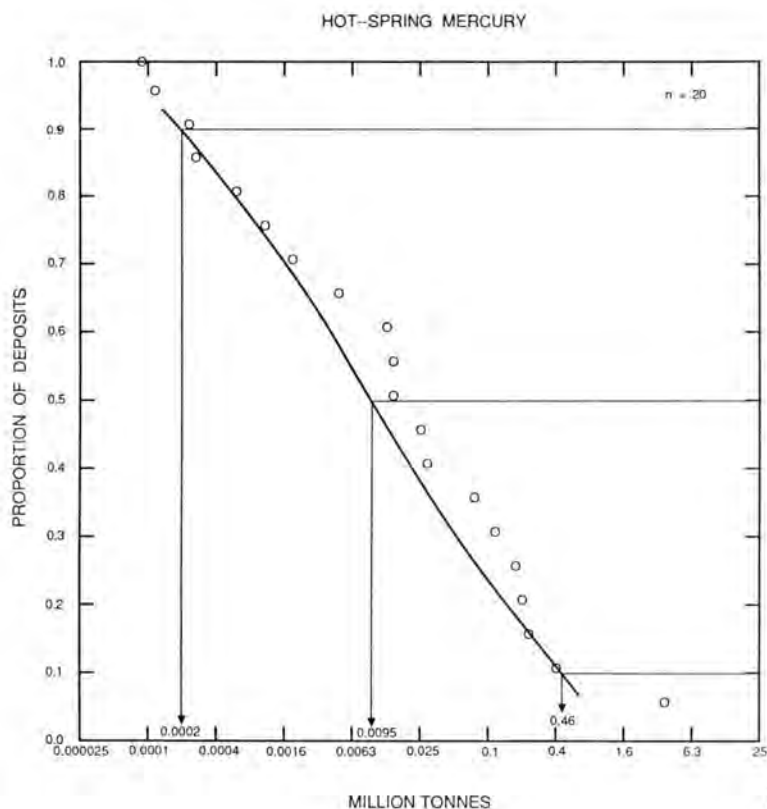
## GRADE AND TONNAGE MODEL OF HOT-SPRING Hg

By James J. Rytuba

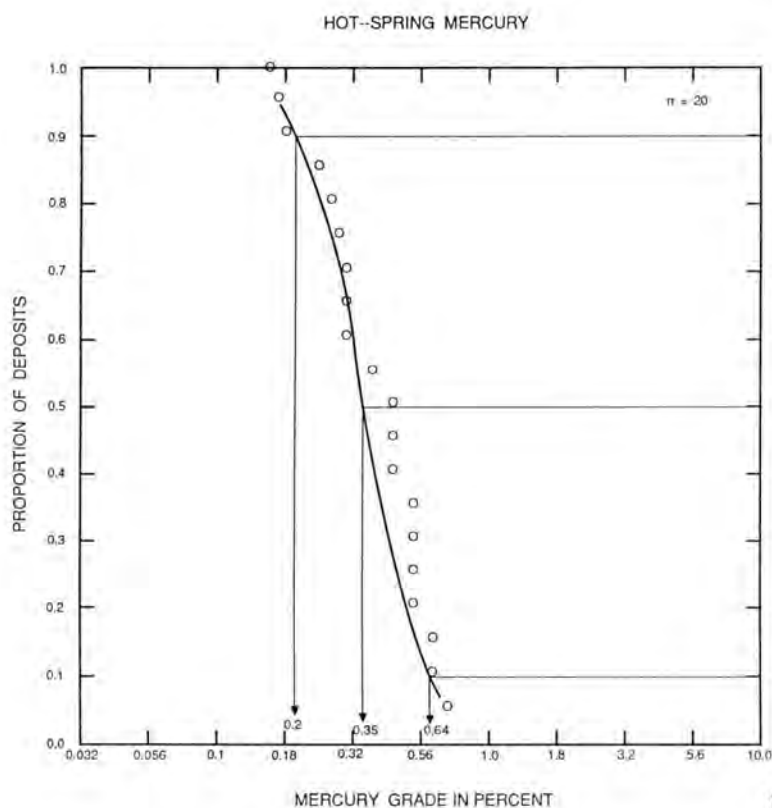
COMMENTS See figs. 136, 137.

DEPOSITS

<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
B and B	USNV	Idaho Almaden	USID
Baldwin	USNV	Mahattan	USCA
Bretz	USOR	McDermitt	USNV
Butte	USNV	Nevada Sulphur co.	USNV
Coleman	USNV	Opalite	USOR
Cordero	USNV	Rim Rock and Homestake	USNV
F and L Mine	USNV	Silver Cloud	USNV
Glass Butte	USOR	Steamboat Springs	USNV
Goldbanks	USNV	Sulphur Bank	USCA
Governor	USNV	Walibu	USCA



**Figure 136.** Tonnages of hot-spring Hg deposits.



**Figure 137.** Mercury grades of hot-spring Hg deposits.

## DESCRIPTIVE MODEL OF ALMADEN Hg

By James J. Rytuba

APPROXIMATE SYNONYM Almaden type.

DESCRIPTION Stratabound disseminated cinnabar and native mercury in volcanoclastic sedimentary rocks.

GENERAL REFERENCE Saupe (1973).

### GEOLOGICAL ENVIRONMENT

Rock Types Unmetamorphosed shale, graywacke, calcareous graywacke, andesitic lava and tuff, andesite dikes. Volcanic vent breccia.

Age Range Almaden is Silurian, but deposits may be any age.

Depositional Environment Permeable sedimentary rocks, andesite dikes possibly near volcanic center.

Tectonic Setting(s) Volcanic centers along major deep-seated fault zone. Absence of regional metamorphism or plutonism following mineralization.

Associated Deposit Types Stibnite veins.

### DEPOSIT DESCRIPTION

Mineralogy Cinnabar ± native mercury + pyrite + calcite + quartz.

Texture/Structure Disseminated.

Ore Controls Mineralized zone follows major fault, highest grade ore in calcareous graywacke.

Geochemical Signature Hg, As, Sb.

### EXAMPLES

Almaden, SPAN	(Saupe, 1973)
Santa Barbara, PERU	(Berry and Singewald, 1922)
Nueva Esperanza, CLBA	(Lozano and others, 1977)

## DESCRIPTIVE MODEL OF SILICA-CARBONATE Hg

By James J. Rytuba

APPROXIMATE SYNONYM New Almaden type.DESCRIPTION Cinnabar at contact of serpentine and siltstone-graywacke above subduction-related thrust.GENERAL REFERENCE Bailey (1964).GEOLOGICAL ENVIRONMENTRock Types Serpentine, siltstone-graywacke.Age Range Tertiary.Depositional Environment Serpentinized intrusive rocks (sills and dikes) into siltstone, and graywacke and siltstone, fractures in altered serpentine.Tectonic Setting(s) Deposits occur in accreted terrane above subduction-related thrust fault.Associated Deposit Types Stibnite veins.DEPOSIT DESCRIPTIONMineralogy Cinnabar, native Hg, other minor sulfides: pyrite, stibnite, chalcopyrite, sphalerite, galena, and bornite.Texture/Structure Replacement and minor veins.Alteration Replacement of serpentine by quartz and dolomite and minor hydrocarbons to form "silica-carbonate" rock.Ore Controls Contact of serpentine with siltstone especially where contact forms antiform. Ore primarily in silica-carbonate rock.Geochemical Signature Unknown, probably Hg + Sb + Cu + Zn.EXAMPLES

New Almaden, USCA (Bailey, 1964)

## GRADE AND TONNAGE MODEL OF SILICA-CARBONATE Hg

By James J. Rytuba and Simon M. Cargill

COMMENTS (See figs. 138, 139)DEPOSITS

<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Abbott	USCA	Helen	USCA
Aetna	USCA	Keystone	USCA
Bella Oak	USCA	Knoxville	USCA
Chicago	USCA	La Joya	USCA
Contact	USCA	La Libertad	USCA
Corona	USCA	Lion Den	USCA
Culver Bear	USCA	Mirabel	USCA
Dewey's	USCA	Mt. Diablo	USCA
Esperanza	USCA	New Almaden	USCA
Great Eastern-Mt. Jackson	USCA	Patriquin	USCA
Harrison	USCA	Polar Star	USCA



Model 27c--Con.

Red Elephant

Red Rick

Reed

USCA

USCA

USCA

Socrates

Twin Peaks

Wall Street

USCA

USCA

USCA

SILICA-CARBONATE MERCURY

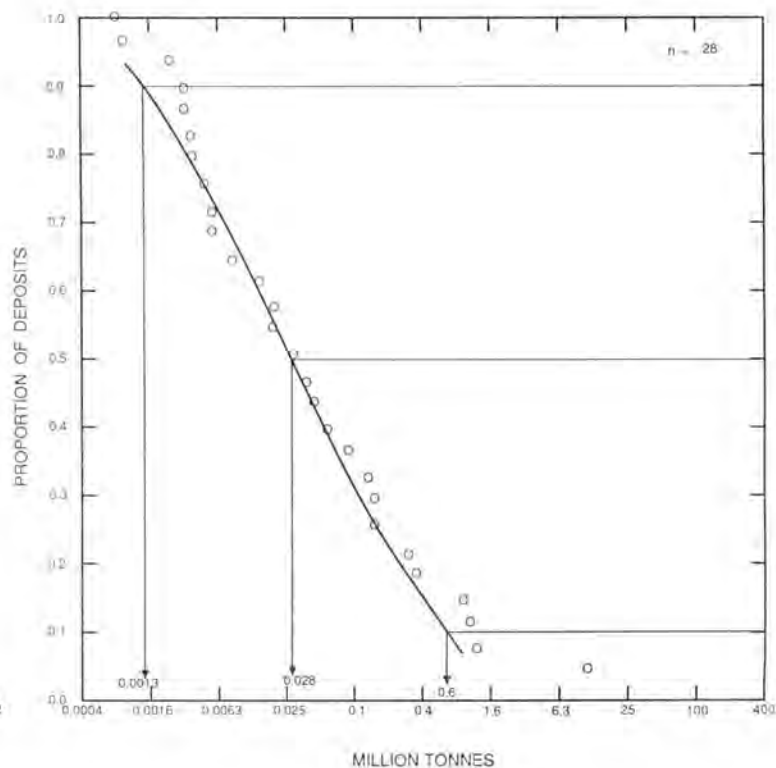


Figure 138. Tonnages of silica-carbonate Hg deposits.

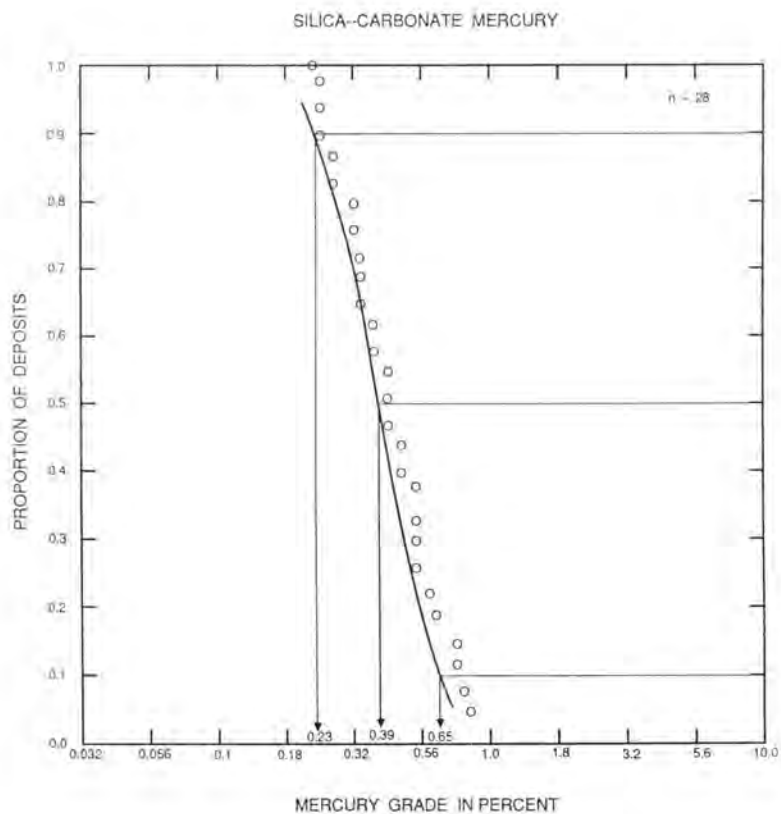


Figure 139. Mercury grades of silica-carbonate Hg deposits.

## DESCRIPTIVE MODEL OF SIMPLE Sb DEPOSITS

By James D. Bliss and Greta J. Orris

APPROXIMATE SYNONYM Deposits of quartz-stibnite ore (Smirnov and others, 1983).DESCRIPTION Stibnite veins, pods, and disseminations in or adjacent to brecciated or sheared fault zones.GENERAL REFERENCES White (1962), Miller (1973).GEOLOGICAL ENVIRONMENTRock Types One or more of the following lithologies is found associated with over half of the deposits: limestone, shale (commonly calcareous), sandstone, and quartzite. Deposits are also found with a wide variety of other lithologies including slate, rhyolitic flows and tuffs, argillite, granodiorite, granite, phyllite, siltstone, quartz mica and chloritic schists, gneiss, quartz porphyry, chert, diabase, conglomerate, andesite, gabbro, diorite, and basalt.Textures Not diagnostic.Age Range Known deposits are Paleozoic to Tertiary.Depositional Environment Faults and shear zones.Tectonic Setting(s) Any orogenic area.Associated Deposit Types Stibnite-bearing veins, pods, and disseminations containing base metal sulfides + cinnabar + silver + gold + scheelite that are mined primarily for lead, gold, silver, zinc, or tungsten; low-sulfide Au-quartz veins; epithermal gold and gold-silver deposits; hot-springs gold; carbonate-hosted gold; tin-tungsten veins; hot-springs and disseminated mercury, gold-silver placers; infrequently with polymetallic veins and tungsten skarns.DEPOSIT DESCRIPTIONMineralogy Stibnite + quartz ± pyrite ± calcite; minor other sulfides frequently less than 1 percent of deposit and included ± arsenopyrite ± sphalerite ± tetrahedrite ± chalcopryrite ± scheelite ± free gold; minor minerals only occasionally found include native antimony, marcasite, calaverite, berthierite, argentite, pyrrargyrite, chalcocite, wolframite, richardite, galena, jamesonite; at least a third (and possibly more) of the deposits contain gold or silver. Uncommon gangue minerals include chalcedony, opal (usually identified to be  $\beta$ -cristobalite by X-ray), siderite, fluorite, barite, and graphite.Texture/Structure Vein deposits contain stibnite in pods, lenses, kidney forms, pockets (locally); may be massive or occur as streaks, grains, and bladed aggregates in sheared or brecciated zones with quartz and calcite. Disseminated deposits contain streaks or grains of stibnite in host rock with or without stibnite vein deposits.Alteration Silicification, sericitization, and argillization; minor chloritization; serpentinization when deposit in mafic, ultramafic rocks.Ore Controls Fissures and shear zones with breccia usually associated with faults; some replacement in surrounding lithologies; infrequent open-space filling in porous sediments and replacement in limestone. Deposition occurs at shallow to intermediate depth.Weathering Yellow to reddish kermesite and white cerrantite or stibiconite (Sb oxides) may be useful in exploration; residual soils directly above deposits are enriched in antimony.Geochemical Signature Sb ± Fe ± As ± Au ± Ag; Hg ± W ± Pb ± Zn may be useful in specific cases.EXAMPLESAmphoe Phra Saeng, THLD  
Caracota, BLVA(Gardner, 1967)  
(U.S. Geological Survey Mineral Resources Data System)

Coimadai Antimony Mine, AUVT	(Fisher, 1952)
Last Chance, USNV	(Lawrence, 1963)
Lake George, CNNE	(Scratch and others, 1984)

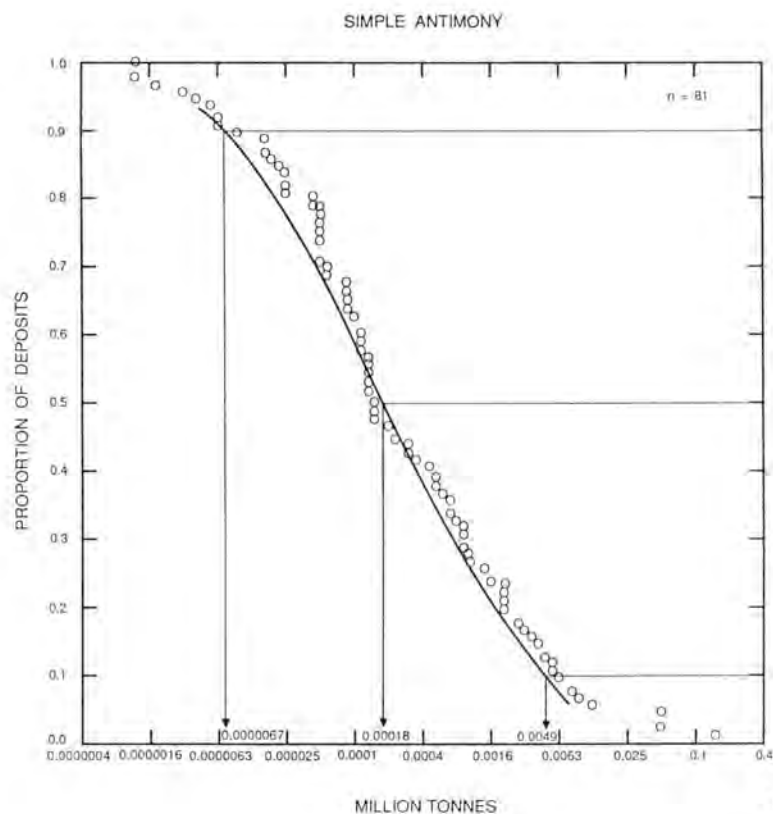
# GRADE AND TONNAGE MODEL OF SIMPLE Sb DEPOSITS

By James D. Bliss and Greta J. Orris

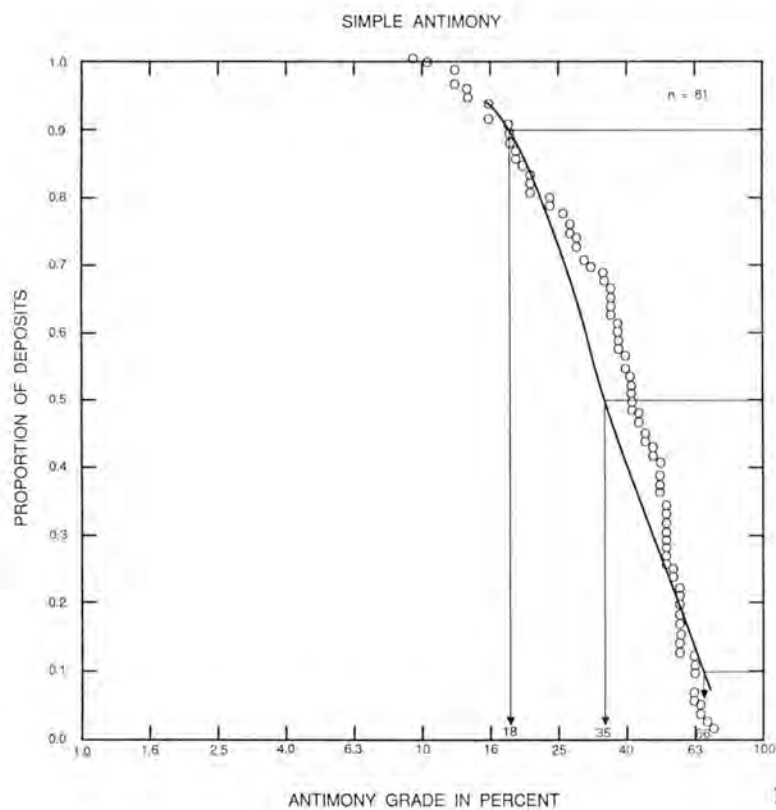
COMMENTS Grade and tonnage have been modeled separately for vein-dominated and disseminated simple antimony deposits. The vein-dominated deposits' grades and tonnages in this model reflect hand-sorting of the ore. A grade-tonnage model for deposits containing disseminated antimony, number 27e, follows this model. At least 15 percent of the simple antimony veins are accompanied by disseminated antimony mineralization. See figs. 140-142.

## DEPOSITS

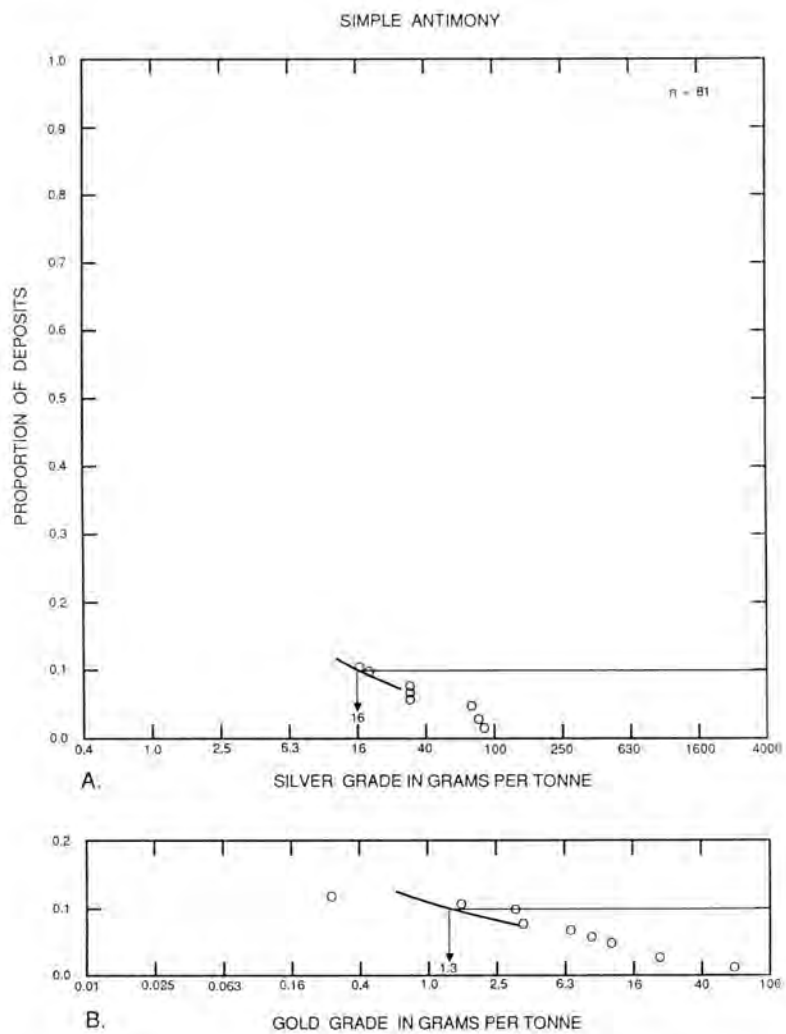
<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Amphoe Phra Saeong	THLD	Gribble	USNV
Antimonial	USNV	Happy Return	USNV
Antimony Canyon	USUT	Hard Luck	USNV
Antimony King I	USNV	Hermada	USID
Antimony King II	USNV	Hollywood	USNV
Antimony Lode	USNV	Hoyt	USNV
Antimony Mines	USMT	Huai Nai Khao	THLD
Antimony Ridge	USID	I.H.X.	USNV
Apex Antimony	USNV	Ichinokawa	JAPN
Black Warrior	USNV	Idaho	USID
Bloody Canyon	USNV	Jay Bird	USOR
Blue Dick	USNV	Jerritt Canyon	USNV
Blue Jay	USOR	Johnson-Heizer	USNV
Blue Nose	USNV	Last Chance	USNV
Blue Ribbon	USNV	Lithia	USNV
Bradley	USNV	Lofthouse	USNV
Bray-Beulah	USNV	Lowry	USNV
Burns Basin	USNV	Lucky Knock	USWA
Cervantite	USNV	Merrimac	USNV
Choates	USNV	Milton Canyon	USNV
Cia Minera Norcro	HNDR	Mizpah	USNV
Coasano	USAK	Mugi	JAPN
Coeur d'Alene	USID	Neardie	AUQL
Coimadai	AUVT	Nevada King	USNV
Conyarigi	TRKY	Nieves	MXCO
Costerfield	AUVT	Ore Drag	USNV
Cottonwood	USNV	Page	USNV
Darwin	USNV	Panther	USNV
Desert	USCA	Prunty	USNV
Doi Pha Khan	THLD	Scrafford	USAK
Donatelli	USNV	Snowdrift	USNV
Drumm	USNV	St. George	AUQL
Dry Canyon	USNV	Stewart May	USAR
Eaton	USNV	Stibnite	USAK
Elalmis	TRKY	Sutherland	USNV
Electric	USNV	Thompson Falls	USMT
Enterprise	USNV	Upper Bellingren	AUNS
Four-of-July	USID	Volcanic Peak	USNV
Fujinokawa	JAPN	W.P.	USNV
Green Antimony	USNV	Wall Canyon	USNV
Grey Eagle	USOR		



**Figure 140.** Tonnages of simple Sb deposits.



**Figure 141.** Antimony grades of simple Sb deposits.



**Figure 142.** Precious-metal grades of simple Sb deposits. A, Silver. B, Gold.

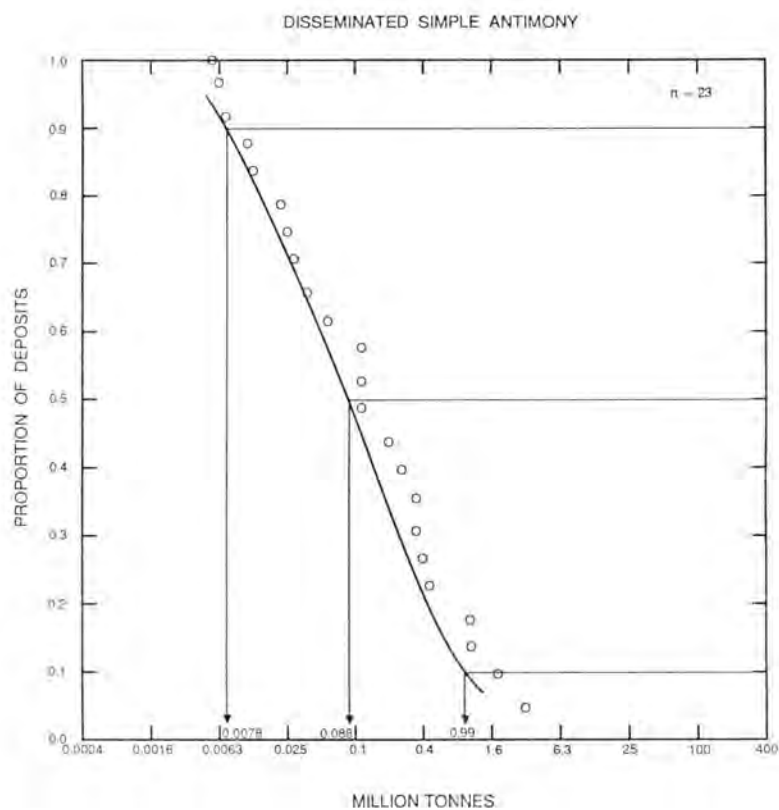
## GRADE AND TONNAGE MODEL OF DISSEMINATED Sb DEPOSITS

By James D. Bliss and Greta J. Orris

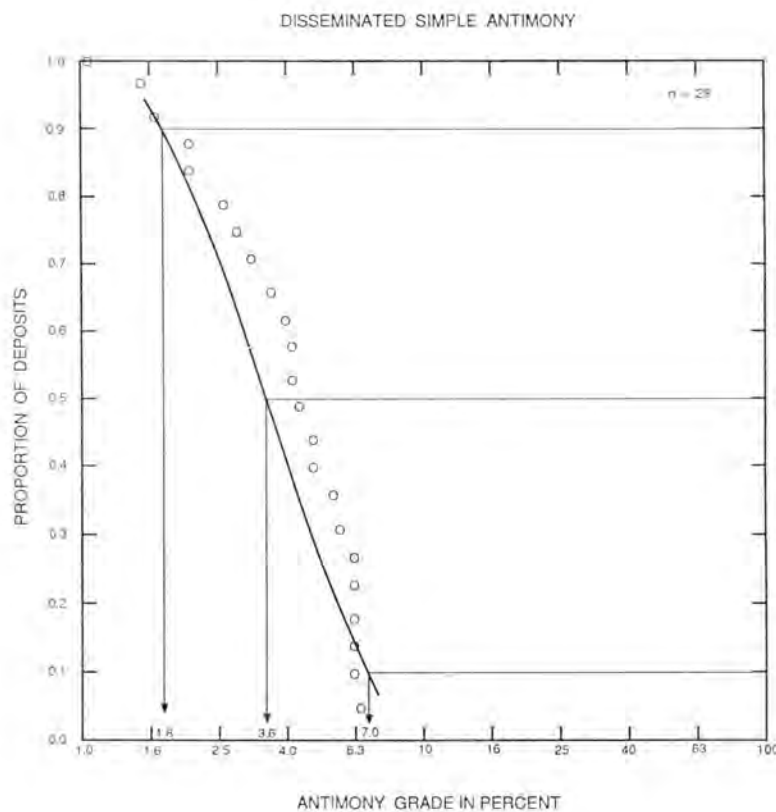
COMMENTS Disseminated simple antimony deposits, model 27e, is presented as an alternative to model 27d because of major differences in grade between the two groups. The two groups are similar geologically and share the same descriptive model. See figs. 143, 144.

DEPOSITS

<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Buyuk Yenice	TRKY	La Cruz	MXCO
Camlica Koyee	TRKY	Lake George	CNNB
Caracota	BLVA	Madeni	TRKY
Dagardi	TRKY	Mitchell River	AUQL
Demirkapi	USNV	Montezuma	USNV
Derekoy	TRKY	Orendere	TRKY
Dudas	USNV	Quien-Sabe	USCA
Emirli	TRKY	San Emigdio	USCA
Eskdale	AUQL	Tasdibi	TRKY
Espiritu Santo	BLVA	West Gore	CNNS
Goynuk	TRKY	Wildrose Canyon	USCA
Kucuk Yenice	TRKY		



**Figure 143.** Tonnages of disseminated simple Sb deposits.



**Figure 144.** Antimony grades of disseminated simple Sb deposits.

## DESCRIPTIVE MODEL OF KUROKO MASSIVE SULFIDE

By Donald A. Singer

APPROXIMATE SYNONYM Noranda type, volcanogenic massive sulfide, felsic to intermediate volcanic type.

DESCRIPTION Copper- and zinc-bearing massive sulfide deposits in marine volcanic rocks of intermediate to felsic composition (see fig. 145).

GENERAL REFERENCES Ishihara (1974), Franklin and others (1981), Hutchinson and others (1982), Ohmoto and Skinner (1983).

### GEOLOGICAL ENVIRONMENT

Rock Types Marine rhyolite, dacite, and subordinate basalt and associated sediments, principally organic-rich mudstone or shale. Pyritic, siliceous shale. Some basalt.

Textures Flows, tuffs, pyroclastics, breccias, bedded sediment, and in some cases felsic domes.

Age Range Archean through Cenozoic.

Depositional Environment Hot springs related to marine volcanism, probably with anoxic marine conditions. Lead-rich deposits associated with abundant fine-grained volcanogenic sediments.

Tectonic Setting(s) Island arc. Local extensional tectonic activity, faults, or fractures. Archean greenstone belt.

Associated Deposit Types Epithermal quartz-adularia veins in Japan are regionally associated but younger than kuroko deposits. Volcanogenic Mn, Algoma Fe.

### DEPOSIT DESCRIPTION

Mineralogy Upper stratiform massive zone (black ore)--pyrite + sphalerite + chalcopyrite ± pyrrhotite ± galena ± barite ± tetrahedrite - tennantite ± bornite; lower stratiform massive zone (yellow ore)--pyrite + chalcopyrite ± sphalerite ± pyrrhotite ± magnetite; stringer (stockwork) zone--pyrite + chalcopyrite (gold and silver). Gahnite in metamorphosed deposits. Gypsum/anhydrite present in some deposits.

Texture/Structure Massive (>60 percent sulfides); in some cases, an underlying zone of ore stockwork, stringers or disseminated sulfides or sulfide-matrix breccia. Also slumped and redeposited ore with graded bedding.

Alteration Adjacent to and blanketing massive sulfide in some deposits--zeolites, montmorillonite (and chlorite?); stringer (stockwork) zone--silica, chlorite, and sericite; below stringer--chlorite and albite. Cordierite and anthophyllite in footwall of metamorphosed deposits, graphitic schist in hanging wall.

Ore Controls Toward the more felsic top of volcanic or volcanic-sedimentary sequence. Near center of felsic volcanism. May be locally brecciated or have felsic dome nearby. Pyritic siliceous rock (exhalite) may mark horizon at which deposits occur. Proximity to deposits may be indicated by sulfide clasts in volcanic breccias. Some deposits may be gravity-transported and deposited in paleo depressions in the seafloor. In Japan, best deposits have mudstone in hanging wall.

Weathering Yellow, red, and brown gossans. Gahnite in stream sediments near some deposits.

Geochemical Signature Gossan may be high in Pb and typically Au is present. Adjacent to deposit--enriched in Mg and Zn, depleted in Na. Within deposits--Cu, Zn, Pb, Ba, As, Ag, Au, Se, Sn, Bi, Fe.



EXAMPLES

Kidd Creek, CNON	(Walker and others, 1975)
Mt. Lyell, AUTS	(Corbett, 1981)
Brittania, CNBC	(Payne and others, 1980)
Buchans, CNNF	(Swanson and others, 1981)

**GRADE AND TONNAGE MODEL OF KUROKO MASSIVE SULFIDE**

By Donald A. Singer and Dan L. Mosier

DATA REFERENCE Mosier and others (1983).

COMMENTS Includes all deposits listed by Mosier and others (1983) that are associated with felsic or intermediate volcanic rocks. Tonnage is correlated with copper grade ( $r = -0.17$ ) and with gold grade ( $r = -0.19$ ,  $n = 238$ ). Zinc grade is correlated with lead grade ( $r = 0.55$ ,  $n = 184$ ) and with silver grade ( $r = 0.52$ ,  $n = 249$ ). Lead grade is correlated with silver ( $r = 0.55$ ,  $n = 153$ ) and with gold grade ( $r = 0.34$ ,  $n = 124$ ). Gold and silver grades are correlated ( $r = 0.39$ ,  $n = 227$ ). See figs. 146-149.

DEPOSITS

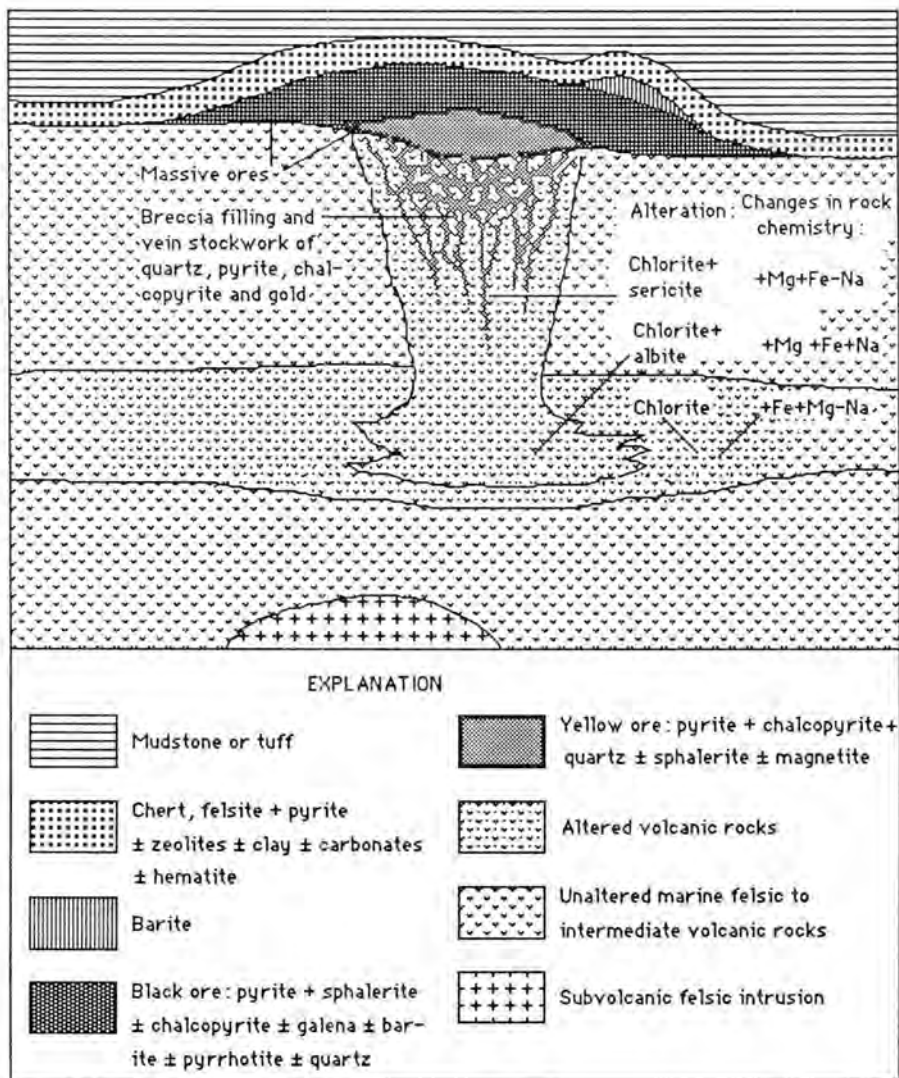
<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Abeshiro (Sakura)	JAPN	Bell Allard	CNQU
Adak-Lindskold	SWDN	Bell Channel	CNQU
Afterthought	USCA	Bidjovagge (A)	NRWY
Aijala	FNLD	Bidjovagge (B)	NRWY
Akarsen	TRKY	Bidjovagge (C)	NRWY
Akkoy	TRKY	Bidjovagge (D)	NRWY
Akulla Vastra	SWDN	Big Bend	USCA
Albert	CNQU	Big Hill	USME
Aldermac	CNQU	Binghampton	USAZ
Allard River	CNQU	Birch Lake	CNSK
Almagrera-Lapilla	SPAN	Bjorkasen	NRWY
Amulet A	CNQU	Bjurfors	SWDN
Amulet F	CNQU	Bjurliden	SWDN
Anayatak-Cakmakcaya	TRKY	Bjurtrask	SWDN
Anderson Lake	CNMN	Blue Ledge	USCA
Angelo	AUWA	Blue Moon	USCA
Anne	NRWY	Bodennec	FRNC
Antler	USAZ	Boliden	SWDN
Arctic	USAK	Bossmo	NRWY
Armstrong (A)	CNNB	Britannia	CNBC
As Safra	SAAR	Bruce	USAZ
Asen-east	SWDN	Brunswick No. 12	CNNB
Asen-west	SWDN	Brunswick No. 6	CNNB
Ash Shizm	SAAR	Buchans (LS-Roth.)	CNNF
Austin Brook	CNNB	Buchans (McLean)	CNNF
Avoca	IRLD	Buchans (OB-Orient.)	CNNF
Aznacollar	SPAN	Bully Hill-Rising St.	USCA
Bagacay	PLPN	Bursi	NRWY
Bailadores	VNZL	Campanario	SPAN
Balaklala	USCA	Canadian Jamieson	CNON
Bald Mountain	USME	Canoe Landing	CNNB
Bandgan	PKTN	Captain	CNNB
Barrett	USME	Captains Flat	AUNS
Barrington Lake	CNMN	Caribou	CNNB
Barvallee-Mogador	CNQU	Carpio	SPAN
Baskoy	TRKY	Castillo Buitron	SPAN
Bathurst-Norsemines	CNNT	Castro Verde	PORT
Bawdin	BRMA	CC	CNBC
Beatson	USAK	Centennial	CNMN
Bedford Hill	CNQU	Chestatee	USGA

Chester	CNNB	Gjersvik	NRWY
Chisel Lake	CNMN	Golden Grove	AUWA
Clinton	CNQU	Goodenough	CNMN
Conception	SPAN	Gray Eagle	USCA
Conigo	CNQU	Green Coast	CNON
Copper Crown	CNBC	Greens Creek	USAK
Copper George	AUWA	Gullbridge	CNNF
Copper Hill	USCA	Hacan	TRKY
Corbet	CNQU	Half Mile Lake (SG)	CNMN
Coronation	CNSK	Halliwell	CNQU
Crandon	USWI	Hanaoka (Doy.-Tsut.)	JAPN
Cronin	CNBC	Hanaoka (Mats.-Sha.)	JAPN
Cueva de la Mora	SPAN	Hanawa (Aket.-Osak.)	JAPN
Cupra D'Estrie	CNQU	Hanson Lake	CNSK
Cuprus	CNMN	Harkoy	TRKY
Davis	USMA	Heath Steele (A-C-D)	CNNB
Deer Isle	USME	Heath Steele (B)	CNNB
Delbridge	CNQU	Heath Steele (E-F)	CNNB
Despina	CNQU	Hercules	AUTN
Detour	CNQU	Herrerias	SPAN
Devils Elbow	CNNB	Hersjo	NRWY
Dickstone	CNMN	High Lake	CNNT
Don Jon	CNMN	Hixbar	PLPN
Double Ed	CNBC	Hoidal	NRWY
Dumagami	CNQU	Hood River	CNNT
Dumont Bourlamque	CNQU	Horne-Quemont	CNQU
Dunraine	CNQU	Hunter	CNQU
Duthie	CNBC	HW	CNBC
Dyce Siding	CNMN	Hyers Island	CNMN
Early Bird	USCA	Iron Dyke	USOR
East Sullivan	CNQU	Iron King	USAZ
Ego	CNON	Iron Mountain	USCA
Embury Lake	CNMN	Irsahan	TRKY
Emerson	USME	Iso-Magusi-New Insco	CNQU
Empire Le Tac	CNQU	Israil	TRKY
Errington	CNON	Iwami east	JAPN
Estacao	CNON	Iwami west	JAPN
Eulaminna	AUWA	Izok Lake	CNNT
Eustis	CNQU	Jabal Sayid	SAAR
F Group	CNON	Jakobsbakken	NRWY
Farewell Lake	CNMN	Jameland	CNON
Filon Sur-Esperanza	SPAN	Jerome	USAZ
Fjeldgruve	NRWY	Joanne	CNMN
FL & DH	CNMN	Joliet	CNQU
Flambeau	USWI	Josselin	CNQU
Flexar	CNSK	Joutel	CNQU
Flin Flon	CNMN	Kalkanli	TRKY
Fonnfjell	NRWY	Kam Kotia	CNON
Fox	CNMN	Kamitkita (Kominosawa)	JAPN
Freddie Wells	AUNS	Kankberg	SWDN
Fretais	PORT	Kedtrask	SWDN
Frotet Lake	CNQU	Kelly-Desmond	CNQU
Fukazawa	JAPN	Key Anacon	CNNB
Furuhaugen	NRWY	Keystone	USCA
Furutobe-Ainai	JAPN	Ketstone-Union	USCA
Gamle Follidal	NRWY	Khans Creek	AUNS
Garon Lake	CNQU	Khnaiguiyah	SAAR
Gaviao	PORT	Kidd Creek	CNON
Gelvenakko	SWDN	Killingdal	NRWY
George Copper	CNBC	Kimheden	SWDN
Ghost Lake	CNMN	Kittelgruvan	SWDN
Giken-Charlotta	NRWY	Kizilkaya	TRKY
Girilambone	AUNS	Koff Zone	CNMN

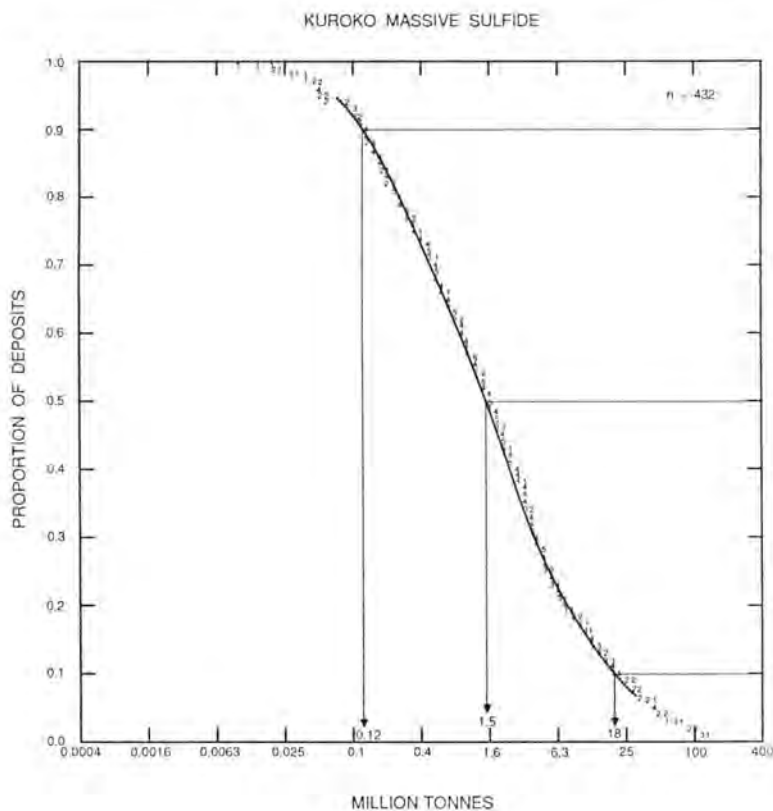
Model 28a--Con.

Koprubasi	TRKY	Murray Brook	CNNB
Kosaka (Motoyama)	JAPN	Myra Falls-Lynx	CNBC
Kosaka (Uch.-Uwa.)	JAPN	Nasliden	SWDN
Kostere	TRKY	Nepisiguit	CNNB
Kristineberg	SWDN	New Bay Pond	CNNF
Kunitomi (3-4-6)	JAPN	New Hosco	CNQU
Kunitomi (7-8)	JAPN	Newton	USCA
Kunitomi (1-5-1N-Fud.)	JAPN	Nine Mile Brook	CNNB
Kurosawa	JAPN	Nordre Gjettryggen	NRWY
Kutcho Creek	CNBC	Norita	CNQU
Kutlular	TRKY	Normetal	CNQU
Kuwarshan	TRKY	North Boundary	CNNB
La Joya	SPAN	North Keystone	USCA
La Torrera	SPAN	North Star	CNMN
La Zarza	SPAN	Northair	CNBC
Lagunazo	SPAN	Nuqrah	SAAR
Lahanos	SPAN	Old Waite	CNQU
Lake Dufault	CNQU	Orange Point	USAK
Lancha	SPAN	Orchan	CNQU
Langdal	SWDN	Orijarvi	FNLD
Langsele	SWDN	Osbourne Lake	CNMN
Lenora-Twin J	CNBC	Oshio	JAPN
Levi	SWDN	Ostra Hogkulla	SWDN
Lingwick	CNQU	Pabineau River	CNNB
Lomero Poyatos	SPAN	Paronen	FNLD
Lost Lake	CNMN	Parys Mountain	GRBR
Lousal	PORT	Pater	CNON
Louvem	CNQU	Paymogo	SPAN
Lyndhurst	CNQU	Pecos	USNM
Lynx	CNQU	Pelican	USWI
Lyon Lake	CNON	Penn	USCA
MacBride Lake	CNMN	Penobscot	USME
Madenkoy	TRKY	Perrunal	SPAN
Malaiba	PLPN	Phelps Dodge	CNQU
Mamie	CNBC	Pilleys Island	CNNF
Mammoth	USCA	Pine Bay	CNMN
Mandy	CNMN	Piray	PLPN
Mankayan	PLPN	Point Leamington	CNNF
Marcos	PLPN	Poirier	CNQU
Mattabi	CNON	Port Aux Moines	FRCN
Mattagami Lake	CNQU	Pot Lake	CNMN
McMaster	CNNB	Price	CNBC
Metsamonttu	FNLD	Pyhasalmi	FNLD
Mic Mac	CNQU	Que River	AUTS
Milan	USNH	Radiore E	CNQU
Millenbach	CNQU	Rail Lake	CNMN
Mobrun	CNQU	Rakkejaur	SWDN
Mofjell	NRWY	Rambler-Ming	CNNF
Moinho	PORT	Ramsey	CNSK
Mokoman Lake	CNSK	Ravliden	SWDN
Moleon Lake	CNQU	Ravlidmyran	SWDN
Monpas	CNQU	Rosebery-Read	AUTS
Mons Cupri	AUWA	Red Wing	CNBC
Mordey	CNON	Reed Lake	CNMN
Mos	NRWY	Renstrom	SWDN
Moskogaissa	NRWY	Rieppe	NRWY
Moulton Hill	CNQU	Rio Tinto	SPAN
Mount Bulga	AUNS	Rocky Turn	CNNB
Mount Chalmers	AUQL	Rod	CNMN
Mount Lyell	AUTS	Rodhammeren	NRWY
Mount Morgan	AUQL	Rodkleiv	NRWY
Mount Mulcahy	AUWA	Romanera	SPAN
Murgul	TRKY	Romerito	SPAN

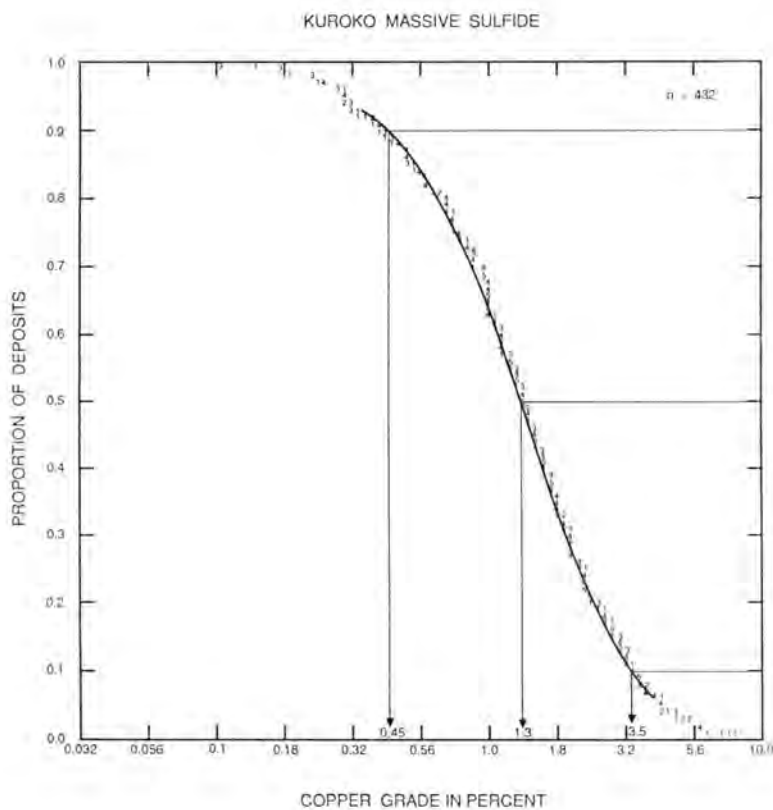
Rostvangen	NRWY	Teahan	CNNB
Rudtjebacken	SWDN	Tedi	CNBC
Ruttan	CNMN	Terra Nova	CNNF
Sabetjok	NRWY	Teutonic Bore	AUWA
Sagmo	NRWY	Texas	CNNB
Sain Bel	FRNC	Third Portage	CNNB
San Antonio	SPAN	Tjokkola	SWDN
San Domingos	PORT	Tomogonops	CNNB
San Guillermo-Sierra	SPAN	Trininty	CNQU
San Mateo	PLPN	Trout Bay	CNON
San Pedro	SPAN	Tsuchihata (Hatabira)	JAPN
San Platon	SPAN	Tsuchihata (Honnoizaw.)	JAPN
San Telmo	SPAN	Tsuchihata (Shiratsue.)	JAPN
Santa Rosa	SPAN	Tsuchihata (Uenono-Ok.)	JAPN
Schist Lake	CNMN	Tsuchihata (Washinosu)	JAPN
Selco-Scott	CNQU	Tulk's Pond	CNNF
Shasta King	USCA	Tulsequah	CNBC
Shunsby	CNON	Tunca	TRKY
Sierrecilla	SPAN	Tverrfjellet	NRWY
Silver Queen	CNBC	Uchi	CNON
Skaide	NRWY	Udden	SWDN
Solbec	CNQU	Undu	FIJI
Sotiel	SPAN	Vaddas	NRWY
Sourdough Bay	CNMN	Vamp	CNMN
South Dufault	CNQU	Vauze	CNQU
South Rusty Hill	CNQU	Vermillion	CNON
Spenceville	USCA	Vigsnes	NRWY
Spruce Point	CNMN	Viscaria	SWDN
Stall Lake	CNMN	Waden Bay	CNSK
Stekenjokk	SWDN	Waite East	CNQU
Stirling	CNNS	Wallaroo	AUWA
Stowell	USCA	Wedge	CNNB
Stralak	CNON	Weedon	CNQU
Stratmat	CNNB	Weiss	TRKY
Sturgeon Lake	CNON	Westarm	CNMN
Suffield	CNQU	Whim Creek	AUWA
Sulat	PLPN	White Lake	CNMN
Sun	CNMN	Whundo	AUWA
Sunshine	CNBC	Wildcat	PLPN
Susu Lake	CNNT	Willecho	CNON
Sutro	USCA	Wim	CNMN
Tache Lake	CNQU	Windy	CNBC
Taisho (Nishimata)	JAPN	Woodlawn	AUQL
Takijug Lake	CNNT	Yava	CNNT
Taknar I	IRAN	Yoichi	JAPN
Taknar II	IRAN	Yokota (Motoyama-Hama.)	JAPN
Tapley	USME	Yoshino (Hisaka)	JAPN
Tashiro	JAPN	Yoshino (Main)	JAPN
Taslica	TRKY	Z	CNMN



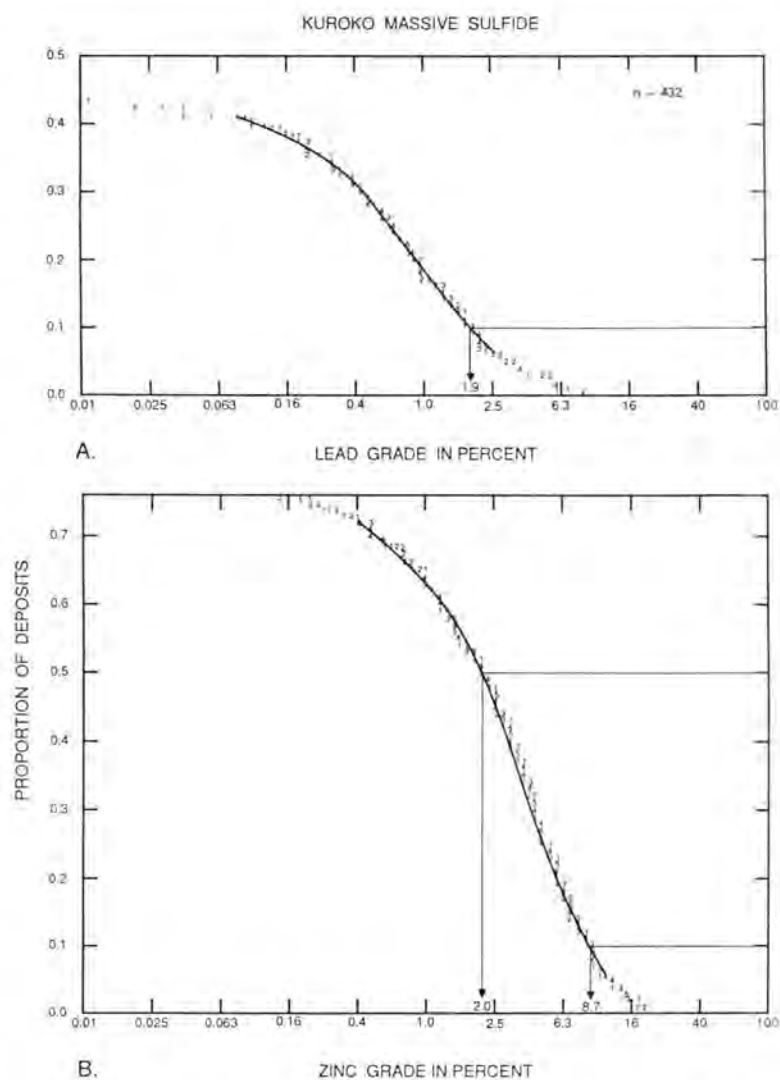
**Figure 145.** Cartoon cross section of kuroko massive sulfide deposit. Modified from Franklin and others (1981).



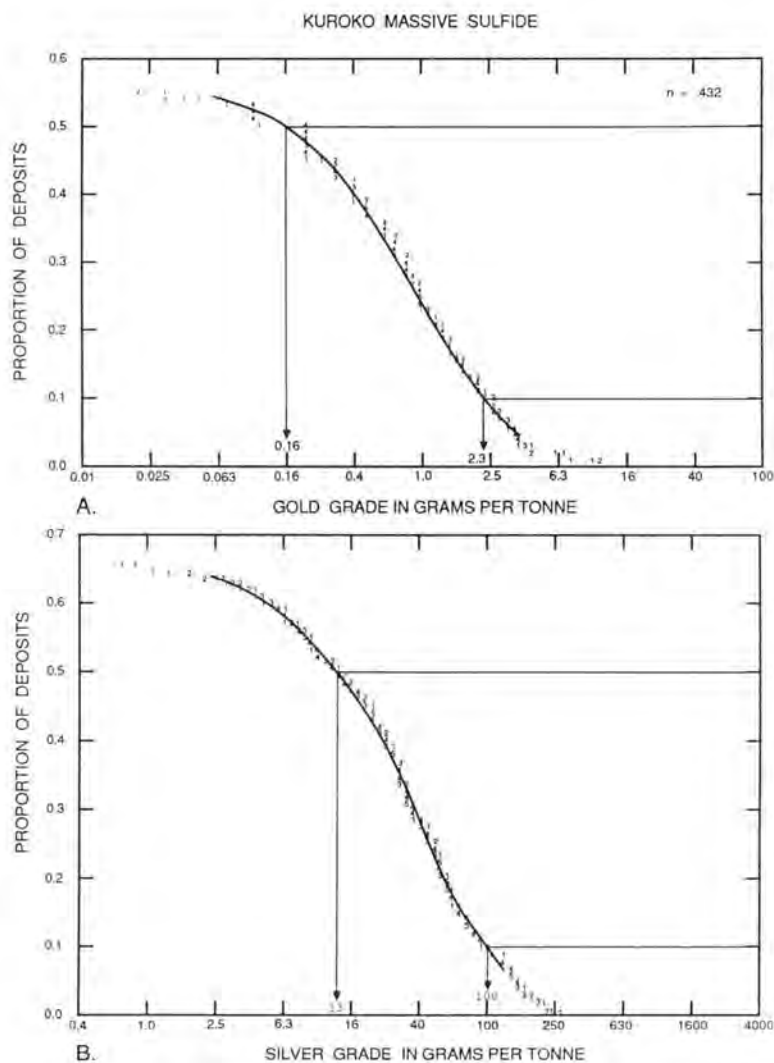
**Figure 146.** Tonnages of kuroko massive sulfide deposits. Individual digits represent number of deposits.



**Figure 147.** Copper grades of kuroko massive sulfide deposits. Individual digits represent number of deposits.



**Figure 148.** Lead-zinc grades of kuroko massive sulfide deposits.  
A, Lead. B, Zinc. Individual digits represent number of deposits.



**Figure 149.** Precious-metal grades of kuroko massive sulfide deposits. **A**, Gold. **B**, Silver. Individual digits represent number of deposits.



DESCRIPTIVE MODEL OF ALGOMA Fe

By William F. Cannon

APPROXIMATE SYNONYM Volcanogenic iron-formation.

DESCRIPTION Beds of banded iron-rich rock typically in volcanic-sedimentary sequences formed in tectonically active oceanic regions. (The grade-tonnage model for Algoma Fe is included under Superior Fe).

GENERAL REFERENCE Goodwin (1973).

GEOLOGICAL ENVIRONMENT

Rock Types Mafic to felsic submarine volcanic rocks and deep-water clastic and volcanoclastic sediments.

Textures Pillowed greenstones, intermediate to felsic tuffs and agglomerates, poorly sorted clastic sediments.

Age Range Mostly Archean.

Depositional Environment Volcano-sedimentary basins (greenstone belts of Precambrian shields) generally with rapid turbidite sedimentation and thick volcanic accumulations.

Tectonic Setting(s) Tectonically active submarine volcanic belts, most commonly preserved in Precambrian shields.

Associated Deposit Types Kuroko massive sulfides and Homestake Au deposits.

DEPOSIT DESCRIPTION

Mineralogy Magnetite, hematite, siderite. Interlayered fine-grained quartz.

Texture/Structure Banded on centimeter scale with chert beds interlayered with Fe-rich beds.

Alteration No syngenetic alteration, but commonly metamorphosed to varying degrees and weathered.

Ore Controls Local controls within general volcano-sedimentary setting are not well established. Sub-basin with low sediment and volcanic input is probably key factor.

Weathering Conversion of iron minerals to Fe-hydroxides; leaching of silica. Intense weathering can form high-grade supergene ores.

Geophysical Signature Magnetic anomalies.

Examples

Vermillion iron-formation, USMN James (1983)

# DESCRIPTIVE MODEL OF QUARTZ PEBBLE CONGLOMERATE Au-U

By Dennis P. Cox

DESCRIPTION Placer Au, U, and PGE in ancient conglomerate.

GENERAL REFERENCES Pretorius (1981), Minter (1982).

## GEOLOGICAL ENVIRONMENT

Rock Types Oligomictic mature conglomerate beds in thick sequence of less mature conglomerate and sandstone deposited on Archean granite-greenstone. Basal volcanic rocks locally. Thick sedimentary sequences underlying Superior type iron-formation.

Textures Well-rounded, well-packed pebbles of vein quartz, chert and pyrite. Bimodal clast-size distribution with well-sorted pebbles and well-sorted matrix. Matrix is quartz, mica, chlorite, pyrite, and fuchsite. Granite clasts are absent.

Age Range Major deposits are Archean to Early Proterozoic (3,100-2,200 m.y.), Tarkwa is 1,900 m.y.

Depositional Environment Very thick onlapping sedimentary deposits in elongate epicontinental basins or half-grabens. Middle and basal reaches of alluvial fans deposited on steeper side of basins. Reducing atmosphere believed to be necessary to preserve detrital pyrite and uraninite.

Tectonic Setting(s) Slow subsidence of Archean craton. Later moderate uplift and erosion to remove Phanerozoic strata and retain Early Proterozoic rocks.

Associated Deposit Types Recent gold placer deposits. Low-sulfide gold quartz veins and Homestake Au in basement rocks. Superior Fe in overlying sequences.

## DEPOSIT DESCRIPTION

Mineralogy Quartz, gold, pyrite, uraninite, brannerite, zircon, chromite, monazite, leucoxene, osmium-iridium alloys, isoferro platinum and sperrylite. By-product Ag. Middle Proterozoic (Tarkwa) and Phanerozoic occurrences have only traces of pyrite and no uraninite.

Texture/Structure Pyrite may occur as rounded grains, and concentrically layered concretions. Gold is in small angular grains, 0.005 to 0.1 mm in diameter.

Ore Controls Braided stream channels in broad unconformity surfaces in alluvial fans. Trough-cross bedding, current- or wave-winnowed bedding surfaces. Gold concentrated at base of mature conglomerate beds deposited on an erosion surface. Carbonaceous layers resembling algal mats deposited at low-energy base of fan contain U and fine Au.

Weathering Residual gold in weathering zone.

Geochemical Signature Au, U, PGE; anomalous radioactivity.

## EXAMPLES

Witwatersrand, SAFR	(Pretorius, 1981; Feather, 1976)
Elliot Lake, CNON	(Roscoe, 1969)
Jacobina, BRZL	(Gross, W., 1968; Cox, 1967)
Tarkwa, GHNA	(Sestini, 1973)

## DESCRIPTIVE MODEL OF OLYMPIC DAM Cu-U-Au

By Dennis P. Cox

DESCRIPTION Hematite, bornite, and other minerals in sedimentary breccia filling grabens in granitic basement.

GENERAL REFERENCE Roberts and Hudson (1983).

### GEOLOGICAL ENVIRONMENT

Rock Types Proterozoic alkali granite with red K-feldspar, brecciated and forming clasts in matrix-rich breccia. Felsic volcanic breccia and tuff. Hematite iron-formation.

Textures Granophyric intergrowth in granite. Breccias grade from clast-supported in interior of basin to matrix-supported in central iron-rich part.

Age Range The only example is 1,500 m.y. old.

Depositional Environment Proterozoic granite basement broken by a deep, narrow graben filled by rapidly deposited breccia, iron-formation, and minor felsic volcanic rocks.

Tectonic Setting(s) Narrow graben transcurrent to broad arch. Local gravity high caused by dense iron-formation. Trace of graben can be detected in post-ore cover rocks as photo lineaments.

Associated Deposit Types Sediment-hosted copper deposits, iron-formation.

### DEPOSIT DESCRIPTION

Mineralogy Stratabound hematite + bornite + chalcopryrite; transgressive hematite + chalcocite + bornite with fluorite, barite, and minor carrollite, cobaltite, native silver, coffinite, brannerite, bastnaesite, and florencite.

Texture/Structure Ore minerals in breccia matrix and in veins. Pisolitic siderite-fluorite-chlorite in stratabound ore.

Alteration Hematite-chlorite and sericite-quartz, also carbonates, fluorite, barite, rutile, and rare anhydrite, tourmaline, and magnetite. Intense chlorite alteration of granite below ore bodies. K-feldspar replaced by chlorite.

Ore Controls Stratiform ore in matrix polymictic-breccia containing clasts of granite, pisolitic rock, hematite, and sulfides. Transgressive ore in fractures parallel to long axis of graben.

Weathering Type example not exposed.

Geochemical and Geophysical Signature Cu + U + Co + Au + Ag + light REE + F + Ba. Dispersion pattern not known. Cu associated with hematite. Co associated with lower pyrite-rich zone. U-REE associated with Cu but Cu not always with U-REE. Au highest in late chalcocite ore. Pb, Zn very low.

Radioactivity would be detectable if exposed or shallow. Magnetic high of unknown origin.

### EXAMPLES

Olympic Dam, AUSA (Roberts and Hudson, 1983)

## DESCRIPTIVE MODEL OF SANDSTONE-HOSTED Pb-Zn

By Joseph A. Briskey

DESCRIPTION Stratabound to stratiform galena and sphalerite in multiple, thin, sheetlike ore bodies in arenaceous sedimentary rocks.

GENERAL REFERENCES Bjørlykke and Sangster (1981), Briskey (1982).

GEOLOGICAL ENVIRONMENT

Rock Types Continental, terrigenous, and marine quartzitic and arkosic sandstone, conglomerate, grit, and siltstone. Local evaporates.

Textures Bedding, crossbedding, paleochannels, liquification structures, and intraformational slump breccias. Quartz and subordinate calcite cement.

Age Range Proterozoic to Cretaceous host rocks.

Depositional Environment Host rocks deposited in combined continental and marine environments including piedmont, fluvial, lagoonal-lacustrine, lagoonal-deltaic, lagoonal-beach, and tidal channel-sand bar environments. Commonly succeeded by marine transgressions.

Tectonic Setting(s) Deep weathering and regional peneplanation during stable tectonic conditions, accompanied by marine platform or piedmont sedimentation associated with at least some orogenic uplift. Sialic basement, mainly "granites" or granitic gneisses.

Associated Deposit Types Sediment-hosted Cu.

DEPOSIT DESCRIPTION

Mineralogy Fine- to medium-crystalline galena with sporadic smaller amounts of sphalerite, pyrite, barite, and fluorite. Minor chalcopryrite, marcasite, pyrrhotite, tetrahedrite-tennantite, chalcocite, freibergite, bournonite, jamesonite, bornite, linnaeite, bravoite, and millerite. Quartz and calcite are usual gangue minerals, and organic debris occurs in some deposits.

Texture/Structure Clots of galena 0.5 to several centimeters in diameter; disseminations 0.1-1 mm in diameter; locally massive. Ore and gangue minerals are intergranular. Galena bands locally highlight crossbedding, and other sedimentary structures in sandstone. Laisvall has crosscutting curvilinear features resembling roll fronts.

Alteration "Sericite" (white mica?) reported in some deposits; but may only be recrystallized sedimentary illite.

Ore Controls Intergranular porosity. Ore may be massive where localized by porous sedimentary structures (above), impermeable barriers, faults, joints, and fractures. Within or immediately above paleochannels, or less commonly, paleoridges.

Weathering Surface oxidation of galena to cerussite, minor anglesite and pyromorphite, chalcopryrite to malachite, azurite, covellite, and chalcocite and (or) sphalerite to smithsonite, hemimorphite, hydrozincite, and goslarite.

Geochemical Signature: Anomalous amounts of Pb and Zn in host rocks and derivative soils; Ba, F, and Ag are enriched in lowermost parts of some deposits. Zinc tends to increase upward in the deposits. Sialic basement may contain anomalous lead concentrations. Background in sandstone: Pb = 7 ppm; Zn = 16 ppm.

EXAMPLES

Laisvall, SWDN  
Vassbo and Guttusjo, SWDN  
Largentièrre, FRNC  
Zeida-Bou Mia, MRCO  
Bou-Sellam, MRCO

(Rickard and others, 1979)  
(Christofferson and others, 1979)  
(Samama, 1976; Michaud, 1980)  
(Schmitt and Thiry, 1977)  
(Caia, 1976)

Model 30a--Con.

Yava (Salmon R.), CNNS  
George Lake, CNSK

Mechernich-Maubach, GRMY

(Hornbrook, 1967; Scott, 1980a, b)  
(Karup-Møller and Brummer, 1970;  
Sangster and Kirkham, 1974)  
(Bjørlykke and Sangster, 1981)

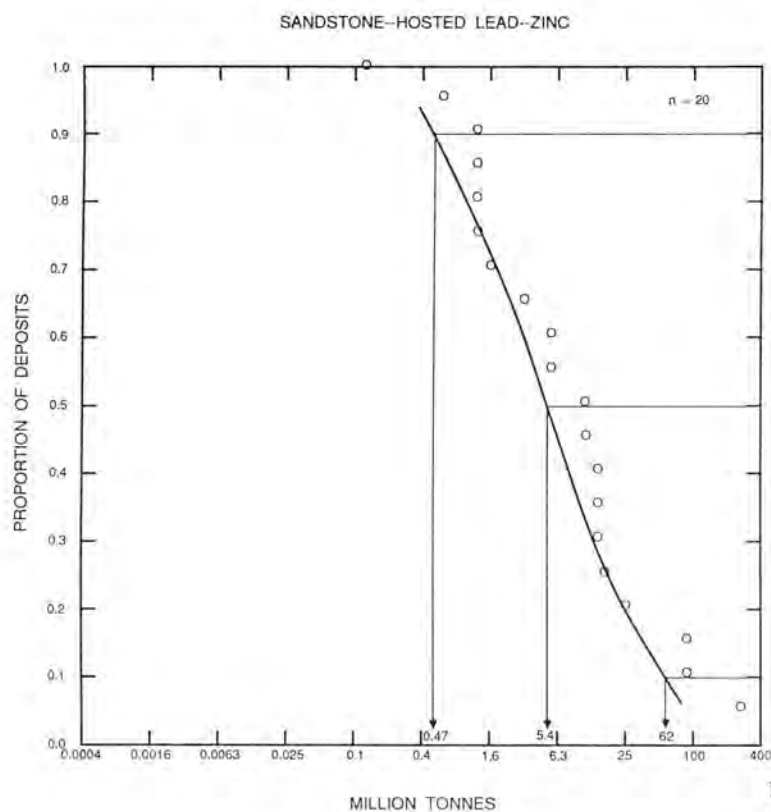
# GRADE AND TONNAGE MODEL OF SANDSTONE-HOSTED Pb-Zn

By Dan L. Mosier

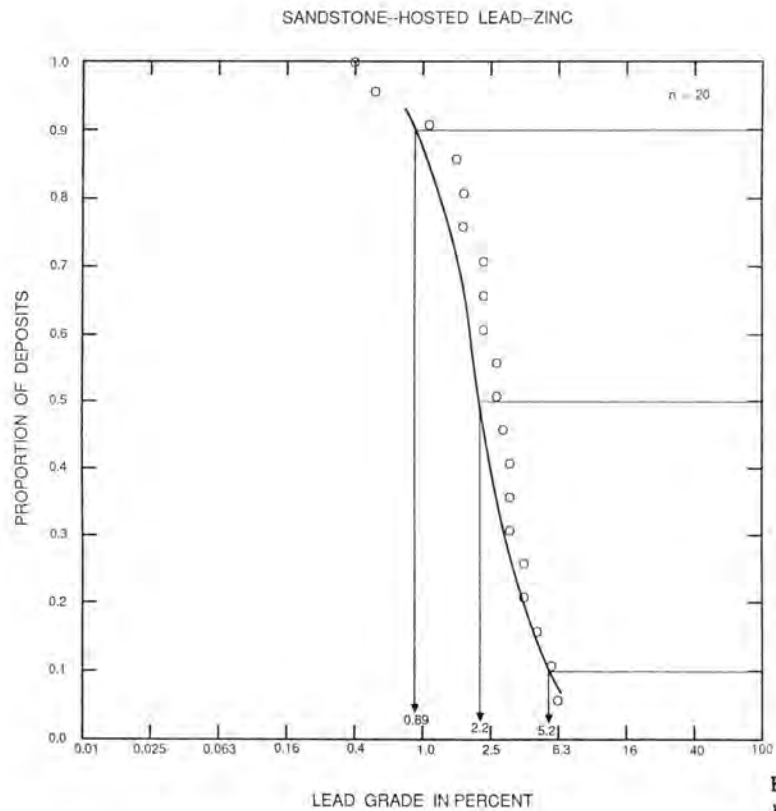
COMMENTS Silver grades tend to be reported for the larger deposits only. See figs. 150-153

## DEPOSITS

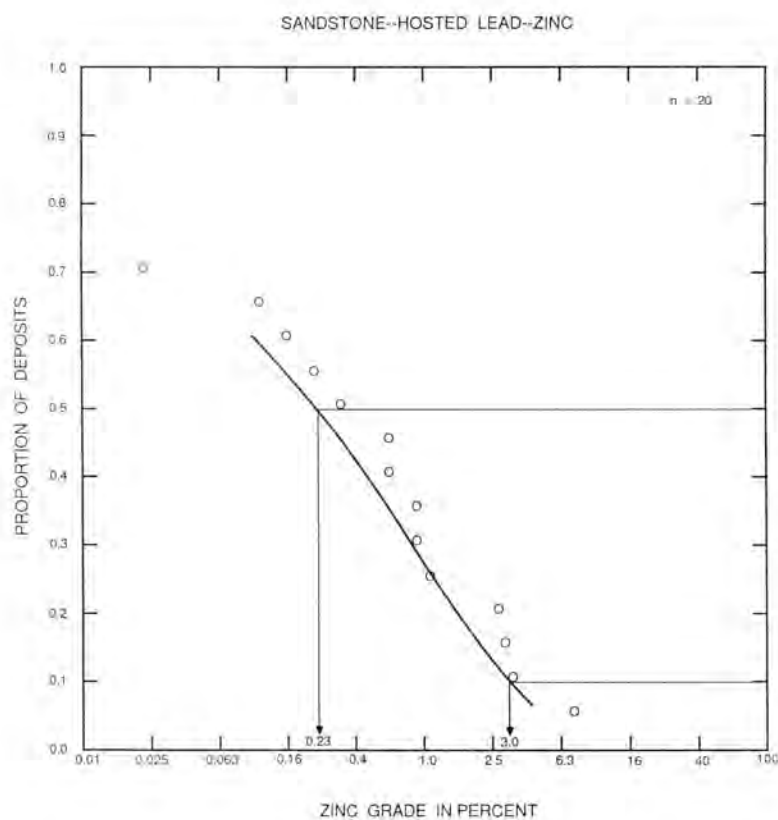
<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Belokany-Laura	URRS	Mechernich	GRMY
Bou Mia	MRCO	Oberpfalz	GRMY
Boylen	CNQU	Osen	NRWY
George Lake	CNSK	Sagliden	SWDN
Guttusjon	SWDN	Shertingdal	NRWY
Laisvall	SWDN	Smithfield	CNNS
Largentiére	FRNC	Tregioivo	ITLY
Lovstrand	SWDN	Vassbo	SWDN
Maiva	SWDN	Yava (Silvermine)	CNNS
Maubach	GRMY	Zeida	MRCO



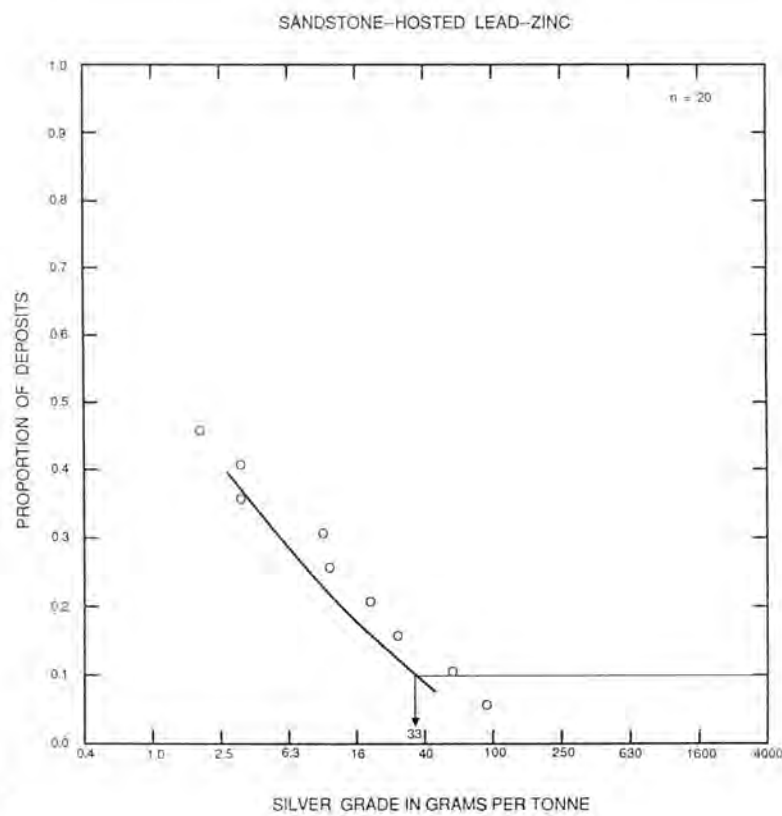
**Figure 150.** Tonnages of sandstone-hosted Pb-Zn deposits.



**Figure 151.** Lead grades of sandstone-hosted Pb-Zn deposits.



**Figure 152.** Zinc grades of sandstone-hosted Pb-Zn deposits.



**Figure 153.** Silver grades of sandstone-hosted Pb-Zn deposits.



## DESCRIPTIVE MODEL OF SEDIMENT-HOSTED Cu

By Dennis P. Cox

APPROXIMATE SYNONYM Sandstone Cu, includes Cu-shale (Lindsey, 1982).

DESCRIPTION Stratabound, disseminated copper sulfides in reduced beds of red-bed sequences.

GENERAL REFERENCES Tourtelot and Vine (1976), Gustafson and Williams (1981).

GEOLOGICAL ENVIRONMENT

Rock Types Red-bed sequence containing green or gray shale, siltstone, and sandstone. Thinly laminated carbonate and evaporite beds. Local channel conglomerate. Some deposits in thinly laminated silty dolomite.

Textures Algal mat structures, mudcracks, crossbedding and scour-and-fill structures. Fossil wood in channels.

Age Range Middle Proterozoic and Permian and early Mesozoic. Other Phanerozoic ages possible.

Depositional Environment Epicontinental shallow-marine basin near paleo-equator. Sabkhas. High evaporation rate. Sediments highly permeable.

Tectonic Setting(s) Intracontinental rift or aulacogen--failed arm of triple junction of plate spreading. Passive continental margin. Major growth faults.

Associated Deposit Types Halite, sylvite, gypsum, anhydrite. Sandstone uranium, basalt copper, and Kipushi Cu-Pb-Zn.

DEPOSIT DESCRIPTION

Mineralogy Chalcocite and other  $\text{Cu}_2\text{S}$  minerals + pyrite  $\pm$  bornite  $\pm$  native silver.  $\text{Cu}_2\text{S}$  replacement of early fine-grained pyrite is common. Deposits may be zoned with centers of chalcocite  $\pm$  bornite, rims of chalcopyrite, and peripheral galena + sphalerite. Some deposits contain carrollite and Co-pyrite and Ge minerals.

Texture/Structure Fine disseminated, stratabound, locally stratiform. Framboidal or colloform pyrite. Cu minerals replace pyrite and cluster around carbonaceous clots or fragments.

Alteration Green, white, or gray (reduced) color in red beds. Regionally metamorphosed red beds may have purple color.

Ore Controls Reducing low-pH environment such as fossil wood, algal mat. Abundant biogenic sulfur. Pyritic sediments. Petroleum in paleoaquifers. High permeability of footwall sediments is critical. Boundaries between oxidized and reduced sediments.

Weathering Surface exposures may be completely leached. Secondary chalcocite enrichment down dip is common.

Geochemical Signature Cu, Ag, Pb, Zn (Mo, V, U) (Co, Ge). Au is low. Weak radioactivity in some deposits.

EXAMPLES

Kupferschiefer, GRMY	(Wedepohl, 1971)
White Pine, USMI	(Brown, 1971)
Western Montana (Belt), USMT	(Harrison 1972, 1982)
Kamoto, ZIRE	(Bartholome and others, 1976)



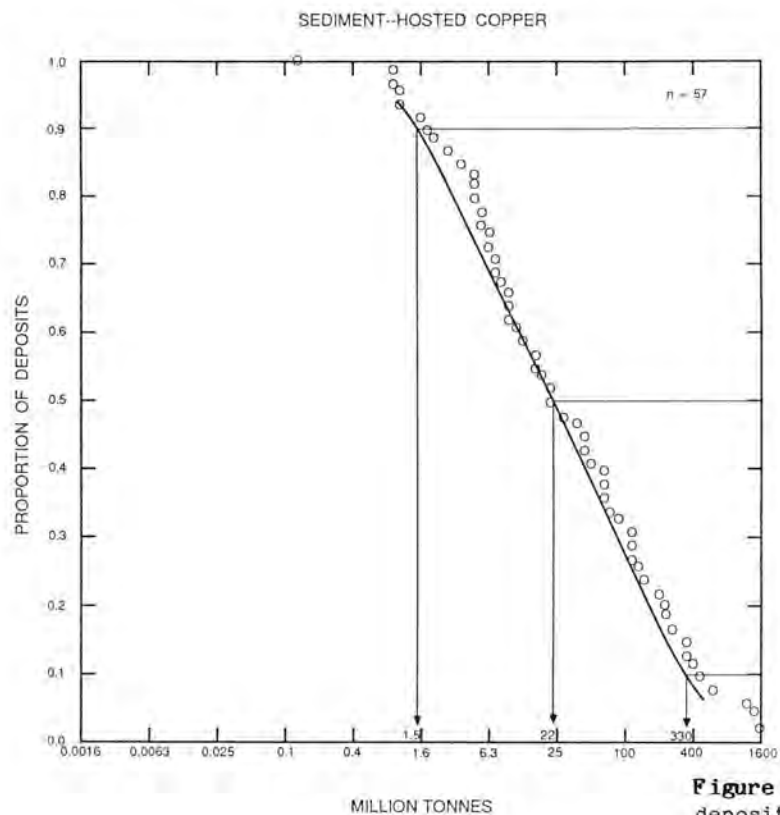
## GRADE AND TONNAGE MODEL OF SEDIMENT-HOSTED Cu

By Dan L. Mosier, Donald A. Singer, and Dennis P. Cox

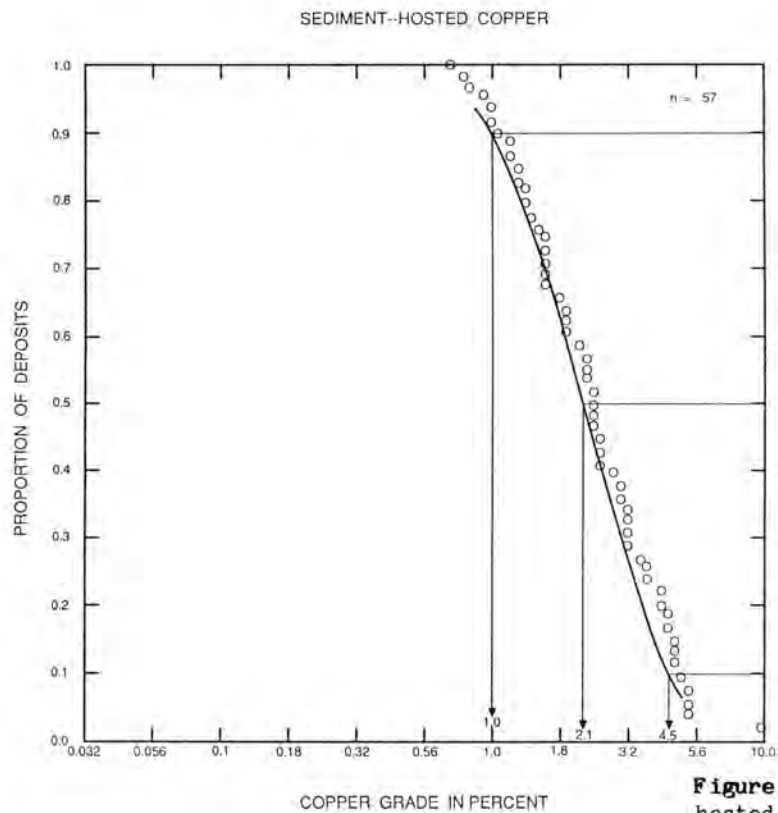
COMMENTS Tonnages are probably underestimated for deposits in Zambia and Zaire due to poor reporting. The extent to which mineralization exists between mines in Zambia and Zaire is not considered. Estimates for the deposits in Russia probably represent districts. See figs. 154-156

DEPOSITS

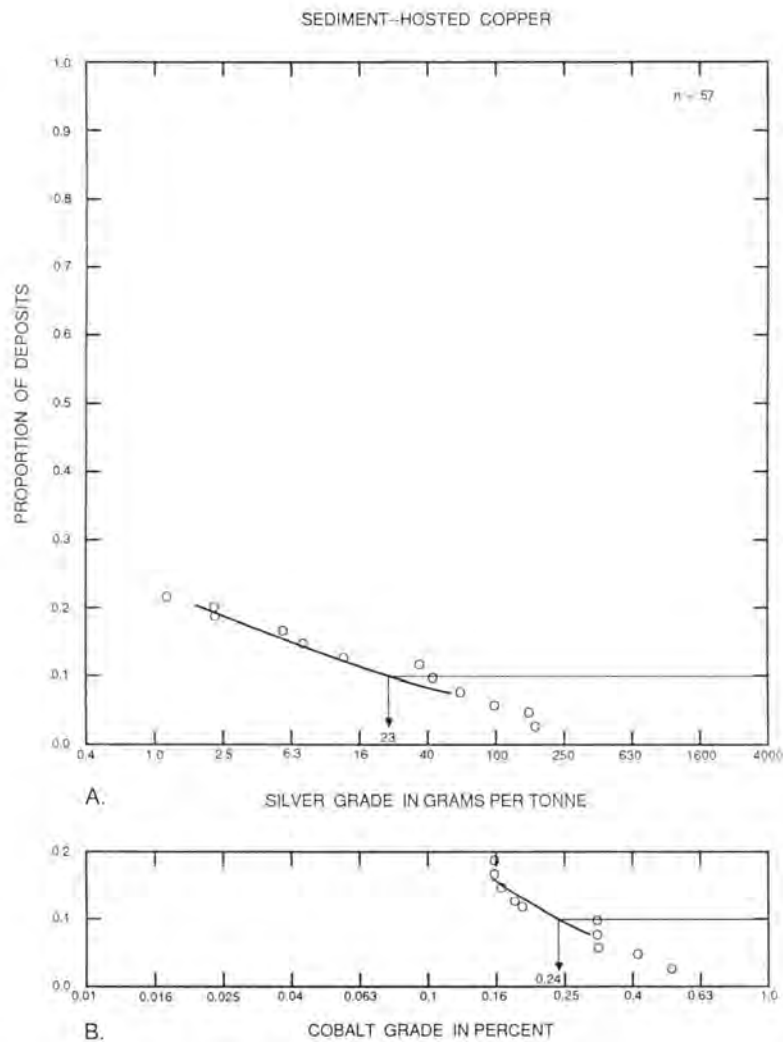
<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Alaska	ZIMB	Mangum	USOK
Baluba	ZMBA	Mansfeld	GRMY
Big Horn (Yarrow Ck)	CNAL	Matchless	NAMB
Burra	AUSA	Matchless West	NAMB
Bwana Mkubwa	ZMBA	Mokambo	ZMBA
Cattle Grid	AUSA	Mt. Gunson	AUSA
Chacarilla	BLVA	Mt. Oxide	AUQL
Chambiashi	ZMBA	Mufulira	ZMBA
Chibuluma	ZMBA	Musoshi	ZIRE
Chibuluma West	ZMBA	Musonoi	ZIRE
Chingola-Nchanga	ZMBA	Nacimiento	USNM
Chongwe	ZMBA	Norah	ZIMB
Corocoro	BLVA	Oamite	NAMB
Creta	USOK	Pintada-Stauber	USNM
Crowell Area	USTX	Presque Isle	USMI
Dikulume-Mashamba	ZIRE	Roan Antelope	
Dzhezhkazgan		(Luanshya)	ZMBA
(Magakyan)	URRS	Rokana (Nkana)	ZMBA
Gwai River	ZIMB	Ruwe (Mutoshi)	ZIRE
Kalengwa	ZMBA	Shackleton	ZIMB
Kalushi (Kalulushi)	ZMBA	Silverside	ZIMB
Kamoto	ZIRE	Snowstorm	USMT
Kanmantoo	AUSA	Spar Lake (Troy)	USMT
Kansanshi	ZMBA	Tenke-Fungurume	ZIRE
Kapunda	AUSA	Tshinsenda	
Kilembe	UGND	(Kinsenda)	ZIRE
Konkola (Bancroft)	ZMBA	Udokan	URRS
Lena	URRS	White Pine	USMI
Lubin (Legnica-			
Glogow)	PLND		
Lumwana	ZMBA		
Mammoth (Gunpowder)	AUQL		
Mangula (Miriam)	ZIMB		



**Figure 154.** Tonnages of sediment-hosted Cu deposits.



**Figure 155.** Copper grades of sediment-hosted Cu deposits.



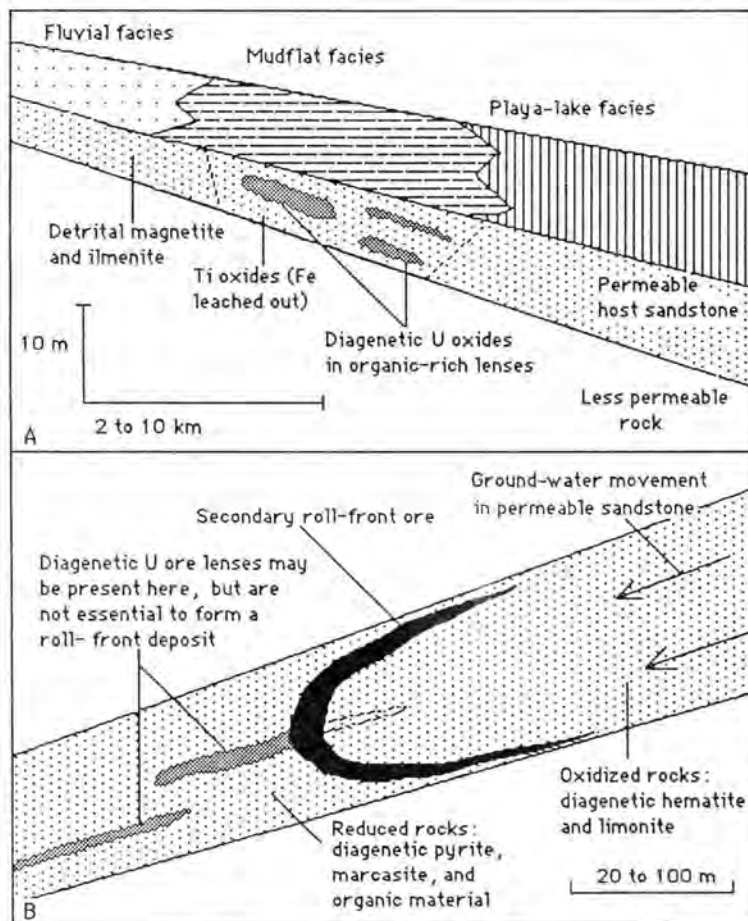
**Figure 156.** By-product grades of sediment-hosted Cu deposits. A, silver. B, Cobalt.

## DESCRIPTIVE MODEL OF SANDSTONE U

By Christine E. Turner-Peterson and Carroll A. Hodges

APPROXIMATE SYNONYMS Tabular U ore, roll front U.DESCRIPTION Microcrystalline uranium oxides and silicates deposited during diagenesis in localized reduced environments within fine- to medium-grained sandstone beds; some uranium oxides also deposited during redistribution by ground water at interface between oxidized and reduced ground (see fig. 157).GENERAL REFERENCE Turner-Peterson and Fishman (1986), Granger and Warren (1969).GEOLOGICAL ENVIRONMENTRock Types Host rocks are feldspathic or tuffaceous sandstone. Pyroclastic material is felsic in composition. Mudstone or shale commonly above and/or below sandstones hosting diagenetic ores (see fig. 157A).Textures Permeable--medium to coarse grained; highly permeable at time of mineralization, subsequently restricted by cementation and alteration.Age Range Most deposits are Devonian and younger. Secondary roll-front deposits mainly Tertiary.Depositional Environment Continental-basin margins, fluvial channels, braided stream deposits, stable coastal plain. Contemporaneous felsic volcanism or eroding felsic plutons are sources of U. In tabular ore, source rocks for ore-related fluids are commonly in overlying or underlying mud-flat facies sediments.Tectonic Setting(s) Stable platform or foreland-interior basin, shelf margin; adjacent major uplifts provide favorable topographic conditions.Associated Deposit Types Sediment-hosted V may be intimately associated with U. Sediment-hosted Cu may be in similar host rocks and may contain U.DEPOSIT DESCRIPTIONMineralogy Uraninite, coffinite, pyrite in organic-rich horizons. Chlorite common.Texture/Structure Stratabound deposits. Tabular U--intimately admixed with pore-filling humin in tabular lenses suspended within reduced sandstone (fig. 157A). Replacement of wood and other carbonaceous material. Roll front U--in crescentic lens that cuts across bedding, at interface between oxidized and reduced ground (fig. 157B).Alteration Tabular--Humic acid mineralizing fluids leach iron from detrital magnetite-ilmenite leaving relict  $TiO_2$  minerals in diagenetic ores. Roll front--Oxidized iron minerals in rock updip, reduced iron minerals in rock downdip from redox interface.Ore Controls Permeability. Tabular--Humin or carbonaceous material the main concentrator of U. Roll front--S species, "sour" gas,  $FeS_2$ . Bedding sequences with low dips; felsic plutons or felsic tuffaceous sediments adjacent to or above host rock are favorable source for U. Regional redox interface marks locus of ore deposition.Weathering Oxidation of primary uraninite or coffinite to a variety of minerals, notably yellow carnotite as bloom in V-rich ores.Geochemical and Geophysical Signature U, V, Mo, Se, locally Cu, Ag. Anomalous radioactivity from daughter products of U. Low magnetic susceptibility in and near tabular ores.EXAMPLES

Colorado Plateau	(Fischer, 1974)
Grants, USNM	(Turner-Peterson and Fishman, 1986)
Texas Gulf Coast	(Reynolds and Goldhaber, 1983)
USWY	(Granger and Warren, 1969)



**Figure 157.** Cartoon sections showing: **A**, Diagenetic mineralization (from Turner-Peterson and Fishman, 1986); **B**, roll-front mineralization in sandstone U deposits (from Nash and others, 1981).

# DESCRIPTIVE MODEL OF SEDIMENTARY EXHALATIVE Zn-Pb

By Joseph A. Briskey

APPROXIMATE SYNONYMS Shale-hosted Zn-Pb; sediment-hosted massive sulfide Zn-Pb.

DESCRIPTION Stratiform basinal accumulations of sulfide and sulfate minerals interbedded with euxinic marine sediments form sheet- or lens-like tabular ore bodies up to a few tens of meters thick, and may be distributed through a stratigraphic interval over 1,000 m (see fig. 158).

GENERAL REFERENCES Large (1980, 1981, 1983).

## GEOLOGICAL ENVIRONMENT

Rock Types Euxinic marine sedimentary rocks including: black (dark) shale, siltstone, sandstone, chert, dolostone, micritic limestone, and turbidites. Local evaporitic sections in contemporaneous shelf facies. Volcanic rocks, commonly of bimodal composition, are present locally in the sedimentary basin. Tuffites are the most common. Slump breccias, fan conglomerates, and similar deposits, as well as facies and thickness changes, are commonly associated with synsedimentary faults.

Textures Contrasting sedimentary thicknesses and facies changes across hinge zones. Slump breccias and conglomerates near synsedimentary faults.

Age Range Known deposits are Middle Proterozoic (1,700-1,400 m.y.); Cambrian to Carboniferous (530-300 m.y.).

Depositional Environment Marine epicratonic embayments and intracratonic basins, with smaller local restricted basins (second- and third-order basins).

Tectonic Setting(s) Epicratonic embayments and intracratonic basins are associated with hinge zones controlled by synsedimentary faults, typically forming half-grabens. Within these grabens (first-order basins), penecontemporaneous vertical tectonism forms smaller basins (second-order basins) and associated rises. Smaller third-order basins (tens of kilometers) within the second-order basins ( $10^2$ - $10^3$  km) are the morphological traps from the stratiform sulfides.

Associated Deposit Types Bedded barite deposits.

## DEPOSIT DESCRIPTION

Mineralogy Pyrite, pyrrhotite, sphalerite, galena, sporadic barite and chalcopyrite, and minor to trace amounts of marcasite, arsenopyrite, bismuthinite, molybdenite, enargite, millerite, freibergite, cobaltite, cassiterite, valleriite, and melnikovite.

Texture/Structure Finely crystalline and disseminated, monomineralic sulfide laminae are typical. Metamorphosed examples are coarsely crystalline and massive.

Alteration Stockwork and disseminated sulfide and alteration (silicification, tourmalization, carbonate depletion, albitization, chloritization, dolomitization) minerals possibly representing the feeder zone of these deposits commonly present beneath or adjacent to the stratiform deposits. Some deposits have no reported alteration. Celsian, Ba-muscovite, and ammonium clay minerals may be present.

Ore Controls Within larger fault-controlled basins, small local basins form the morphological traps that contain the stratiform sulfide and sulfate minerals. The faults are synsedimentary and serve as feeders for the stratiform deposits. Euxinic facies.

Weathering Surface oxidation may form large gossans containing abundant carbonates, sulfates, and silicates of lead, zinc, and copper.

Geochemical Signature Metal zoning includes lateral Cu-Pb-Zn-Ba sequence extending outward from feeder zone; or a vertical Cu-Zn-Pb-Ba sequence extending upward.  $\text{NH}_3$  anomalies may be present. Exhalative chert interbedded with stratiform sulfide and sulfate minerals; peripheral hematite-

Model 31a--Con.

chert formations. Local (within 2 km) Zn, Pb, and Mn haloes. Highest expected background in black shales: Pb = 500 ppm; Zn = 1,300 ppm; Cu = 750 ppm; Ba = 1,300 ppm; in carbonates: Pb = 9 ppm; Zn = 20; Cu = 4 ppm; Ba = 10.

#### EXAMPLES

Sullivan mine, CNBC	(Hamilton and others, 1982)
Meggen mine, GRMY	(Krebs, 1981)
Navan, Silvermines, Tynagh, IRLD	(Boyce and others, 1983; Taylor, 1984)

#### GRADE AND TONNAGE MODEL OF SEDIMENTARY EXHALATIVE Zn-Pb

By W. David Menzie and Dan L. Mosier

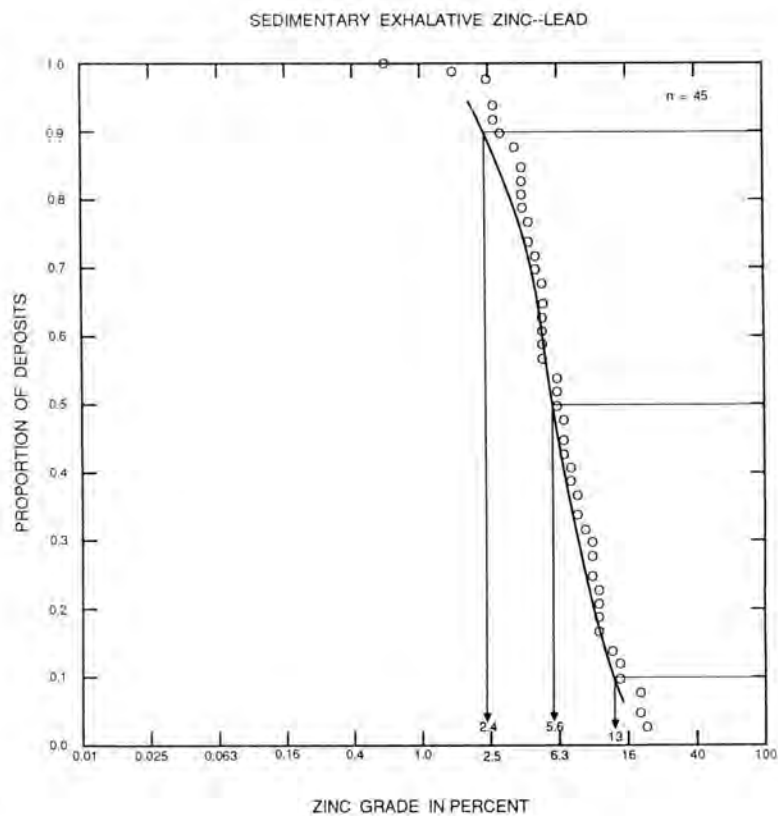
COMMENTS Deposits in this model include most commonly identified deposits of this type. Nevertheless, examination of the distribution of silver grade suggests the presence of two subtypes. Lead grades are significantly correlated with silver grades ( $r = 0.77$ ,  $n = 39$ ). See figs. 159-163.

#### DEPOSITS

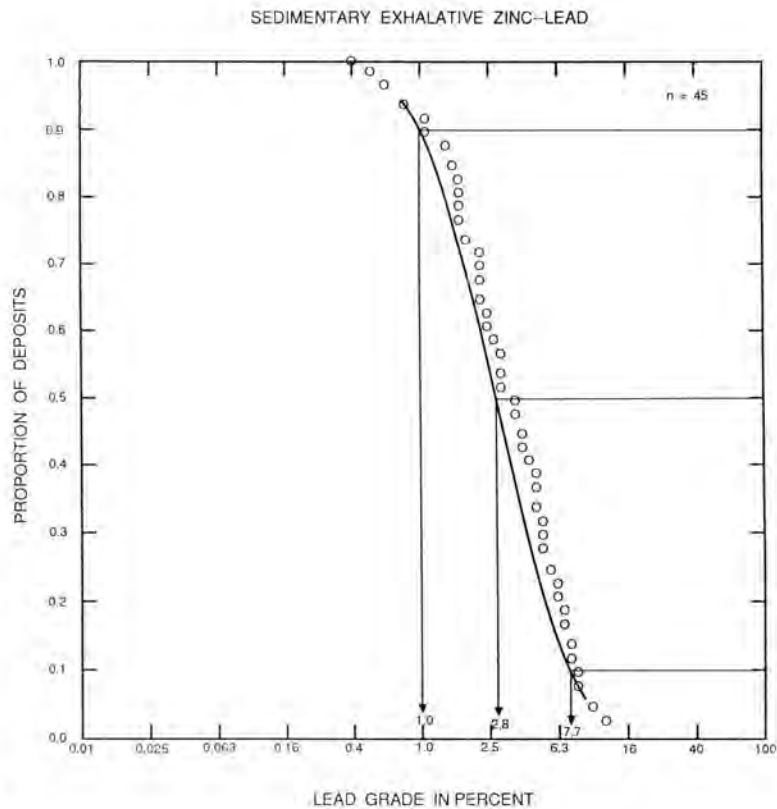
<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Balmat	USNY	McArthur	AUNT
Baroi	INDA	Meggen	GRMY
Big Syncline	SAFR	Mineral King	CNBC
Black Mtn.	SAFR	Mount Isa	AUQL
Broken Hill	SAFR	Navan	IRLD
Broken Hill	AUNT	Rajpura-Daiba	INDA
Cirque	CNBC	Rammelsberg	GRMY
Dugald River	AUQL	Rampura-Agucha	INDA
Duncan Lake	CNBC	Red Dog	USAK
Dy	CNYT	Reeves MacDonald	CNBC
Faro	CNYT	Rosh Pinah	NAMB
Fx	CNBC	Silvermines	IRLD
Grum	CNYT	Squirrel Hills	AUQL
HB	CNBC	Sullivan	CNBC
Hilton	AUQL	Swim Lake	CNYT
Homestake	CNBC	Tom	CNYT
Howards Pass	CNYT	Tynagh	IRLD
Jersey Emerald	CNBC	Vangorda	CNYT
King Fissure	CNBC	Woodcutters	AUNT
Lady Loretta	AUQL	Wigwam	CNBC
MacMillan	CNYT	Zawar	INDA
Matt Berry	CNYT	Zawarmala	INDA



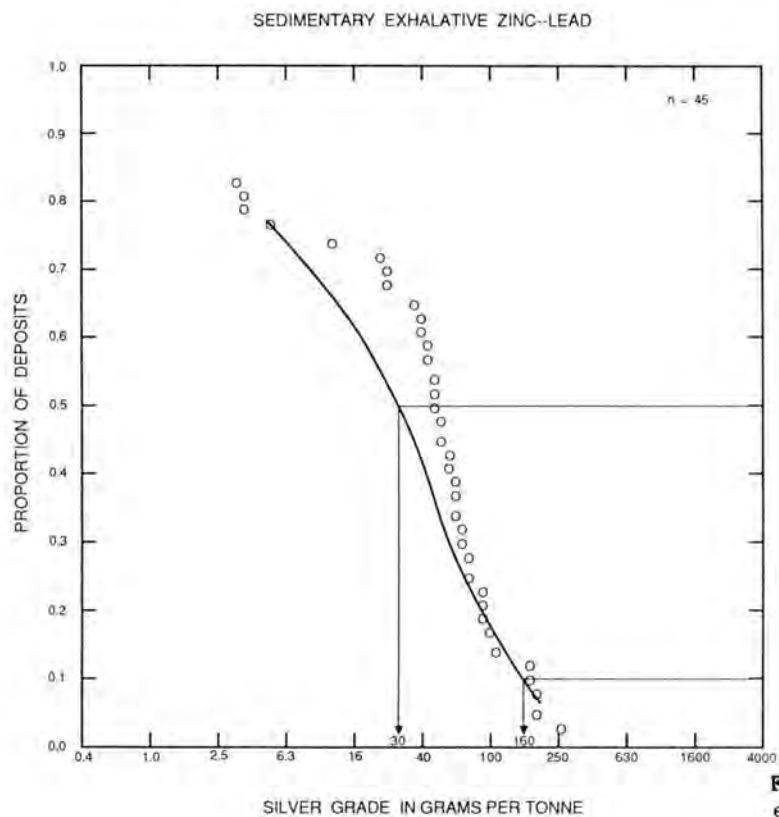




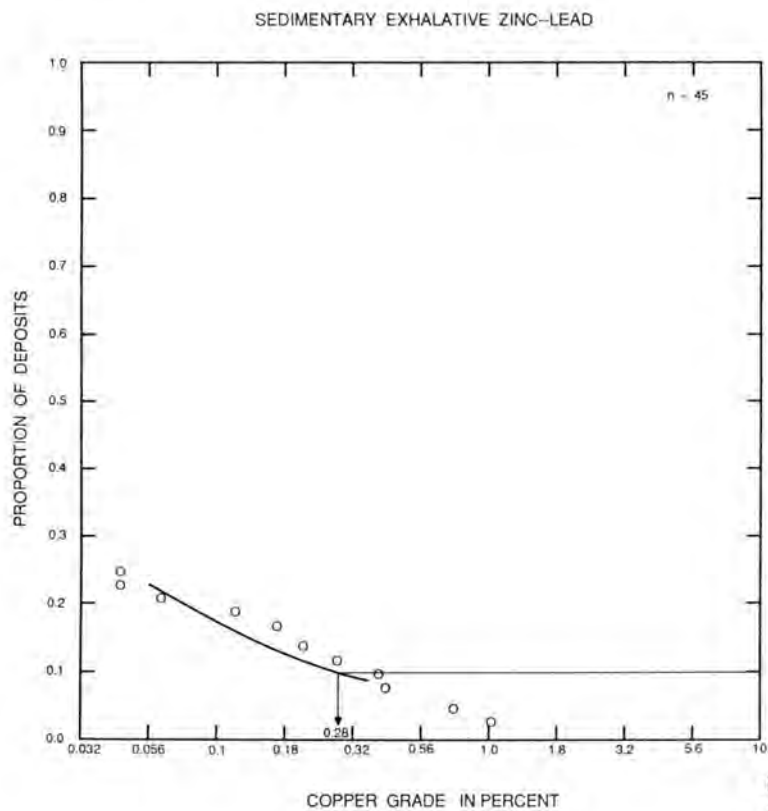
**Figure 160.** Zinc grades of sedimentary exhalative Zn-Pb deposits.



**Figure 161.** Lead grades of sedimentary exhalative Zn-Pb deposits.



**Figure 162.** Silver grades of sedimentary exhalative Zn-Pb deposits.



**Figure 163.** Copper grades of sedimentary exhalative Zn-Pb deposits.

## DESCRIPTIVE MODEL OF BEDDED BARITE

By Greta J. Orris

APPROXIMATE SYNONYM Stratiform barite.DESCRIPTION Stratiform deposits of barite interbedded with dark-colored cherty and calcareous sedimentary rocks.GEOLOGICAL ENVIRONMENTRock Types Generally dark-colored chert, shale, mudstone, limestone or dolostone. Also with quartzite, argillite, and greenstone.Age Range Proterozoic and Paleozoic.Depositional Environment Epicratonic marine basins or embayments (often with smaller local restricted basins).Tectonic Setting(s) Some deposits associated with hinge zones controlled by synsedimentary faults.Associated Deposit Types Sedimentary exhalative Zn-Pb (see fig. 158).DEPOSIT DESCRIPTIONMineralogy Barite  $\pm$  minor witherite  $\pm$  minor pyrite, galena, or sphalerite. Barite typically contains several percent organic matter plus some  $H_2S$  in fluid inclusions.Texture/Structure Stratiform, commonly lensoid to poddy; ore laminated to massive with associated layers of barite nodules or rosettes; barite may exhibit primary sedimentary features. Small country rock inclusions may show partial replacement by barite.Alteration Secondary barite veining; weak to moderate sericitization has been reported in or near some deposits in Nevada.Ore Controls Deposits are localized in second- and third-order basins.Weathering Indistinct, generally resembling limestone or dolostone; occasionally weathered-out rosettes or nodules.Geochemical Signature Ba; where peripheral to sediment-hosted Zn-Pb, may have lateral (Cu)-Pb-Zn-Ba zoning or regional manganese haloes. High organic C content.EXAMPLES

Meggen, GRMY	(Krebs, 1981)
Magnet Cove, USAR	(Scull, 1958)
Northumberland, USNV	(Shawe and others, 1969)

## GRADE AND TONNAGE MODEL OF BEDDED BARITE

By Greta J. Orris

COMMENTS See figs. 164-165.DEPOSITS

<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Ballynoe	IRLD	Brookfield	CNNS
Barite Mtn.	CNYT	Castle Island	USAK
Barite (Mouse)	CNYT	Cathy (Walt)	CNYT
Barite Valley	SAFR	Cirque Barite	CNBC
Baw Hin Khao	THLD	Greystone	USNV

Gurranda	AUNS	Mountain Springs	USNV
Kempfield	AUNS	Nimiuktuk	USAK
Khuzdar	PKTN	Rammelsberg Barite	GRMY
Magnet Cove	USAR	Snake Mountain	USNV
Mangampetta N.	INDA	Tea	CNYT
Mangampetta S.	INDA	Uribe	USWA
Meggen Barite	GRMY	Weedaroo	AUSA
Mel Barite	CNYT		

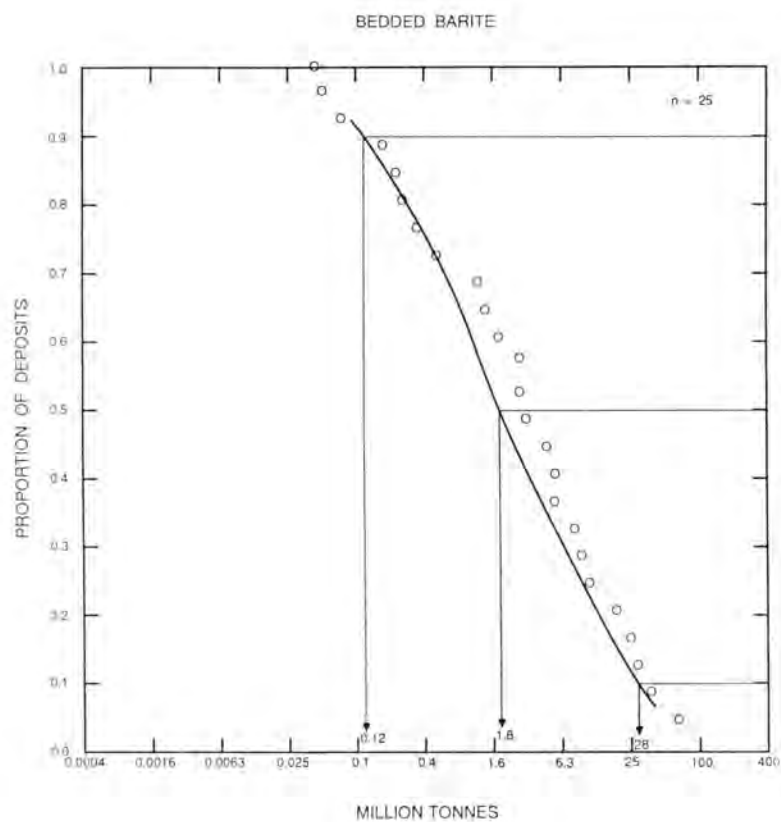


Figure 164. Tonnages of bedded barite deposits.

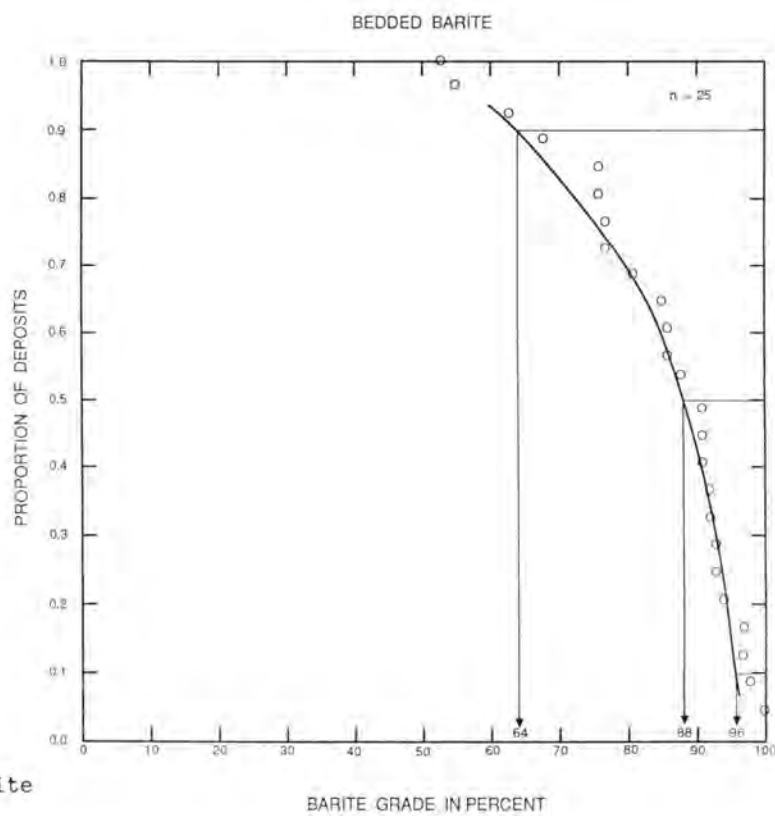


Figure 165. Barite grades of bedded barite deposits.

## DESCRIPTIVE MODEL OF EMERALD VEINS

By Dennis P. Cox

DESCRIPTION Emerald in plagioclase-dolomite veins in black shale.GENERAL REFERENCES Sinkankas (1981), p. 338-358, 407-435.GEOLOGICAL ENVIRONMENTRock Types Black shale, claystone, siltstone, locally calcareous. Minor sandstone, limestone, conglomerate, and evaporites. Locally coarse dolomite breccia filled by carbonates and oligoclase.Textures Diabasic dikes present but not prominent.Age Range Cretaceous and Tertiary.Depositional Environment Thick epicontinental anoxic marine shale. Evaporites may have provided saline solutions.Tectonic Setting(s) Major faults. Minor intrusions may have provided heat sources for fluid circulation.Associated Deposit Types May be associated with Pb-Zn deposits on a regional scale.DEPOSIT DESCRIPTIONMineralogy Emerald + greenish beryl + oligoclase + dolomite + calcite + pyrite + fluorite + rutile + quartz. Apatite, parisite, and REE dolomite reported from Muzo.Texture/Structure Crustified banding, vuggy, coarsely crystalline.Alteration Shale altered to black hornfels, fossils replaced by oligoclase. Dolomitization.Ore Controls Major fault at intersections of minor cross faults, sharp-walled veins, and tabular breccia bodies. Veins locally confined to sedimentary strata that overlie or underlie ferruginous beds.Weathering Plagioclase weathers to pockets of kaolinite.Geochemical Signature In veins: high Be, Na, Mg; low Li, Ba, K, Mo, Pb relative to shale outside of mineralized areas. At Muzo, REE in veins, Cu in underlying beds.EXAMPLES

Gachala district, CLBA	(Escovar, 1979)
Muzo district, CLBA	(Sinkankas, 1981)

## DESCRIPTIVE MODEL OF SOUTHEAST MISSOURI Pb-Zn

By Joseph A. Briskey

SYNONYMS Carbonate-hosted Pb-Zn; Mississippi Valley type.

DESCRIPTION Stratabound, carbonate-hosted deposits of galena, sphalerite, and chalcopyrite in rocks having primary and secondary porosity, commonly related to reefs on paleotopographic highs (see fig. 166). (For grade-tonnage model see Appalachian Zn deposit model.)

GENERAL REFERENCES Snyder and Gerdemann (1968), Thacker and Anderson (1977).

### GEOLOGICAL ENVIRONMENT

Rock Types Dolomite; locally ore bodies also occur in sandstone, conglomerate, and calcareous shales.

Textures Calcarenites are most common lithology. Tidalites, stromatolite finger reefs, reef breccias, slump breccias; oolites, crossbedding, micrites.

Age Range Known deposits are in Cambrian to Lower Ordovician strata.

Depositional Environment Host rocks are shallow-water marine carbonates, with prominent facies control by reefs growing on flanks of paleotopographic basement highs. Deposits commonly occur at margins of clastic basins.

Tectonic Setting(s) Stable cratonic platform.

Associated Deposit Types Precambrian volcanic-hosted magnetite; Ba-Pb deposits occur higher in the Cambrian section.

### DEPOSIT DESCRIPTION

Mineralogy Galena, sphalerite, chalcopyrite, pyrite, marcasite. Minor siegenite, bornite, tennantite, barite, bravoite, digenite, covellite, arsenopyrite, fletcherite, adularia, pyrrhotite, magnetite, millerite, polydymite, vaesite, djurleite, chalcocite, anilite, and enargite in order of abundance. Dolomite and minor quartz.

Texture/Structure Early fine-grained replacement; main stage coarse-grained replacement and vuggy or colloform open space filling. Hypogene leaching of galena is common.

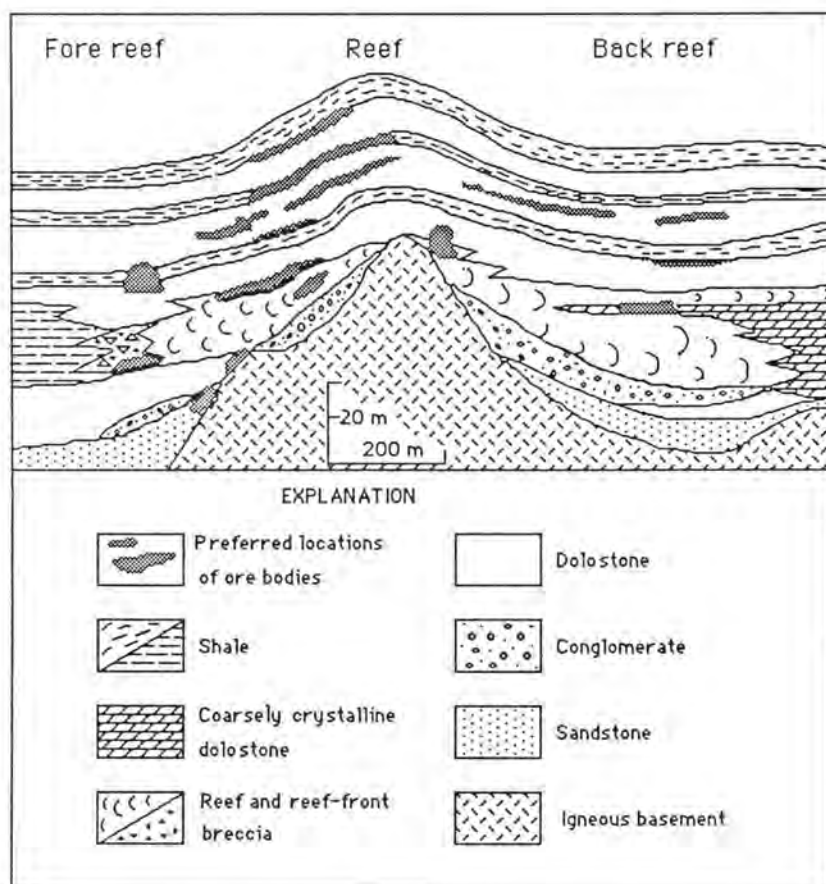
Alteration Regional dolomitization; latter brown, ferroan, and bitumen-rich dolomite; extensive carbonate dissolution and development of residual shale; mixed-layer illite-chlorite altered to 2M muscovite; dickite and kaolinite in vugs; very minor adularia.

Ore Controls Open-space filling and replacement, most commonly at the interface between gray and tan dolomite, but also in traps at any interface between permeable and impermeable units. Any porous units may host ore: sandstone pinchouts; dissolution collapse breccias; faults; permeable reefs; slump, reef, and fault breccias; coarsely crystalline dolostone.

Geochemical Signature Regional anomalous amounts of Pb, Zn, Cu, Mo, Ag, Co, and Ni in insoluble residues. Zoning is roughly Cu ( $\pm$  Ni  $\pm$  Co)-Pb-Zn-iron sulfide going up section; ores contain about 30 ppm Ag; inconsistent lateral separation of metal zones. Background for carbonates: Pb = 9 ppm; Zn = 20; Cu = 4.

### EXAMPLES

Viburnum subdistrict, USMO (Economic Geology 1977; Heyl, 1982)



**Figure 166.** Cartoon cross section of a southeast Missouri Pb-Zn deposit (modified from Evans, 1977).



## DESCRIPTIVE MODEL OF APPALACHIAN Zn

By Joseph A. Briskey

SYNONYMS Carbonate-hosted Zn; Mississippi Valley type.

DESCRIPTION Stratabound deposits of sphalerite and minor galena in primary and secondary voids in favorable beds or horizons in thick platform dolostone and limestone (see fig. 167).

GENERAL REFERENCE Hoagland (1976).

### GEOLOGICAL ENVIRONMENT

Rock Types Dolostone and limestone.

Textures Subtidal, intratidal, and supratidal textures with high porosity are common, especially in the dolostones; limestones are commonly micritic, some with birdseye textures.

Age Range Appalachian deposits occur in rocks of Cambrian to Middle Ordovician age. Other deposits are in rocks as old as Proterozoic and as young as Triassic.

Depositional Environment Shallow-water, tidal and subtidal marine environments.

Tectonic Setting(s) Stable continental shelf.

Associated Deposit Types Stratabound carbonate-hosted deposits of barite-fluorite-sphalerite.

### DEPOSIT DESCRIPTION

Mineralogy Sphalerite, with variable but subordinate pyrite and minor marcasite, and with minor barite, fluorite, gypsum, and anhydrite. Galena is usually absent or rare, but may be abundant locally.

Texture/Structure Mainly open space filling of coarse to medium crystalline sphalerite and pinkish dolomite. Sphalerite commonly displays banding. Locally, fine sphalerite in finely varved dolomite composes the breccia matrix.

Alteration Extensive finely crystalline dolostone occurs regionally and coarse crystalline dolomite is more common nearer to ore bodies. Silicification is typically closely associated with ore bodies. Extensive limestone dissolution and development of residual shale.

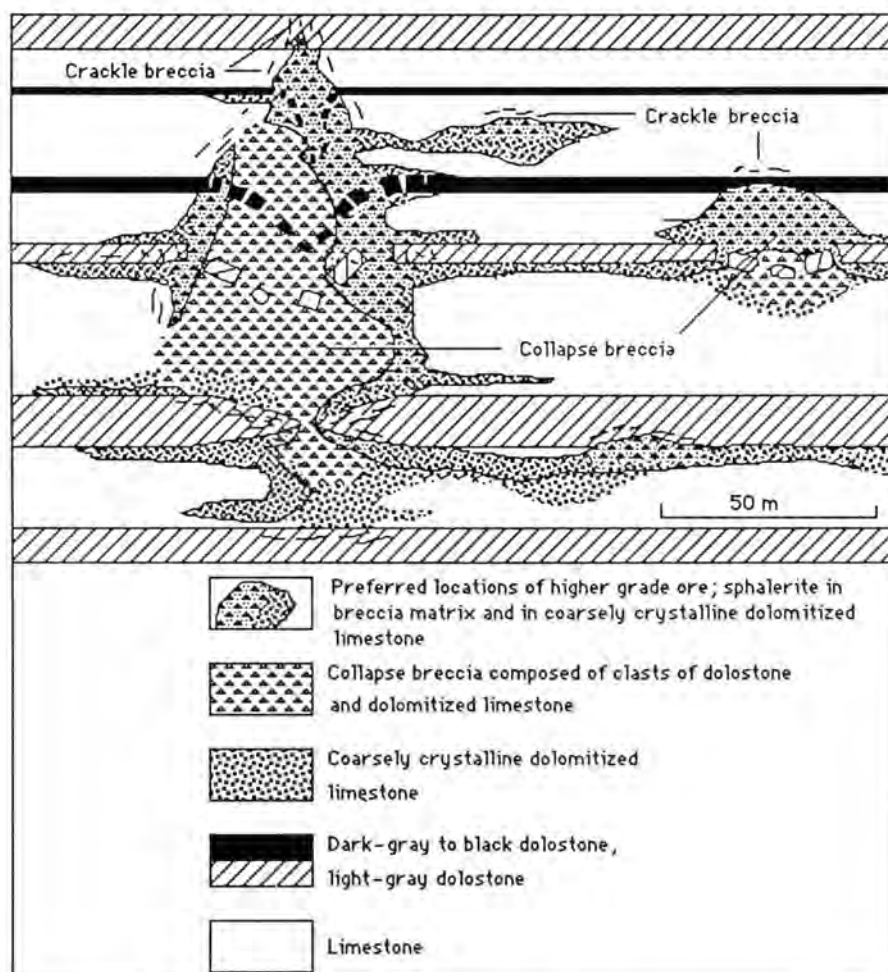
Ore Controls Ore occurs within dissolution collapse breccias that occur (1) throughout readily soluble limestone beds, or (2) in paleo-aquifer solution channels controlled by fractures or folds in limestone. Breccias commonly have domal cross sections above limestone aquifers that have been thinned by solution.

Weathering Zinc silicate and carbonate ores form in the zone of weathering and oxidation.

Geochemical Signature Readily detectable zinc anomalies in residual soils and in stream sediments. Primary zinc haloes in carbonate rocks near ore are not large enough to assist in exploration. Background in carbonate rocks: Zn = 20 ppm; Pb = 9 ppm.

### EXAMPLES

Mascot-Jefferson City district, USTN	(Crawford and Hoagland, 1968; McCormick and others, 1971; Fulweiler and McDougal, 1971)
Copper Ridge district, USTN	(Hill and others, 1971)



**Figure 167.** Cartoon cross section showing relationship of zinc ore to collapse breccia and dolomitized limestone in the Mascott-Jefferson City district, Tennessee. Modified from Armstrong and Lawrence (1983).

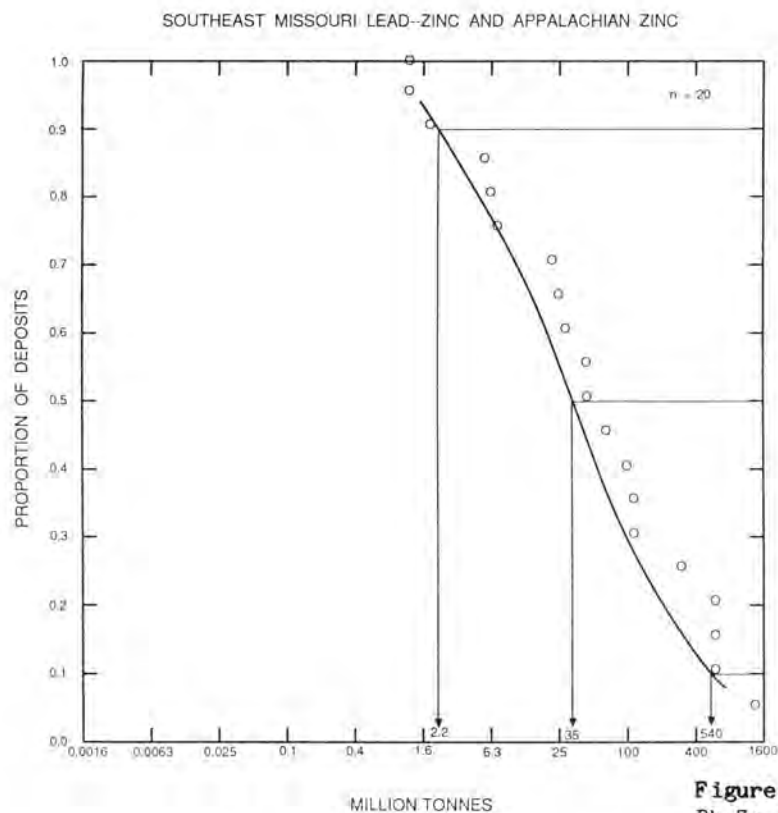
## GRADE AND TONNAGE MODEL OF SOUTHEAST MISSOURI Pb-Zn AND APPALACHIAN Zn DEPOSITS

By Dan L. Mosier and Joseph A. Briskey

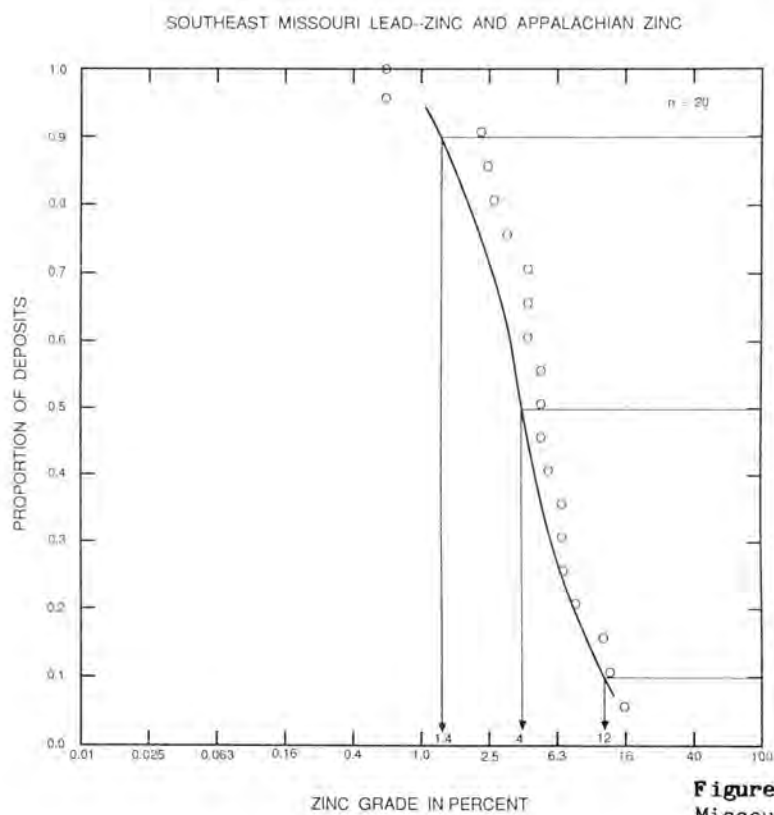
COMMENTS The models for stratabound carbonate-hosted Pb-Zn deposits, and for stratabound carbonate-hosted Zn deposits, are treated as end members that, in a general way, define a larger class of geologically complex stratabound carbonate-hosted deposits containing variable proportions of Pb or Zn. Grade-tonnage estimates were made for districts only, because of difficulties in defining the limits of an individual deposit within these typically large regionally mineralized systems. Numerous small districts containing less than about a million tonnes of ore are not included in this compilation, mainly because of the paucity of reliable data about reserves and past production, but also because they are outside the scope of this investigation. Lead grade is correlated with silver grade ( $r = 0.87$ ,  $n = 10$ ). See figs. 168-171.

DEPOSITS

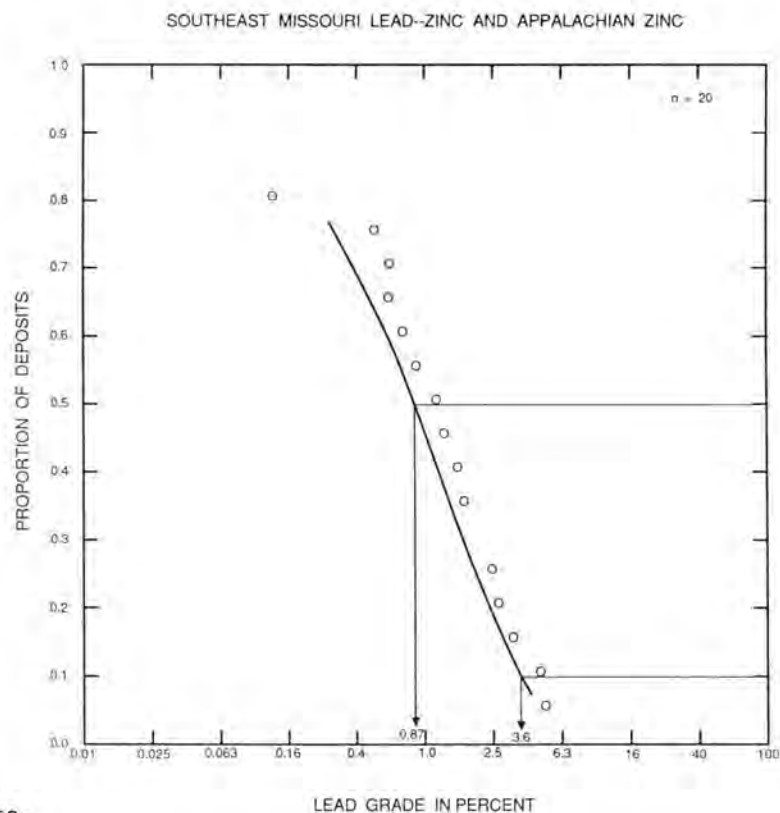
<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Alpine-Lafatsch	ASTR-ITLY-YUGO	Nanisivik	CNNT
Austinville	USVA	Newfoundland Zinc	CNNF
Central Missouri	USMO	North Arkansas-Ozark	USAR
Central Tennessee	USTN	Pine Point	CNNT
East Tennessee	USTN	Polaris-Eclipse	CNNT
Friedensville	USPA	Robb Lake	CNBC
Gayna R.-Godlin L.	CNNT	Southeast Missouri	USMO
Kentucky-Illinois	USKN	Tri State	USMO-USOK
Metalline	USWA	Upper Mississippi Valley	USWI
Monarch-Kicking Horse	CNBC	Upper Silesia	PLND



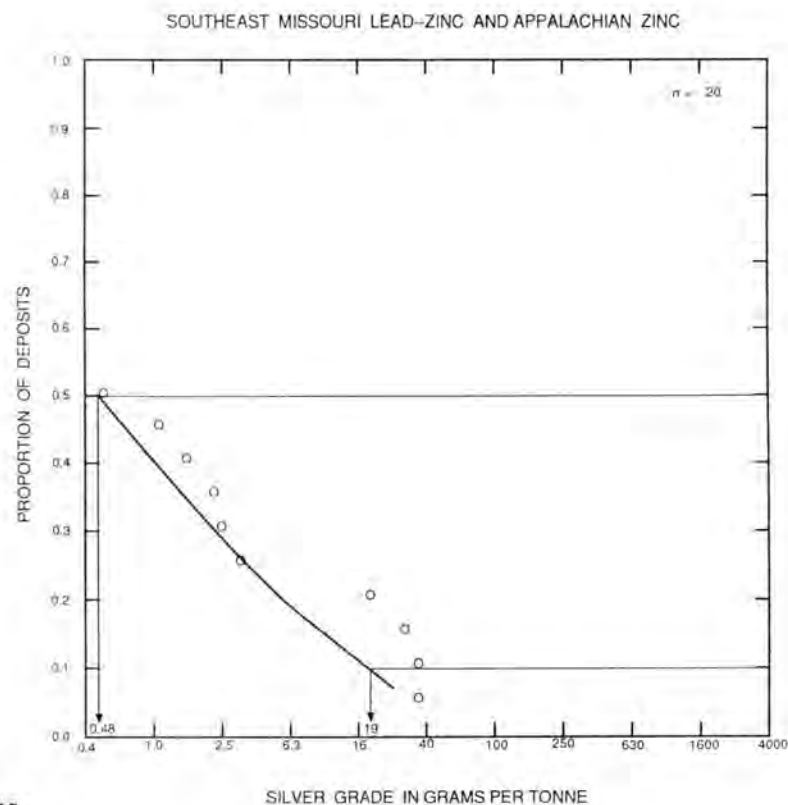
**Figure 168.** Tonnages of southeast Missouri Pb-Zn and Appalachian Zn deposits.



**Figure 169.** Zinc grades of southeast Missouri Pb-Zn and Appalachian Zn deposits.



**Figure 170.** Lead grades of southeast Missouri Pb-Zn and Appalachian Zn deposits.



**Figure 171.** Silver grades of southeast Missouri Pb-Zn and Appalachian Zn deposits.

# DESCRIPTIVE MODEL OF KIPUSHI Cu-Pb-Zn

By Dennis P. Cox and Lawrence R. Bernstein

DESCRIPTION Massive base-metal sulfides and As-sulfosalts in dolomite breccias characterized by minor Co, Ge, Ga, U, and V.

## GEOLOGICAL ENVIRONMENT

Rock Types Dolomite, shale. No rocks of unequivocal igneous origin are related to ore formation. [The pseudoaplite at Tsumeb is herein assumed to be a metasedimentary rock following H. D. LeRoex (1955, unpublished report).]

Textures Fine-grained massive and carbonaceous, laminated, stromatolitic dolomites.

Age Range Unknown; host rocks are Proterozoic in Africa, Devonian in Alaska, Pennsylvanian in Utah.

Depositional Environment High fluid flow along tabular or pipe-like fault- or karst (?) breccia zones.

Tectonic Setting(s) Continental platform or shelf terrane with continental or passive margin rifting. Ore formation at Tsumeb and Ruby Creek predates folding.

Associated Deposit Types Sedimentary copper, U-veins, barite veins. Sedimentary exhalative Pb-Zn may be a lateral facies.

## DEPOSIT DESCRIPTION

Mineralogy Ruby Creek: pyrite, bornite, chalcocite, chalcopyrite, carrollite, sphalerite, tennantite. Tsumeb: galena, sphalerite, bornite, tennantite, enargite. Kipushi: sphalerite, bornite, chalcopyrite, carrollite, chalcocite, tennantite, pyrite. Less abundant minerals in these deposits are linnaeite, Co-pyrite, germanite, renierite, gallite, tungstenite, molybdenite, and native Bi. Bituminous matter in vugs. At Apex mine, marcasite.

Texture/Structure Massive replacement, breccia filling, or stockwork. Replacement textures of pyrite after marcasite at Ruby Creek and Apex.

Alteration Dolomitization, sideritization, and silicification may be related to mineralization. Early pyrite or arsenopyrite as breccia filling or dissemination.

Ore Controls Abundant diagenetic pyrite or other source of S acts as precipitant of base metals in zones of high porosity and fluid flow. Bitumens indicate reducing environment at site of ore deposition.

Weathering Malachite-azurite, black Co-oxide, or pink Co-arsenate. Oxidation at Tsumeb has produced large crystals of many rare minerals. Oxidized Ge-Ga ore at Apex consists of iron oxides and jarosite; Ge and Ga minerals are not observed.

Geochemical and Geophysical Signature Cu, Zn, Pb, As, Co, Ag, Ge, Ga, Mo, W, Sn, Bi, U and V. Metal ratios: high Cu/Fe and locally high Cu/S in interior zones; high Co/Ni, As/Sb and Ag/Au. May be weakly radioactive.

## EXAMPLES

Ruby Creek, ASAK	(Runnels, 1969)
Tsumeb, NAMB	(Sohnge, 1961); Wilson (1977)
Kipushi, ZIRE	(Intiomale and Oosterbosch, 1974)
Apex Mine, USUT	(Bernstein, 1986)

**DESCRIPTIVE MODEL OF SUPERIOR Fe**

By William F. Cannon

DESCRIPTION Banded iron-rich sedimentary rock, generally of great lateral extent, typically layered on centimeter scale with siliceous (chert) beds interlayered with iron-rich beds.

GENERAL REFERENCE James (1954).

GEOLOGICAL ENVIRONMENT

Rock Types Commonly interlayered with quartzite, shale, dolomite.

Textures Iron-formations and host rocks commonly contain sedimentary textures typical of shallow-water deposition in tectonically stable regions.

Age Range Mostly Early Proterozoic ( $2.0 \pm 0.2$  b.y.). Less commonly Middle and Late Proterozoic.

Depositional Environment Stable, shallow-water marine environment, commonly on stable continental shelf or intracratonic basin.

Tectonic Setting(s) Now commonly preserved in forelands of Proterozoic orogenic belts.

Associated Deposit Types Sedimentary manganese deposits may occur stratigraphically near or be interbedded with iron-formations.

DEPOSIT DESCRIPTION

Mineralogy Hematite, magnetite, siderite, fine-grained quartz.

Texture/Structure Nearly always banded at centimeter scale; very fine grained where not metamorphosed.

Alteration None related to ore deposition. Commonly metamorphosed to varying degrees or weathered and enriched by supergene processes.

Ore Controls No primary controls of local importance. Supergene ores may be localized by irregularities in present or paleo erosion surface.

Weathering Alteration of original iron mineral to Fe-hydroxides and hematite. Silica partly to totally leached. End product of weathering is high-grade supergene ore.

Geophysical Signature Magnetic anomalies.

EXAMPLES

Mesabi Range, USMN (James, 1983)

**GRADE AND TONNAGE MODEL OF SUPERIOR Fe AND ALGOMA Fe DEPOSITS**

By Dan L. Mosier and Donald A. Singer

COMMENTS Archean and Proterozoic deposits (Algoma and Superior types) are both included because they are not significantly different in tonnage or grades. See figs. 172-174

DEPOSITS

<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Altamira-Frontera	VNZL	Bellary	INDA
Amapa	BRZL	Bicholim	INDA
An-shan	CINA	Burnt Hill-Knob Lake	CNQU
Bahia	BRZL	Cerro Bolivar	VNZL
Bailadila	INDA	Chityal and others	INDA

Cuyuna	USMN	Moose Mountain	CNON
Dhalli-Rajhara	INDA	Mount Gibson	AUWA
El Pao	VNZL	Mount Gould	AUWA
Fiskefjord	NRWY	Mount Hale	AUWA
Fort Apache	USAZ	Mount Philip	AUQL
Fort Gourand	MAUR	Musan	NKOR
Gogebic	USMN	Mutum	BLVA
Gorumahisani and others	INDA	Noamundi-Joda-Gua etc.	INDA
Goulais	CNON	Norberg	SWDN
Guntur	INDA	Pa-pan-ling	CINA
Isua	GRLD	Pen-chi-hu	CINA
Iron Monarch-Iron Knob	AUSA	Piacoa	VNZL
Jussaari	FNLD	Porkonen	FNLD
Kanjamalai and others	INDA	Rowghat	INDA
Kemmangundi and others	INDA	Sangalwara	INDA
Koolyanobbing	AUWA	Santa Barbara	VNZL
Krivoi-Rog	URRS	Serria do Carajas	BRZL
Kudremukh and others	INDA	Sirigao	INDA
Kung-changling	CINA	Ssu-chia-ying	CINA
Kusalpur	INDA	Stripa-Striberg	SWDN
Labrador Quebec	CNQU	Sydvanger	NRWY
Lohara and others	INDA	Tallering Peak	AUWA
Los Castillos	VNZL	Thabazimbi	SAFR
Maria Luisa	VNZL	Tonkolili	SRLN
Marquette	USMN	Vermilion	USMN
Mato Grosso	BRZL	Vestpolltind	NRWY
Menominee	USMN	Weld Range-Wilgie Mia	AUWA
Mesabi	USMN		
Minas Gerais	BRZL		

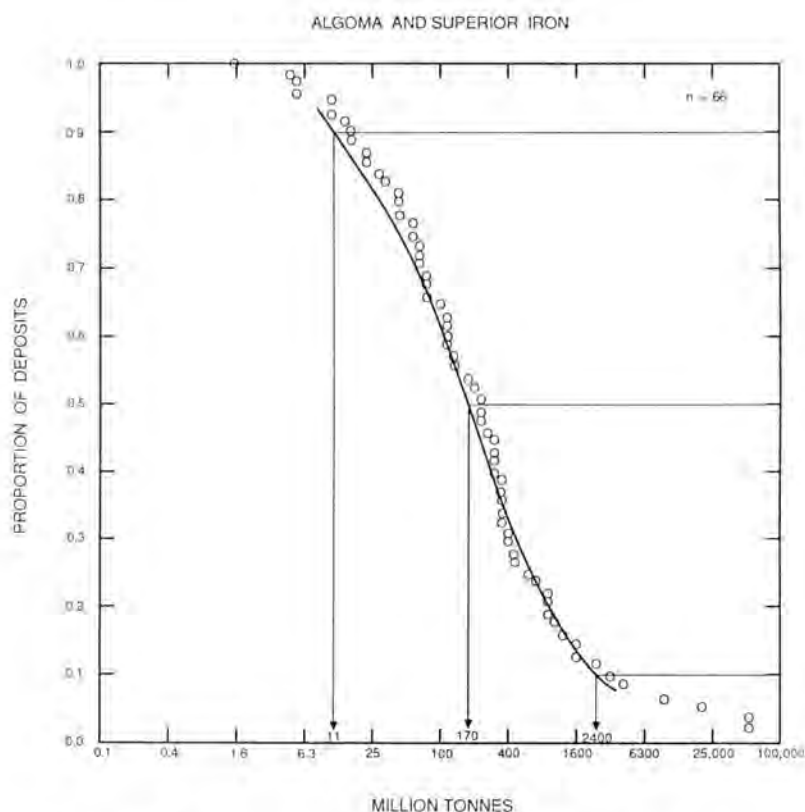
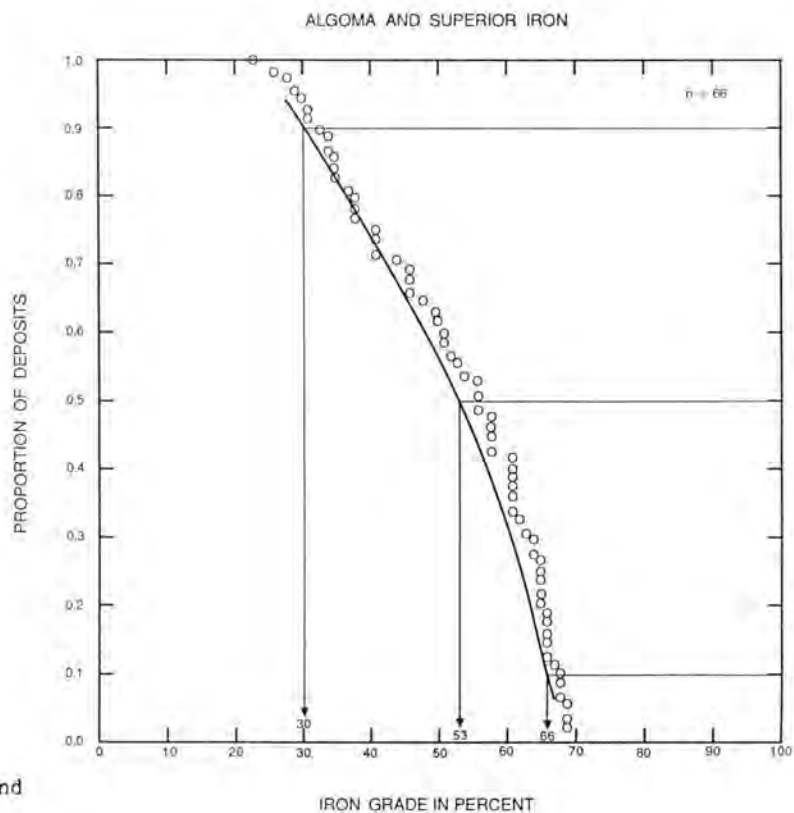
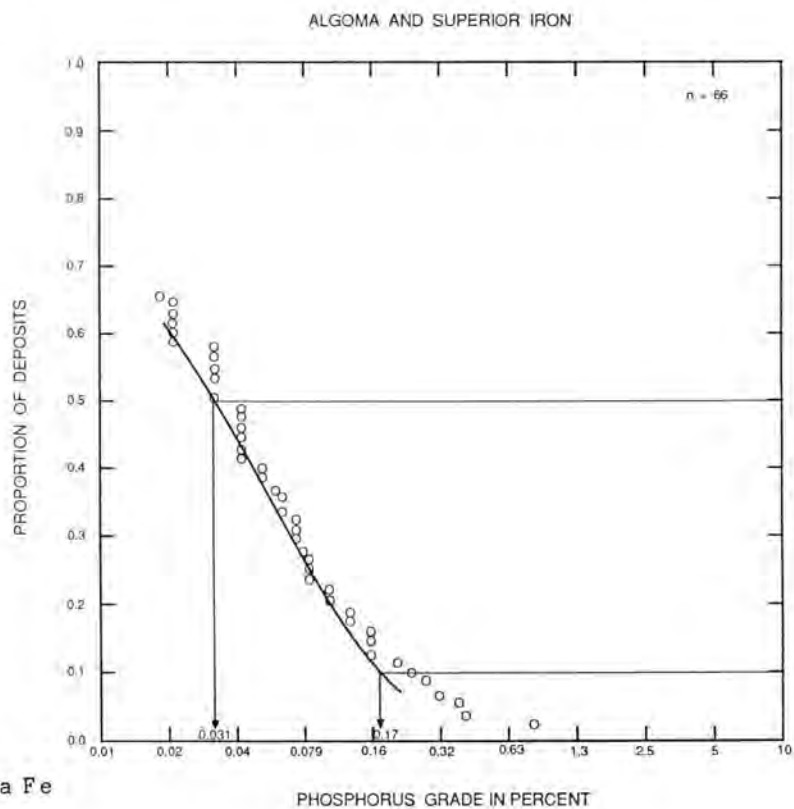


Figure 172. Tonnages of Algoma Fe and Superior Fe deposits.





**Figure 173.** Iron grades of Algoma Fe and Superior Fe deposits.



**Figure 174.** Phosphorus grades of Algoma Fe and Superior Fe deposits.

**DESCRIPTIVE MODEL OF SEDIMENTARY Mn**

By William F. Cannon and Eric R. Force

APPROXIMATE SYNONYM Bathtub-ring Mn.DESCRIPTION Shallow marine (non-volcanogenic) sedimentary Mn deposits formed around rims of anoxic basins during transgression (see fig. 175).GENERAL REFERENCE Cannon and Force (1983).GEOLOGICAL ENVIRONMENTRock Types Shallow marine sediments, most commonly carbonates, clay, and glauconitic sand, commonly with shellbeds, in transgressive sequences associated with anoxic basins.Age Range Mostly in "anoxic events," narrow time periods within the early Paleozoic, Jurassic, and mid-Cretaceous, but may be in rocks of any age associated with anoxic basins.Depositional Environment Shallow (50-300 m) marine, commonly in sheltered sites around paleo-islands. Most deposits overlie oxidized substrates, but basinward, carbonate deposits may be in chemically reduced settings.Tectonic Setting(s) Stable cratonic interior basin or margin.Associated Deposit Types Locally, sedimentary phosphorites, sediment-hosted Cu.DEPOSIT DESCRIPTIONMineralogy A variety of Mn carbonates (mostly basinward) and oxides (mostly landward).Texture/Structure Commonly as oolites, pisolites, laminae, and shell replacements.Alteration Supergene alteration to high-grade ore is common.Ore Controls Oxidation-reduction interface (involves age, paleobasin reconstruction, paleodepth of site) and lack of clastic dilution.Weathering Mn carbonates may weather to brown, nondescript rock. Black secondary oxides are common.Geochemical Signature None known.EXAMPLES

Molango (Jurassic), MXCO	(Tavera and Alexandri, 1972)
Nikopol (Oligocene), USSR	(Sapozhnikov, 1970)
Groote Eyland (Cretaceous), AUTN	(Frakes and Bolton, 1984)

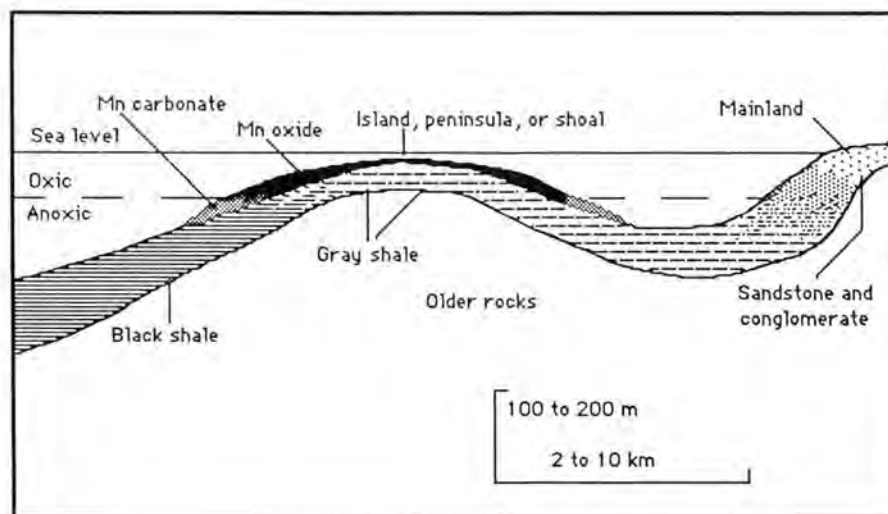
**GRADE AND TONNAGE MODEL OF SEDIMENTARY Mn**

By Dan L. Mosier

DATA REFERENCES Most data from DeYoung and others (1984).COMMENTS Because available grade and tonnage estimates represent mines from, in some cases, very extensive deposits and because the numbers are calculated at differing cutoff grades, the endowment of these deposits is undoubtedly much larger than indicated in these figures. See figs. 176-177.

DEPOSITS

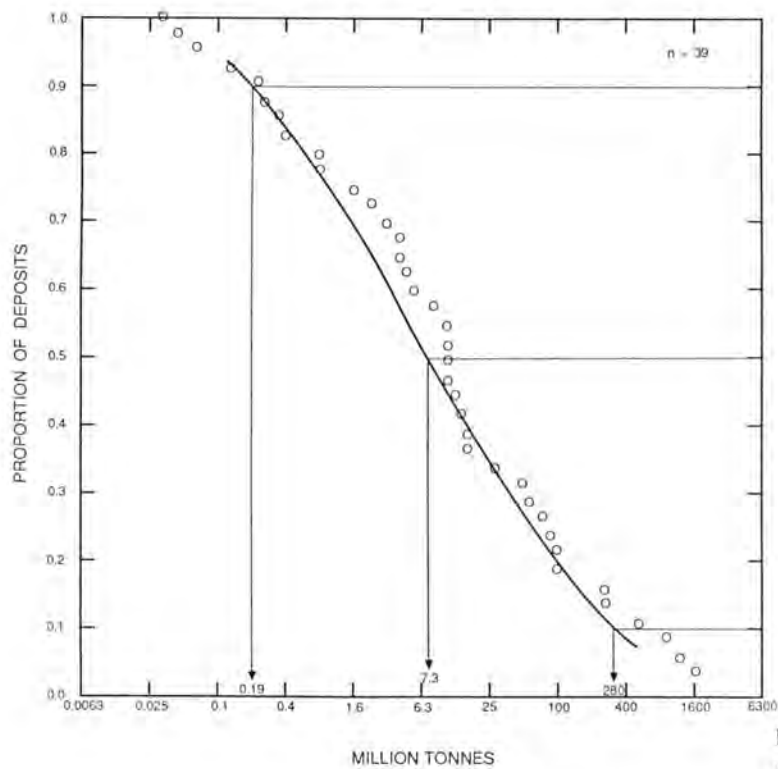
<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Akviran	TRKY	Matese-Ciocciaria	ITLY
Andhra Pradesh	INDA	Molango	MXCO
Ansongo	MALI	Morro da Mina	BRZL
Azul-Carajas	BRZL	Naniango	UVOL
Bolske-Tokmak	URRS	Nikolaevskoe	URRS
Chiatura	URRS	Nikopol	URRS
Chiwekwe	ZIMB	Nizne-Udinskaja	URRS
Groote Eylandt	AUNT	Otjosundu	SAFR
Gujarat	INDA	Ravensthorpe	AUWA
Horseshoe	AUWA	Seiba	URRS
Hsiangtan	CINA	Shimoga (Karnataka)	INDA
Imini	MRCO	Timna	ISRL
Istranca	TRKY	Uracum	BRZL
Kalahari	SAFR	Urkut	HUNG
Kamenskoe	URRS	Usinsk	URRS
Kaochiao	CINA	Varna	BULG
Madhya Pradesh	INDA	Wafangtzu	CINA
Manuel Killigrews	CNNF		



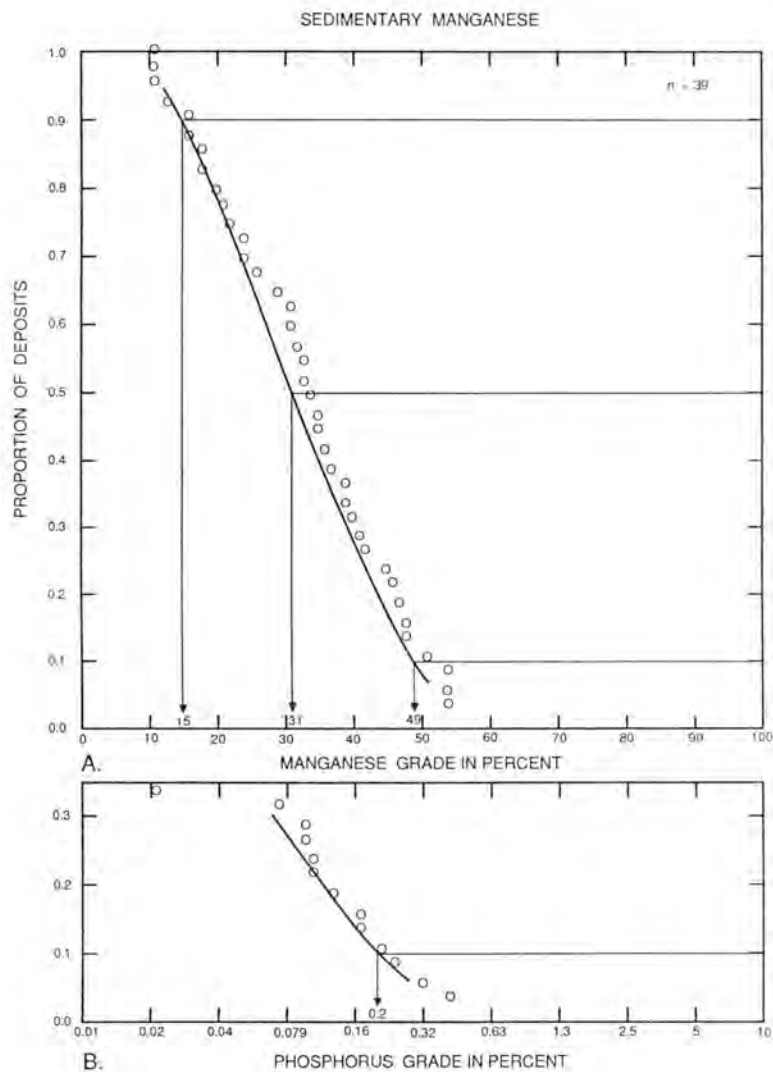
**Figure 175.** Cartoon cross section showing relation of sedimentary facies to sedimentary Mn deposits.

# SEDIMENTARY MANGANESE

Model 34b--Con.



**Figure 176.** Tonnages of sedimentary Mn deposits.



**Figure 177.** Metal grades of sedimentary Mn deposits. A, Manganese. B, Phosphorus.

## DESCRIPTIVE MODEL OF UPWELLING TYPE PHOSPHATE DEPOSITS

By Dan L. Mosier

DESCRIPTION Phosphorite sediments form a major stratigraphic unit within a sequence of marine sediments in upwelling areas in basins with good connection to the open sea.

GENERAL REFERENCES Slansky (1980), Sheldon (1964).

### GEOLOGICAL ENVIRONMENT

Rock Types Phosphorite, marl, shale, chert, limestone, dolomite, and volcanic materials.

Age Range Precambrian through Miocene.

Depositional Environment Marine sedimentary basins with good connection to the open sea and upwelling, areas highly productive of plankton. Deposition occurs mostly in warm latitudes, mostly between the 40th parallels.

Tectonic Setting(s) Intra-plate shelf, platform, miogeosynclines, and eugeosynclines.

Associated Deposit Types Sedimentary manganese.

### DEPOSIT DESCRIPTION

Mineralogy Apatite + fluorapatite + dolomite + calcite + quartz + clays (montmorillonite or illite) ± halite ± gypsum ± iron oxides ± siderite ± pyrite ± carnotite.

Texture/Structure Pellets, nodules, phosphatized shell and bone material.

Alteration None related to ore.

Ore Controls Basins, or parts of basins, favorable for the accumulation of organic rich sediments and for their evolution into phosphorites. Individual beds may be a meter thick or more and may extend over hundreds of square kilometers.

Weathering Limonite and goethite.

Geochemical Signature P, N, F, C, and U. Anomalously radioactive.

### EXAMPLES

Southeast, USID	(Gulbrandsen and Krier, 1980)
Meskala, MRCO	(British Sulphur Corp. Ltd., 1980)
Stra Quertane, TUNS	(British Sulphur Corp. Ltd., 1980)

## GRADE AND TONNAGE MODEL OF UPWELLING TYPE PHOSPHATE DEPOSITS

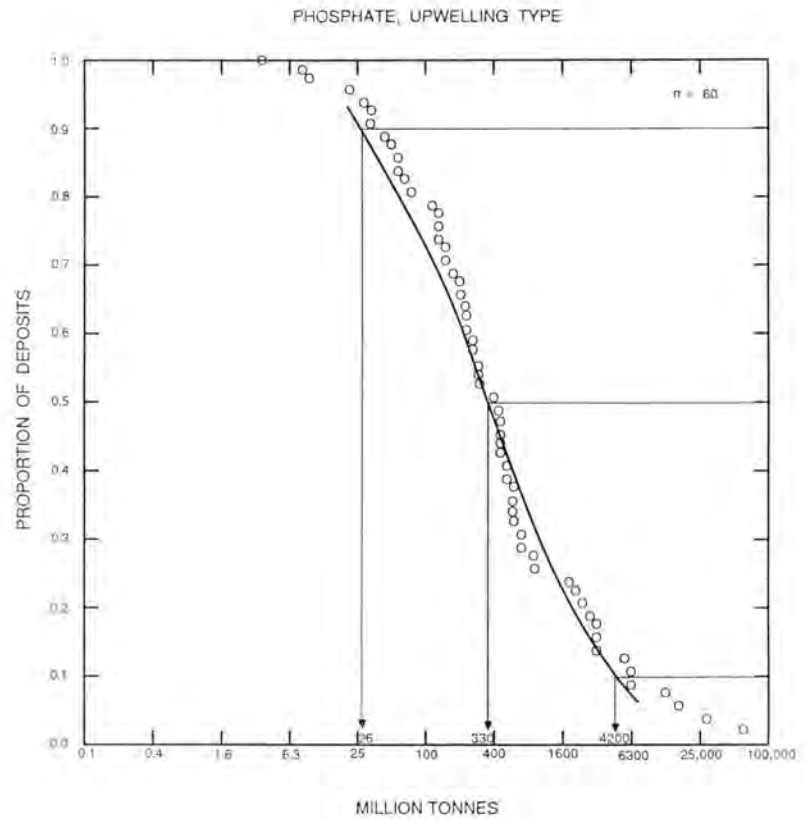
By Dan L. Mosier

COMMENTS See figs. 178-179.

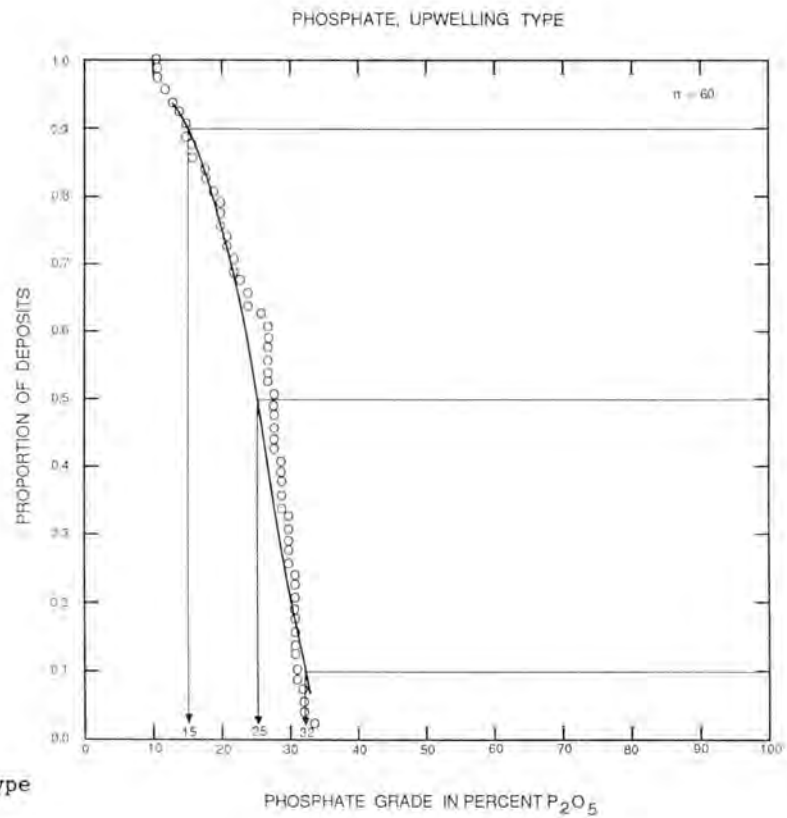
DATA REFERENCE Krauss and others (1984).

DEPOSITS

<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Abu Tartur	EGPT	Mdilla	TUNS
Akashat	IRAQ	Meskala	MRCO
Aktyubinsk	URRS	Metalaoui	TUNS
Al-Hasa/Oatrana	JRDN	Montana	USMT
Arad	ISRL	Moulares	TUNS
Beersheva	ISRL	Mrata	TUNS
Bu Craa	MRCO	Mzaita	ALGR
Brooks Range	USAK	Nahal-Zin	ISRL
Chilisai	URRS	New Cuyama	USCA
Djebel Onk	ALGR	Oronta	ISRL
D-Tree	AUQL	Oulad-Abdoun	MRCO
Duchess	AUQL	Patos de Minas	BRZL
Eastern A&B	SYRA	Qusseir	EGPT
El Hamrawein	EGPT	Redeyef	TUNS
Ganntour	MRCO	Ruseifa	JRDN
Hahotoe	TOGO	Safagar	EGPT
Haikou	CINA	San Juan de la Costa	MXCO
Hubsugul	MNGL	Sechura	PERU
Idfu-Qena	EGPT	Sehib	TUNS
Kalaa Khasba	TUNS	S.E. Idaho	USID
Kara Tau	URRS	Shediyah	JRDN
Khneifiss	SYRA	Sherrin Creek	AUQL
Kondonakasi	ANGL	Stra Quertane	TUNS
Kun Ming	CINA	Taiba	SNGL
Lady Annie	AUQL	Thamar-Kotra	INDA
Lee Creek	USNC	Thies	SNGL
Le Kouif	ALGR	Uinta Mtns	USUT
Lily Creek	AUQL	Vernal	USUT
Makhtesh	USRL	Warm Springs	USMT
Mazidagi	TRKY	Wyoming	USWY



**Figure 178.** Tonnages of upwelling-type phosphate deposits.



**Figure 179.**  $P_2O_5$  grades of upwelling-type phosphate deposits.

## DESCRIPTIVE MODEL OF WARM-CURRENT TYPE PHOSPHATE DEPOSITS

By Dan L. Mosier

DESCRIPTION Phosphorites formed in warm currents along the eastern coasts of continents; consist of phosphatic limestone or sandstone.

GENERAL REFERENCES Cathcart and Gulbrandsen (1973), Sheldon (1964).

### GEOLOGICAL ENVIRONMENT

Rock Types Phosphatic limestone and sandstone; chert and diatomaceous material may be present.

Age Range Early Cretaceous through Pliocene.

Depositional Environment Basins of structural lows on the flanks of rising domes, at the mouths of rivers and estuaries. Deposition occurs in warm latitudes, mostly between the 40th parallels. Deposits are formed by dynamic upwelling or by the cool countercurrent associated with warm density current.

Tectonic Setting(s) Continental shelf; may be associated with eugeosynclinal rocks.

### DEPOSIT DESCRIPTION

Mineralogy Fluorapatite + quartz + dolomite + montmorillonite + kaolinite + calcite ± wavellite ± crandallite ± illite ± clinoptilolite ± palygorskite ± smectite ± collophane.

Texture/Structure Phosphatic pellets and fossil fragments with a carbonate matrix.

Ore Controls Stratigraphic phosphatic horizons within embayments and estuarine environments in proximity to the open sea. Basins on flanks of structural highs (domes, arches, anticlines) are important controls for phosphate deposition.

Weathering Goethite.

Geochemical Signature P, C, U, N, F. Anomalously radioactive.

### EXAMPLES

Paulista, BRZL	(British Sulphur Corp. Ltd. 1980)
East, north, and south Florida, USFL	
Offshore Savannah, USGA	(Zellars-Williams Inc., 1978)

## GRADE AND TONNAGE MODEL OF WARM-CURRENT TYPE PHOSPHATE DEPOSITS

By Dan L. Mosier

DATA REFERENCE Krauss and others, (1984).

COMMENTS About half of the deposits are actually districts. Grades have been adjusted to reflect in-place grades rather than commonly reported concentrate grades. See figs. 180-181.

### DEPOSITS

<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Big Four	USFL	Haynsworth	USFL
Bonny Lake	USFL	Kingsford	USFL
Clear Springs	USFL	Lonesome	USFL
East Florida	USFL	Noralyn-Phosphoria	USFL
Fort Green	USFL	North Florida	USFL
Hard Rock	USFL	North Carolina	USNC



Northeast Florida  
Offshore Savannah  
Paulista

USFL  
USGA  
BRZL

Rockland  
Savannah River  
South Florida

USFL  
USGA  
USFL

PHOSPHATE, WARM-CURRENT TYPE

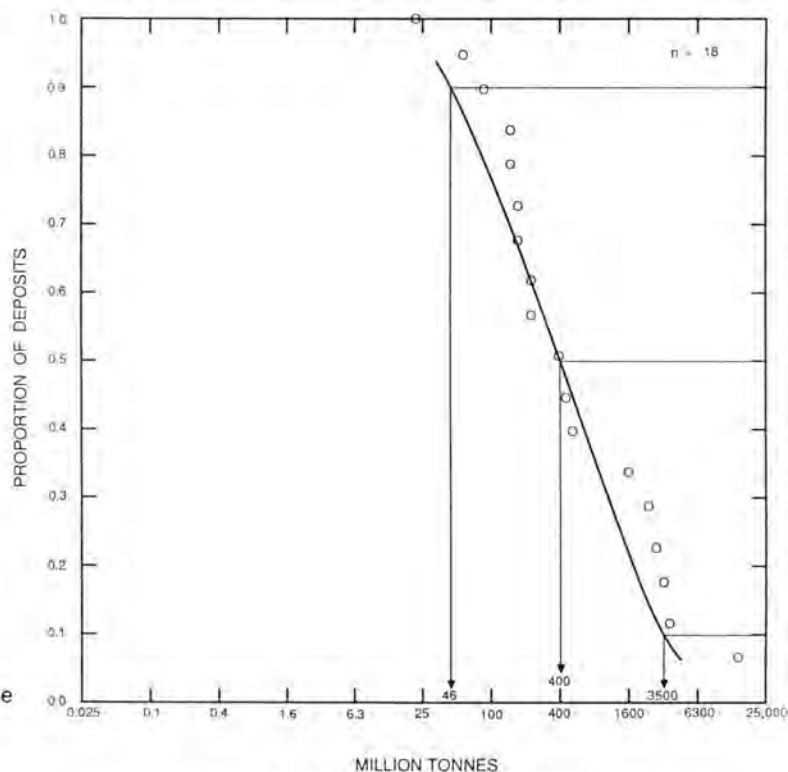


Figure 180. Tonnages of warm-current type phosphate deposits.

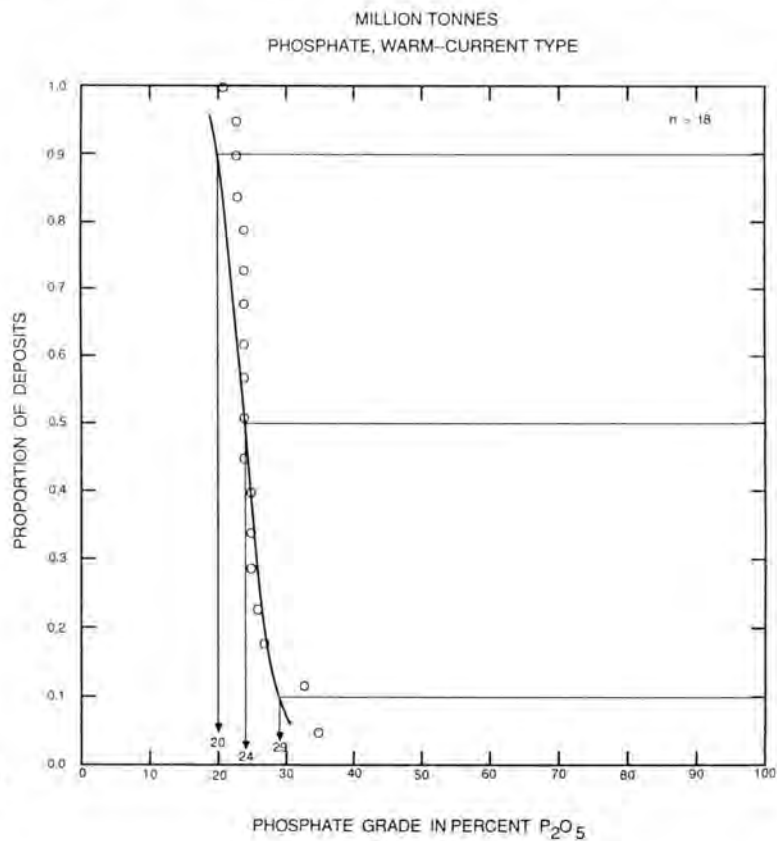


Figure 181.  $P_2O_5$  grades of warm-current type phosphate deposits.

# DESCRIPTIVE MODEL OF LOW-SULFIDE Au-QUARTZ VEINS

By Byron R. Berger

APPROXIMATE SYNONYMS Mesothermal quartz veins, Mother Lode veins.

DESCRIPTION Gold in massive persistent quartz veins mainly in regionally metamorphosed volcanic rocks and volcanic sediments.

## GEOLOGICAL ENVIRONMENT

Rock Types Greenstone belts; oceanic metasediments; regionally metamorphosed volcanic rocks, graywacke, chert, shale, and quartzite. Alpine gabbro and serpentine. Late granitic batholiths.

Age Range Precambrian to Tertiary.

Depositional Environment Continental margin mobile belts, accreted margins. Veins are generally post-metamorphic and locally cut granitic rocks.

Tectonic Setting(s) Fault and joint systems produced by regional compression.

Associated Deposit Types Placer Au-PGE, kuroko massive sulfide, Homestake gold.

## DEPOSIT DESCRIPTION

Mineralogy Quartz + native gold + pyrite + galena + sphalerite + chalcopryrite + arsenopyrite + pyrrhotite. Locally tellurides + scheelite + bismuth + tetrahedrite + stibnite + molybdenite + fluorite. Productive quartz is grayish or bluish in many instances because of fine-grained sulfides. Carbonates of Ca, Mg, and Fe abundant.

Texture/Structure Saddle reefs, ribbon quartz, open-space filling textures commonly destroyed by vein deformation.

Alteration Quartz + siderite and (or) ankerite + albite in veins with halo of carbonate alteration. Chromian mica + dolomite and talc + siderite in areas of ultramafic rocks. Sericite and disseminated arsenopyrite + rutile in granitic rocks.

Ore Controls Veins are persistent along regional high-angle faults, joint sets. Best deposits overall in areas with greenstone. High-grade ore shoots locally at metasediment-serpentine contacts. Disseminated ore bodies where veins cut granitic rocks.

Weathering Abundant quartz chips in soil. Gold may be recovered from soil by panning.

Geochemical Signature Arsenic best pathfinder in general; Ag, Pb, Zn, Cu.

## EXAMPLES

Grass Valley, USCA	(Lindgren, 1896)
Mother Lode, USCA	(Knopf, 1929)
Ballarat Goldfield,	
Victoria, AUVT	(Baragwanath, 1953)
Goldfields of Nova Scotia, CNNS	(Malcolm, 1929)

# GRADE AND TONNAGE MODEL OF LOW-SULFIDE Au-QUARTZ VEINS

By James D. Bliss

COMMENTS All mines within 1.6 km were combined and only deposits containing more than 99 tonnes are included. Gold grade is correlated with tonnage ( $r = -0.30$ ) and with silver grade ( $r = 0.45$ ,  $n = 39$ ). See figs. 182-183.

DEPOSITS

<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Al	AUVT	Colfax	USCA
Achilles	NZLD	Colombo	USCA
Alabama Shoot	AUVT	Comet	USAK
Alex Hill-Mad Kiss	GUYN	Confidence	USCA
Alice	USCA	Coulterville	USCA
Alleghany East	USCA	Coulterville South	USCA
Alleghany West	USCA	Country Harbour	CNNS
Alto	USCA	Cove District	USCA
Amador City	USCA	Cow Bay	CNNS
American Bar	USCA	Cox, Bolyan & Loberg	USAK
Ample	CNBC	Cranberry Hill	CNNS
Angels-Carson	USCA	Dalesford	AUVT
Argo	USCA	Damascus	USCA
Argus Hill	AUVT	Defender	USCA
Ashland	USOR	Delta	USCA
Atlas	USCA	Demarest	USCA
Bagby	USCA	Dinero	USCA
Bagby Valley	USCA	Dominion Consolidated	NZLD
Ballarat	AUVT	Dorothea	USOR
Barrandum	USCA	Eagle Bluff-River Bend	USCA
Bear Valley	USCA	Eagle Shawmut	USCA
Bear Valley South	USCA	Early-Sweetwater	USCA
Beaver Dam	CNNS	East Rawdon	CNNS
Belden	USCA	Eclipse No. 1	USCA
Bendigo	AUVT	Ecum Secum	CNNS
Bendigo	NZLD	El Dorado	USCA
Berry Creek	USCA	El Portal	USCA
Bethanga	AUVT	Eliza-Schroeder	USCA
Big Oak Flat	USCA	Empire-Lone Star	USCA
Birthday-William Fancy	AUVT	Enterprise	USCA
Black Bear	USCA	Esmeralda	USCA
Black Boy	USCA	Ester Dome SE	USAK
Blackstone	USCA	Experimental	USCA
Blockhouse	CNNS	Felicianna	USCA
Blue Lead	USAK	Fifteen-mile Brook	CNNS
Blue Mountain	USCA	Fifteen-mile Stream	CNNS
Bonanza	NZLD	Fifty-five	USCA
Bondurant	USCA	Fine Gold	USCA
Braden	USOR	Finney	USCA
Bralorne-Pioneer	CNBC	Five Pines	USCA
Broken Hills	USCA	Forbestown	USCA
Brookfield	CNNS	Ford	USCA
Buller-Mokihinui	NZLD	Forest Hill	CNNS
Caledonia	AUVT	Four Hells Mine	USCA
Canyon Creek-East Fork	USCA	Fourth Crossing	USCA
Caribou	CNNS	Francis Ormand	AUVT
Caribou-Aurum	CNBC	Franklin	USCA
Carleton	CNNS	French	USCA
Carolyn	CNBC	French Gulch	USCA
Cassilis	AUVT	Fryer's Creek	AUVT
Central	USCA	Gabriels Cully	NZLD
Central Rawdon	CNNS	Galice North	USOR
Chewton	AUVT	Gabretta	USCA
Chichagof	USAK	Gabrinus	USCA
Cleary Hill	USAK	Gem	USCA
Clunes Goldfield	AUVT	Gem Olive	USCA
Coarsegold	USCA	German Bar	USCA
Cobol	USAK	Giant King	USCA
Cochrane Hill	CNNS	Gibraltar	USCA

Gladstone	USCA	Lone Mary	USCA
Glencoe-Woodhouse	USCA	Long Tunnel	AUVT
Globe-Ralston	USCA	Lord Nelson	AUVT
Gold Bug	USCA	Lucky Bart	USOR
Gold Point	USCA	Lucky Shot-War Baby	USAK
Gold Reef	USCA	Lyell Goldfield	NZLD
Gold River	USCA	Mabel	USAK
Gold Chariot	USCA	Malden North	AUVT
Golden Eagle	USCA	Mammoth	USCA
Golden Jubilee	USCA	Mariners	AUVT
Golden-El Dorado	USCA	Mariposa	USCA
Goldenville	CNNS	Maude & Yellow Girl	AUVT
Grand Victory	USCA	Midas	USCA
Granite Hill	USOR	Mikado	USAK
Granite King	USCA	Miller Lake	CNNS
Grant	USAK	Minto	CNBC
Grass Valley	USCA	Mizpah	USAK
Green Excelsior	USCA	Mohawk-Dome View	USAK
Greenback	USOR	Mokelumne	USCA
Gwynne	USCA	Molega	CNNS
Hall Creek	CNBC	Montague	CNNS
Ham & Birney	USCA	Moore's Flat	USCA
Harriet	CNBC	Moose River	CNNS
Harrigan Cove	CNNS	Moosehead	CNNS
Hathaway	USCA	Mooseland	CNNS
Hazel	USCA	Mormon Bar	USCA
Hedley Camp	CNBC	Morning Star	AUVT
Henry Ford	USAK	Morris Ravine	USCA
Herman	USCA	Mount Bullion	USCA
Hi-Yu	USAK	Mount Gaines	USCA
Hillgrove	AUNS	Mount Pleasant	USCA
Hirst-Chichagof	USAK	Mount Shasta	USCA
Homestake-McCarty	USAK	Mount Uniacke	CNNS
Hornitos	USCA	Mount Vernon	USCA
Horseshoe I	USCA	Mountain King	USCA
Hunter Valley	USCA	Nalden South	AUVT
Iconoclast	USCA	Nashville	USCA
Indian Path Mine	CNNS	National	USCA
Invincible Lode	NZLD	new Bendigo	AUVT
Isaac's Harbour	CNNS	New Era-Rowe	AUVT
Jabal Guyan	SAAR	Nimrod	AUVT
Jamestown	USCA	North Murphy	USCA
Joe Walker	USCA	North Star	USAK
Jubilee	NZLD	Nuggetty	AUVT
Jubilee-New Jubilee	AUVT	O'Connors	AUVT
Julian-Banner	USCA	Old Diggings	USCA
K.C.	USCA	Oldham	CNNS
Kelsey	USCA	Ophir	USCA
Kelsey North	USCA	Oregon Bell	USOR
Kemptville	CNNS	Oriental	AUVT
Killag	CNNS	Oro Grande-Buena Vista	USCA
Kinsley	USCA	Oturehua Field	NZLD
Kinsley North	USCA	Ovens	CNNS
Kotchkar Mines	USSR	Oya	JAPN
Lake Catcha	CNNS	Paloma-Gwin	USCA
Lamphear	USCA	Paparoa Range	NZLD
Lawrencetown	CNNS	Patrick	USCA
Leipsigate	CNNS	Penryn	USCA
Leviathan	AUVT	Phoenix	USCA
Liberty	USCA	Pipestem	CNBC
Little Squaw	USAK	Placerville	USCA
Locarno	USCA	Pleasant River	CNNS
Loch Fyne	AUVT	Porto Rico	CNBC

Model 36a--Con.

Pyramid	USCA
R.R. Flat South	USCA
Rainbow	USOR
Rainbow	USCA
Ranch	USCA
Ravenswood	NZLD
Reefton Goldfield	NZLD
Reicher Trost	PLND
Renfrew	CNNS
Rich	USCA
Rich Gulch	USCA
Rich Gulch (Virgilia)	USCA
Rindge No. 1	USCA
Robert E	USOR
Robertson	USOR
Rose of Denmark	AUVT
Rosethistle & Shamrock	AUVT
Royal Mountain King	USCA
Ryan	USCA
Ryan Group	USAK
S. Branch Stwejacke	CNNS
Sailor's Gully	AUVT
Salmon River	CNNS
Salsigne	FRNC
Sambas	AUVT
Sandford	USAK
Scott Bar	USCA
Seal Harbour	CNNS
Second Relief	CNBC
Sesson Mine	USCA
Sheep Ranch	USCA
Shenandoah Mine	USCA
Sliger	USCA
Soo	USAK

Soulsbyville	USCA
South Uniacke	CNNS
Spring Gully	AUVT
Stonewall	USCA
Sultan	AUVT
Surf Inlet	CNBC
Sutter Creek	USCA
Sylvanite	USOR
Tangier	CNNS
Taylor	USCA
Tipperary Mine	NZLD
Toombou	AUVT
Treadwell Mines	USAK
Truscott	USCA
Uncle Sam	USCA
Upper Seal Harbour	CNNS
Valley View	USCA
Vogler's Cove	CNNS
Ward	CNBC
Warrington	USCA
Washington	USCA
Wattle Gully	AUVT
Waverley	CNNS
Wayside	CNBC
West Gore	CNNS
West Jacksonville	USCA
Westland	NZLD
Whiteburn	CNNS
Whitlock East	USCA
Whitlock West	USCA
Wilshire-Bishop	USCA
Wine Harbour	CNNS
Yankee Hill	USCA
Zeila	USCA

LOW-SULFIDE GOLD-QUARTZ VEIN

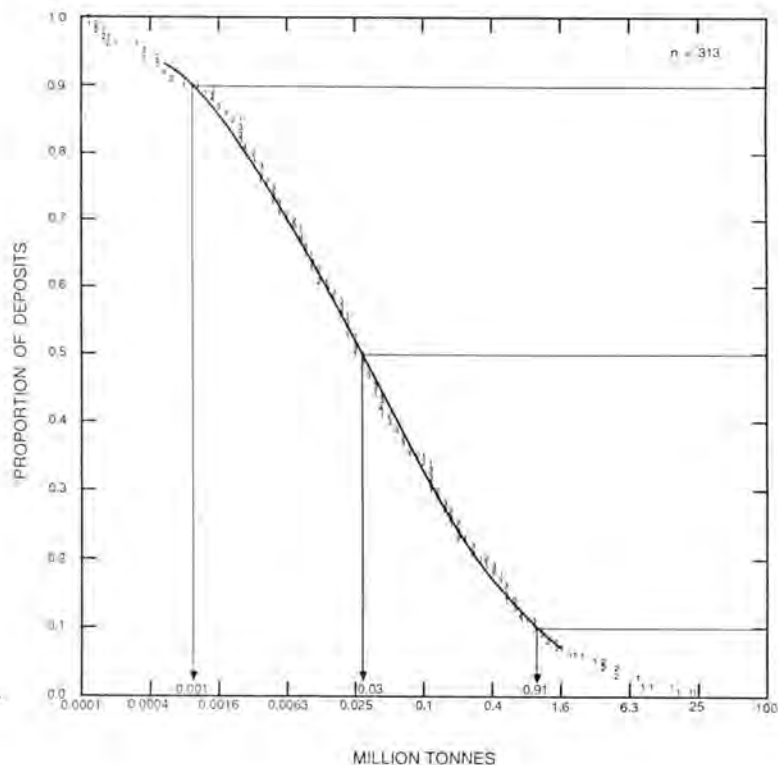
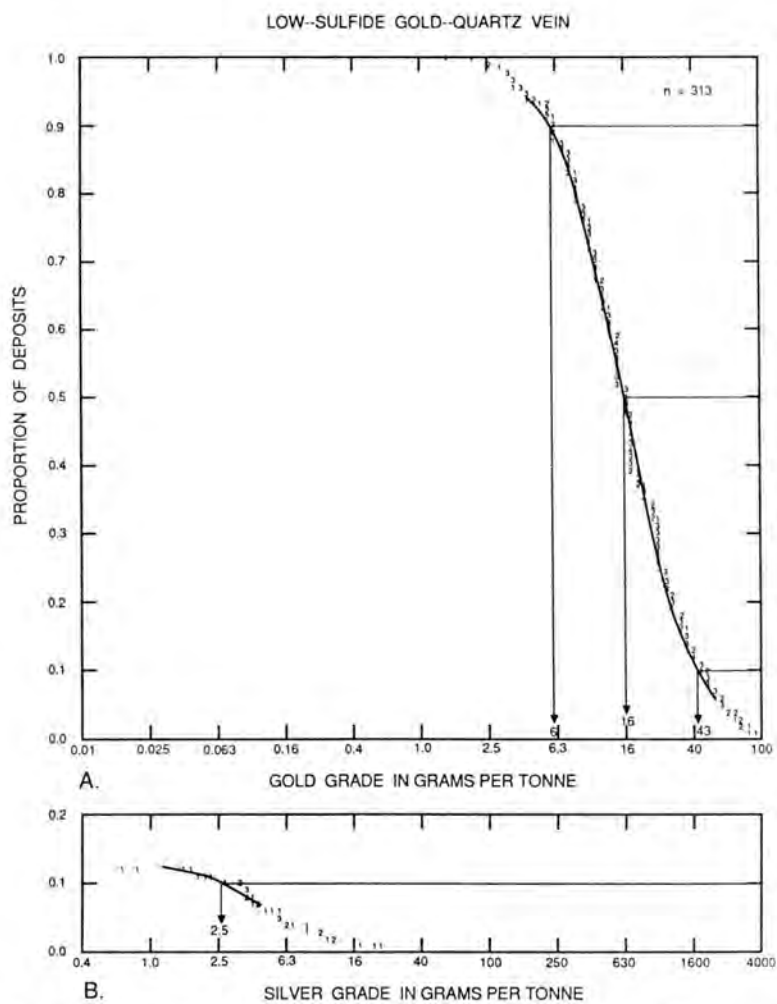


Figure 182. Tonnages of low-sulfide Au-quartz vein deposits.



**Figure 183.** Precious-metal grades of low-sulfide Au-quartz vein deposits. A, Gold. B, Silver.

# DESCRIPTIVE MODEL OF HOMESTAKE Au

By Byron R. Berger

APPROXIMATE SYNONYMS Volcanogenic gold, iron-formation-hosted Au, Archean lode gold.

DESCRIPTION Stratabound to stratiform gold deposits in iron-rich chemical sediments in Archean metavolcanic terrane.

GENERAL REFERENCES Ridler (1970), Hutchinson (1976), Philips and others (1984), Fripp (1976), Colvine and others (1984).

## GEOLOGICAL ENVIRONMENT

Rock Types Regionally metamorphosed mafic and felsic metavolcanic rocks, komatiites, and volcaniclastic sediments interlayered with banded iron-formation. Intruded by felsic plutonic rocks and locally by quartz porphyry, and syenite porphyry.

Age Range Mainly Archean.

Depositional Environment Controversial: submarine hot-spring activity related to volcanism, or later hydrothermal activity related to intrusive rocks.

Tectonic Setting(s) Archean greenstone belts. Commonly near regional division or "break" between predominantly metavolcanic and predominantly metasedimentary rocks. Greenschist-facies metamorphism.

Associated Deposit Types Kuroko massive sulfide deposits, Algoma Fe, low-sulfide gold-quartz veins.

## DEPOSIT DESCRIPTION

Mineralogy Native gold + pyrite + pyrrhotite ± arsenopyrite ± magnetite ± sphalerite ± chalcopyrite. May contain minor tetrahedrite + scheelite + wolframite + molybdenite ± fluorite ± stibnite. Realgar at Hemlo deposit. Some deposits show zoning from proximal pyrrhotite ± magnetite to distal arsenopyrite.

Texture/Structure Narrow thinly laminated beds, veins, or lenses, overlying stringers (stockworks).

Alteration Host rocks contain quartz + siderite and (or) ankerite + tourmaline + chlorite + magnetite in mafic volcanic terranes. Chromian mica and chlorite particularly around veins and stockworks. Banded oxide-facies iron-formation replaced by pyrite or pyrrhotite.

Ore Controls Bedded ores in Fe-rich siliceous or carbonate-rich chemical sediments with vein and stockworks in feeder zones to these sediments, often interlayered with flow rocks. Beds may be cut by concordant or sharply discordant quartz-carbonate veins with gold.

Weathering Gossans from oxide and carbonate iron-formation.

Geochemical Signature Au + Fe + As + B + Sb (+ platinum-group metals in mafic volcanic terranes). Bi, Hg, and minor Cu-Pb-Zn-Ag-Mo.

## EXAMPLES

Homestake, USSD	(Rye and Rye, 1974)
Passagem, BRZL	(Fleisher and Routhier, 1973)
Dome Mine, CNON	(Fryer and others, 1979)
Agnico Eagle, CNQB	(Barnett and others, 1982)
Vubachikwe, ZIMB	(Fripp, 1976)



## GRADE AND TONNAGE MODEL OF HOMESTAKE Au

By Dan L. Mosier

COMMENTS Deposits were combined when they occur within 1.6 km of each other. Grades and tonnages were not found to be significantly different for deposits associated with different host rocks. See figs. 184-186

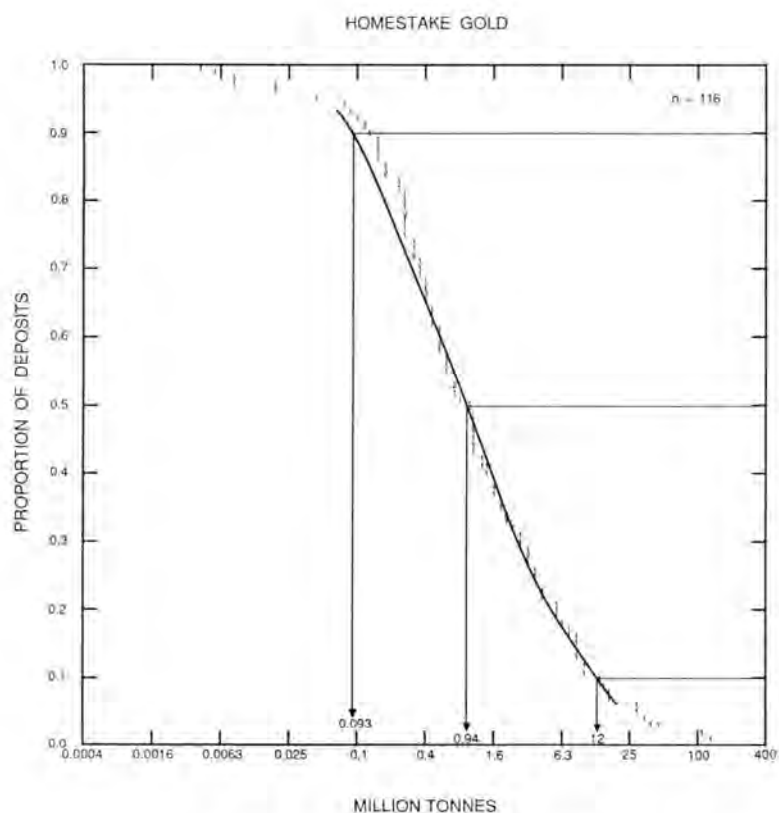
## DEPOSITS

Name	Country	Name	Country
Agassiz	CNMN	Gurney	CNMN
Albino	CNON	Hard Rock-McLeod-Cockshutt	CNON
Ankerite-Aunor-Delnite	CNON	Hasaga-Howey	CNON
Arrowhead	CNQU	Hollinger and others	CNON
Ashley	CNON	Homestake	USSD
Bankfield-Tombill	CNON	Hutti	INDA
Barbara-Surprise	AUWA	Ida H.	AUWA
Barber-Larder	CNON	Island Lake	CNMN
Barberton	SAFR	Jason	CNON
Barry Hollinger	CNON	Jerome	CNON
Bellevue	AUWA	Kerr Addison	CNON
Bidgood-Moffatt-Hall	CNON	Kiabakari	TNZN
Big Bell	AUWA	Kilo-Moto	CNGO
Black Range-Oroya	AUWA	Kolar	INDA
Bob	ZIMB	Laguerre	CNON
Bonnievale	AUWA	Lancefield	AUWA
Bouscadillac and others	CNON	Lapa Cadillac	CNQU
Broulan and others	CNON	Leitch-Sand River	CNON
Buffalo Red Lake	CNON	Lingman	CNON
Burbanks	AUWA	Little Long Lac	CNON
Calder-Bousquet	CNQU	Madsen	CNON
Campbell Red Lake-Dickenson	CNON	Magnet Cons.	CNON
Carshaw-Tommy Burns	CNON	Marble Bar	AUWA
Cathroy Larder	CNON	Martin-Bird	CNON
Central Manitoba	CNMN	Matachewan Cons. & others	CNON
Central Patricia	CNON	Matona-Stairs	CNON
Cheminis-Fernland-Omega	CNON	McFinley	CNON
Chesterville	CNON	McMarmac	CNON
Connemara	ZIMB	McWatters	CNQU
Coolgardie	AUWA	Menzies	AUWA
Copperhead	AUWA	Minto-Tyranite	CNON
Cosmopolitan	AUWA	Morris-Kirkland	CNON
Cullaton Lake	CNNT	Morro Velho	BRZL
Davidson	CNON	Mt. Magnet	AUWA
Day Dawn-Main Line	AUWA	Mt. Morgans	AUWA
De Santis	CNON	Naybob	CNON
Dome-Paymaster-Preston	CNON	Nobles Nob	AUWA
Edna May	AUWA	Norseman-Dundas	AUWA
Emu-Great Eastern	AUWA	Orpit	CNON
Fraser's	AUWA	Paddy's Flat	AUWA
Fuller-Tisdale	CNON	Palmer's Find	AUWA
Geita	TNZN	Passagem	BRZL
Gimlet-Slippery	AUWA	Pickle Crow	CNON
Gladstome-Sand Queen	AUWA	Queenston	CNON
God's Lake	CNMN	Raposos	BRZL
Gold Eagle-McKenzie	CNON	Red Crest	CNON
Gold Hawk	CNON	Red Lake Gold Shore	CNON
Gold Hill	CNON	Ross	CNON
Golden Ridge	AUWA	Rouyn Merger	CNQU
Gongo Socco	BRZL	Sanshaw	CNON

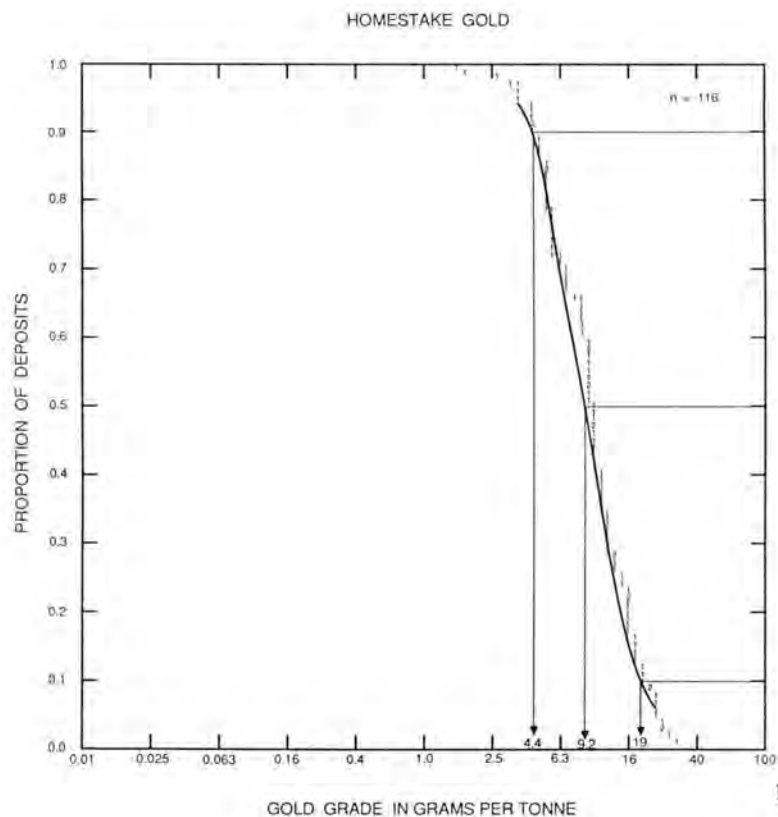


Model 36b--Con.

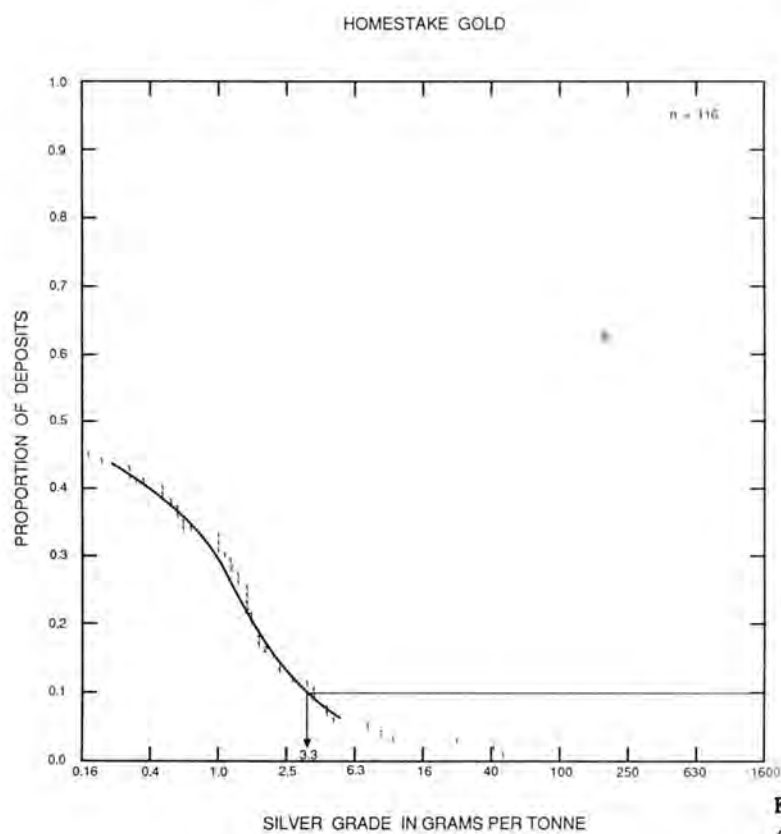
Shamva-Cymric Gp.	ZIMB	Uchi	CNON
Son of Gwalia	AUWA	Upper Beaver	CNON
Stadacona	CNQU	Upper Canada	CNON
Starratt-Olsen	CNON	Wasa Lake	CNQU
Talmora Longlac	CNON	White Feather	AUWA
Thompson Bousquet	CNQU	Wilmar and others	CNON
Timoni	AUWA	Wiluna-Moonlight	AUWA
Triton	AUWA	Youanmi	AUWA



**Figure 184.** Tonnages of Homestake Au deposits.



**Figure 185.** Gold grades of Homestake Au deposits.



**Figure 186.** Silver grades of Homestake Au deposits.

## DESCRIPTIVE MODEL OF UNCONFORMITY U-Au

By Richard I. Grauch and Dan L. Mosier

APPROXIMATE SYNONYM Veinlike type U (Dahlkamp and Adams, 1981).

DESCRIPTION Uranium mineralization occurs as fracture- and breccia-filling in metapelites, metapsammites and quartz arenites located below, above, or across an unconformity separating Early and Middle Proterozoic rocks.

GENERAL REFERENCE Nash and others (1981).

### GEOLOGICAL ENVIRONMENT

Rock Types Regionally metamorphosed carbonaceous pelites, psammites, carbonate rocks. Younger unmetamorphosed quartz arenites.

Textures Metamorphic foliation and later brecciation.

Age Range In rocks of Early and Middle Proterozoic age (1,800-1,200 m.y.), affected by Proterozoic regional metamorphism.

Depositional Environment Host rocks are sedimentary shelf deposits and overlying continental sandstone. Deposits result from complex processes including regional metamorphism, weathering and supergene enrichment related to Proterozoic unconformity, and later remobilization and enrichment beneath cover of younger strata.

Tectonic Setting(s) Intracratonic sedimentary basins on the flanks of Archean domes. Tectonically stable since Middle Proterozoic.

Associated Deposit Types Gold- and nickel-rich uranium deposits may occur but are poorly understood and no models are available.

### DEPOSIT DESCRIPTION

Mineralogy Pitchblende + uraninite ± coffinite ± pyrite ± chalcopryrite ± galena ± sphalerite ± arsenopyrite ± niccolite. Chlorite + quartz + calcite + dolomite + hematite + siderite + sericite. Locally late quartz-chlorite veins contain native gold or silver, uraninite, galena, and tellurides of Bi, Ni, Pb and Pd. Latest quartz-calcite veins contain pyrite, chalcopryrite, and bituminous matter.

Texture/Structure Breccia filling, veins, and disseminations. Coarse euhedral uraninite and fine colloform pitchblende. Latest quartz-calcite veins show open-space fillings, colloform texture.

Alteration Multistage chloritization is dominant. Local sericitization, dolomitization, hematitization, kaolinitization. Incipient and vuggy vein-type silicification occur throughout the alteration envelope. Alteration envelope is variably enriched in Mg, P, REE, and a variety of metals. Alkali elements are depleted.

Ore Controls Fracture porosity controlled ore distribution in the metamorphites and to a limited extent in the overlying quartz arenite. The unconformity acted as a major disruption in the flow of ore-forming fluids but did not necessarily act as a locus of ore formation.

Weathering Secondary U minerals uranyl-phosphate, metatorbernite, autunite, uranophane, gummite, sklodowskite.

Geochemical and Geophysical Signature Increase in U, Mg, P and locally in Ni, Cu, Pb, Zn, Co, As; decrease in SiO<sub>2</sub>. Locally Au, associated with Ag, Te, Ni, Pd, Re, Mo, Hg, REE, Y and Rb. Anomalous radioactivity. Graphitic schists in some deposits are strong electromagnetic conductors.

### EXAMPLES

Rabbit Lake, CNSK	(Hoeve and Sibbald, 1978)
Cluff Lake, CNSK	(Laine, 1985)

Key Lake, CNSK  
 Jabiluka, AUNT  
 Ranger, AUNT

(Dahlkamp, 1978)  
 (Binns and others, 1980, Grauch, 1984)  
 (Eupene, 1979)

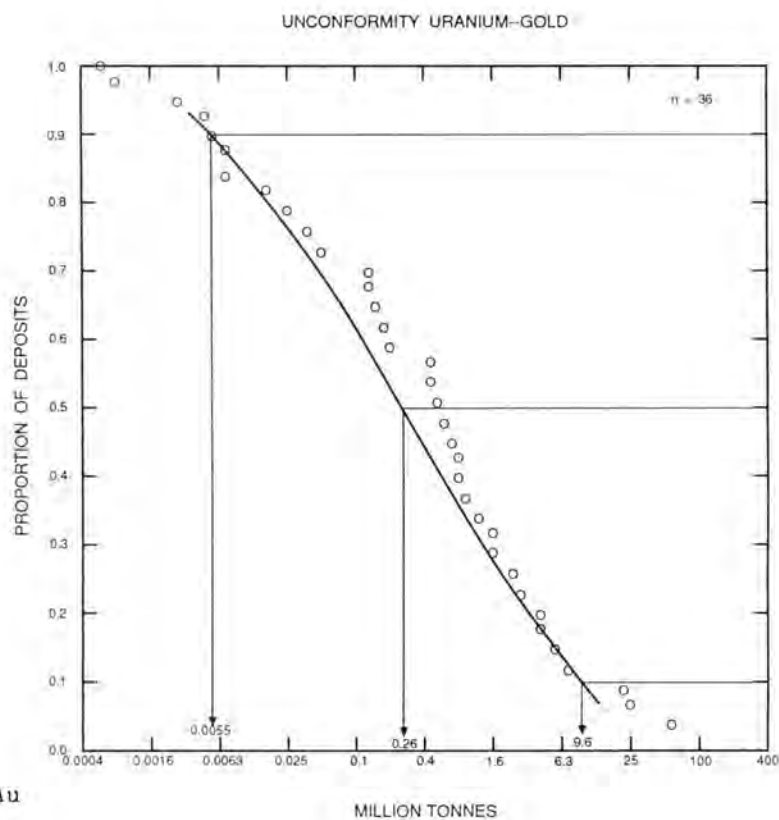
# GRADE AND TONNAGE MODEL OF UNCONFORMITY U-Au

By Dan L. Mosier

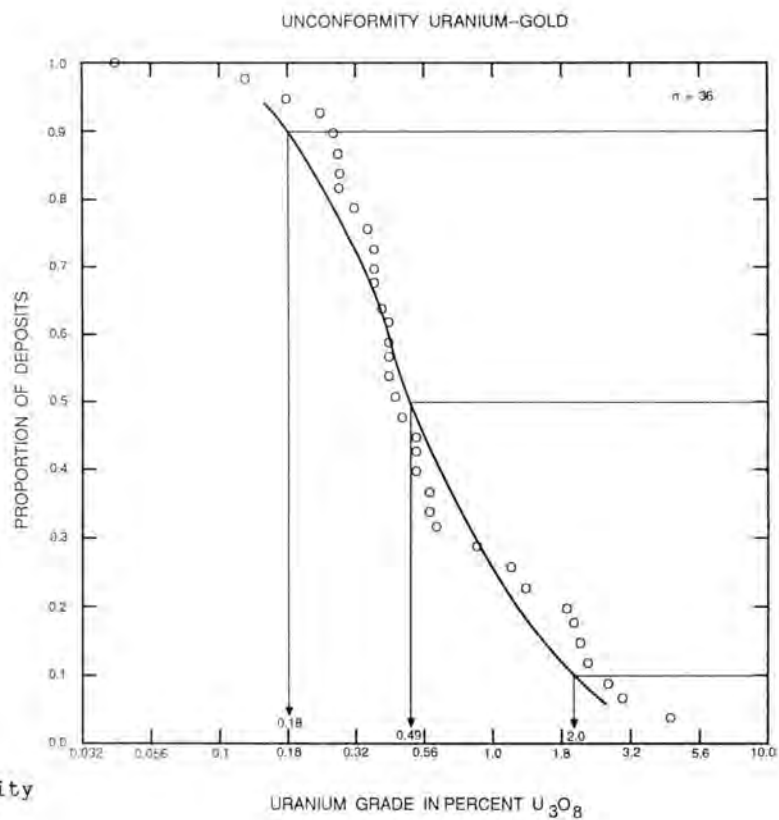
COMMENTS Deposits are defined by a separation of 100 m stratigraphically and along strike. Sufficient number of Au grades were not available to construct a plot. See figs. 187, 188.

## DEPOSITS

<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Cluff Lake-Claude	CNSK	McClean Lake	CNSK
Cluff Lake D	CNSK	Maurice Bay	CNSK
Cluff Lake N	CNSK	Midwest Lake	CNSK
Cluff Lake OP	CNSK	Mount Burton (Rum Jungle)	AUNT
Cluff Lake R	CNSK	Mount Finch (Rum Jungle)	AUNT
Cluff Bay A	CNSK	Nabarlek	AUNT
Cluff Bay B	CNSK	Palette	AUNT
Dawn Lake	CNSK	Rabbit Lake	CNSK
Dyson's (Rum Jungle)	AUNT	Ranger No. 1	AUNT
El Sherana	AUNT	Ranger No. 3	AUNT
El Sherana West	AUNT	Rockhole-Teages	AUNT
Fond-du-Lac	CNON	Rum Jungle Creek South	AUNT
Jabiluka I	AUNT	Scinto 5	AUNT
Jabiluka II	AUNT	Skull	AUNT
Key Lake (Deilmann)	CNSK	Sleisbeck	AUNT
Key Lake (Gaertner)	CNSK	Stewart Island	CNSK
Koolpin Creek	AUNT	West Bear	CNSK
Koongarra	AUNT	White's (Rum Jungle)	AUNT



**Figure 187.** Tonnages of unconformity U-Au deposits.



**Figure 188.** Uranium grades of unconformity U-Au deposits.

## DESCRIPTIVE MODEL OF GOLD ON FLAT FAULTS

By Bruce A. Bouley\*

DESCRIPTION Disseminated gold in breccia along low-angle faultsGENERAL REFERENCE Wilkins (1984).GEOLOGICAL ENVIRONMENTRock Types Breccia derived from granitic rocks, gneiss, schist, mylonite and unmetamorphosed sedimentary and volcanic rocks. Rhyolitic dikes and plugs.Textures Chaotic jumble of rock and vein material.Age Range Unknown. Examples in southern California and southwestern Arizona are mainly Mesozoic and Tertiary.Depositional Environment Permeable zones: source of heat and fluids unknown.Tectonic Setting(s) Low-angle faults in crystalline and volcanic terrane. Including detachment faults related to some metamorphic core complexes and thrust faults related to earlier compressive regimes.Associated Deposit Types Epithermal quartz adularia veins in hanging-wall rocks of some districts.DEPOSIT DESCRIPTIONMineralogy Gold, hematite, chalcopyrite, minor bornite, barite, and fluorite.Texture/Structure Micrometer-size gold and specular hematite in stockwork veining and brecciated rock.Alteration Hematite, quartz, and chlorite. Silicification. Carbonate minerals.Ore Controls Intensely brecciated zones along low-angle faults. Steep normal faults in hanging wall. Sheeted veins.Weathering Most ore is in oxidized zone because of lower cost of recovery. Mn oxides.Geochemical Signature Au, Cu, Fe, F, Ba. Very low level anomalies in Ag, As, Hg, and W.EXAMPLES:

Picacho, USCA	(Van Nort and Harris, 1984)
Copper Penny and Swansea, USAZ	(Wilkins and Heidrick, 1982)

\* Present address: Callahan Mining Corp., 6245 North 24th Street, Phoenix, AZ 85016.

## DESCRIPTIVE MODEL OF LATERITIC Ni

By Donald A. Singer

DESCRIPTION Nickel-rich, in situ lateritic weathering products developed from dunites and peridotites. Ni-rich iron oxides are most common. Some deposits are predominantly Ni silicates.

GENERAL REFERENCE Evans and others (1979).

### GEOLOGICAL ENVIRONMENT

Rock Types Ultramafic rocks, particularly peridotite, dunite, and serpentized peridotite.

Age Range Precambrian to Tertiary source rocks, typically Cenozoic weathering.

Depositional Environment Relatively high rates of chemical weathering (warm-humid climates) and relatively low rates of physical erosion.

Tectonic Setting(s) Convergent margins where ophiolites have been emplaced. Uplift is required to expose ultramafics to weathering.

Associated Deposit Types Podiform chromite, PGE placers, serpentine-hosted asbestos.

### DEPOSIT DESCRIPTION

Mineralogy Garnierite, poorly defined hydrous silicates, quartz, and goethite. Goethite commonly contains much Ni.

Texture/Structure Red-brown pisolitic soils, silica-rich boxworks.

Alteration Zoned--from top: (1) Red, yellow, and brown limonitic soils; (2) saprolites--continuous transition from soft saprolite below limonite zone, hard saprolite and saprolitized peridotite, to fresh peridotite. Boxwork of chalcedony and garnierite occurs near bedrock-weathered rock.

Ore Controls Upper limonite zone containing 0.5-2 percent Ni in iron-oxides; lower saprolite and boxwork zone typically contains 2-4 percent Ni in hydrous silicates. The oxide and silicate ores are end members and most mineralization contains some of both.

Weathering The profile from red-brown pisolitic soil down to saprolite represents the products of chemically weathered ultramafic rocks.

Geochemical Signature Enriched in Ni, Co, Cr; depleted in MgO relative to fresh peridotite (less than 40 percent MgO).

### EXAMPLES

Porco, NCAL	(Troly and others, 1979)
Cerro Matoso, CLBA	(Gomez and others, 1979)
Nickel Mountain, USOR	(Chace and others, 1969)
Greenvale, AUQL	(Burger, 1979)

## GRADE AND TONNAGE MODEL OF LATERITIC Ni

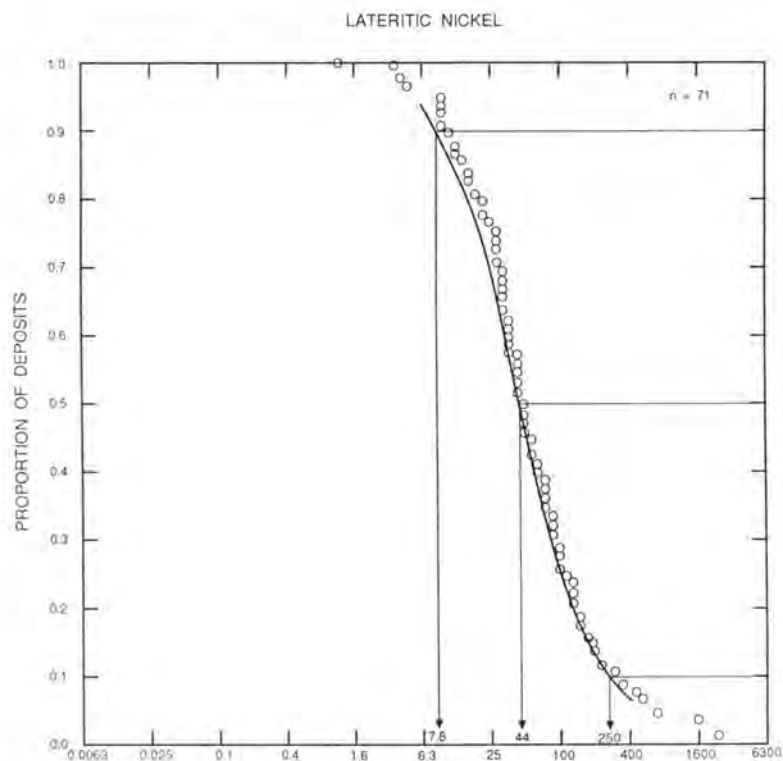
By Donald A. Singer

COMMENTS Higher grades are typically associated with the silicate type. Numerous low-grade (less than 1 percent Ni) and low-tonnage deposits are not included. Nickel grade is correlated with tonnage ( $r = -0.31$ ). See figs. 189, 190.

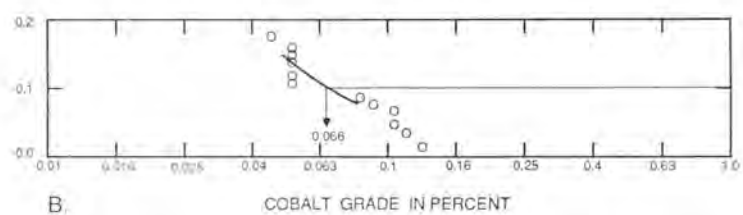
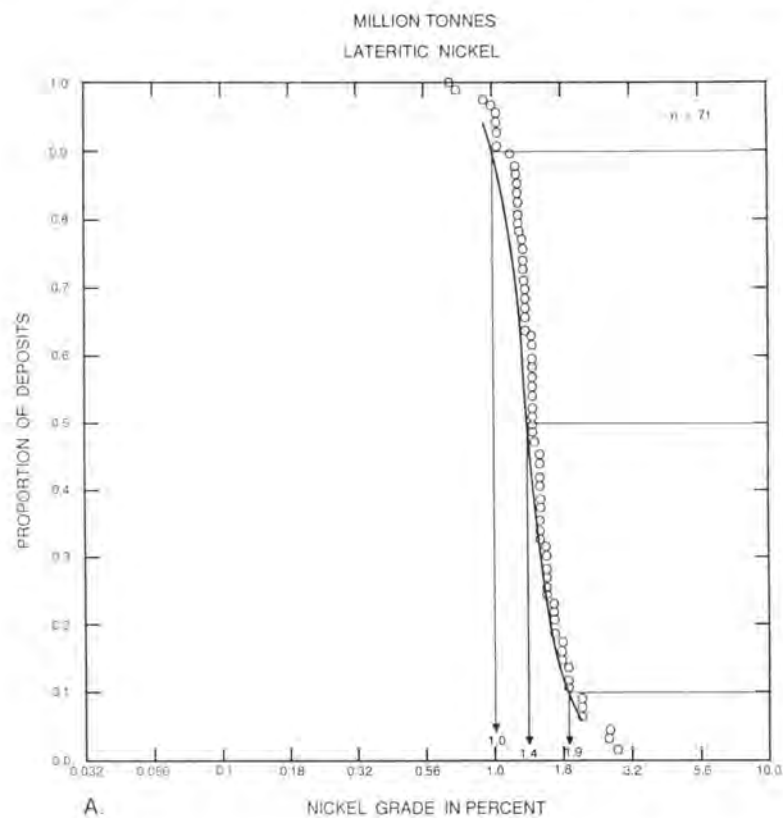
DEPOSITS

<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Ambatory	MDGS	Moa Bay	CUBA
Analumay	MDGS	Moorson	PLPN
Barro Alto	BRZL	Moramanga	MDGS
Berong	PLPN	Morro de Engenho	BRZL
Bhimatanga	INDA	Mwaytung	BRMA
Blue Ridge	PLPN	Nepoui	NCAL
Br. Solomon Is.	SLMN	New Frontier	PLPN
Buka	PLPN	Niquelandia	BRZL
Cabo Rojo	PTRC	Nonoc	PLPN
Cerro Matoso	CLBA	Obi	INDS
Claude Hills	AUSA	Ora Banda	AUWA
Cyclops	INDS	Orsk	URRS
Dinagat Is.	PLPN	Pujada Pen.	PLPN
Euboea	GREC	Pomalea	INDS
Exmibal	GUAT	Poros	NCAL
Falconbridge	DMRP	Poum	NCAL
Gag Is.	INDS	Pratapolis	BRZL
Golesh Mt.	YUGO	Prony	NCAL
Golos	YUGO	Ramona-Loma	CUBA
Goro	NCAL	Riddle	USOR
Greenvale	AUQL	Rio Tuba	PLPN
Hagios Ioannis	GREC	Sablayon	PLPN
Halmahera	INDS	Sao Joaodo Piaui	BRZL
Ipaneme	BRZL	Santa Cruz	PLPN
Jacupuenga	BRZL	Saruabi	INDA
Kaliapani	INDA	S.E. Kalimantan	INDS
Kansa	INDA	Sidamo	ETHP
Kauadarc	YUGO	Simlipal	INDA
Laguney	PLPN	Soroako	INDS
Lake Joanina	GREC	Sukinda	INDA
Leviso R.	CUBA	Suriagao	PLPN
Loma de Hierro	VNZL	Taco Bay	CUBA
Long Point	PLPN	Thio	NCAL
Marlborough	AUQL	Tiebaghi	NCAL
Masinloc	PLPN	Wingelinna-Daisy	AUWA
Mayari	CUBA		





**Figure 189.** Tonnages of lateritic Ni deposits.



**Figure 190.** Metal grades of lateritic Ni deposits. A, Nickel. B, Cobalt.

## DESCRIPTIVE MODEL OF LATERITE TYPE BAUXITE DEPOSITS

By Sam H. Patterson

APPROXIMATE SYNONYM Aluminum ore (Patterson, 1967).

DESCRIPTION Weathered residual material in subsoil formed on any rock containing aluminum.

GENERAL REFERENCE Patterson (1984).

### GEOLOGICAL ENVIRONMENT

Rock Types Weathered rock formed on aluminous silicate rocks.

Textures Pisolitic, massive, nodular, earthy.

Age Range Mainly Cenozoic, one Cretaceous deposit known.

Depositional Environment Surficial weathering on well-drained plateaus in region with warm to hot and wet climates. Locally deposits in poorly drained areas low in Fe due to its removal by organic complexing.

Tectonic Setting(s) Typically occurs on plateaus in tectonically stable areas.

Associated Deposit Types Overlain by thin "A" horizon soil, underlain by saprolite (parent rock in intermediate stages of weathering).

### DEPOSIT DESCRIPTION

Mineralogy Mainly gibbsite and mixture of gibbsite and boehmite; gangue minerals hematite, goethite, anatase, locally quartz.

Texture/Structure Pisolitic, massive, earthy, nodular.

Alteration Aluminous rocks are altered by weathering to bauxite.

Ore Controls Thoroughly weathered rock, commonly erosional boundaries of old plateau remnants.

Weathering Intensive weathering required to form bauxite. Bauxite continues to form in present weathering environment in most deposits.

Geochemical Signature: Al, Ga.

### EXAMPLES

Australia, Brazil, Guinea  
examples are reviewed in Patterson (1967)

## GRADE AND TONNAGE MODEL OF LATERITE TYPE BAUXITE DEPOSITS

By Dan L. Mosier

REFERENCES Patterson (1967) and numerous other papers.

COMMENTS A district has been defined as a deposit or a group of deposits in which each deposit is not separated by more than 20 km from an adjacent deposit. Using this rule, most district names in the published literature have been retained; however, some previously regarded districts have been divided into two or more districts, which therefore are named after the largest deposit in that district or a local place name. See figs. 191, 192.

DEPOSITS

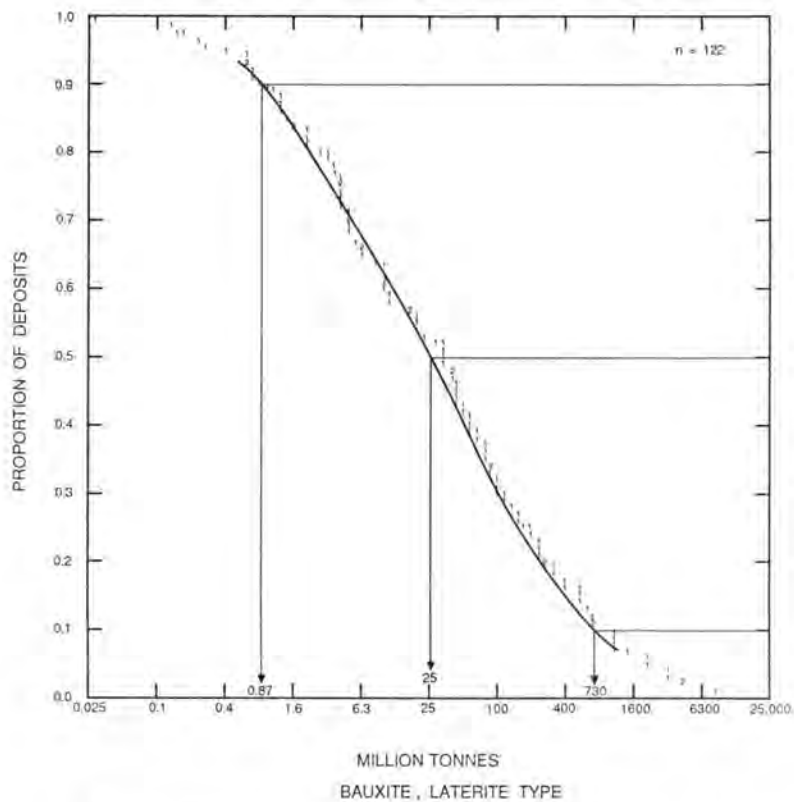
<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Affoh	GHNA	Khushab (Sargohda)	PKTN
Almeirim	BRZL	Kibi	GHNA
Alumen	MZMB	Kolaba-Ratnagiri	INDA
Analavory	MDGS	Kolhapur	INDA
Anantagiri	INDA	Koro Plateau	CHAD
Asafo	GHNA	Kutch	INDA
Aurukum	AUQL	Los Pijiguaos	VNZL
Awaso	GHNA	Maikala Range	INDA
Ayekoye	GNEA	Mainpat	INDA
Bihar	INDA	Manantenina	MDGS
Bakhuis Mountains	SRNM	Manus Island	PPNG
Balea-Sitaouma	MALI	Marangaka	MDGS
Bamboutos	CMRN	Marchinbar Island	AUNT
Bangam	CMRN	Mariana	BRZL
Barao de Cocais-Caete	BRZL	Mazagao	BRZL
Barra do Pirai	BRZL	Mimoso do Sul	BRZL
Bhavnagar	INDA	Minim-Martap	CMRN
Bilaspur	INDA	Mitchell Plateau	AUWA
Bintan Island	INDS	Mlanje Mountain	MLWI
Blue Mountains-		Moengo	SRNM
Okoko Mountains	GUYN	Mogi das Cruzes	BRZL
Boe	GNBS	Mokanji Hills	SRLN
Bom Repouso-Cambui	BRZL	Monghyr	INDA
Boolarra	AUVT	Moss Vale	AUNS
Caldas	BRZL	Mount Ejuanema-Nsisreso	AUNS
Cape Bougainville	AUWA	Mount Saddleback	AUWA
Caroline Islands	CARL	Myalla	AUNT
Cataguases	BRZL	Nassau Mountains	SRNM
Champagne (Oakwood)	AUNS	Nhamunda	BRZL
Chintapalli-Gurtedu	INDA	Nilgiri Hills	INDA
Chittering	AUWA	North Weipa	AUQL
Croker Island	AUNT	Northern Ireland	IRLD
D'Analamaitso	MDGS	Nuria	VNZL
D'Ankazobe	MDGS	NW Group	GUYN
Dabola	GNEA	Nyinahin	GHNA
Debele (Kindia)	GNEA	Ourem	BRZL
Del Park-Huntly	AUWA	Ouse	AUTS
Descoberto	BRZL	Palni Hills	INDA
Divinolândia de Minas	BRZL	Paragominas	BRZL
East Maui	USHI	Paranam	SRNM
Emmaville	AUNS	Parish	AUNS
Fenoarivo	MDGS	Pocos de Caldas-Aguas	
Fongo Tongo	CMRN	de Prata	BRZL
Fria-Kimbo	GNEA	Ramunia-Telok Ramunia	MLYS
Gambe	BRZL	Ranchi-Palamau	INDA
Gove	AUNT	St. Leonards	AUTS
Hampton	AUQL	Salem Hills	USOR
Iles de Los	GNEA	Saline-Pulaski	USAR
Intendencia de Arauca	CLBA	Sambalpur	INDA
Irituia	BRZL	Sangaredi	GNEA
Itanhandu-Resende	BRZL	Santa Barbara	BRZL
Jamirapat-Khuria	INDA	Sao Domingos do Capim	BRZL
Jamnagar (Saurashtra)	INDA	Sao Paulo	BRZL
Jarrahdale	AUWA	Shevaroy Hills	INDA
Kalahandi-Koraput	INDA	South Weipa	AUQL
Kauai	USHI	Tamborine Mountain	AUQL
Kaw Mountains	FRGN	Tougue	GNEA
Kerikeri	NZLD	Trombetas	BRZL
Kheda (Kaira)	INDA	Turtle Head	AUQL

Upata  
Valle del General  
Weipa-Andoom-Pera Head

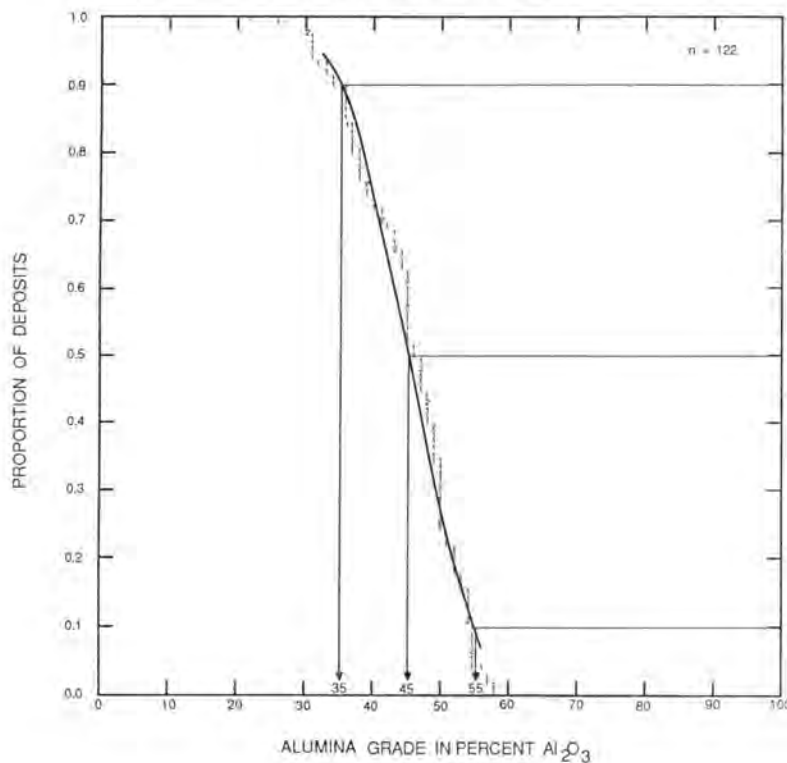
VNZL  
CORI  
AUQL  
BAUXITE, LATERITE TYPE

Wenlock River  
West Maui  
Weza

AUQL  
USHI  
SAFR



**Figure 191.** Tonnages of laterite-type bauxite deposits. Individual digits represent number of deposits.



**Figure 192.** Alumina grades of laterite-type bauxite deposits. Individual digits represent number of deposits.

# DESCRIPTIVE MODEL OF KARST TYPE BAUXITE DEPOSITS

By Sam H. Patterson

APPROXIMATE SYNONYM Aluminum ore (Bardossy, 1982).

DESCRIPTION Weathered residual and transported materials.

GENERAL REFERENCE Bardossy (1982).

## GEOLOGICAL ENVIRONMENT

Rock Types Residual and transported material on carbonate rocks. Transported material may be felsic volcanic ash from a distant source or any aluminous sediments washed into the basin of deposition.

Textures Pisolithic, nodular, massive, earthy.

Age Range Paleozoic to Cenozoic.

Depositional Environment Surficial weathering mainly in wet tropical area.

Tectonic Setting(s) Stable land areas allowing time for weathering and protected from erosion.

Associated Deposit Types Limestone, dolomite, and shale; some are associated with minor coal and are low in Fe due to organic complexing and removal of Fe during formation.

## DEPOSIT DESCRIPTION

Mineralogy Mainly gibbsite in Quaternary deposits in tropical areas. Gibbsite and boehmite mixed in older Cenozoic deposits, boehmite in Mesozoic deposits and in Paleozoic deposits; gangue minerals hematite, goethite, anatase, kaolin minerals, minor quartz.

Texture/Structure Pisolithic, massive, nodular.

Alteration Formation of bauxite is itself a form of alteration of aluminous sediments.

Ore Controls Deposits tend to be concentrated in depressions on karst surfaces.

Weathering Intense weathering required to form bauxite. Bauxite continues to form in the present weathering environment in most deposits.

Geochemical Signature Al, Ga.

EXAMPLE European and Jamaican examples are reviewed in Bardossy (1982).

# GRADE AND TONNAGE MODEL OF KARST TYPE BAUXITE DEPOSITS

By Dan L. Mosier

COMMENTS See figs. 193, 194.

## DEPOSITS

<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Abruzzi	ITLY	Camarasa-Oliana	SPAN
Aceitillar	DMRP	Campania	ITLY
Adana-Saimbeyli	TRKY	Clarendon Plateau	JMCA
Akeski	TRKY	Drnis-Obrovac	YUGO
Beceite-		Fenyoto	HUNG
Fuendesplada	SPAN	Gant	HUNG
Bulbula	IRAN	Halimba	HUNG

Imotski-Mostar	YUGO	Padurea Craiului	RMNA
Islahiye	TRKY	Parnassus-Helikon	GREC
Iszkaszentgyorgy	HUNG	Payas	TRKY
Jajce	YUGO	Punch	INDA
LangSen	VTNM	Rochelois Plat.	HATI
Maggotty	JMCA	San Giovanni	
Manchester Plat.	JMCA	Rotondo	ITLY
Megara-Eleusis	GREC	Seydisehr	TRKY
Muzaffarabad	PKTN	Sohodol-Cimpeni	RMNA
Nagyegyhaza	HUNG	Spinazzola	ITLY
N.C. Puerto Rico	PTRC	St. Ann Plateau	JMCA
N.E. Alabama	USAL	Unterlaussa	ASTR
Niksicka Zupa	YUGO	Vlasenica	YUGO
N.W. Georgia	USGA	Zonguldak	TRKY
Nyirad	HUNG		

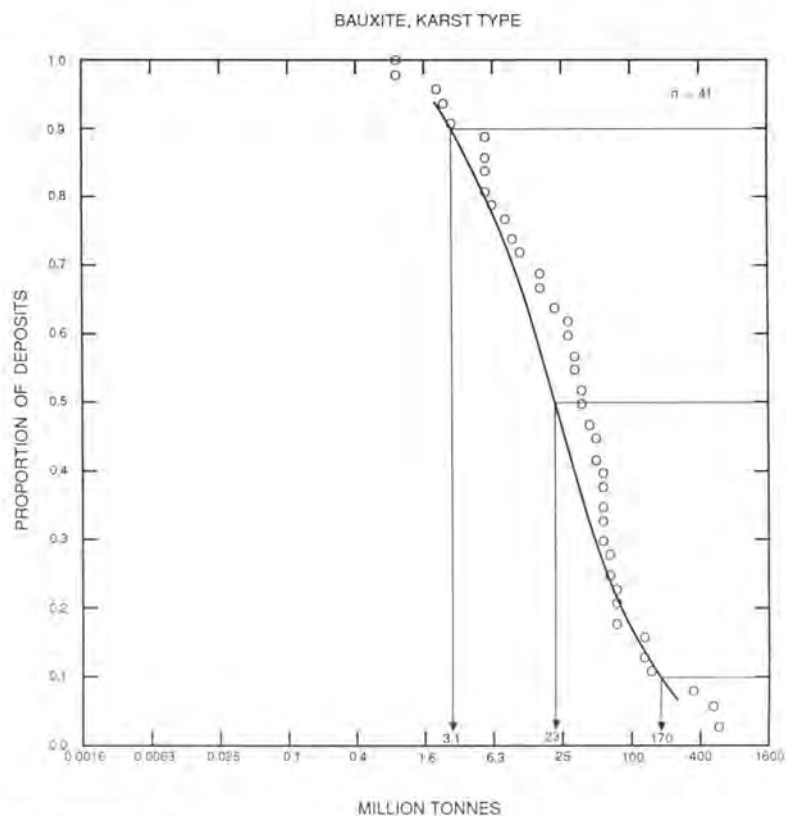


Figure 193. Tonnages of karst-type bauxite deposits.

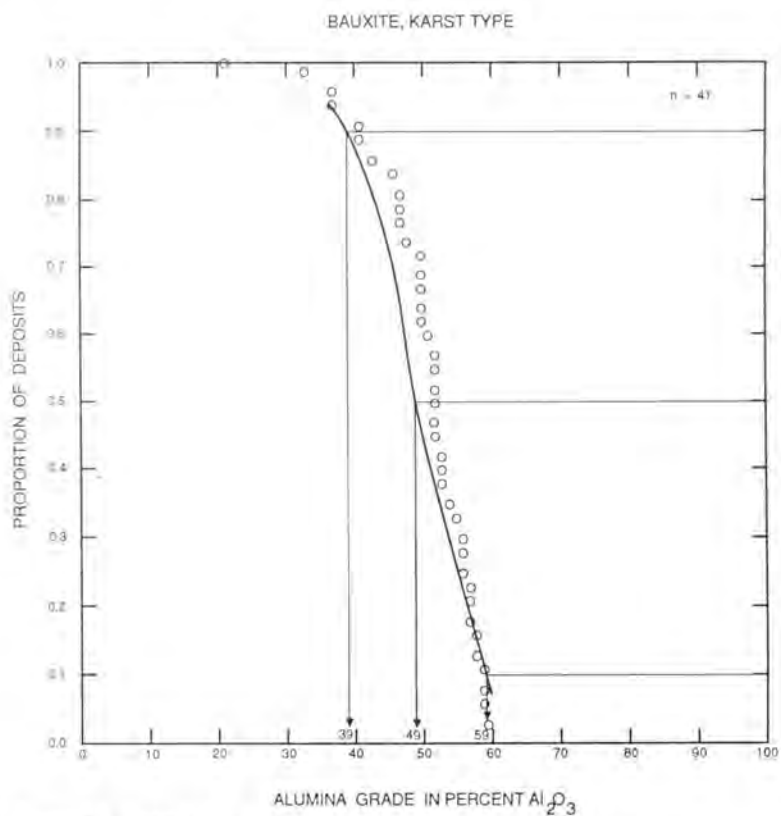


Figure 194. Alumina grades of karst-type bauxite deposits.

## DESCRIPTIVE MODEL OF PLACER Au-PGE

By Warren E. Yeend

DESCRIPTION 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 (see fig. 195).

GENERAL REFERENCES Boyle (1979), Wells (1973), Lindgren (1911).

GEOLOGICAL ENVIRONMENT

Rock Types Alluvial gravel and conglomerate with white quartz clasts. Sand and sandstone of secondary importance.

Textures Coarse clastic.

Age Range Cenozoic. Older deposits may have been formed but their preservation is unlikely.

Depositional Environment High-energy alluvial where gradients flatten and river velocities lessen, as at the inside of meanders, below rapids and falls, beneath boulders, and in vegetation mats. Winnowing action of surf caused Au concentrations in raised, present, and submerged beaches.

Tectonic Setting(s) Tertiary conglomerates along major fault zones, shield areas where erosion has proceeded for a long time producing multicycle sediments; high-level terrace gravels.

Associated Deposit Types Black sands (magnetite, ilmenite, chromite); yellow sands (zircon, monazite). Au placers commonly derive from various Au vein-type deposits as well as porphyry copper, Cu skarn, and polymetallic replacement deposits.

DEPOSIT DESCRIPTION

Mineralogy Au, platinum-iron alloys, osmium-iridium alloys; gold commonly with attached quartz, magnetite, or ilmenite.

Texture/Structure Flattened, rounded edges, flaky, flour gold extremely fine grained flakes; very rarely equidimensional nuggets.

Ore Controls Highest Au values at base of gravel deposits in various gold "traps" such as natural riffles in floor of river or stream, fractured bedrock, slate, schist, phyllite, dikes, bedding planes, all structures trending transverse to direction of water flow. Au concentrations also occur within gravel deposits above clay layers that constrain the downward migration of Au particles.

Geochemical Signature Anomalous high amounts of Ag, As, Hg, Sb, Cu, Fe, S, and heavy minerals magnetite, chromite, ilmenite, hematite, pyrite, zircon, garnet, rutile. Au nuggets have decreasing Ag content with distance from source.

EXAMPLES

Sierra Nevada, USCA	(Lindgren, 1911; Yeend, 1974)
Victoria, AUVT	(Knight, 1975)

## GRADE AND TONNAGE MODEL OF PLACER Au-PGE

By Greta J. Orris and James D. Bliss

REFERENCE Orris and Bliss (1985).

COMMENTS Placers used for this model are predominantly Quaternary in age and alluvial in nature. Many of the placer deposits contain a mix of depositional environments and energy level--deposits along minor tributaries have been worked with deposits downstream on a higher order stream, bench (or terrace) gravels have been mined with more recent deposits on valley floor. Some of the placers included in this model were formed by complex glacial-fluvial processes. Deposits not



included in this model are those primarily cataloged as desert placers, pre-Tertiary or Tertiary age placers, beach placers, eolian placers, residual placers, eluvial placers, and gravel-plain deposits. These types, however, may be minor components of those deposits selected to be included. In most cases, the grade and tonnage figures are for districts or for placer operations within one mile (1.6 km) of one another. For some placers, early production figures were missing due to poor records of early gold rush work. In most cases, reserve figures (if a reserve is known) are not available. Some tonnage figures were estimated from approximate size of workings. Some grades were based on very limited information and in some cases extrapolated from information on manpower figures, type of equipment used, and estimates of the total contained gold produced.

Cutoff grades are dependent on the mining methods used to exploit placers. Methods of placer mining included in this model are as diverse as the depositional environment. These methods include panning, sluicing, hydraulic mining, and dredging. Draglines were used to mine some placers. Cut-off grades are also dependent on the value of gold during the period, or periods, of operation.

Some placer deposits were excluded due to grade or tonnage figures not compatible with the majority of placers found in the model. Placers exploited through drift mining exhibit grades that are too large and tonnages that are too small to be included in this model. Similarly, the large regional placers formed at the junction of mountainous areas and an adjacent plain or valley were excluded because they can be mined with large-volume dredges which are economic at grades not viable under other conditions. Both grades and tonnages of these placers are incompatible with this model.

Placer sizes were initially recorded in terms of cubic meters and the grades recorded as grams per cubic meter. In order to conform to other deposit models herein, deposit volume and grades have been converted to metric tons and grams per metric ton using 2.0 metric tons per cubic meter--the average density of wet sand and gravel. Gold grade is correlated with tonnage ( $r = -0.35$ ) and with silver grade ( $r = 0.66$ ,  $n = 16$ ). See figs. 196, 197.

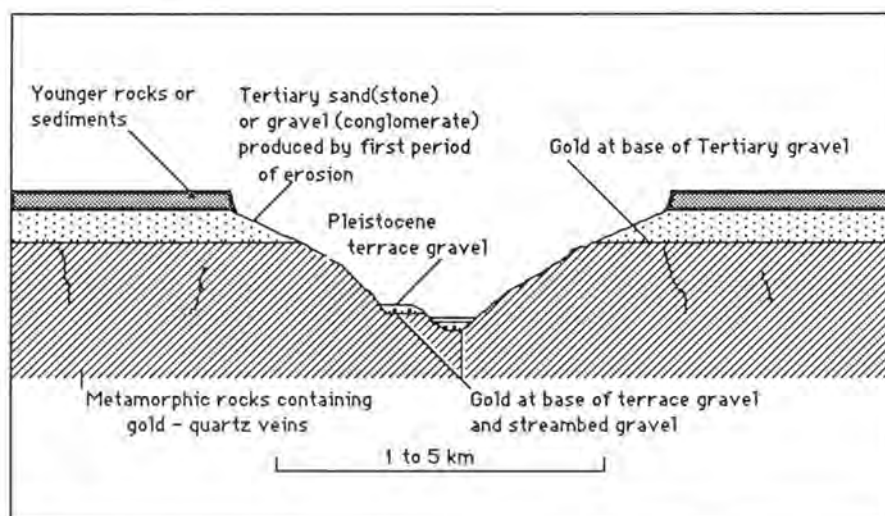
#### DEPOSITS

Name	Country	Name	Country
Adelong Creek	AUNS	Humbug Creek	USOR
Alma (Mills) Placer	USCO	Hundred Dollar Gulch	USID
Araluen Valley	AUNS	Iowa Gulch	USCO
Bannack	USMT	Jembaicumbene Creek	AUNS
Big Badja River	AUNS	Jordan Creek	USID
Blue River	USCO	Lamb Creek	USID
Boulder River	USMT	Llano de Oro	USOR
Bullrun Placer	USOR	Lowe Placer	USCO
Buxton Creek	CNBC	Lower Beaver Creek	USCO
Camanche	USCA	Lowland Creek	USMT
Cobweb Diggings	AUNS	Lynx Creek	USAZ
Copper Basin	USAZ	Missouri Creek	USCO
Corduroy Creek	USID	Mitchell Creek	USMT
Crooked Creek	USID	Nugget Creek (South Fork)	USID
Cullengoral	AUNS	Ophir	USMT
Deep Gravel	USOR	Pactolus	USCO
Dixie Placer	USOR	Picuris	USNM
El Dorado	USMT	Pioneer	USMT
Elkhorn Creek	USMT	Prickly Pear Creek	USMT
Elliston	USMT	Rio Challana	BLVA
Fall Creek	USID	Rio Chimate	BLVA
Foots Creek	USOR	Rio Tuichi (upper reach)	BLVA
Forest Creek	USOR	Rio Yolosano	BLVA
French Gulch	USCO	Rio Yuyo	BLVA
George Prezel	USID	Sand Creek	USID
Georgia Gulch	USCO	Schissler Creek	USID
Gold Run (Summit Co.)	USCO	Snowstorm area	USCO
Gold Run (Boulder Co.)	USCO	Sterling Creek	USOR
Golden Rule	USID	Sumpter Bar	USOR
Green River	USUT	Swan River	USCO
Horse Prairie	USMT	T93-R77W Placer	USCO

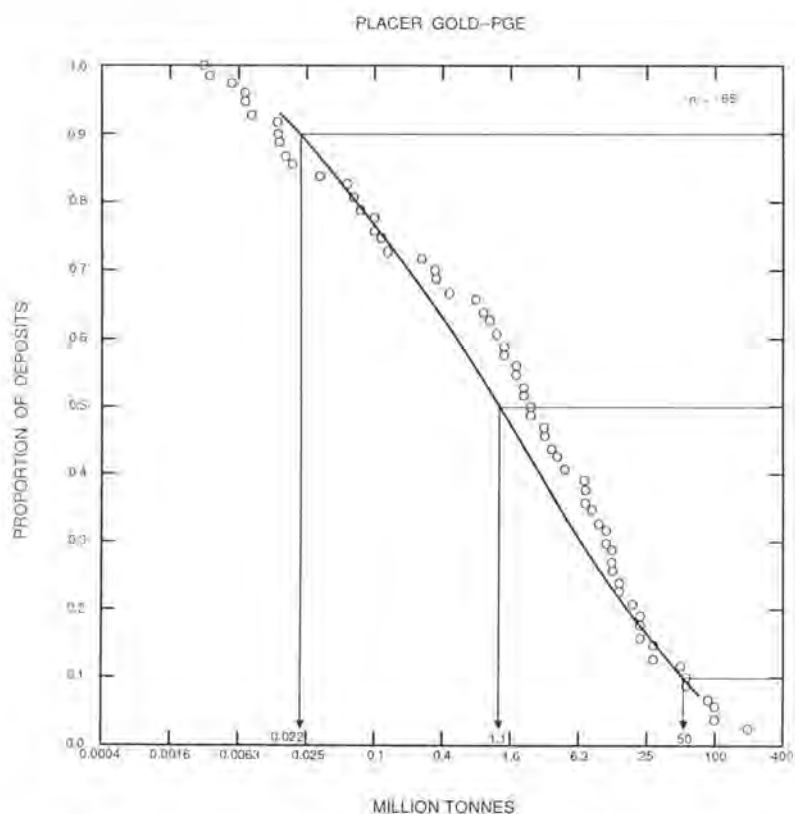
Vermilion River  
WellingtonUSMT  
AUNS

Wombat Creek

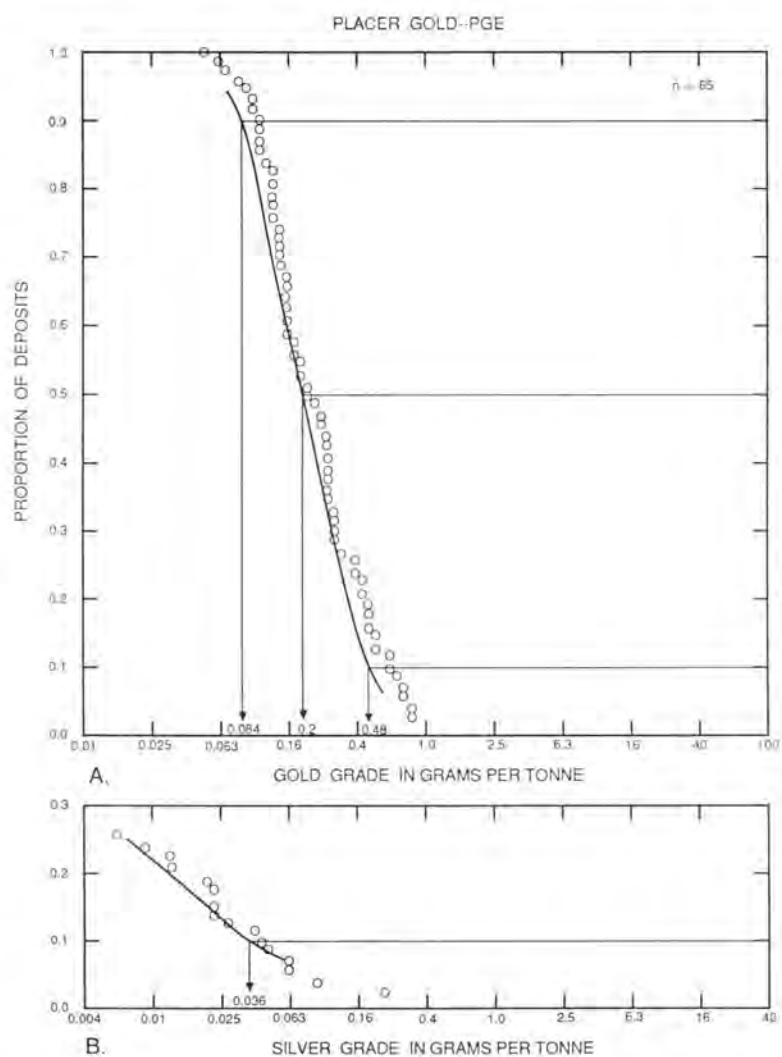
AUNS



**Figure 195.** Cartoon cross section showing three stages of heavy mineral concentrations typical of placer Au-PGE deposits.



**Figure 196.** Tonnages of placer Au-PGE deposits. Individual digits represent number of deposits.



**Figure 197.** Precious-metal grades of placer Au-PGE deposits. A, Gold. B, Silver.

## DESCRIPTIVE MODEL OF PLACER PGE-Au

By Warren E. Yeend and Norman J Page

DESCRIPTION Platinum-group alloys and elemental gold in grains and (rarely) nuggets in gravel, sand, silt, and clay, and their consolidated equivalents, in alluvial, beach, eolian, and (rarely) glacial deposits derived from ultramafic sources.

GENERAL REFERENCES Boyle (1979), Wells (1973), Lindgren (1911), Mertie (1969).

GEOLOGICAL ENVIRONMENT

Rock Types Alluvial gravel and conglomerate and heavy minerals indicative of ultramafic sources and low-grade metamorphic terrane. Sand and sandstone of secondary importance.

Textures Coarse to fine clastic.

Age Range Tertiary to Holocene. Older deposits may have been formed but their preservation is unlikely.

Depositional Environment Marine (near shore), rivers and streams (medium to low gradient), desert (eolian) sand dunes, in-situ weathering.

Tectonic Setting(s) Paleozoic to Mesozoic accreted terranes, Tertiary conglomerates along major fault zones; low terrace deposits; high-level terrace gravels.

Associated Deposit Types Alaskan PGE deposits.

DEPOSIT DESCRIPTION

Mineralogy Platinum-iron alloys (isoferroplatinum with rarer ferroanplatinum, tetraferroplatinum, and tulameenite), platinum-iridium, gold, osmium-iridium alloys; magnetite, chromite, or ilmenite.

Texture/Structure Flattened, rounded edges, flaky, flour-sized alloys and gold; very rarely equidimensional nuggets.

Ore Controls Highest Au values at base of gravel deposits or on argillaceous to clayey beds within gravel sequence; metal alloys concentrated in "traps" such as natural riffles in floor of river or stream, fractured bedrock, slate, schist, phyllite, dikes, bedding planes, and in structures trending transverse to direction of water flow. For PGE, predominantly zoned "Alaskan" type ultramafic complexes and minor ophiolites as source rocks; streams or rivers usually head in regions of ultramafic rocks.

Geochemical Signature Anomalously high amounts of Ag, As, Hg, Sb, Cu, Fe, S, Cr.

EXAMPLES

Urals, USSR	(Duparc and Tikonovitch, 1920; Mertie, 1969)
Goodnews Bay District, USAK	(Mertie, 1969)
Choco, CLBA	(Mertie, 1969)
Tulameen District, CNBC	(O'Neill and Gunning, 1934)

## GRADE AND TONNAGE MODEL OF PLACER PGE-Au

By Donald A. Singer and Norman J Page

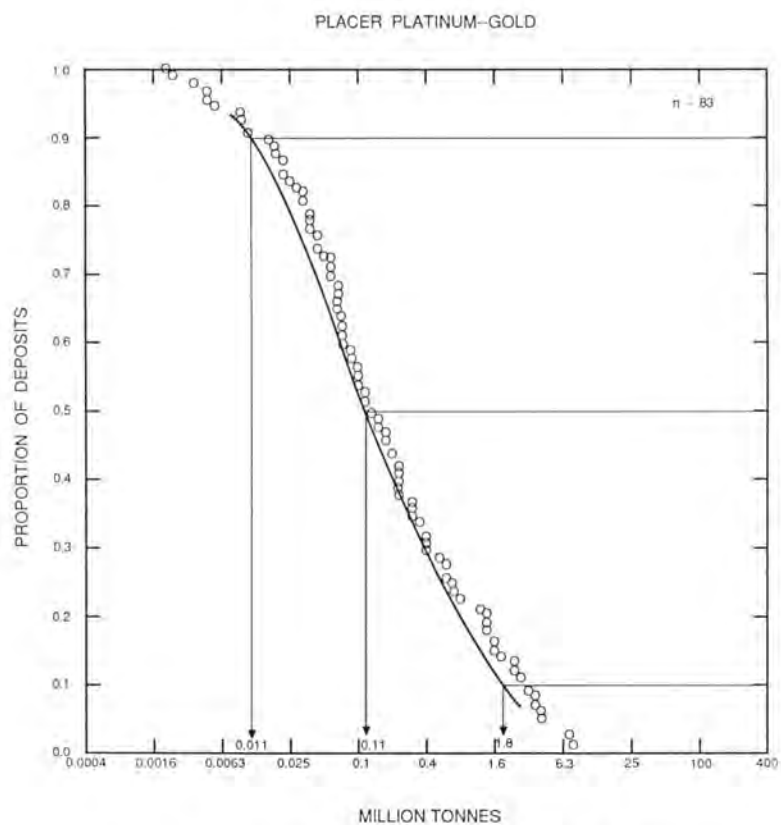
DATA REFERENCE Calkins and others, 1978.

COMMENTS All deposits used for the model are from the Urals of USSR. The platinum grade plot suggests three populations. Many of the deposits with grades less than 1,000 ppb Pt were probably mined by dredges, whereas the majority of deposits were mined by conventional placering methods. Some of the very high grades may represent reporting errors such as grades for a high-grade portion of a deposit being reported as representative of the total deposit. Probably because of the

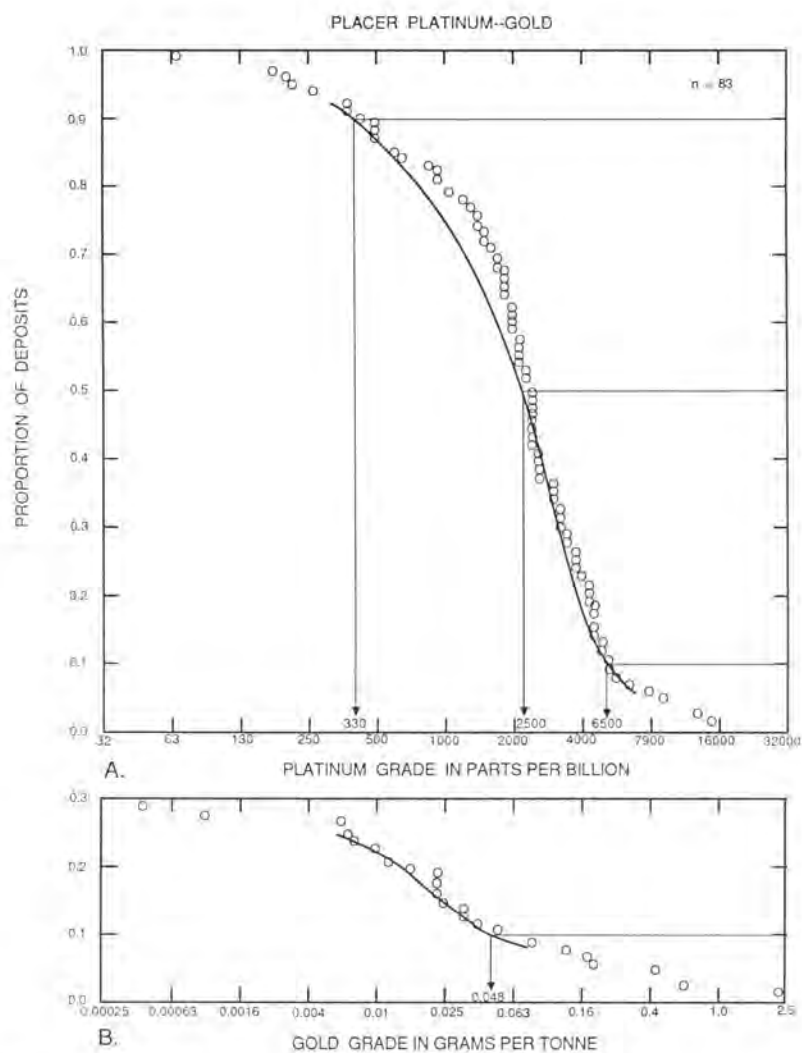
effects of combining deposits mined by two technologies, tonnage is correlated with platinum grade ( $r = -0.42$ ) and with gold grade ( $r = -0.54$ ,  $n = 23$ ). Platinum grade is correlated with gold grade ( $r = 0.58$ ,  $n = 23$ ), with osmium grade ( $r = 0.89$ ,  $n = 21$ ), with iridium grade ( $r = 0.98$ ,  $n = 10$ ), and with palladium grade ( $r = 0.99$ ,  $n = 13$ ). Osmium grade is correlated with iridium grade ( $r = 0.97$ ,  $n = 9$ ) and with palladium grade ( $r = 0.89$ ,  $n = 12$ ). Iridium grade is correlated with palladium grade ( $r = 0.97$ ,  $n = 9$ ). Other correlations were not significant with the available number of samples. See figs. 198-200.

## DEPOSITS

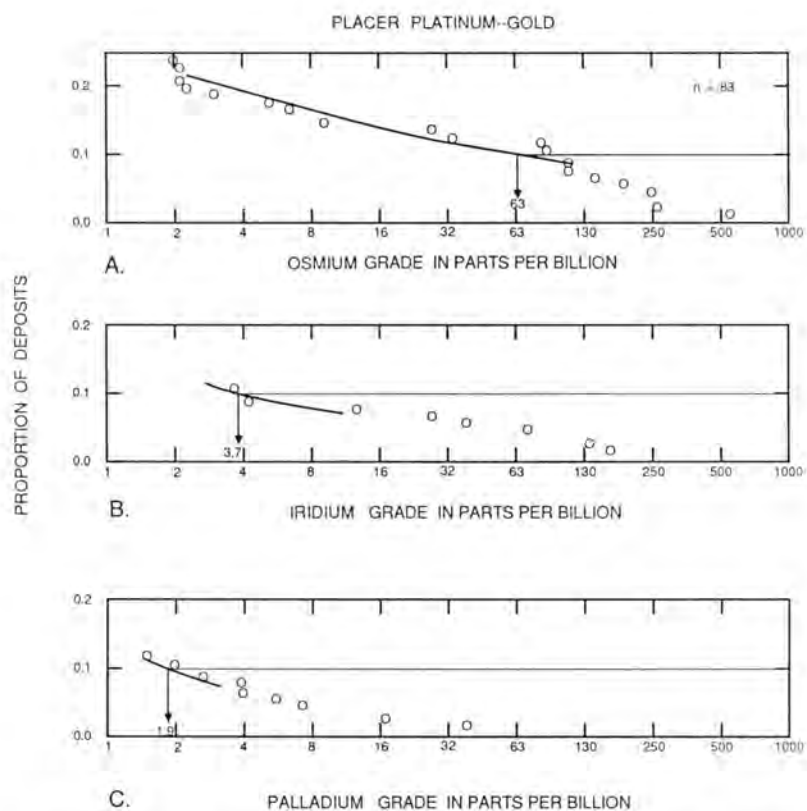
Name	Country	Name	Country
Aleksandrovskii Log	URRS	Malaia Prostokischenka	URRS
Alexii-Olginsky Log	URRS	Malaia Sosnowka	URRS
Anianowsky Lojok	URRS	Malomalsky-Priisk	URRS
Arkhangelskii Log	URRS	Malot Pokap	URRS
Besimianni Log	URRS	Martian R.	URRS
Bielgorsky Log	URRS	Melnitschnaia	URRS
Bobrowka River	URRS	Molitchowka	URRS
Bolshaya Choumika R.	URRS	Morphine-Log	URRS
Bolshaya Kamenouchka	URRS	Niasman R.	URRS
Bolshaya Ossokina R.	URRS	Nikolai-Tschoudotworsky	URRS
Bolshaya Prostokischenka	URRS	Novoi-Log	URRS
Bolshaya Sosnovka	URRS	Obodranny-Lojok	USSR
Bolshoi Pokap R.	URRS	Panowka	URRS
Bolshoi Sakeiam	URRS	Patchek	URRS
Boyandinskaia	URRS	Pestchanka R.	URRS
Ejowka	URRS	Phedinan R.-Triok	URRS
Gloubokia 1	URRS	Podbornaia	URRS
Gloubokia 2	URRS	Podmoskowi-Log	URRS
Illinsky Log	URRS	Popowsky-Lojok	URRS
Ivov R.	URRS	Popretschne-Log	URRS
Jerusalimsky-Priisk	URRS	Roublewik R.	URRS
Jourawlik R.	URRS	Sirkov Log	URRS
Judinsky-Lojok	URRS	Small unnamed-Weressow	URRS
Kamenka	URRS	Solovyevskii Log	URRS
Kamenka R.	URRS	Soukhai Log	URRS
Kisslaia-Peruonatchainik	URRS	Srednia-Prostokischenka	URRS
Kitlim, Severniy R.	URRS	Stepanoff-Log	URRS
Korobowsky Lojok	URRS	Syssim R.	URRS
Kossia R.	URRS	Tilai R.	URRS
Kossoi-Log	URRS	Toura R.	URRS
Kossorgskii Log	URRS	Trudny-Log	URRS
Krutoi Log	URRS	Tsauch R.	URRS
Lobwa R.	URRS	Tschachewitaia	URRS
Log No. 1-Propretschnoi	URRS	Tschch R.	URRS
Log No. 2-Suftlii Bor	URRS	Unnamed creek-B. Sosnowka	URRS
Log No. 3-Suftlii Bor	URRS	Verkho-Tourie	URRS
Log No. 6-Suftlii Bor	URRS	Wyssim R.	URRS
Log No. 7-Suftlii Bor	URRS	Yermakof-Log	URRS
Logwinska	URRS	Zaetzeff, R.	URRS
Lojok at Bisserskaya	URRS	Zemlianoi-Mostik Log	URRS
Lojok No. 1&2 Omoutnaia	URRS		
Main Valley of Kisslaia	URRS		
Malaia Koswa R.	URRS		



**Figure 198.** Tonnages of placer PGE-Au deposits.



**Figure 199.** Precious-metal grades of placer PGE-Au deposits. A, Platinum. B, Gold.



**Figure 200.** Other PGE grades of placer PGE-Au deposits. A, Osmium. B, Iridium. C, Palladium.



# DESCRIPTIVE MODEL OF SHORELINE PLACER Ti

By Eric R. Force

DESCRIPTION Ilmenite and other heavy minerals concentrated by beach processes and enriched by weathering.

GENERAL REFERENCE Force (1976).

## GEOLOGICAL ENVIRONMENT

Rock Types Well-sorted medium- to fine-grained sand in dune, beach, and inlet deposits commonly overlying shallow marine deposits.

Age Range Commonly Miocene to Holocene, but may be any age.

Depositional Environment Stable coastal region receiving sediment from deeply weathered metamorphic terranes of sillimanite or higher grade.

Tectonic Setting(s) Margin of craton. Crustal stability during deposition and preservation of deposits.

## DEPOSIT DESCRIPTION

Mineralogy Altered (low Fe) ilmenite  $\pm$  rutile  $\pm$  zircon. Trace of monazite, magnetite, and pyroxene; amphibole rare or absent. Quartz greatly exceeds feldspar.

Texture/Structure Elongate "shoestring" ore bodies parallel to coastal dunes and beaches.

Ore Controls High-grade metamorphic source; stable coastline with efficient sorting and winnowing; weathering of beach deposits.

Weathering Leaching of Fe from ilmenite and destruction of labile heavy minerals results in residual enrichment of deposits.

Geochemical and Geophysical Signature High Ti, Zr, REE, Th and U. Gamma radiometric anomalies resulting from monazite content. Induced-polarization anomalies from ilmenite.

## EXAMPLES

Green Cove Springs, USFL	(Pirkle and others, 1974)
Trail Ridge, USFL	(Pirkle and Yoho, 1970)
Lakehurst, USNJ	(Markiewicz, 1969)
Eneabba, AUWA	(Lissiman and Oxenford, 1973)

# GRADE AND TONNAGE MODEL OF SHORELINE PLACER Ti

By Emil D. Attanasi and John H. DeYoung, Jr.

COMMENTS Grade and tonnage estimates represent mining units rather than individual lenses. Grades are represented as percent  $TiO_2$  from rutile, ilmenite, leucoxene, percent  $ZrO_2$  from zircon, and percent rare-earth oxides from monazite. Zircon is correlated with rutile ( $r = 0.49$ ,  $n = 50$ ), ilmenite ( $r = 0.58$ ,  $n = 52$ ), leucoxene ( $r = 0.55$ ,  $n = 24$ ), and monazite ( $r = 0.55$ ,  $n = 29$ ). Ilmenite is correlated with leucoxene ( $r = 0.66$ ,  $n = 24$ ) and with monazite ( $r = 0.66$ ,  $n = 29$ ). See figs. 201-205.

## DEPOSITS

<u>Name</u>	<u>Country</u>	<u>Name</u>	<u>Country</u>
Agnes Waters	AUQL	Boulougne-Folkston	USFL
Barrytown	NZLD	Bridge Hill Ridge	AUNS
Birchfield	NZLD	Brunswick-Altamaha	USGA
Bothaville-		Camaratuba	BRZL
Wolmaransstad	SAFR	Capel Shoreline	AUWA

Carolina	SAFR	Munbinea Shoreland	AUWA
Charleston-B	USSC	Munmorah	AUNS
Charleston-C	USSC	Muriwai	NZLD
Charleston-I	USSC	N.L. Industries	
Charleston-K	USSC	(Aurora)	USNC
Charleston-L	USSC	N. Stradbroke Island	AUQL
Charleston-N	USSC	Natchez Trace State	
Cumberland Island	USGA	Park	USTN
Curtis Island	AUQL	North Camden (Keer-	
East Rosetta	EGPT	McGee)	USTN
Eneabba Shoreline	AUWA	Oak Grove (Ethyl)	USTN
Evans Head-Wooli area	AUNS	Orissa (Chatrapur)	INDA
Fraser Island	AUQL	Poerua River	NZLD
Gingin Shoreline	AUWA	Pulmoddai	SRIL
Gladstone Mainland	AUQL	Quilon (Chavara)	INDA
Green Cove Springs	USFL	Richards Bay	SAFR
Highland-Trail Ridge	USFL	Ross	NZLD
Hilton Head Island	USSC	Scott River	AUWA
Hokitika North	NZLD	Ship Island	USMS
Hokitika South	NZLD	Silica Mine	USTN
Inskip Point (Cooloola		Stockton Bight	AUNS
area)	AUQL	Tuncurry-Tomago area	AUNS
Jacksonville Area	USFL	Waiho River	NZLD
Karamea	NZLD	Waroona Shoreline	AUWA
Lakehurst (Glidden)	USNJ	Westport	NZLD
Manavalakurichi	INDA	Yoganup Shoreline	AUWA
Manchester (Asarco)	USNJ	Yulee	USFL
Moreton Island	AUQL		

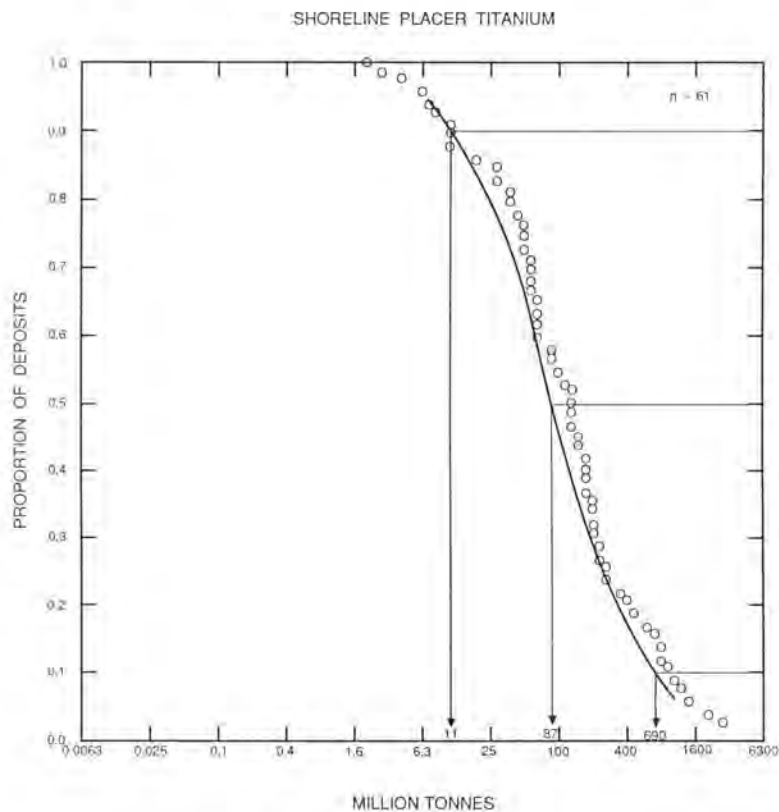
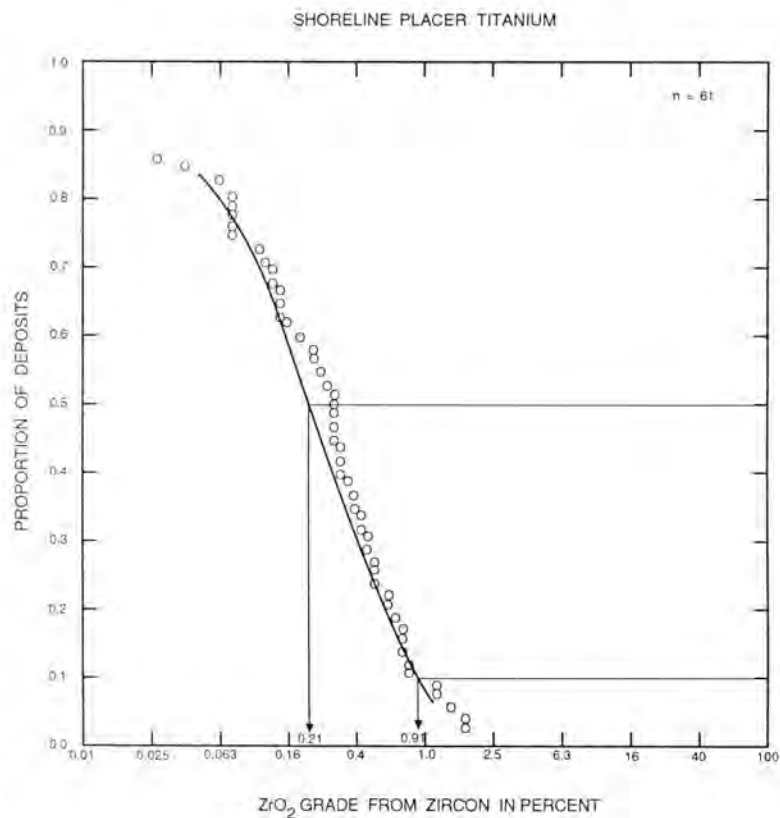
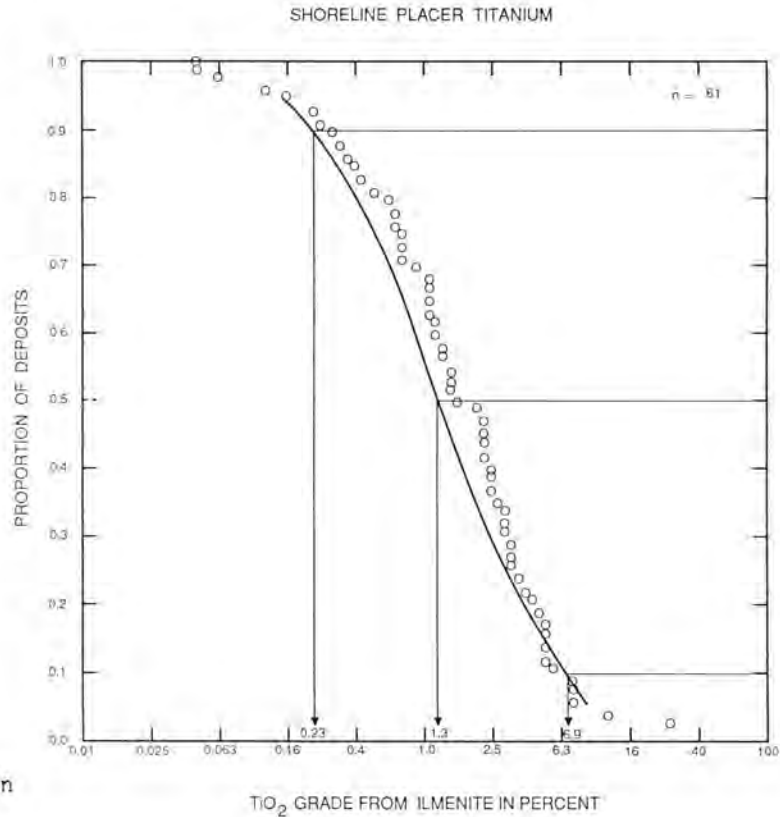


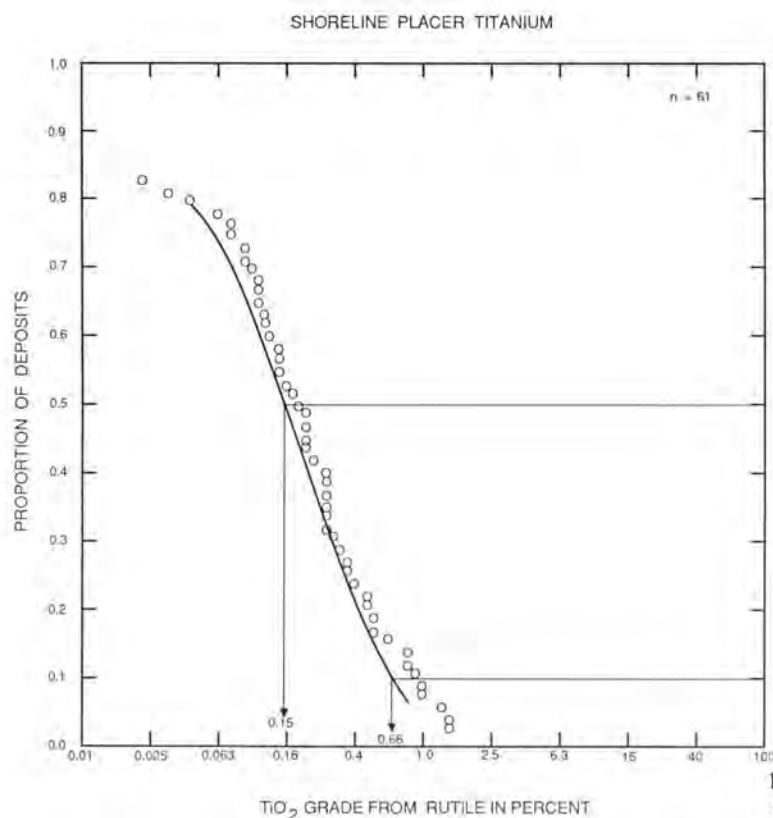
Figure 201. Tonnages of shoreline placer Ti deposits.



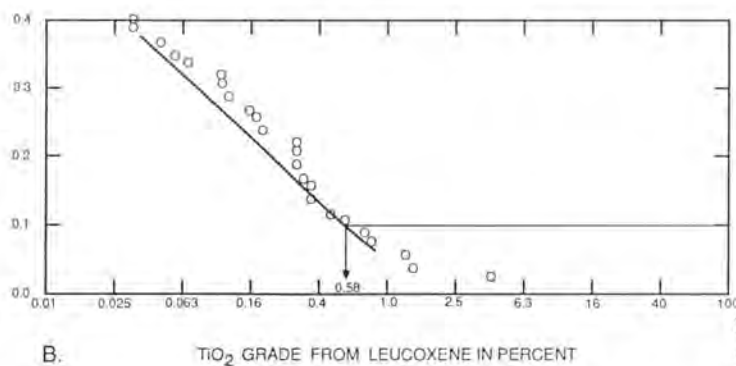
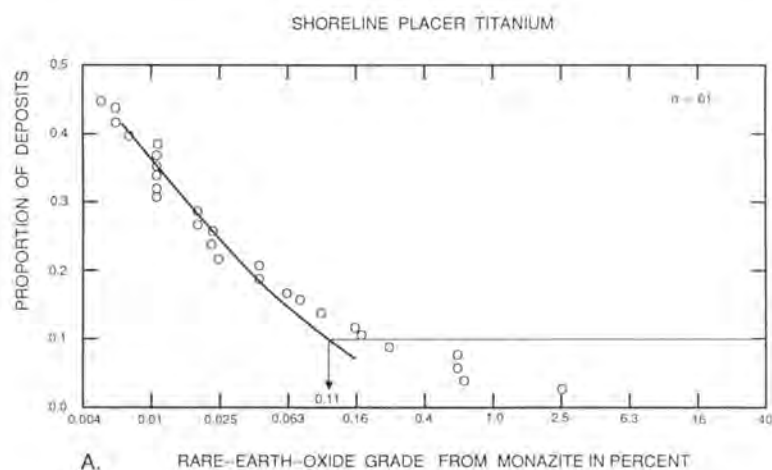
**Figure 202.** ZrO<sub>2</sub> grades from zircon in shoreline placer Ti deposits.



**Figure 203.** TiO<sub>2</sub> grades from ilmenite in shoreline placer Ti deposits.



**Figure 204.** TiO<sub>2</sub> grades from rutile in shoreline placer Ti deposits.



**Figure 205.** Other metal grades of shoreline placer Ti deposits. A, REE oxide from monazite. B, TiO<sub>2</sub> from leucoxene.

## DESCRIPTIVE MODEL OF DIAMOND PLACERS

By Dennis P. Cox

DESCRIPTION Diamonds in alluvial and beach sediments and in sandstone and conglomerate.

GENERAL REFERENCES Orlov (1973), Lampietti and Sutherland (1978).

### GEOLOGICAL ENVIRONMENT

Rock Types Sand and gravel alluvial and beach deposits. Conglomerate beds may contain paleoplacers.

Textures Coarse clastic.

Age Range Tertiary and Quaternary.

Depositional Environment Streams draining areas of kimberlite pipes or diamond concentrations in sedimentary or metamorphic rocks. Alluvial diamond deposits may be 1,000 km from source. It is possible that some diamonds may have been derived from Archean greenstone belts.

Tectonic Setting(s) Stable craton.

Associated Deposit Types Diamond pipes.

### DEPOSIT DESCRIPTION

Mineralogy Diamond, bort or carbonado (polycrystalline, generally dark colored), ballas (spherulitic, polycrystalline and amorphous carbonado).

Texture/Structure Diamonds derived from ancient placers in sedimentary rock commonly retain sand grains cemented to grooves or indentations in the crystal.

Ore Controls Diamonds are concentrated in low-energy parts of stream systems with other heavy minerals. Diamonds decrease in size and increase in quality (fewer polycrystalline types) with distance from their source.

Geochemical Signature Cr, Ti, Mn, Ni, Co, PGE, Ba. Anomalous Ni and Nb together with the heavy minerals pyrope, Mg-ilmenite, and phlogopite indicate nearby kimberlite pipes.

### EXAMPLES

African deposits	(Sutherland, 1982)
Venezuelan deposits	(Fairbairn, 1971; Reid and Bisque, 1975)

## DESCRIPTIVE MODEL OF ALLUVIAL PLACER Sn

By Bruce L. Reed

DESCRIPTION Cassiterite and associated heavy minerals in silt- to cobble-size nuggets concentrated by the hydraulics of running water in modern and fossil streambeds.

GENERAL REFERENCES Hosking (1974), Taylor (1979), Sainsbury and Reed (1973).

GEOLOGICAL ENVIRONMENT

Rock Types Alluvial sand, gravel, and conglomerate indicative of rock types that host lode tin deposits.

Textures Fine to very coarse clastic.

Age Range Commonly late Tertiary to Holocene, but may be any age.

Depositional Environment Generally moderate to high-level alluvial, where stream gradients lie within the critical range for deposition of cassiterite (for instance, where stream velocity is sufficient to result in good gravity separation but not enough so the channel is swept clean). Stream placers may occur as offshore placers where they occupy submerged valleys or strandlines.

Tectonic Setting(s) Alluvial deposits derived from Paleozoic to Cenozoic accreted terranes or stable cratonic foldbelts that contain highly evolved granitoid plutons or their extrusive equivalents (see Model 14b, geochemical signature). Tectonic stability during deposition and preservation of alluvial deposits.

Associated Deposit Types Alluvial gravels may contain by-product ilmenite, zircon, monazite, and, where derived from cassiterite-bearing pegmatites, columbite-tantalite. Economic placers are generally within a few (<8) kilometers of the primary sources. Any type of cassiterite-bearing tin deposit may be a source. The size and grade of the exposed source frequently has little relation to that of the adjacent alluvial deposit.

DEPOSIT DESCRIPTION

Mineralogy Cassiterite; varying amounts of magnetite, ilmenite, zircon, monazite, allanite, xenotime, tourmaline, columbite, garnet, rutile, and topaz may be common heavy resistates.

Texture/Structure Cassiterite becomes progressively coarser as the source is approached; euhedral crystals indicate close proximity to primary source. Where a marine shoreline intersects or transgresses a stream valley containing alluvial cassiterite the shoreline placers normally have a large length-to-width ratio.

Ore Controls Cassiterite tends to concentrate at the base of stream gravels and in traps such as natural riffles, potholes, and bedrock structures transverse to the direction of water flow. The richest placers lie virtually over the primary source. Streams that flow parallel to the margin of a tin-bearing granite are particularly favorable for placer tin accumulation.

Geochemical Signature Anomalously high amounts of Sn, As, B, F, W, Be, W, Cu, Pb, Zn. Panned concentrate samples are the most reliable method for detection of alluvial cassiterite.

EXAMPLES

Southeast Asian tin fields	(Hosking, 1974)
	(Newell, 1971)
	(Simatupang and others, 1974)
	(Westerveld, 1937)



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# Appendix A. Locality Abbreviations

AGTN	Argentina	IRLD	Ireland
ALGR	Algeria	ISRL	Israel
ANGL	Angola	ITLY	Italy
ASTR	Austria	IVCO	Ivory Coast
AUNS	Australia, New South Wales	JAPN	Japan
AUNT	Australia, N. Territory	JMCA	Jamaica
AUQL	Australia, Queensland	JRDN	Jordan
AUSA	Australia, South Australia	KNYA	Kenya
AUTS	Australia, Tasmania	MALI	Mali
AUVT	Australia, Victoria	MAUR	Mauritania
AUWA	Australia, Western Australia	MDGS	Madagascar (Malagasy Rep.)
BLVA	Bolivia	MLWI	Malawi
BOTS	Botswana	MLYS	Malaysia
BRMA	Burma	MNGL	Mongolia
BRZL	Brazil	MRCO	Morocco
BULG	Bulgaria	MXCO	Mexico
CARL	Caroline Islands	MZMB	Mozambique
CHAD	Chad	NAMB	Namibia
CILE	Chile	NCAL	New Caledonia
CINA	China	NCRG	Nicaragua
CLBA	Colombia	NKOR	North Korea
CMRN	Cameroon	NRWY	Norway
CNAL	Canada, Alberta	NZLD	New Zealand
CNBC	Canada, British Columbia	OMAN	Oman
CNGO	Congo	PANA	Panama
CNMN	Canada, Manitoba	PERU	Peru
CNNB	Canada, New Brunswick	PKTN	Pakistan
CNNF	Canada, Newfoundland	PLND	Poland
CNNS	Canada, Nova Scotia	PLPN	Philippines
CNNT	Canada, Northwest Territories	PORT	Portugal
CNON	Canada, Ontario	PPNG	Papua New Guinea
CNQU	Canada, Quebec	PTRC	Puerto Rico
CNSK	Canada, Saskatchewan	RMNA	Romania
CNYT	Canada, Yukon Territory	SAAR	Saudi Arabia
CORI	Costa Rica	SAFR	South Africa
CUBA	Cuba	SKOR	South Korea
CYPS	Cyprus	SLMN	Solomon Islands
CZCL	Czechoslovakia	SNGL	Senegal
DMRP	Dominican Republic	SPAN	Spain
ECDR	Ecuador	SRIL	Sri Lanka
EGPT	Egypt	SRLN	Sierra Leon
ELSA	El Salvador	SRNM	Surinam
ETHP	Ethiopia	SUDN	Sudan
FIJI	Fiji	SWAF	SW Africa
FNLD	Finland	SWAZ	Swaziland
FRNC	France	SWDN	Sweden
GHNA	Ghana	SYRA	Syria
GNBS	Guinea-Bissau	THLD	Thailand
GNEA	Guinea	TIWN	Taiwan
GRBR	Great Britain	TNZN	Tanzania
GREC	Greece	TOGO	Togo
GRLD	Greenland	TRKY	Turkey
GRME	East Germany	TUNS	Tunisia
GRMY	West Germany	UGND	Uganda
GUAT	Guatemala	UVOL	Upper Volta (Burkina Fasso)
GUYN	Guyana	URAM	USSR, Armenia
HATI	Haiti	URKZ	USSR, Kazakhstan
HNDR	Honduras	URRS	USSR, Russian Rep.
HONG	Hong Kong	URTD	USSR, Tadzhikistan
HUNG	Hungary	URUZ	USSR, Uzbekistan
INDA	India	USAK	US, Alaska
INDS	Indonesia	USAR	US, Arkansas
IRAN	Iran	USAZ	US, Arizona
IRAQ	Iraq	USCA	US, California

Appendix A. Locality Abbreviations--Continued

USCO	US, Colorado	USOK	US, Oklahoma
USFL	US, Florida	USOR	US, Oregon
USGA	US, Georgia	USPA	US, Pennsylvania
USHI	US, Hawaii	USTN	US, Tennessee
USID	US, Idaho	USTX	US, Texas
USKY	US, Kentucky	USUT	US, Utah
USMA	US, Massachusetts	USVA	US, Virginia
USME	US, Maine	USVT	US, Vermont
USMI	US, Michigan	USWA	US, Washington
USMN	US, Minnesota	USWI	US, Wisconsin
USMO	US, Missouri	USWY	US, Wyoming
USMT	US, Montana	VNZL	Venezuela
USNC	US, North Carolina	VTNM	Vietnam
USND	US, North Dakota	YUGO	Yugoslavia
USNJ	US, New Jersey	ZIMB	Zimbabwe
USNM	US, New Mexico	ZIRE	Zaire
USNV	US, Nevada	ZMBA	Zambia
USNY	US, New York		

Appendix B. Summary statistics of grade-tonnage models by Donald A. Singer  
 [Logarithms (base 10) except  $\text{Al}_2\text{O}_3$ , Fe,  $\text{Cr}_2\text{O}_3$ , fiber, Mn, and  $\text{P}_2\text{O}_5$ , which are percent.  
 S. D., standard deviation]

Deposit type	Komatiitic Ni-Cu			Dunitic Ni-Cu			Synorogenic-synvolcanic Ni-Cu		
	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits
Tonnage (metric) .....	6.235	0.7266	31	7.451	0.7664	22	6.300	0.6996	32
$\text{RE}_2\text{O}_3$ (pct) .....	--	--	--	--	--	--	--	--	--
Monazite (pct REO) .....	--	--	--	--	--	--	--	--	--
$\text{U}_3\text{O}_8$ (pct) .....	--	--	--	--	--	--	--	--	--
Zircon (pct $\text{ZrO}_2$ ) .....	--	--	--	--	--	--	--	--	--
$\text{Nb}_2\text{O}_5$ (pct) .....	--	--	--	--	--	--	--	--	--
Fiber (pct) .....	--	--	--	--	--	--	--	--	--
Barite (pct) .....	--	--	--	--	--	--	--	--	--
$\text{Al}_2\text{O}_3$ (pct) .....	--	--	--	--	--	--	--	--	--
P (pct) .....	--	--	--	--	--	--	--	--	--
$\text{P}_2\text{O}_5$ (pct) .....	--	--	--	--	--	--	--	--	--
Ilmenite (pct $\text{TiO}_2$ ) .....	--	--	--	--	--	--	--	--	--
Rutile (pct $\text{TiO}_2$ ) .....	--	--	--	--	--	--	--	--	--
Leucocite (pct $\text{TiO}_2$ ) .....	--	--	--	--	--	--	--	--	--
$\text{Cr}_2\text{O}_3$ (pct) .....	--	--	--	--	--	--	--	--	--
Mn (pct) .....	--	--	--	--	--	--	--	--	--
Fe (pct) .....	--	--	--	--	--	--	--	--	--
Co (pct) .....	-1.250	.3608	8	-1.592	.4286	3	-1.333	.3506	3
Ni (pct) .....	.1790	.2600	31	-.0048	.2337	22	-.1175	.2580	32
Cu (pct) .....	-.8450	.2548	21	-1.415	.4886	12	-.3170	.3101	29
Mo (pct) .....	--	--	--	--	--	--	--	--	--
$\text{WO}_3$ (pct) .....	--	--	--	--	--	--	--	--	--
Pd (ppb) .....	-.4703	.2898	11	-.8564	.4467	5	-1.005	.2799	3
Pt (ppb) .....	-.6967	.2213	5	--	--	--	-1.508	.1849	2
Rh (ppb) .....	--	--	--	--	--	--	--	--	--
Ir (ppb) .....	-1.145	.4086	9	-1.822	.7000	5	--	--	--
Ru (ppb) .....	--	--	--	--	--	--	--	--	--
Os (ppb) .....	--	--	--	--	--	--	--	--	--
Ag (g/t) .....	--	--	--	--	--	--	--	--	--
Au (g/t) .....	-1.443	.5335	10	-1.722	.1830	5	-.9408	.4151	3
Zn (pct) .....	--	--	--	--	--	--	--	--	--
Hg (pct) .....	--	--	--	--	--	--	--	--	--
Sn (pct) .....	--	--	--	--	--	--	--	--	--
Pb (pct) .....	--	--	--	--	--	--	--	--	--
Sb (pct) .....	--	--	--	--	--	--	--	--	--

Deposit type	Minor podiform Cr			Major podiform Cr			Serpentine-hosted asbestos		
	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits
Tonnage (metric) .....	2.112	0.9292	435	4.321	0.7598	174	7.419	0.5874	50
$\text{RE}_2\text{O}_3$ (pct) .....	--	--	--	--	--	--	--	--	--
Monazite (pct REO) .....	--	--	--	--	--	--	--	--	--
$\text{U}_3\text{O}_8$ (pct) .....	--	--	--	--	--	--	--	--	--
Zircon (pct $\text{ZrO}_2$ ) .....	--	--	--	--	--	--	--	--	--
$\text{Nb}_2\text{O}_5$ (pct) .....	--	--	--	--	--	--	--	--	--
Fiber (pct) .....	--	--	--	--	--	--	.6618	.1859	50
Barite (pct) .....	--	--	--	--	--	--	--	--	--
$\text{Al}_2\text{O}_3$ (pct) .....	--	--	--	--	--	--	--	--	--
P (pct) .....	--	--	--	--	--	--	--	--	--
$\text{P}_2\text{O}_5$ (pct) .....	--	--	--	--	--	--	--	--	--
Ilmenite (pct $\text{TiO}_2$ ) .....	--	--	--	--	--	--	--	--	--
Rutile (pct $\text{TiO}_2$ ) .....	--	--	--	--	--	--	--	--	--
Leucocite (pct $\text{TiO}_2$ ) .....	--	--	--	--	--	--	--	--	--
$\text{Cr}_2\text{O}_3$ (pct) .....	42.13	7.775	435	44.03	7.291	174	--	--	--
Mn (pct) .....	--	--	--	--	--	--	--	--	--
Fe (pct) .....	--	--	--	--	--	--	--	--	--
Co (pct) .....	--	--	--	--	--	--	--	--	--
Ni (pct) .....	--	--	--	--	--	--	--	--	--
Cu (pct) .....	--	--	--	--	--	--	--	--	--
Mo (pct) .....	--	--	--	--	--	--	--	--	--
$\text{WO}_3$ (pct) .....	--	--	--	--	--	--	--	--	--
Pd (ppb) .....	.6723	.4671	31	.5411	.3694	16	--	--	--
Pt (ppb) .....	1.489	.4564	33	1.156	.1948	12	--	--	--
Rh (ppb) .....	.9088	.3940	69	1.116	.1683	14	--	--	--
Ir (ppb) .....	1.815	.3126	38	1.894	.3003	9	--	--	--
Ru (ppb) .....	2.278	.2217	29	2.344	.0763	7	--	--	--
Os (ppb) .....	--	--	--	--	--	--	--	--	--
Ag (g/t) .....	--	--	--	--	--	--	--	--	--
Au (g/t) .....	--	--	--	--	--	--	--	--	--
Zn (pct) .....	--	--	--	--	--	--	--	--	--
Hg (pct) .....	--	--	--	--	--	--	--	--	--
Sn (pct) .....	--	--	--	--	--	--	--	--	--
Pb (pct) .....	--	--	--	--	--	--	--	--	--
Sb (pct) .....	--	--	--	--	--	--	--	--	--



Appendix B. Summary statistics of grade-tonnage models--Continued

Deposit type	Carbonatite			W skarn			Sn skarn		
	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits
Tonnage (metric) .....	7.777	0.4414	20	6.016	1.025	28	6.774	0.6178	4
RE <sub>2</sub> O <sub>3</sub> (pct) .....	-1.013	1.207	5	--	--	--	--	--	--
Monazite (pct REO) .....	--	--	--	--	--	--	--	--	--
U <sub>3</sub> O <sub>8</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Zircon (pct ZrO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Nb <sub>2</sub> O <sub>5</sub> (pct) .....	-1.951	.3562	20	--	--	--	--	--	--
Fiber (pct) .....	--	--	--	--	--	--	--	--	--
Barite (pct) .....	--	--	--	--	--	--	--	--	--
Al <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
P (pct) .....	--	--	--	--	--	--	--	--	--
P <sub>2</sub> O <sub>5</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Ilmenite (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Rutile (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Leucocite (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Cr <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Mn (pct) .....	--	--	--	--	--	--	--	--	--
Fe (pct) .....	--	--	--	--	--	--	--	--	--
Co (pct) .....	--	--	--	--	--	--	--	--	--
Ni (pct) .....	--	--	--	--	--	--	--	--	--
Cu (pct) .....	--	--	--	--	--	--	--	--	--
Mo (pct) .....	--	--	--	--	--	--	--	--	--
WO <sub>3</sub> (pct) .....	--	--	--	-1.1828	.2430	28	--	--	--
Pd (ppb) .....	--	--	--	--	--	--	--	--	--
Pt (ppb) .....	--	--	--	--	--	--	--	--	--
Rh (ppb) .....	--	--	--	--	--	--	--	--	--
Ir (ppb) .....	--	--	--	--	--	--	--	--	--
Ru (ppb) .....	--	--	--	--	--	--	--	--	--
Os (ppb) .....	--	--	--	--	--	--	--	--	--
Ag (g/t) .....	--	--	--	--	--	--	--	--	--
Au (g/t) .....	--	--	--	--	--	--	--	--	--
Zn (pct) .....	--	--	--	--	--	--	--	--	--
Hg (pct) .....	--	--	--	--	--	--	--	--	--
Sn (pct) .....	--	--	--	--	--	--	-1.5031	.3014	4
Pb (pct) .....	--	--	--	--	--	--	--	--	--
Sb (pct) .....	--	--	--	--	--	--	--	--	--

Deposit type	Replacement Sn			W vein			Sn vein		
	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits
Tonnage (metric) .....	6.720	0.5493	6	5.748	0.8574	16	5.374	1.000	43
RE <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Monazite (pct REO) .....	--	--	--	--	--	--	--	--	--
U <sub>3</sub> O <sub>8</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Zircon (pct ZrO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Nb <sub>2</sub> O <sub>5</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Fiber (pct) .....	--	--	--	--	--	--	--	--	--
Barite (pct) .....	--	--	--	--	--	--	--	--	--
Al <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
P (pct) .....	--	--	--	--	--	--	--	--	--
P <sub>2</sub> O <sub>5</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Ilmenite (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Rutile (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Leucocite (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Cr <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Mn (pct) .....	--	--	--	--	--	--	--	--	--
Fe (pct) .....	--	--	--	--	--	--	--	--	--
Co (pct) .....	--	--	--	--	--	--	--	--	--
Ni (pct) .....	--	--	--	--	--	--	--	--	--
Cu (pct) .....	--	--	--	--	--	--	--	--	--
Mo (pct) .....	--	--	--	--	--	--	--	--	--
WO <sub>3</sub> (pct) .....	--	--	--	-0.0400	.1408	16	--	--	--
Pd (ppb) .....	--	--	--	--	--	--	--	--	--
Pt (ppb) .....	--	--	--	--	--	--	--	--	--
Rh (ppb) .....	--	--	--	--	--	--	--	--	--
Ir (ppb) .....	--	--	--	--	--	--	--	--	--
Ru (ppb) .....	--	--	--	--	--	--	--	--	--
Os (ppb) .....	--	--	--	--	--	--	--	--	--
Ag (g/t) .....	--	--	--	--	--	--	--	--	--
Au (g/t) .....	--	--	--	--	--	--	--	--	--
Zn (pct) .....	--	--	--	--	--	--	--	--	--
Hg (pct) .....	--	--	--	--	--	--	--	--	--
Sn (pct) .....	-0.0965	.1265	6	--	--	--	.1038	.2028	43
Pb (pct) .....	--	--	--	--	--	--	--	--	--
Sb (pct) .....	--	--	--	--	--	--	--	--	--

Appendix B. Summary statistics of grade-tonnage models--Continued

Deposit type	Sn greisen			Climax Mo			Porphyry copper		
	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits
Tonnage (metric) .....	6.8572	0.7449	10	8.305	0.5020	9	8.159	0.6864	208
RE <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Monazite (pct REO) ....	--	--	--	--	--	--	--	--	--
U <sub>3</sub> O <sub>8</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Zircon (pct ZrO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Nb <sub>2</sub> O <sub>5</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Fiber (pct) .....	--	--	--	--	--	--	--	--	--
Barite (pct) .....	--	--	--	--	--	--	--	--	--
Al <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
P (pct) .....	--	--	--	--	--	--	--	--	--
P <sub>2</sub> O <sub>5</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Ilmenite (pct TiO <sub>2</sub> ) ..	--	--	--	--	--	--	--	--	--
Rutile (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Leucocite (pct TiO <sub>2</sub> ) ..	--	--	--	--	--	--	--	--	--
Cr <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Mn (pct) .....	--	--	--	--	--	--	--	--	--
Fe (pct) .....	--	--	--	--	--	--	--	--	--
Co (pct) .....	--	--	--	--	--	--	--	--	--
Ni (pct) .....	--	--	--	--	--	--	--	--	--
Cu (pct) .....	--	--	--	--	--	--	-.2690	.1900	208
Mo (pct) .....	--	--	--	-.7171	.1363	9	-1.907	.4343	103
WO <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Pd (ppb) .....	--	--	--	--	--	--	--	--	--
Pt (ppb) .....	--	--	--	--	--	--	--	--	--
Rh (ppb) .....	--	--	--	--	--	--	--	--	--
Ir (ppb) .....	--	--	--	--	--	--	--	--	--
Ru (ppb) .....	--	--	--	--	--	--	--	--	--
Os (ppb) .....	--	--	--	--	--	--	--	--	--
Ag (g/t) .....	--	--	--	--	--	--	.2180	.3646	76
Au (g/t) .....	--	--	--	--	--	--	-.9077	.7012	81
Zn (pct) .....	--	--	--	--	--	--	--	--	--
Hg (pct) .....	--	--	--	--	--	--	--	--	--
Sn (pct) .....	-.5491	.1707	10	--	--	--	--	--	--
Pb (pct) .....	--	--	--	--	--	--	--	--	--
Sb (pct) .....	--	--	--	--	--	--	--	--	--

Deposit type	Porphyry Cu, skarn-related			Cu skarn			Zn-Pb skarn		
	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits
Tonnage (metric) .....	7.901	0.4726	18	5.747	0.9505	64	6.151	0.7302	34
RE <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Monazite (pct REO) ....	--	--	--	--	--	--	--	--	--
U <sub>3</sub> O <sub>8</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Zircon (pct ZrO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Nb <sub>2</sub> O <sub>5</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Fiber (pct) .....	--	--	--	--	--	--	--	--	--
Barite (pct) .....	--	--	--	--	--	--	--	--	--
Al <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
P (pct) .....	--	--	--	--	--	--	--	--	--
P <sub>2</sub> O <sub>5</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Ilmenite (pct TiO <sub>2</sub> ) ..	--	--	--	--	--	--	--	--	--
Rutile (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Leucocite (pct TiO <sub>2</sub> ) ..	--	--	--	--	--	--	--	--	--
Cr <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Mn (pct) .....	--	--	--	--	--	--	--	--	--
Fe (pct) .....	--	--	--	--	--	--	--	--	--
Co (pct) .....	--	--	--	--	--	--	--	--	--
Ni (pct) .....	--	--	--	--	--	--	--	--	--
Cu (pct) .....	-.0081	.2211	18	.2266	.2880	64	-.3377	.4585	17
Mo (pct) .....	-1.657	.2591	4	--	--	--	--	--	--
WO <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Pd (ppb) .....	--	--	--	--	--	--	--	--	--
Pt (ppb) .....	--	--	--	--	--	--	--	--	--
Rh (ppb) .....	--	--	--	--	--	--	--	--	--
Ir (ppb) .....	--	--	--	--	--	--	--	--	--
Ru (ppb) .....	--	--	--	--	--	--	--	--	--
Os (ppb) .....	--	--	--	--	--	--	--	--	--
Ag (g/t) .....	.6798	.4185	9	1.331	.6955	15	2.059	.3908	22
Au (g/t) .....	-.4829	.5020	6	.2496	.6107	16	-.3489	.5134	7
Zn (pct) .....	--	--	--	--	--	--	.7719	.2709	34
Hg (pct) .....	--	--	--	--	--	--	--	--	--
Sn (pct) .....	--	--	--	--	--	--	--	--	--
Pb (pct) .....	--	--	--	--	--	--	.5076	.3053	30
Sb (pct) .....	--	--	--	--	--	--	--	--	--

Appendix B. Summary statistics of grade-tonnage models--Continued

Deposit type	Fe skarn			Polymetallic replacement			Replacement Mn		
	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits
Tonnage (metric) .....	6.858	1.041	168	6.261	0.6884	52	4.348	1.073	37
RE <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Monazite (pct REO) .....	--	--	--	--	--	--	--	--	--
U <sub>3</sub> O <sub>8</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Zircon (pct ZrO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Nb <sub>2</sub> O <sub>5</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Fiber (pct) .....	--	--	--	--	--	--	--	--	--
Barite (pct) .....	--	--	--	--	--	--	--	--	--
Al <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
P (pct) .....	--	--	--	--	--	--	-1.481	.4493	3
P <sub>2</sub> O <sub>5</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Ilmenite (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Rutile (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Leucocite (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Cr <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Mn (pct) .....	--	--	--	--	--	--	32.54	11.28	37
Fe (pct) .....	49.61	10.28	168	--	--	--	--	--	--
Co (pct) .....	--	--	--	--	--	--	--	--	--
Ni (pct) .....	--	--	--	--	--	--	--	--	--
Cu (pct) .....	--	--	--	-.6327	.5121	35	-.0546	.2839	4
Mo (pct) .....	--	--	--	--	--	--	--	--	--
WO <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Pd (ppb) .....	--	--	--	--	--	--	--	--	--
Pt (ppb) .....	--	--	--	--	--	--	--	--	--
Rh (ppb) .....	--	--	--	--	--	--	--	--	--
Ir (ppb) .....	--	--	--	--	--	--	--	--	--
Ru (ppb) .....	--	--	--	--	--	--	--	--	--
Os (ppb) .....	--	--	--	--	--	--	--	--	--
Ag (g/t) .....	--	--	--	2.286	.4599	45	--	--	--
Au (g/t) .....	--	--	--	-.1462	.7319	35	--	--	--
Zn (pct) .....	--	--	--	.5937	.5361	51	--	--	--
Hg (pct) .....	--	--	--	--	--	--	--	--	--
Sn (pct) .....	--	--	--	--	--	--	--	--	--
Pb (pct) .....	--	--	--	.7041	.4749	52	--	--	--
Sb (pct) .....	--	--	--	--	--	--	--	--	--

Deposit type	Porphyry Cu-Au			Porphyry Cu-Mo			Porphyry Mo, low-F		
	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits
Tonnage (metric) .....	8.005	0.4746	40	8.706	0.4831	16	7.974	0.6053	33
RE <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Monazite (pct REO) .....	--	--	--	--	--	--	--	--	--
U <sub>3</sub> O <sub>8</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Zircon (pct ZrO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Nb <sub>2</sub> O <sub>5</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Fiber (pct) .....	--	--	--	--	--	--	--	--	--
Barite (pct) .....	--	--	--	--	--	--	--	--	--
Al <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
P (pct) .....	--	--	--	--	--	--	--	--	--
P <sub>2</sub> O <sub>5</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Ilmenite (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Rutile (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Leucocite (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Cr <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Mn (pct) .....	--	--	--	--	--	--	--	--	--
Fe (pct) .....	--	--	--	--	--	--	--	--	--
Co (pct) .....	--	--	--	--	--	--	--	--	--
Ni (pct) .....	--	--	--	--	--	--	--	--	--
Cu (pct) .....	-.2968	.1205	40	-.3777	.1679	16	--	--	--
Mo (pct) .....	-2.516	.3681	20	-1.802	.2683	16	-1.070	.1459	33
WO <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Pd (ppb) .....	--	--	--	--	--	--	--	--	--
Pt (ppb) .....	--	--	--	--	--	--	--	--	--
Rh (ppb) .....	--	--	--	--	--	--	--	--	--
Ir (ppb) .....	--	--	--	--	--	--	--	--	--
Ru (ppb) .....	--	--	--	--	--	--	--	--	--
Os (ppb) .....	--	--	--	--	--	--	--	--	--
Ag (g/t) .....	.2012	.3720	27	.0852	.4162	16	--	--	--
Au (g/t) .....	-.4178	.2138	40	-1.908	.4189	16	--	--	--
Zn (pct) .....	--	--	--	--	--	--	--	--	--
Hg (pct) .....	--	--	--	--	--	--	--	--	--
Sn (pct) .....	--	--	--	--	--	--	--	--	--
Pb (pct) .....	--	--	--	--	--	--	--	--	--
Sb (pct) .....	--	--	--	--	--	--	--	--	--

Appendix B. Summary statistics of grade-tonnage models--Continued

Deposit type	Polymetallic vein			Cyprus massive sulfide			Besshi massive sulfide		
	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits
Tonnage (metric) .....	3.880	1.109	75	6.105	0.8765	49	5.339	0.9701	44
RE <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Monazite (pct REO) .....	--	--	--	--	--	--	--	--	--
U <sub>3</sub> O <sub>8</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Zircon (pct ZrO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Nb <sub>2</sub> O <sub>5</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Fiber (pct) .....	--	--	--	--	--	--	--	--	--
Barite (pct) .....	--	--	--	--	--	--	--	--	--
Al <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
P (pct) .....	--	--	--	--	--	--	--	--	--
P <sub>2</sub> O <sub>5</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Ilmenite (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Rutile (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Leucocite (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Cr <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Mn (pct) .....	--	--	--	--	--	--	--	--	--
Fe (pct) .....	--	--	--	--	--	--	--	--	--
Co (pct) .....	--	--	--	--	--	--	--	--	--
Ni (pct) .....	--	--	--	--	--	--	--	--	--
Cu (pct) .....	-.7169	.8378	33	.2040	.3068	49	.1633	.2798	44
Mo (pct) .....	--	--	--	--	--	--	--	--	--
WO <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Pd (ppb) .....	--	--	--	--	--	--	--	--	--
Pt (ppb) .....	--	--	--	--	--	--	--	--	--
Rh (ppb) .....	--	--	--	--	--	--	--	--	--
Ir (ppb) .....	--	--	--	--	--	--	--	--	--
Ru (ppb) .....	--	--	--	--	--	--	--	--	--
Os (ppb) .....	--	--	--	--	--	--	--	--	--
Ag (g/t) .....	2.938	.5935	74	1.109	.6457	15	.8956	.3838	14
Au (g/t) .....	-.2088	1.166	54	-.0417	.6893	15	-.4650	.4697	14
Zn (pct) .....	.4439	.3718	60	-.1021	.7085	16	-.2506	.2755	6
Hg (pct) .....	--	--	--	--	--	--	--	--	--
Sn (pct) .....	--	--	--	--	--	--	--	--	--
Pb (pct) .....	.9529	.4426	75	-1.333	.5774	3	--	--	--
Sb (pct) .....	--	--	--	--	--	--	--	--	--

Deposit type	Volcanogenic Mn			Creede epithermal vein			Comstock epithermal vein		
	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits
Tonnage (metric) .....	4.674	0.9607	93	6.151	0.9382	27	5.884	0.8379	41
RE <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Monazite (pct REO) .....	--	--	--	--	--	--	--	--	--
U <sub>3</sub> O <sub>8</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Zircon (pct ZrO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Nb <sub>2</sub> O <sub>5</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Fiber (pct) .....	--	--	--	--	--	--	--	--	--
Barite (pct) .....	--	--	--	--	--	--	--	--	--
Al <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
P (pct) .....	-1.055	.5115	8	--	--	--	--	--	--
P <sub>2</sub> O <sub>5</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Ilmenite (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Rutile (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Leucocite (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Cr <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Mn (pct) .....	38.80	9.723	93	--	--	--	--	--	--
Fe (pct) .....	--	--	--	--	--	--	--	--	--
Co (pct) .....	--	--	--	--	--	--	--	--	--
Ni (pct) .....	--	--	--	--	--	--	--	--	--
Cu (pct) .....	--	--	--	.5254	.4843	19	-1.816	.7955	18
Mo (pct) .....	--	--	--	--	--	--	--	--	--
WO <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Pd (ppb) .....	--	--	--	--	--	--	--	--	--
Pt (ppb) .....	--	--	--	--	--	--	--	--	--
Rh (ppb) .....	--	--	--	--	--	--	--	--	--
Ir (ppb) .....	--	--	--	--	--	--	--	--	--
Ru (ppb) .....	--	--	--	--	--	--	--	--	--
Os (ppb) .....	--	--	--	--	--	--	--	--	--
Ag (g/t) .....	--	--	--	2.099	.4766	27	2.060	.8156	41
Au (g/t) .....	--	--	--	.3265	.5874	23	.8726	.4410	41
Zn (pct) .....	--	--	--	.2744	.5545	26	-1.594	1.702	3
Hg (pct) .....	--	--	--	--	--	--	--	--	--
Sn (pct) .....	--	--	--	--	--	--	--	--	--
Pb (pct) .....	--	--	--	.4057	.2740	24	-1.870	.9817	19
Sb (pct) .....	--	--	--	--	--	--	--	--	--

Appendix B. Summary statistics of grade-tonnage models--Continued

Deposit type	Sado epithermal vein			Epithermal quartz-alunite Au			Volcanogenic U		
	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits
Tonnage (metric) .....	5.472	0.7876	20	5.109	0.6663	8	5.535	0.9451	21
RE <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Monazite (pct REO) .....	--	--	--	--	--	--	--	--	--
U <sub>3</sub> O <sub>8</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Zircon (pct ZrO <sub>2</sub> ) .....	--	--	--	--	--	--	-0.9353	.2656	21
Nb <sub>2</sub> O <sub>5</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Fibser (pct) .....	--	--	--	--	--	--	--	--	--
Barite (pct) .....	--	--	--	--	--	--	--	--	--
Al <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
P (pct) .....	--	--	--	--	--	--	--	--	--
P <sub>2</sub> O <sub>5</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Ilmenite (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Rutile (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Leucocite (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Cr <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Mn (pct) .....	--	--	--	--	--	--	--	--	--
Fe (pct) .....	--	--	--	--	--	--	--	--	--
Co (pct) .....	--	--	--	--	--	--	--	--	--
Ni (pct) .....	--	--	--	--	--	--	--	--	--
Cu (pct) .....	-0.7200	1.153	9	-0.6255	1.045	5	--	--	--
Mo (pct) .....	--	--	--	--	--	--	--	--	--
WO <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Pd (ppb) .....	--	--	--	--	--	--	--	--	--
Pt (ppb) .....	--	--	--	--	--	--	--	--	--
Rh (ppb) .....	--	--	--	--	--	--	--	--	--
Ir (ppb) .....	--	--	--	--	--	--	--	--	--
Ru (ppb) .....	--	--	--	--	--	--	--	--	--
Os (ppb) .....	--	--	--	--	--	--	--	--	--
Ag (g/t) .....	1.579	.6647	20	1.251	.6788	8	--	--	--
Au (g/t) .....	.8363	.4007	18	.8927	.2341	8	--	--	--
Zn (pct) .....	-.602	--	1	--	--	--	--	--	--
Hg (pct) .....	--	--	--	--	--	--	--	--	--
Sn (pct) .....	--	--	--	--	--	--	--	--	--
Pb (pct) .....	-2.372	.2129	2	--	--	--	--	--	--
Sb (pct) .....	--	--	--	--	--	--	--	--	--

Deposit type	Epithermal Mn			Rhyolite-hosted Sn			Volcanic-hosted magnetite		
	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits
Tonnage (metric) .....	4.372	0.8246	59	2.992	0.4937	132	7.602	0.8222	39
RE <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Monazite (pct REO) .....	--	--	--	--	--	--	--	--	--
U <sub>3</sub> O <sub>8</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Zircon (pct ZrO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Nb <sub>2</sub> O <sub>5</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Fibser (pct) .....	--	--	--	--	--	--	--	--	--
Barite (pct) .....	--	--	--	--	--	--	--	--	--
Al <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
P (pct) .....	--	--	--	--	--	--	-0.3979	.2874	36
P <sub>2</sub> O <sub>5</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Ilmenite (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Rutile (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Leucocite (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Cr <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Mn (pct) .....	30.59	8.538	59	--	--	--	--	--	--
Fe (pct) .....	--	--	--	--	--	--	53.72	11.08	39
Co (pct) .....	--	--	--	--	--	--	--	--	--
Ni (pct) .....	--	--	--	--	--	--	--	--	--
Cu (pct) .....	--	--	--	--	--	--	--	--	--
Mo (pct) .....	--	--	--	--	--	--	--	--	--
WO <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Pd (ppb) .....	--	--	--	--	--	--	--	--	--
Pt (ppb) .....	--	--	--	--	--	--	--	--	--
Rh (ppb) .....	--	--	--	--	--	--	--	--	--
Ir (ppb) .....	--	--	--	--	--	--	--	--	--
Ru (ppb) .....	--	--	--	--	--	--	--	--	--
Os (ppb) .....	--	--	--	--	--	--	--	--	--
Ag (g/t) .....	--	--	--	--	--	--	--	--	--
Au (g/t) .....	--	--	--	--	--	--	--	--	--
Zn (pct) .....	--	--	--	--	--	--	--	--	--
Hg (pct) .....	--	--	--	--	--	--	--	--	--
Sn (pct) .....	--	--	--	-0.4130	.3352	132	--	--	--
Pb (pct) .....	--	--	--	--	--	--	--	--	--
Sb (pct) .....	--	--	--	--	--	--	--	--	--

Appendix B. Summary statistics of grade-tonnage models--Continued

Deposit type	Carbonate-hosted Au-Ag			Hot-spring Hg			Silica-carbonate Hg		
	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits
Tonnage (metric) .....	6.706	0.5202	35	3.978	1.312	20	4.448	1.038	28
RE <sub>2</sub> O <sub>3</sub> (pet) .....	--	--	--	--	--	--	--	--	--
Monazite (pet REO) .....	--	--	--	--	--	--	--	--	--
U <sub>3</sub> O <sub>8</sub> (pet) .....	--	--	--	--	--	--	--	--	--
Zircon (pet ZrO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Nb <sub>2</sub> O <sub>5</sub> (pet) .....	--	--	--	--	--	--	--	--	--
Fiber (pet) .....	--	--	--	--	--	--	--	--	--
Barite (pet) .....	--	--	--	--	--	--	--	--	--
Al <sub>2</sub> O <sub>3</sub> (pet) .....	--	--	--	--	--	--	--	--	--
P (pet) .....	--	--	--	--	--	--	--	--	--
P <sub>2</sub> O <sub>5</sub> (pet) .....	--	--	--	--	--	--	--	--	--
Ilmenite (pet TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Rutile (pet TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Leucocite (pet TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Cr <sub>2</sub> O <sub>3</sub> (pet) .....	--	--	--	--	--	--	--	--	--
Mn (pet) .....	--	--	--	--	--	--	--	--	--
Fe (pet) .....	--	--	--	--	--	--	--	--	--
Co (pet) .....	--	--	--	--	--	--	--	--	--
Ni (pet) .....	--	--	--	--	--	--	--	--	--
Cu (pet) .....	--	--	--	--	--	--	--	--	--
Mo (pet) .....	--	--	--	--	--	--	--	--	--
WO <sub>3</sub> (pet) .....	--	--	--	--	--	--	--	--	--
Pd (ppb) .....	--	--	--	--	--	--	--	--	--
Pt (ppb) .....	--	--	--	--	--	--	--	--	--
Rh (ppb) .....	--	--	--	--	--	--	--	--	--
Ir (ppb) .....	--	--	--	--	--	--	--	--	--
Ru (ppb) .....	--	--	--	--	--	--	--	--	--
Os (ppb) .....	--	--	--	--	--	--	--	--	--
Ag (g/t) .....	1.340	.7148	5	--	--	--	--	--	--
Au (g/t) .....	.4106	.3914	34	--	--	--	--	--	--
Zn (pet) .....	--	--	--	--	--	--	--	--	--
Hg (pet) .....	--	--	--	.4522	.2002	20	.4070	.1738	28
Sn (pet) .....	--	--	--	--	--	--	--	--	--
Pb (pet) .....	--	--	--	--	--	--	--	--	--
Sb (pet) .....	--	--	--	--	--	--	--	--	--

Deposit type	Sb veins			Disseminated Sb			Kuroko massive sulfide		
	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits
Tonnage (metric) .....	2.256	1.117	81	4.943	0.8211	23	6.175	0.8495	432
RE <sub>2</sub> O <sub>3</sub> (pet) .....	--	--	--	--	--	--	--	--	--
Monazite (pet REO) .....	--	--	--	--	--	--	--	--	--
U <sub>3</sub> O <sub>8</sub> (pet) .....	--	--	--	--	--	--	--	--	--
Zircon (pet ZrO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Nb <sub>2</sub> O <sub>5</sub> (pet) .....	--	--	--	--	--	--	--	--	--
Fiber (pet) .....	--	--	--	--	--	--	--	--	--
Barite (pet) .....	--	--	--	--	--	--	--	--	--
Al <sub>2</sub> O <sub>3</sub> (pet) .....	--	--	--	--	--	--	--	--	--
P (pet) .....	--	--	--	--	--	--	--	--	--
P <sub>2</sub> O <sub>5</sub> (pet) .....	--	--	--	--	--	--	--	--	--
Ilmenite (pet TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Rutile (pet TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Leucocite (pet TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Cr <sub>2</sub> O <sub>3</sub> (pet) .....	--	--	--	--	--	--	--	--	--
Mn (pet) .....	--	--	--	--	--	--	--	--	--
Fe (pet) .....	--	--	--	--	--	--	--	--	--
Co (pet) .....	--	--	--	--	--	--	--	--	--
Ni (pet) .....	--	--	--	--	--	--	--	--	--
Cu (pet) .....	--	--	--	--	--	--	.0999	.3493	432
Mo (pet) .....	--	--	--	--	--	--	--	--	--
WO <sub>3</sub> (pet) .....	--	--	--	--	--	--	--	--	--
Pd (ppb) .....	--	--	--	--	--	--	--	--	--
Pt (ppb) .....	--	--	--	--	--	--	--	--	--
Rh (ppb) .....	--	--	--	--	--	--	--	--	--
Ir (ppb) .....	--	--	--	--	--	--	--	--	--
Ru (ppb) .....	--	--	--	--	--	--	--	--	--
Os (ppb) .....	--	--	--	--	--	--	--	--	--
Ag (g/t) .....	1.561	.2851	8	.0792	--	1	1.459	.5133	284
Au (g/t) .....	.7111	.6872	9	.5278	1.172	2	.1080	.5281	238
Zn (pet) .....	--	--	--	--	--	--	.4482	.4626	330
Hg (pet) .....	--	--	--	--	--	--	--	--	--
Sn (pet) .....	--	--	--	--	--	--	--	--	--
Pb (pet) .....	--	--	--	--	--	--	.1269	.5506	184
Sb (pet) .....	1.540	.2200	81	.5505	.2308	23	--	--	--

## Appendix B. Summary statistics of grade-tonnage models--Continued

Deposit type	Algoma Fe and Superior Fe			Sandstone-hosted Pb-Zn			Sediment-hosted Cu		
	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits
Tonnage (metric) .....	8.218	0.9105	66	6.729	0.8268	20	7.341	0.9186	57
RE <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Monazite (pct REO) .....	--	--	--	--	--	--	--	--	--
U <sub>3</sub> O <sub>8</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Zircon (pct ZrO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Nb <sub>2</sub> O <sub>5</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Fiber (pct) .....	--	--	--	--	--	--	--	--	--
Barite (pct) .....	--	--	--	--	--	--	--	--	--
Al <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
P (pct) .....	-1.256	.4853	47	--	--	--	--	--	--
P <sub>2</sub> O <sub>5</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Ilmenite (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Rutile (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Leucocite (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Cr <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Mn (pct) .....	--	--	--	--	--	--	--	--	--
Fe (pct) .....	50.83	13.65	66	--	--	--	--	--	--
Co (pct) .....	--	--	--	--	--	--	-.6226	.1919	10
Ni (pct) .....	--	--	--	--	--	--	--	--	--
Cu (pct) .....	--	--	--	--	--	--	.3317	.2540	57
Mo (pct) .....	--	--	--	--	--	--	--	--	--
WO <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Pd (ppb) .....	--	--	--	--	--	--	--	--	--
Pt (ppb) .....	--	--	--	--	--	--	--	--	--
Rh (ppb) .....	--	--	--	--	--	--	--	--	--
Ir (ppb) .....	--	--	--	--	--	--	--	--	--
Ru (ppb) .....	--	--	--	--	--	--	--	--	--
Os (ppb) .....	--	--	--	--	--	--	--	--	--
Ag (g/t) .....	--	--	--	1.050	.5824	3	1.208	.7646	12
Au (g/t) .....	--	--	--	--	--	--	--	--	--
Zn (pct) .....	--	--	--	-.2320	.6769	19	--	--	--
Hg (pct) .....	--	--	--	--	--	--	--	--	--
Sn (pct) .....	--	--	--	--	--	--	--	--	--
Pb (pct) .....	--	--	--	.3332	.3011	20	--	--	--
Sb (pct) .....	--	--	--	--	--	--	--	--	--

Deposit type	Sedimentary exhalative Zn-Pb			Bedded barite			Southeast Missouri Pb-Zn and Appalachian Zn		
	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits
Tonnage (metric) .....	7.167	0.7315	45	6.259	0.9271	25	7.542	0.9285	20
RE <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Monazite (pct REO) .....	--	--	--	--	--	--	--	--	--
U <sub>3</sub> O <sub>8</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Zircon (pct ZrO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Nb <sub>2</sub> O <sub>5</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Fiber (pct) .....	--	--	--	--	--	--	--	--	--
Barite (pct) .....	--	--	--	83.02	13.80	25	--	--	--
Al <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
P (pct) .....	--	--	--	--	--	--	--	--	--
P <sub>2</sub> O <sub>5</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Ilmenite (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Rutile (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Leucocite (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Cr <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Mn (pct) .....	--	--	--	--	--	--	--	--	--
Fe (pct) .....	--	--	--	--	--	--	--	--	--
Co (pct) .....	--	--	--	--	--	--	--	--	--
Ni (pct) .....	--	--	--	--	--	--	--	--	--
Cu (pct) .....	-.7273	.4797	11	--	--	--	--	--	--
Mo (pct) .....	--	--	--	--	--	--	--	--	--
WO <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Pd (ppb) .....	--	--	--	--	--	--	--	--	--
Pt (ppb) .....	--	--	--	--	--	--	--	--	--
Rh (ppb) .....	--	--	--	--	--	--	--	--	--
Ir (ppb) .....	--	--	--	--	--	--	--	--	--
Ru (ppb) .....	--	--	--	--	--	--	--	--	--
Os (ppb) .....	--	--	--	--	--	--	--	--	--
Ag (g/t) .....	1.6367	.4705	37	--	--	--	.6693	.6917	10
Au (g/t) .....	--	--	--	--	--	--	--	--	--
Zn (pct) .....	.7519	.2908	45	--	--	--	.6079	.3623	20
Hg (pct) .....	--	--	--	--	--	--	--	--	--
Sn (pct) .....	--	--	--	--	--	--	--	--	--
Pb (pct) .....	.4443	.3443	45	--	--	--	.0893	.4068	16
Sb (pct) .....	--	--	--	--	--	--	--	--	--



## Appendix B. Summary statistics of grade-tonnage models--Continued

Deposit type	Sedimentary Mn			Phosphate, upwelling			Phosphate, warm current		
	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits
Tonnage (metric) .....	6.862	1.240	39	8.520	0.8611	60	8.603	0.7360	18
RE <sub>2</sub> O <sub>3</sub> (pet) .....	--	--	--	--	--	--	--	--	--
Monazite (pet REO) .....	--	--	--	--	--	--	--	--	--
U <sub>3</sub> O <sub>8</sub> (pet) .....	--	--	--	--	--	--	--	--	--
Zircon (pet ZrO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Nb <sub>2</sub> O <sub>5</sub> (pet) .....	--	--	--	--	--	--	--	--	--
Fiber (pet) .....	--	--	--	--	--	--	--	--	--
Barite (pet) .....	--	--	--	--	--	--	--	--	--
Al <sub>2</sub> O <sub>3</sub> (pet) .....	--	--	--	--	--	--	--	--	--
P (pet) .....	.9034	.3273	13	--	--	--	--	--	--
P <sub>2</sub> O <sub>5</sub> (pet) .....	--	--	--	23.96	6.604	60	24.16	3.402	18
Ilmenite (pet TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Rutile (pet TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Leucocite (pet TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Cr <sub>2</sub> O <sub>3</sub> (pet) .....	--	--	--	--	--	--	--	--	--
Mn (pet) .....	31.38	13.05	39	--	--	--	--	--	--
Fe (pet) .....	--	--	--	--	--	--	--	--	--
Co (pet) .....	--	--	--	--	--	--	--	--	--
Ni (pet) .....	--	--	--	--	--	--	--	--	--
Cu (pet) .....	--	--	--	--	--	--	--	--	--
Mo (pet) .....	--	--	--	--	--	--	--	--	--
WO <sub>3</sub> (pet) .....	--	--	--	--	--	--	--	--	--
Pd (ppb) .....	--	--	--	--	--	--	--	--	--
Pt (ppb) .....	--	--	--	--	--	--	--	--	--
Rh (ppb) .....	--	--	--	--	--	--	--	--	--
Ir (ppb) .....	--	--	--	--	--	--	--	--	--
Ru (ppb) .....	--	--	--	--	--	--	--	--	--
Os (ppb) .....	--	--	--	--	--	--	--	--	--
Ag (g/t) .....	--	--	--	--	--	--	--	--	--
Au (g/t) .....	--	--	--	--	--	--	--	--	--
Zn (pet) .....	--	--	--	--	--	--	--	--	--
Hg (pet) .....	--	--	--	--	--	--	--	--	--
Sn (pet) .....	--	--	--	--	--	--	--	--	--
Pb (pet) .....	--	--	--	--	--	--	--	--	--
Sb (pet) .....	--	--	--	--	--	--	--	--	--

Deposit type	Low-sulfide Au-quartz veins			Homestake Au			Unconformity U-Au		
	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits
Tonnage (metric) .....	4.470	1.163	313	5.974	0.8592	116	5.356	1.274	36
RE <sub>2</sub> O <sub>3</sub> (pet) .....	--	--	--	--	--	--	--	--	--
Monazite (pet REO) .....	--	--	--	--	--	--	--	--	--
U <sub>3</sub> O <sub>8</sub> (pet) .....	--	--	--	--	--	--	.2816	.4167	36
Zircon (pet ZrO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Nb <sub>2</sub> O <sub>5</sub> (pet) .....	--	--	--	--	--	--	--	--	--
Fiber (pet) .....	--	--	--	--	--	--	--	--	--
Barite (pet) .....	--	--	--	--	--	--	--	--	--
Al <sub>2</sub> O <sub>3</sub> (pet) .....	--	--	--	--	--	--	--	--	--
P (pet) .....	--	--	--	--	--	--	--	--	--
P <sub>2</sub> O <sub>5</sub> (pet) .....	--	--	--	--	--	--	--	--	--
Ilmenite (pet TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Rutile (pet TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Leucocite (pet TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Cr <sub>2</sub> O <sub>3</sub> (pet) .....	--	--	--	--	--	--	--	--	--
Mn (pet) .....	--	--	--	--	--	--	--	--	--
Fe (pet) .....	--	--	--	--	--	--	--	--	--
Co (pet) .....	--	--	--	--	--	--	--	--	--
Ni (pet) .....	--	--	--	--	--	--	--	--	--
Cu (pet) .....	--	--	--	--	--	--	--	--	--
Mo (pet) .....	--	--	--	--	--	--	--	--	--
WO <sub>3</sub> (pet) .....	--	--	--	--	--	--	--	--	--
Pd (ppb) .....	--	--	--	--	--	--	--	--	--
Pt (ppb) .....	--	--	--	--	--	--	--	--	--
Rh (ppb) .....	--	--	--	--	--	--	--	--	--
Ir (ppb) .....	--	--	--	--	--	--	--	--	--
Ru (ppb) .....	--	--	--	--	--	--	--	--	--
Os (ppb) .....	--	--	--	--	--	--	--	--	--
Ag (g/t) .....	.6961	.3563	39	.2093	.5234	52	--	--	--
Au (g/t) .....	1.203	.3327	313	.9647	.2518	116	--	--	--
Zn (pet) .....	--	--	--	--	--	--	--	--	--
Hg (pet) .....	--	--	--	--	--	--	--	--	--
Sn (pet) .....	--	--	--	--	--	--	--	--	--
Pb (pet) .....	--	--	--	--	--	--	--	--	--
Sb (pet) .....	--	--	--	--	--	--	--	--	--



Appendix B. Summary statistics of grade-tonnage models--Continued

Deposit type	Lateritic Ni			Laterite bauxite			Karst bauxite		
	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits
Tonnage (metric) .....	7.645	0.5864	71	7.401	1.142	122	7.366	0.6811	41
RE <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Monazite (pct REO) .....	--	--	--	--	--	--	--	--	--
U <sub>3</sub> O <sub>8</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Zircon (pct ZrO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Nb <sub>2</sub> O <sub>5</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Fiber (pct) .....	--	--	--	--	--	--	--	--	--
Barite (pct) .....	--	--	--	--	--	--	--	--	--
Al <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	44.37	7.747	122	49.18	7.930	41
P (pct) .....	--	--	--	--	--	--	--	--	--
P <sub>2</sub> O <sub>5</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Ilmenite (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Rutile (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Leucocite (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	--	--	--
Cr <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Mn (pct) .....	--	--	--	--	--	--	--	--	--
Fe (pct) .....	--	--	--	--	--	--	--	--	--
Co (pct) .....	-1.159	.1665	12	--	--	--	--	--	--
Ni (pct) .....	.1346	.1043	71	--	--	--	--	--	--
Cu (pct) .....	--	--	--	--	--	--	--	--	--
Mo (pct) .....	--	--	--	--	--	--	--	--	--
WO <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Pd (ppb) .....	--	--	--	--	--	--	--	--	--
Pt (ppb) .....	--	--	--	--	--	--	--	--	--
Rh (ppb) .....	--	--	--	--	--	--	--	--	--
Ir (ppb) .....	--	--	--	--	--	--	--	--	--
Ru (ppb) .....	--	--	--	--	--	--	--	--	--
Os (ppb) .....	--	--	--	--	--	--	--	--	--
Ag (g/t) .....	--	--	--	--	--	--	--	--	--
Au (g/t) .....	--	--	--	--	--	--	--	--	--
Zn (pct) .....	--	--	--	--	--	--	--	--	--
Hg (pct) .....	--	--	--	--	--	--	--	--	--
Sn (pct) .....	--	--	--	--	--	--	--	--	--
Pb (pct) .....	--	--	--	--	--	--	--	--	--
Sb (pct) .....	--	--	--	--	--	--	--	--	--

Deposit type	Placer Au-PGE			Placer PGE-Au			Shoreline placer Ti		
	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits	Mean	S.D.	Number of deposits
Tonnage (metric) .....	6.030	1.312	65	5.112	0.8548	83	7.942	0.7014	61
RE <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Monazite (pct REO) .....	--	--	--	--	--	--	-1.5262	.8190	29
U <sub>3</sub> O <sub>8</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Zircon (pct ZrO <sub>2</sub> ) .....	--	--	--	--	--	--	-1.5703	.4221	52
Nb <sub>2</sub> O <sub>5</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Fiber (pct) .....	--	--	--	--	--	--	--	--	--
Barite (pct) .....	--	--	--	--	--	--	--	--	--
Al <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
P (pct) .....	--	--	--	--	--	--	--	--	--
P <sub>2</sub> O <sub>5</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Ilmenite (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	.1026	.5755	61
Rutile (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	-.6723	.4220	50
Leucocite (pct TiO <sub>2</sub> ) .....	--	--	--	--	--	--	-.6469	.5439	24
Cr <sub>2</sub> O <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Mn (pct) .....	--	--	--	--	--	--	--	--	--
Fe (pct) .....	--	--	--	--	--	--	--	--	--
Co (pct) .....	--	--	--	--	--	--	--	--	--
Ni (pct) .....	--	--	--	--	--	--	--	--	--
Cu (pct) .....	--	--	--	--	--	--	--	--	--
Mo (pct) .....	--	--	--	--	--	--	--	--	--
WO <sub>3</sub> (pct) .....	--	--	--	--	--	--	--	--	--
Pd (ppb) .....	--	--	--	-2.825	.3818	13	--	--	--
Pt (ppb) .....	--	--	--	.2010	.5701	83	--	--	--
Rh (ppb) .....	--	--	--	--	--	--	--	--	--
Ir (ppb) .....	--	--	--	-2.077	1.193	10	--	--	--
Ru (ppb) .....	--	--	--	--	--	--	--	--	--
Os (ppb) .....	--	--	--	-1.805	1.068	21	--	--	--
Ag (g/t) .....	-1.571	.3954	16	--	--	--	--	--	--
Au (g/t) .....	-.6083	.2928	65	-1.531	.8495	23	--	--	--
Zn (pct) .....	--	--	--	--	--	--	--	--	--
Hg (pct) .....	--	--	--	--	--	--	--	--	--
Sn (pct) .....	--	--	--	--	--	--	--	--	--
Pb (pct) .....	--	--	--	--	--	--	--	--	--
Sb (pct) .....	--	--	--	--	--	--	--	--	--

Appendix C. Commodity/Geochemical Index by Paul B. Barton

This file shows economic (or potentially economic) commodities as primary products or by-products; it also indicates geochemical anomalies. These represent the elements present anywhere in the deposit, not solely in haloes distinct from ore. The listing covers only those deposits for which models are present elsewhere in this compilation. Figure 206 is a graphical presentation of some of the information in the following table. It provides an overview of the distribution of the elements among deposit types.

In an effort to represent the commonness or rarity of features, numbers are assigned. Universally present products/anomalies rate a +5 (shown simply as "5") grading down through 0 to -5 (shown as "(-5)") in a system similar to PROSPECTOR. The "0" value will seldom, if ever, be shown as it is the "don't know" (or "don't care") default. Note that negative numbers for "Primary" or "By-product" are not used, although they might be applied to indicate serious deleterious elements, such as phosphorus in iron ores. In almost all instances at present, these values will be guesses based on experience, not hard data; however, we do urge the compilation of data to make such assignments possible eventually. It is our intent to have the "1", "2", "3", "4", and "5" scores correspond respectively to the 0-10, 10-30, 30-70, 70-90, and 90-100 percent frequency relationship between the element and the deposit type. Obviously such statistical approaches are meaningless for deposit types having few representatives, such as emerald veins (31c), but the value can still be useful as an estimate of the compiler's opinion regarding the probable generality of the observation. The abbreviated suffixes "(prox.)" and "(dist.)" indicate respectively proximal (or nearer source) and distal (or farther from the source). For more complex relations please refer back to the models.

Figure 206 shows only the presence of an element at some unspecified anomalous level, either proximally or distally with respect to the deposit. The elements are grouped in such a way that the distinction between those of granitic and mafic associations can be easily made. The elements of high mobility in hydrothermal environments form a distinct grouping on the right side of the matrix.

It should be obvious from examination of the table and figure below that the presence of a given element seldom, if ever, "proves" the existence of an ore deposit. Anomalous amounts of some elements such as copper, gold, iron, and zinc are so common in so many settings that their presence tells very little about the possible character of the host deposit. Their presence is encouraging, however, and indicates that additional studies may be warranted.

Element	Primary	By-product	Geochemical anomaly	Deposit type and model number
Ag			3	Sn skarn (14b)
		3	4(dist.)	porphyry Cu (17)
		3	5	porphyry Cu, skarn-related (18a)
		4	5	Cu skarn (18b)
		4	5	Zn-Pb skarn (18c)
		5(dist.)	4	polymetallic replacement (19a)
			4	replacement Mn (19b)
			4(dist.)	porphyry Sn (20a)
	3	3	5	Sn-polymetallic veins (20b)
		4	5(prox.)	porphyry Cu-Au (20c)
		4	5(dist.)	porphyry Cu-Mo (21a)
			5(dist.)	porphyry Mo, low-F (21b)
	3	5	5	volcanic-hosted Cu-As-Sb (22a)
	2	5	5	Au-Ag-Te veins (22b)
	4	2	5	polymetallic veins (22c)
		3	4	basaltic Cu (23)
		3	4	Cyprus massive sulfide (24a)
		3	5	Besshi massive sulfide (24b)
		2	3	Blackbird Co-Cu (24d)
	3	4	5(prox.)	hot-spring Au-Ag (25a)

Model Number	Deposit Type	Li	Na	K	Rb	Cs	Be	B	REE	U	Th	Zr	Nb	Ta	Mg	Ca	Sr	Ba	Al	Ga	P	Ti	V	Cr	Mn	Fe
*1*	Stillwater Ni-Cu														*											
*2a*	Bushveld Cr														*											
*2b*	Merensky Reef PGE														*											
*3*	Bushveld Fe-Ti-V														*											
*5a*	Duluth Cu-Ni-PGE														*											
*5b*	Noril'sk Cu-Ni-PGE														*											
*6a*	Komatiitic Ni-Cu														*											
*6b*	Dunitic Ni-Cu														*											
*7a*	Synorogenic-Synvolcanic Ni-Cu														*											
*7b*	Anorthositic Ti														*											
*8a & 8b*	Podiform chromite														*											
*8c*	Umassol Forest Co-Ni														*											
*8d*	Serpentine-hosted asbestos														*											
*9*	Alaskan Cr-Pt														*											
*10*	Carbonatite	*						*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
*12*	Diamond pipes			*											*			*				*	*	*	*	*
*14a*	W skarn				*		*								*											
*14b*	Sn skarn	*			*	*	*	*	*	*	*	*	*	*	*											
*14c*	Replacement Sn	*			*		*							*	*											
*15a*	W veins	*			*	*	*	*	*	*	*	*	*	*	*											
*15b*	Sn veins	*			*	*	*	*	*	*	*	*	*	*	*											
*15c*	Sn greisen	*			*	*	*	*	*	*	*	*	*	*	*											
*16*	Climax Mo			*	*	*								*	*											
*17*	Porphyry Cu			*				*						*	*											
*18a*	Porphyry Cu, skarn-related			*				*						*	*											
*18b*	Cu skarn													*	*											
*18c*	Zn-Pb skarn						*							*	*											
*18d*	Fe skarn						*							*	*											
*18e*	Carbonate-hosted asbestos													*	*											
*19a*	Polymetallic replacement													*	*											
*19b*	Replacement Mn													*	*											
*20a*	Porphyry Sn							*						*	*											
*20b*	Sn-polymetallic vein							*						*	*											
*20c*	Porphyry Cu-Au							*						*	*											
*21a*	Porphyry Cu-Mo			*		*		*						*	*											
*21b*	Porphyry Mo, low-F			*		*		*						*	*											
*22a*	Volcanic-hosted Cu-Au-Sb			*		*		*						*	*											
*22b*	Au-Ag-Te veins			*		*		*						*	*											
*22c*	Polymetallic veins			*		*		*						*	*											
*23*	Basaltic Cu													*	*											
*24a*	Cyprus massive sulfide													*	*											
*24b*	Besshi massive sulfide													*	*											
*24c*	Volcanogenic Mn													*	*											
*24d*	Blackbird Co-Cu							*						*	*											
*25a*	Hot-spring Au-Ag													*	*											
*25b*	Greensalt epithermal vein													*	*											
*25c*	Cornstock epithermal vein													*	*											
*25d*	Sado epithermal vein													*	*											
*25e*	Epithermal quartz-alunite Au													*	*											
*25f*	Volcanogenic U							*	*	*	*	*	*	*	*											
*25g*	Epithermal Mn							*	*	*	*	*	*	*	*											
*25h*	Rhyolite-hosted Sn	*					*	*	*	*	*	*	*	*	*											
*25i*	Volcanic-hosted magnetite						*	*	*	*	*	*	*	*	*											
*26a*	Carbonate-hosted Au-Ag													*	*											
*27a*	Hot-spring Hg													*	*											
*27b*	Almaden Hg													*	*											
*27c*	Silica-carbonate Hg													*	*											
*27d*	Sb veins													*	*											
*28a*	Kuroko massive sulfide													*	*											
*28b*	Alzoma Fe													*	*											
*29a*	Quartz pebble conglomerate Au-U									*	*	*	*	*	*											
*29b*	Olympic Dam Cu-U-Au								*	*	*	*	*	*	*											
*30a*	Sandstone-hosted Pb-Zn								*	*	*	*	*	*	*											
*30b*	Sediment-hosted Cu								*	*	*	*	*	*	*											
*30c*	Sandstone U								*	*	*	*	*	*	*											
*31a*	Sedimentary exhalative Zn-Pb								*	*	*	*	*	*	*											
*31b*	Bedded barite								*	*	*	*	*	*	*											
*31c*	Emerald vein	*	*	*			*	*	*	*	*	*	*	*	*											
*32a*	Southeast Missouri Pb-Zn						*	*	*	*	*	*	*	*	*											
*32b*	Appalachian Zn						*	*	*	*	*	*	*	*	*											
*32c*	Kipushi Cu-Pb-Zn						*	*	*	*	*	*	*	*	*											
*34a*	Superior Fe													*	*											
*34b*	Sedimentary manganese													*	*											
*34c*	Phosphate, upwelling type								*	*	*	*	*	*	*											
*34d*	Phosphate, warm current type								*	*	*	*	*	*	*											
*36a*	Low sulfide Au-quartz vein								*	*	*	*	*	*	*											
*36b*	Homestake Au							*	*	*	*	*	*	*	*											
*37a*	Unconformity U-Au				*			*	*	*	*	*	*	*	*											
*37b*	Gold on flat faults				*			*	*	*	*	*	*	*	*											
*38a*	Lateritic Ni													*	*											
*38b*	Bauxite, laterite type													*	*											
*38c*	Bauxite, karst type													*	*											
*39a*	Placer Au-PGE													*	*											
*39b*	Placer PGE-Au													*	*											
*39c*	Shoreline placer Ti								*	*	*	*	*	*	*											
*39d*	Diamond placer								*	*	*	*	*	*	*											
*39e*	Alluvial placer Sn	*					*	*	*	*	*	*	*	*	*											

Figure 206. Matrix diagram showing deposit models and their geochemical signature. Closed and open circles indicate that the element is anomalous proximally or distally to the deposit respectively.

Model Number	Deposit Type	Co	Ni	Cu	Mo	W	Re	PGE	Ag	Au	Zn	Cd	Hg	Ti	Ge	Sn	Pb	As	Sb	Bi	Te	Se	S	F	Br	C	NH3
*1*	Stillwater Ni-Cu	*	*	*				*																			
*2a*	Bushveld Cr	*	*	*				*																			
*2b*	Merensky Reef PGE	*	*	*				*																			
*3*	Bushveld Fe-Ti-V	*	*	*				*																			
*5a*	Duluth Cu-Ni-PGE	*	*	*				*																			
*5b*	Norilsk Cu-Ni-PGE	*	*	*				*																			
*6a*	Komatiite Ni-Cu	*	*	*				*		*																	
*6b*	Dunite Ni-Cu	*	*	*				*		*																	
*7a*	Synorogenic-Synvolcanic Ni-Cu	*	*	*				*		*																	
*7b*	Anorthosite Ti	*	*	*				*		*																	
*8a & 8b*	Podiform chromite	*	*	*				*		*																	
*8c*	Limassol Forest Co-Ni	*	*	*				*		*																	
*8d*	Serpentine-hosted asbestos	*	*	*				*		*																	
*9*	Alaskan Cr-Pt	*	*	*				*		*																	
*10*	Carbonatite	*	*	*	*	*		*		*																	
*12*	Diamond pipes	*	*	*				*		*																	
*14a*	W skarn	*	*	*	*	*		*		*																	
*14b*	Sn skarn	*	*	*	*	*		*		*																	
*14c*	Replacement Sn	*	*	*	*	*		*		*																	
*15a*	W veins	*	*	*	*	*		*		*																	
*15b*	Sn veins	*	*	*	*	*		*		*																	
*15c*	Sn greisen	*	*	*	*	*		*		*																	
*16*	Climax Mo	*	*	*	*	*		*		*																	
*17*	Porphyry Cu	*	*	*	*	*		*		*																	
*18a*	Porphyry Cu, skarn-related	*	*	*	*	*		*		*																	
*18b*	Cu skarn	*	*	*	*	*		*		*																	
*18c*	Zn-Pb skarn	*	*	*	*	*		*		*																	
*18d*	Fe skarn	*	*	*	*	*		*		*																	
*18e*	Carbonate-hosted asbestos	*	*	*	*	*		*		*																	
*19a*	Polymetallic replacement	*	*	*	*	*		*		*																	
*19b*	Replacement Mn	*	*	*	*	*		*		*																	
*20a*	Porphyry Sn	*	*	*	*	*		*		*																	
*20b*	Sn-polymetallic vein	*	*	*	*	*		*		*																	
*20c*	Porphyry Cu-Au	*	*	*	*	*		*		*																	
*21a*	Porphyry Cu-Mo	*	*	*	*	*		*		*																	
*21b*	Porphyry Mo, low-F	*	*	*	*	*		*		*																	
*22a*	Volcanic-hosted Cu-Au-Sb	*	*	*	*	*		*		*																	
*22b*	Au-Ag-Te veins	*	*	*	*	*		*		*																	
*22c*	Polymetallic veins	*	*	*	*	*		*		*																	
*23*	Basaltic Cu	*	*	*	*	*		*		*																	
*24a*	Cyprus massive sulfide	*	*	*	*	*		*		*																	
*24b*	Besshi massive sulfide	*	*	*	*	*		*		*																	
*24c*	Volcanogenic Mn	*	*	*	*	*		*		*																	
*24d*	Blackbird Co-Cu	*	*	*	*	*		*		*																	
*25a*	Hot-spring Au-Ag	*	*	*	*	*		*		*																	
*25b*	Greene epithermal vein	*	*	*	*	*		*		*																	
*25c*	Comstock epithermal vein	*	*	*	*	*		*		*																	
*25d*	Sado epithermal vein	*	*	*	*	*		*		*																	
*25e*	Epithermal quartz-galena Au	*	*	*	*	*		*		*																	
*25f*	Volcanogenic U	*	*	*	*	*		*		*																	
*25g*	Epithermal Mn	*	*	*	*	*		*		*																	
*25h*	Rhyolite-hosted Sn	*	*	*	*	*		*		*																	
*25i*	Volcanic-hosted magnetite	*	*	*	*	*		*		*																	
*26a*	Carbonate-hosted Au-Ag	*	*	*	*	*		*		*																	
*27a*	Hot-spring Hg	*	*	*	*	*		*		*																	
*27b*	Almaden Hg	*	*	*	*	*		*		*																	
*27c*	Silica-carbonate Hg	*	*	*	*	*		*		*																	
*27d*	Sb veins	*	*	*	*	*		*		*																	
*28a*	Kuroko massive sulfide	*	*	*	*	*		*		*																	
*28b*	Algoma Fe	*	*	*	*	*		*		*																	
*29a*	Quartz pebble conglomerate Au-U	*	*	*	*	*		*		*																	
*29b*	Olympic Dam Cu-U-Au	*	*	*	*	*		*		*																	
*30a*	Sandstone-hosted Pb-Zn	*	*	*	*	*		*		*																	
*30b*	Sediment-hosted Cu	*	*	*	*	*		*		*																	
*30c*	Sandstone U	*	*	*	*	*		*		*																	
*31a*	Sedimentary exhalative Zn-Pb	*	*	*	*	*		*		*																	
*31b*	Bedded barite	*	*	*	*	*		*		*																	
*31c*	Emerald vein	*	*	*	*	*		*		*																	
*32a*	Southeast Missouri Pb-Zn	*	*	*	*	*		*		*																	
*32b*	Appalachian Zn	*	*	*	*	*		*		*																	
*32c*	Kipushi Cu-Pb-Zn	*	*	*	*	*		*		*																	
*34a*	Superior Fe	*	*	*	*	*		*		*																	
*34b*	Sedimentary manganese	*	*	*	*	*		*		*																	
*34c*	Phosphate, upwelling type	*	*	*	*	*		*		*																	
*34d*	Phosphate, warm current type	*	*	*	*	*		*		*																	
*36a*	Low sulfide Au-quartz vein	*	*	*	*	*		*		*																	
*36b*	Homestake Au	*	*	*	*	*		*		*																	
*37a*	Unconformity U-Au	*	*	*	*	*		*		*																	
*37b*	Gold on flat faults	*	*	*	*	*		*		*																	
*38a*	Laterite Ni	*	*	*	*	*		*		*																	
*38b*	Bauxite, laterite type	*	*	*	*	*		*		*																	
*38c*	Bauxite, karst type	*	*	*	*	*		*		*																	
*39a*	Placer Au-PGE	*	*	*	*	*		*		*																	
*39b*	Placer PGE-Au	*	*	*	*	*		*		*																	
*39c*	Shoreline placer Ti	*	*	*	*	*		*		*																	
*39d*	Diamond placer	*	*	*	*	*		*		*																	
*39e*	Alluvial placer Sn	*	*	*	*	*		*		*																	

Figure 206. Continued.

## Appendix C. Commodity/Geochemical Index--Continued

Element	Primary	By-product	Geochemical anomaly	Deposit type and model number
Ag (cont.)	4	2	5	Creede epithermal vein (25b)
	4	3	5	Comstock epithermal vein (25c)
	3	4	5	Sado epithermal vein (25d)
		2	3	epithermal quartz-alunite Au (25e)
			3	epithermal Mn (25g)
		2		carbonate-hosted Au-Ag (26a)
		1	3	simple Sb (27d)
	1	4	5	Kuroko massive sulfide (28a)
		2	5	Olympic Dam Cu-U-Au (29b)
		3	4	sandstone-hosted Pb-Zn (30a)
	2	5	5	sediment-hosted Cu (30b)
		4	5	sedimentary exhalative Zn-Pb (31a)
		4	4	southeast Missouri Pb-Zn (32a)
		3	5	Kipushi Cu-Pb-Zn (32c)
		5	5	low-sulfide Au-quartz veins (36a)
		3	3	Homestake Au (36b)
		3	5	placer Au-PGE (39a)
		1	4	placer PGE-Au (39b)
			3	unconformity U-Au (37a)
			3	gold on flat faults (37b)
Al			5	volcanic-hosted Cu-As-Sb (22a)
			5	epithermal quartz-alunite Au (25e)
	5		5	bauxite, laterite type (38b)
	5		5	bauxite, karst type (38c)
			4	unconformity U-Au (37a)
As			5	Limassol Forest Co-Ni (8c)
			4	Alaskan PGE (9)
			4	W skarn (14a)
			5	replacement Sn (14c)
			3	W veins (15a)
			4	Sn veins (15b)
			4	Sn greisen (15c)
			3(dist.)	porphyry Cu (17)
			2(dist.)	Cu skarn (18b)
			4	Zn-Pb skarn (18c)
			3	polymetallic replacement (19a)
			4(dist.)	porphyry Sn (20a)
			4	Sn-polymetallic veins (20b)
			5(dist.)	porphyry Cu-Mo (21a)
	2		5	volcanic-hosted Cu-As-Sb (22a)
			4	polymetallic veins (22c)
			5	Blackbird Co-Cu (24d)
			4(dist.)	hot-spring Au-Ag (25a)
			4	Creede epithermal vein (25b)
			4	Comstock epithermal vein (25c)
			5	epithermal quartz-alunite Au (25e)
			4	Sado epithermal vein (25d)
			4(prox.)	volcanogenic U (25f)
			3	rhyolite-hosted Sn (25h)
			5	carbonate-hosted Au (26a)
			5	hot-spring Hg (27a)
			4	Almaden Hg (27b)
			5	simple Sb (27d)
			4	Kuroko massive sulfide (28a)
			4	Homestake Au (28c)
			3	sedimentary exhalative Zn-Pb (31a)
			5	Kipushi Cu-Pb-Zn (32c)
			5	low-sulfide Au-quartz veins (36a)
			5	Homestake Au (36b)



## Appendix C. Commodity/Geochemical Index--Continued

Element	Primary	By-product	Geochemical anomaly	Deposit type and model number
As (cont.)			4	unconformity U-Au (37a)
			1	gold on flat faults (37b)
			4	placer Au-PGE (39a)
			4	placer PGE-Au (39b)
Au		2	3	komatiitic Ni-Cu (6a)
		4	5	porphyry Cu (17)
		3	4	porphyry Cu, skarn-related (18a)
		4	4	Cu skarn (18b)
		4	4	Zn-Pb skarn (18c)
	1	5	5(prox.)	porphyry Cu-Au (20c)
		3	5(dist.)	porphyry Cu-Mo (21a)
		3	4	Fe skarn (18d)
	1	3	4	polymetallic replacement (19a)
			4	replacement Mn (19b)
		3	4	Sn-polymetallic veins (20b)
		4	4(dist.)	porphyry Mo, low-F (21b)
	5		4	volcanic-hosted Cu-As-Sb (22a)
			5	Au-Ag-Te veins (22b)
	2	4	5(prox.)	polymetallic veins (22c)
			(-3)	basaltic Cu (23)
	2	4	5	Cyprus massive sulfide (24a)
	1	3	4	Besshi massive sulfide (24b)
		2	3	Blackbird Co-Cu (24d)
	4	2	5	hot-spring Au-Ag (25a)
	2	4	4	Creede epithermal vein (25b)
	4	3	5	Comstock epithermal vein (25c)
	4	3	5	Sado epithermal vein (25d)
	5		5	epithermal quartz-alunite Au (25e)
			3	epithermal Mn (25g)
	5		5	carbonate-hosted Au (26a)
		1	3	hot-spring Hg (27a)
		1	3	simple Sb (27d)
		3	5	kuroko massive sulfide (28a)
	5		5	Homestake Au (28c)
	4	2	5	quartz pebble conglomerate Au-U (29a)
		3	5	Olympic Dam Cu-U-Au (29b)
	5		5	low-sulfide Au-quartz veins (36a)
	5		5	Homestake Au (36b)
		3	5	unconformity U-Au (37a)
			5	gold on flat faults (37b)
	5	1	5	placer Au-PGE (39a)
		1	4	placer PGE-Au (39b)
B			1	carbonatite (10)
			5	Sn skarn (14b)
			4	replacement Sn (14c)
			2	W veins (15a)
			4	Sn veins (15b)
			4	Sn greisen (15c)
			3	porphyry copper (17)
			4(prox.)	porphyry Sn (20a)
			3	Blackbird Co-Cu (24d)
			3	kuroko massive sulfide (28a)
			3	sedimentary exhalative Zn-Pb (31a)
			4	Homestake Au (36b)
Ba	1		4	carbonatite (10)
			3	diamond pipes (12)
			3	polymetallic replacement (19a)
			4(dist.)	porphyry Sn (20a)

## Appendix C. Commodity/Geochemical Index--Continued

Element	Primary	By-product	Geochemical anomaly	Deposit type and model number
Ba (cont.)			3	Au-Ag-Te veins (22b)
			4(dist.)	polymetallic veins (22c)
			3	volcanogenic Mn (24c)
			4	Creede epithermal vein (25b)
			3	volcanic-hosted magnetite (25i)
			3	carbonate-hosted Au (26a)-Ag
		1	3	kuroko massive sulfide (28a)
			3	Olympic Dam Cu-U-Au (29b)
			3	sandstone-hosted Pb-Zn (30a)
			4(dist.)	sedimentary exhalative Zn-Pb (31a)
	5		5	bedded barite (31b)
			3(dist.)	southeast Missouri Pb-Zn (32a)
			3	Appalachian Zn (32b)
			3	gold on flat faults (37b)
			3	diamond placers (39d)
Be			1	carbonatite (10)
			5	W skarn (14a)
		1	4	Sn skarn (14b)
			3	W veins (15a)
			3	Sn greisen (15c)
			2	Zn-Pb skarn (18c)
			4	rhyolite-hosted Sn (25h)
	5		5	emerald veins (31c)
Bi			4	W skarn (14a)
		1	5	W veins (15a)
			3	Sn greisen (15c)
			2	porphyry Cu (17)
			2	Cu skarn (18b)
			3	Zn-Pb skarn (18c)
			3	polymetallic replacement (19a)
		2	4	Sn-polymetallic veins (20b)
			2	Creede epithermal vein (25b)
			3	rhyolite-hosted Sn (25h)
			3	volcanic-hosted magnetite (25i)
			2	kuroko massive sulfide (28a)
			3	Kipushi Cu-Pb-Zn (32c)
			3	Homestake Au (36b)
			3	unconformity U-Au (37a)
Br		2	5	marine potash
			3	southeast Missouri Pb-Zn (32a)
C (diamond)				
	5			diamond pipes (12)
	5			diamond placers (39d)
C (organic)				
			5	carbonate-hosted Au (26a)
			5	sandstone U (30c)
			4	sedimentary exhalative Zn-Pb (31a)
			4	quartz pebble conglomerate Au-U (29a)
			3	southeast Missouri Pb-Zn (32a)
			4	phosphate, upwelling type (34c)
			3	phosphate, warm-current type (34d)
			3	unconformity U-Au (37a)
Cu				
			(-4)	kuroko massive sulfide (28a)
			(-4)	Cyprus massive sulfide (24a)
			(-5)	southeast Missouri Pb-Zn (32a)

## Appendix C. Commodity/Geochemical Index--Continued

Element	Primary	By-product	Geochemical anomaly	Deposit type and model number
Ca (cont.)			(-5) (-3) 3	Appalachian Zn (32b) Blackbird Co-Cu (24d) unconformity U (37a)
Cd		4 4		southeast Missouri Pb-Zn (32a) Appalachian Zn (32b)
Co		3	5 4	Stillwater Ni-Cu (1) Duluth Cu-Ni-PGE (5a)
		3	5	Noril'sk Cu-Ni-PGE (5b)
		2	3	komatiitic Ni-Cu (6a)
		2	5	dunitic Ni (6b)
		1	5	synorogenic-synvolcanic Ni-Cu (7a)
	5		5	Limassol Forest Co-Ni (8c)
			4	diamond pipes (12)
			2	Cu skarn (18b)
			3	Zn-Pb skarn (18c)
		1	2	Fe skarn (18d)
			1	basaltic Cu (23)
			3	Cyprus massive sulfide (24a)
			4	Besshi massive sulfide (24b)
	5		5	Blackbird Co-Cu (24d)
			3	Olympic Dam Cu-U-Au (29b)
	1	1	2	sediment-hosted Cu (30b)
			2	sedimentary exhalative Zn-Pb (31a)
		2	4	southeast Missouri Pb-Zn (32a)
		4	3	Kipushi Cu-Pb-Zn (32c)
		3	5	lateritic Ni (38a)
			3	Homestake Au (36b)
			4	unconformity U (37a)
			3	diamond placers (39d)
Cr	5		5	Bushveld Cr (2a)
			5	Merensky Reef PGE (2b)
	5		5	dunitic Ni (6b)
	2	1	5	podiform Cr (8a)
			5	Alaskan PGE (9)
			5	diamond pipes (12)
			3	Besshi massive sulfide (24b)
		1	5	lateritic Ni (38a)
			5	placer PGE-Au (39b)
			3	diamond placers (39d)
Cs			4	Sn skarn (14b)
			4	Climax Mo (16)
Cu	1	4	5	Stillwater Ni-Cu (1)
		1	5	Merensky Reef PGE (2b)
		3	5	Duluth Cu-Ni-PGE (5a)
	1	4	5	Noril'sk Cu-Ni-PGE (5b)
		3	5	komatiitic Ni-Cu (6a)
			4	dunitic Ni (6b)
		3	5	synorogenic-synvolcanic Ni-Cu (7a)
		1	5	Alaskan PGE (9)
	1		3	carbonatite (10)
		1	4	W skarn (14a)
		1	4	Sn skarn (14b)
		2	5	replacement Sn (14c)
			3	W veins (15a)
			4(prox.)	Climax Mo (16)
	5		5(prox.)	porphyry Cu (17)



Appendix C. Commodity/Geochemical Index--Continued

Element	Primary	By-product	Geochemical anomaly	Deposit type and model number
Cu (cont.)	5		5	porphyry Cu, skarn-related (18a)
	5		5(prox.)	Cu skarn (18b)
		4	5	Zn-Pb skarn (18c)
		1	4	Fe skarn (18d)
	3	4	5(prox.)	polymetallic replacement (19a)
			4	replacement Mn (19b)
			4(dist.)	porphyry Sn (20a)
	3	2	5	Sn-polymetallic veins (20b)
	5		5(prox.)	porphyry Cu-Au (20c)
	5		5(prox.)	porphyry Cu-Mo (21a)
			5(prox.)	porphyry Mo, low-F (21b)
	5		5	volcanic-hosted Cu-As-Sb (22a)
			4	Au-Ag-Te veins (22b)
	2	4	5(prox.)	polymetallic veins (22c)
	5		5	basaltic Cu (23)
	5		5	Cyprus massive sulfide (24a)
	5		5	Besshi massive sulfide (24b)
			3	volcanogenic Mn (24c)
		3	5	Blackbird Co-Cu (24d)
		3	5	Creede epithermal vein (25b)
		3	5	Comstock epithermal vein (25c)
		3	5	Sado epithermal vein (25d)
		3	5	epithermal quartz-alunite Au (25e)
			3	epithermal Mn (25g)
			3	volcanic-hosted magnetite (25i)
			3	silica-carbonate Hg (27c)
	5		5	kuroko massive sulfide (28a)
	5		5	Olympic Dam Cu-U-Au (29b)
	5		5	sediment-hosted Cu (30b)
		1	4	sandstone U (30c)
		1	5(prox.)	sedimentary exhalative Zn-Pb (31a)
		2	5	southeast Missouri Pb-Zn (32a)
	4	2	5	Kipushi Cu-Pb-Zn (32c)
			4	low-sulfide Au-quartz veins (36a)
			4	Homestake Au (36b)
			4	unconformity U (37a)
			5	gold on flat faults (37b)
			3	placer Au-PGE (39a)
			3	placer PGE-Au (39b)
F			2	carbonatite (10)
			2	W skarn (14a)
		1	4	Sn skarn (14b)
			5	replacement Sn (14c)
			4	W veins (15a)
			5	Sn greisen (15c)
			5	Climax Mo (16)
			3	Zn-Pb skarn (18c)
			3	porphyry Mo, low-F (21b)
			5	Au-Ag-Te veins (22b)
			5(prox.)	volcanogenic U (25f)
			4	rhyolite-hosted Sn (25h)
			3	volcanic-hosted magnetite (25i)
			2	carbonate-hosted Au (26a)
			3	Olympic Dam Cu-U-Au (29b)
			3	sandstone-hosted Pb-Zn (30a)
			2	southeast Missouri Pb-Zn (32a)
			3(dist.)	Appalachian Zn (32b)
		3	5	phosphate, upwelling type (34c)
		3	5	phosphate, warm current type (34d)
			4	gold on flat faults 37b

## Appendix C. Commodity/Geochemical Index--Continued

Element	Primary	By-product	Geochemical anomaly	Deposit type and model number
Fe		3	5 5 5 1 5 5 5 1 5 5 5 5 4 4 4 4	many, including: Bushveld Fe-Ti-V (3) anorthosite Ti (7b) carbonatite (10) Fe skarn (18d) Cyprus massive sulfide (24a) volcanic-hosted magnetite (25i) kuroko massive sulfide (28a) Olympic Dam Cu-U-Au (29b) Algoma Fe (28b) sedimentary exhalative Zn-Pb (31a) Superior Fe (34a) gold on flat faults (37b) placer Au-PGE (39a) placer PGE-Au (39b) shoreline placer Ti (39c)
Ga		3 3 3	3 5 5	Kipushi Cu-Pb-Zn (32c) bauxite, laterite type (38b) bauxite, karst type (38c)
Ge		2 2	4 3	sediment-hosted Cu (30b) Kipushi Cu-Pb-Zn (32c)
Hg	1  1  5 5 5		5 4 4(dist.) 2 3 4(dist.) 4 5 5 5 4 3 3 3	carbonate-hosted Au-Ag (26a) Au-Ag-Te veins (22b) hot-spring Au-Ag (25a) Creede epithermal vein (25b) Comstock epithermal vein (25c) volcanogenic U (25f) carbonate-hosted Au (26a) hot-spring Hg (27a) Almaden Hg (27b) silica-carbonate Hg (27c) simple Sb (27d) Homestake Au (36b) placer Au-PGE (39a) placer PGE-Au (39b)
Ir (see PGE)				
K			(-4) (-5) (-5) 4 (-3) 4	Stillwater Ni-Cu (1) Bushveld Cr (2a) Merensky Reef PGE (2b) diamond pipes (12) emerald veins (31c) unconformity U (37a)
Li			2 4 5 4(dist.) 4 (-3)	carbonatite (10) Sn skarn (14b) replacement Sn (14c) volcanogenic U (25f) rhyolite-hosted Sn (25h) emerald veins (31c)
Mg			5 5 5 5 5 3	Stillwater Ni-Cu (1) Bushveld Cr (2a) Merensky Reef PGE (2b) komatiitic Ni-Cu-(6b) dunitic Ni (6b) kuroko massive sulfide (28a)

Appendix C. Commodity/Geochemical Index--Continued

Element	Primary	By-product	Geochemical anomaly	Deposit type and model number
Mg (cont.)			3	dolomitic Cu-Co
			5	southeast Missouri Pb-Zn (32a)
			5	Appalachian Zn (32b)
			4	emerald veins (31c)
Mn			3	carbonatite (10)
			4	diamond pipes (12)
			4(dist.)	porphyry Cu (17)
			5	Zn-Pb skarn (18c)
			4(dist.)	polymetallic replacement (19a)
	5		5	replacement Mn (19b)
			4(dist.)	porphyry Cu-Au (20c)
			4(dist.)	porphyry Cu-Mo (21a)
			5(dist.)	polymetallic veins (22c)
			4(dist.)	Cyprus massive sulfide (24a)
	5		5	volcanogenic Mn (24c)
			4	Blackbird Co-Cu (24d)
			3	Creede epithermal vein (25b)
	5		5	epithermal Mn (25g)
			4(dist.)	sedimentary exhalative Zn-Pb (31a)
	5		5	sedimentary Mn (34b)
			4	unconformity U (37a)
			4	diamond placers (39d)
Mo			4	carbonatite (10)
		2	5	W skarn (14a)
		2	5	W veins (15a)
		1	5	Sn greisen (15c)
		5	5(prox.)	Climax Mo (16)
		3	5(prox.)	porphyry Cu (17)
		2	5	porphyry Cu, skarn-related (18a)
		1	4	Cu skarn (18b)
		1	5(dist.)	porphyry Cu-Au (20c)
		4	5(prox.)	porphyry Cu-Mo (21a)
	5		5(prox.)	porphyry Mo, low-F (21b)
			5(prox.)	volcanogenic U (25f)
			2	carbonate-hosted Au (26a)
			3	sediment-hosted Cu (30b)
			4	sandstone U (30c)
			2	sedimentary exhalative Zn-Pb (31a)
			(-3)	emerald veins (31c)
			4	southeast Missouri Pb-Zn (32a)
			3	Kipushi Cu-Pb-Zn (32c)
			2	Homestake Au (36b)
			2	unconformity U-Au (37a)
N (as $\text{NH}_4^+$ )			3	carbonate-hosted Au (26a)
			3	sedimentary exhalative Zn-Pb (31a)
			3	phosphate, upwelling type (34c)
			3	phosphate, warm-current type (34d)
Na			(-4)	Stillwater Ni-Cu (1)
			(-5)	Bushveld Cr (2a)
			(-5)	Merensky Reef PGE (2b)
			(-3)	Blackbird Co-Cu (24d)
Nb			(-4)	kuroko massive sulfide (28a)
			(-5)	Cyprus massive sulfide (24a)
			5	emerald veins (31c)
	4	1	4	carbonatite (10)
			4	diamond pipes (12)

Appendix C. Commodity/Geochemical Index--Continued

Element	Primary	By-product	Geochemical anomaly	Deposit type and model number
Nb (cont.)			3	Climax Mo (16)
			4	diamond placers (39d)
Ni	4	1	5	Stillwater Ni-Cu (1)
		2	5	Merensky Reef PGE (2b)
	4	1	5	Duluth Cu-Ni-PGE (5a)
	4	1	5	Noril'sk Cu-Ni-PGE (5b)
	5		5	komatiitic Ni-Cu-(6a)
	5		5	dunitic Ni (6b)
	5		5	synorogenic-synvolcanic Ni-Cu (7a)
	1	3	5	Limassol Forest Co-Ni (8c)
	1	3	5	Alaskan PGE (9)
			5	diamond pipes (12)
			3	Besshi massive sulfide (24b)
		1	4	southeast Missouri Pb-Zn (32a)
			5	unconformity U (37a)
	5		5	lateritic Ni (38a)
			4	diamond placers (39d)
Os (see PGE)				
P	1	1	5	carbonatite (10)
			(-4)	Stillwater Ni-Cu (1)
			(-5)	Bushveld Cr (2a)
			(-5)	Merensky Reef PGE (2b)
			5	anorthosite-Ti (7b)
			4	replacement Mn (19b)
			4	epithermal Mn (25g)
		2	5	volcanic-hosted magnetite (25i)
	5		5	phosphate, upwelling type (34c)
	5		5	phosphate, warm-current type (34d)
Pb			3	carbonatite (10)
			3	Sn skarn (14b)
			4	replacement Sn (14c)
			3	W veins (15a)
			4(dist.)	Climax Mo (16)
			4(dist.)	porphyry Cu (17)
			3	porphyry Cu, skarn-related (18a)
		1	4(dist.)	Cu skarn (18b)
	2	4	5	Zn-Pb skarn (18c)
	4	2	5(dist.)	polymetallic replacement (19a)
			4	replacement Mn (19b)
			4(dist.)	porphyry Sn (20a)
		2	4	Sn-polymetallic veins (20b)
			4(dist.)	porphyry Cu-Au (20c)
			4(dist.)	porphyry Cu-Mo (21a)
			4(dist.)	porphyry Mo, low-F (21b)
			4	Au-Ag-Te veins (22b)
	3	2	5	polymetallic veins (22c)
		4	5	Creede epithermal vein (25b)
		4	5	Comstock epithermal vein (25c)
		3	3(prox.)	epithermal quartz-alunite Au (25e)
			4	epithermal Mn (25g)
			3	rhyolite-hosted Sn (25h)
			3	simple Sb (27d)
	1	3	5	kuroko massive sulfide (28a)
	5		5	sandstone-hosted Pb-Zn (30a)
			3	sediment-hosted Cu (30b)
	4		5	sedimentary exhalative Zn-Pb (31a)
			(-3)	emerald veins (31c)

## Appendix C. Commodity/Geochemical Index--Continued

Element	Primary	By-product	Geochemical anomaly	Deposit type and model number
Pb (cont.)	5		5	southeast Missouri Pb-Zn (32a)
		2	3	Appalachian Zn (32b)
	3	3	5	Kipushi Cu-Pb-Zn (32c)
			4	low-sulfide Au-quartz veins (36a)
			4	Homestake Au (36b)
			4	unconformity U-Au (37a)
Pd (see PGE)				
Pt (incl. all PGE)		4	5	Stillwater Ni-Cu (1)
		4	5	Bushveld Cr (2a)
		5	5	Merensky Reef PGE (2b)
		4	5	Duluth Cu-Ni-PGE (5a)
		4	5	Noril'sk Cu-Ni-PGE (5b)
		3	5	komatiitic Ni-Cu (6a)
		2	5	dunitic Ni (6b)
		1	4	synorogenic-synvolcanic Ni-Cu (7a)
			5	podiform Cr (8a)
	1	3	5	Alaskan PGE (9)
			5	diamond pipes (12)
		1	2	Au-Ag-Te veins (22b)
			2	Homestake Au (28c)
		2	4	quartz pebble conglomerate Au-U (29a)
	1	1	3	placer Au-PGE (39a)
	5		5	placer PGE-Au (39b)
			4	diamond placers (39d)
Rare Earths				
	2	2	5	carbonatite (10)
		1	3	W veins (15a)
			3	volcanogenic U (25f)
			2	rhyolite-hosted Sn (25h)
			3	Olympic Dam Cu-U-Au (29b)
			5	emerald veins (31c)
		1	4	phosphate, upwelling type (34c)
		1	4	phosphate, warm-current type (34d)
			3	unconformity U-Au (37a)
		2	5	shoreline placer Ti (39c)
Rb			5	Sn skarn (14b)
			5	replacement Sn (14c)
			4	Climax Mo (16)
			3(dist.)	porphyry Cu (17)
			4(dist.)	porphyry Cu-Mo (21a)
			3	unconformity U-Au (37a)
Re			4	Sn skarn (14b)
			5	Climax Mo (16)
			5	Porphyry Mo, low-F (21b)
			3	Unconformity U-Au (37a)
Rh (see PGE)				
Ru (see PGE)				
S	1	2	5	kuroko massive sulfide (28a)
	1	2	5	Cyprus massive sulfide (24a)
Sb			3(dist.)	porphyry Cu (17)
			3	polymetallic replacement (19a)

## Appendix C. Commodity/Geochemical Index--Continued

Element	Primary	By-product	Geochemical anomaly	Deposit type and model number
Sb (cont.)			4(dist.)	porphyry Sn (20a)
			4(dist.)	porphyry Cu-Mo (21a)
		3	3	volcanic-hosted Cu-As-Sb (22a)
			4	Au-Ag-Te veins (22b)
			4(dist.)	hot-spring Au-Ag (25a)
			4	Creede epithermal vein (25b)
			4	Comstock epithermal vein (25c)
			4	volcanogenic U (25f)
			3	rhyolite-hosted Sn (25h)
			4	carbonate-hosted Au (26a)
		1	5	hot spring Hg (27a)
			4	Almaden Hg (27b)
			4	silica-carbonate Hg (27c)
	5		5	simple Sb (27d)
			4	kuroko massive sulfide (28a)
			2	sedimentary exhalative Zn-Pb (31a)
			4	Homestake Au (36a)
			2	placer Au-PGE (39a)
			2	placer PGE-Au (39b)
Se			3	porphyry Cu (17)
			2	kuroko massive sulfide (28a)
			5	sandstone U (30c)
Si			5	almost all epigenetic deposits
Sn			1	carbonatite (10)
			5	W skarn (14a)
	3	3	5	Sn skarn (14b)
	5		5	replacement Sn (14c)
		2	5	W veins (15a)
	5		5	Sn veins (15b)
	5		5	Sn greisen (15c)
		2	5(prox.)	Climax Mo (16)
			3(dist.)	porphyry Cu (17)
			3	Zn-Pb skarn (18c)
			1	Fe skarn (18d)
	5		5	porphyry Sn (20a)
	5		5	Sn-polymetallic veins (20b)
			2	volcanic-hosted Cu-As-Sb (22a)
	5		5	rhyolite-hosted Sn (25h)
			4	kuroko massive sulfide (28a)
		1	2	sedimentary exhalative Zn-Pb (31a)
			3	Kipushi Cu-Pb-Zn (32c)
Sr			3	carbonatite (10)
			3	Au-Ag-Te veins (22b)
Ta			1	carbonatite (10)
			3	Climax Mo (16)
Te			4(dist.)	porphyry Cu (17)
			4(dist.)	porphyry Cu-Mo (21a)
			3	polymetallic replacement (19a)
			5	Au-Ag-Te veins (22b)
			3	Comstock epithermal vein (25c)
Te (cont.)			3	Sado epithermal vein (25d)
			3	epithermal quartz-alunite Au (25e)
			3	unconformity U-Au (37a)
Th			5	carbonatite (10)

## Appendix C. Commodity/Geochemical Index--Continued

Element	Primary	By-product	Geochemical anomaly	Deposit type and model number
Th (cont.)		2	5	shoreline placer Ti (39c)
Ti			4	Merensky Reef PGE (2b)
			5	Bushveld Fe-Ti-V (3)
			4	Duluth Cu-Ni-PGE (5a)
	5		5	anorthosite-Ti (7b)
			4	Alaskan PGE (9)
			4	carbonatite (10)
	5		5	diamond pipes (12)
			5	shoreline placer Ti (39c)
			5	diamond placers (39d)
Tl			4(dist.)	hot-spring Au-Ag (25a)
			4	carbonate-hosted Au (26a)
U		1	5	carbonatite (10)
			3(dist.)	Climax Mo (16)
	1	4	4	quartz pebble conglomerate Au-U (29a)
		3	4	Olympic Dam Cu-U-Au (29b)
	5		2	sediment-hosted Cu (30b)
			5	sandstone U (30c)
			2	Kipushi Cu-Pb-Zn (32c)
		2	5	phosphate, upwelling type (34c)
		2	5	phosphate, warm-current type (34d)
	5		5	unconformity U (37a)
		1	5	shoreline placer Ti (39c)
V	3		5	Bushveld Fe-Ti-V (3)
		1	5	anorthosite-Ti (7b)
			4	Alaskan PGE (9)
		1	4	volcanic-hosted magnetite (25i)
			2	sediment-hosted Cu (30b)
	1	4	5	sandstone U (30c)
			3	Kipushi Cu-Pb-Zn (32c)
W			1	carbonatite (10)
	5		5	W skarn (14a)
	5		5	Sn skarn (14b)
		1	4	replacement Sn (14c)
	5		5	W veins (15a)
			5	Sn veins (15b)
		1	5(prox.)	Climax Mo (16)
			3(prox.)	porphyry Cu (17)
			2	porphyry Cu, skarn-related (18a)
		1	3	Zn-Pb skarn (18c)
		2	4	Sn-polymetallic veins (20b)
			4(prox.)	porphyry Cu-Mo (21a)
		1	5(prox.)	porphyry Mo, low-F (21b)
			2	Creede epithermal vein (25b)
			2	Comstock epithermal vein (25c)
			1	epithermal quartz-alunite Au (25e)
			2	volcanogenic U (25f)
		1	3	epithermal Mn (25g)
			4	carbonate-hosted Au (26a)
			4	simple Sb (27d)
			3	Kipushi Cu-Pb-Zn (32c)
Zn		1	4	W skarn (14a)
		1	4	Sn skarn (14b)
			4	replacement Sn (14c)
		1	3	W veins (15a)

## Appendix C. Commodity/Geochemical Index--Continued

Element	Primary	By-product	Geochemical anomaly	Deposit type and model number
Zn (cont.)			3(dist.)	Climax Mo (16)
			4(dist.)	porphyry Cu (17)
			3	porphyry Cu, skarn-related (18a)
		2	4(dist.)	Cu skarn (18b)
	5		5	Zn-Pb skarn (18c)
	4	1	5(dist.)	polymetallic replacement (19a)
			4	replacement Mn (19b)
			4(dist.)	porphyry Sn (20a)
	2	3	5	Sn-polymetallic veins (20b)
			4(dist.)	porphyry Cu-Au (20c)
			4(dist.)	porphyry Cu-Mo (21a)
			3(dist.)	porphyry Mo, low-F (21b)
			4	volcanic-hosted Cu-As-Sb (22a)
			3	Au-Ag-Te veins (22b)
	2	2	4(dist.)	polymetallic veins (22c)
			3	basaltic Cu (23)
		3	5	Cyprus massive sulfide (24a)
		2	5	Besshi massive sulfide (24b)
			3	volcanogenic Mn (24c)
		3	5	Creede epithermal vein (25b)
		2	4(prox.)	epithermal quartz-alunite Au (25e)
			3	rhyolite-hosted Sn (25h)
			3	silica-carbonate Hg (27c)
			3	simple Sb (27d)
	5		5	kuroko massive sulfide (28a)
	1	3	5	sandstone-hosted Pb-Zn (30a)
			3	sediment-hosted Cu (30b)
	5		5	sedimentary exhalative Zn-Pb (31a)
	5		5	southeast Missouri Pb-Zn (32a)
	5		5	Appalachian Zn (32b)
	4	1	5	Kipushi Cu-Pb-Zn (32c)
			3	low-sulfide Au-quartz veins (36a)
			4	Homestake Au (36b)
			3	unconformity U (37a)
Zr			4	anorthosite-Ti (7b)
	1	1	4	carbonatite (10)
		3	5	shoreline placer Ti (39c)



# Appendix D. Mineralogical Index by Paul B. Barton

The mineralogy of the deposits is indicated in six categories describing the mode of occurrence of the mineral. Each category, which constitutes a column, is labeled as follows: "Ore mineral" (the mineral is commonly the source of the metal or other valuable product of the deposit), "Gangue mineral" (the mineral has no value but is closely associated in time and space with the ore minerals), "Host rock mineral" and "Associated rock mineral" (the mineral is characteristic of the rocks in which the deposit is found or with which it is genetically associated), "Alteration mineral" (the mineral is produced in rocks near the deposit by hydrothermal processes related to ore deposition or transport), and "Weathering mineral" (the mineral is produced by weathering or supergene enrichment).

An "ore" mineral is so designated if it is a mineral which under reasonable circumstances might be used to provide a concentrate of a valuable substance. Thus traces of bismuthinite are "ores", as are pyrite or arsenopyrite crystals that carry gold, and so is pyrite in sufficient abundance that it might be used as a source of sulfur. But accessory pyrite without economic values is "gangue" because neither iron nor sulfur would normally be produced from it; multiple entries for some minerals are expected. The "host" category is necessarily incomplete inasmuch as variations in host lithology are not necessarily critical parts of the model; for example a vein could cut a pegmatite containing minerals such as beryl or spodumene, neither of which would be very informative if added to the "host" minerals list.

Numerical values are given as a measure of the degree to which a mineral is present in the deposit of the type considered; the numbers are NOT the amount of mineral, but its universality anywhere in the deposit among all deposits of that class. The values "1", "2", "3", "4", and "5" correspond respectively to 0-10, 10-30, 30-70, 70-90, and 90-100 percent and, until definitive documentation for a given model type is available, will usually be no better than guesses based on experience. The numbers are modified by a letter suffix to give a qualitative estimate of the abundance of the mineral: "m" indicates a major component, which we define as 10 volume percent; "t" indicates traces, which we define as 1 volume percent; intermediate values are given no designation. Detail on the spatial distribution of minerals resides in the models themselves.

Mineral	Ore min- eral	Gangue min- eral	Host rock min- eral	Assoc- iated rock min- eral	Alter- ation min- eral	Weath- ering min- eral	Deposit type and model number
Adularia (also see feldspar)		4 3 4 3 3 3 4 2t					Au-Ag-Te veins (22b) polymetallic veins (22c) hot-spring Au-Ag (25a) Creede epithermal vein (25b) Comstock epithermal vein (25c) Sado epithermal vein (25d) volcanogenic U (25f) rhyolite-hosted Sn (25h) hot-spring Hg (27a) southeast Missouri Pb-Zn (32a)
Albite (also see feldspar)			4		4m 3 4 3 3		W veins (15a) porphyry Cu (17) Besshi massive sulfide (24b) volcanic-hosted magnetite (25i) kuroko massive sulfide (28a) sedimentary exhalative Zn-Pb (31a) emerald veins (31c) low-sulfide Au-quartz veins (36a)

## Appendix D. Mineralogical Index--Continued

Mineral	Ore min- eral	Gangue min- eral	Host rock min- eral	Assoc- iated rock min- eral	Alter- ation min- eral	Weath- ering min- eral	Deposit type and model number
<u>Alleghenyite</u>		2					volcanogenic Mn (24c)
<u>Al oxides and hydroxides</u>							
	5m					5m	bauxite, laterite type (38b)
	5m					5m	bauxite, karst type (38c)
<u>Alunite</u>							Alunite is a common result of the oxidation of sulfides in Al-bearing carbonate-poor rocks.
					3		porphyry Cu (17)
					4		volcanic-hosted Cu-As-Sb (22a)
	3						hot-spring Au-Ag (25a)
	2						Creede epithermal vein (25b)
					3		Sado epithermal vein (25d)
	3				5		epithermal quartz-alunite Au (25e)
					4		volcanogenic U (25f)
			4				hot-spring Hg (27a)
<u>Amphibole</u>							Amphibole is a common late-stage alteration in skarns of all types.
Mn-rich		4			4		Zn-Pb skarn (18c)
actinolite		3			3		porphyry Cu (17)
(includes		3			4		porphyry Cu, skarn-related (18a)
tremolite)		3			3		Cu skarn (18b)
					4		Zn-Pb skarn (18c)
		4				4	porphyry Cu-Au (20c)
			4				Besshi massive sulfide (24b)
					4		volcanic-hosted magnetite (25i)
			3				serpentine-hosted asbestos (8d)
anthophyllite				3	3		kuroko massive sulfide (28a)
cumingtonite			3m	3m			Homestake Au (28c)
<u>Anatase</u>			4			4	bauxite, laterite type (38b)
			4			4	bauxite, karst type (38c)
<u>Andalusite</u>						2	porphyry Cu (17)
					2		porphyry Cu-Mo (21a)
					4		volcanic-hosted Cu-As-Sb (22a)
					3		epithermal quartz-alunite Au (25e)
<u>Anhydrite</u>				3m			Duluth Cu-Ni-PGE (5a)
				3m			Noril'sk Cu-Ni-PGE (5b)
	3				3		porphyry Cu (17)
	3				4		porphyry Cu-Au (20c)
	3				3		porphyry Cu-Mo (21a)
	2						Cyprus massive sulfide (24a)
	2m		1m	2m	2		kuroko massive sulfide (28a)
	2						Olympic Dam Cu-U-Au (29b)
	2						Appalachian Zn (32b)

Appendix D. Mineralogical Index--Continued

Mineral	Ore min- eral	Gangue min- eral	Host rock min- eral	Assoc- iated rock min- eral	Alter- ation min- eral	Weath- ering min- eral	Deposit type and model number
<u>Apatite</u> apatite, (includes fluor- francolite, collophane)							
		3					anorthosite-Ti (7b)
	1m	4					carbonatite (10)
		5					volcanic-hosted magnetite (25i)
	5m						phosphate, upwelling type (34c)
	5m						phosphate, warm-current type (34d)
<u>Antimony</u> (native)	2t						simple Sb (27d)
<u>Argentite</u>							
					5		Argentite is a common product of the supergene enrichment of silver ores.
	3t						polymetallic replacement (19a)
	3t						Sn-polymetallic veins (20b)
	3t						polymetallic veins (22c)
	3t						Creede epithermal vein (25b)
	5t						Comstock epithermal vein (25c)
	4t						Sado epithermal vein (25d)
	2t						simple Sb (27d)
<u>Arsenates</u>							
		3					rhyolite-hosted Sn (25h)
<u>Arsenides</u>							
	4t	2					Merensky Reef PGE (2b)
	3	3					Noril'sk Cu-Ni-PGE (5b)
	1t	3t					dunitic Ni (6b)
	4	4					Limassol Forest Co-Ni (8c)
	3t						Alaskan PGE (9)
		2					Cu skarn (18b)
<u>Arsenopyrite</u>							
	4t						W skarn (14a)
	3						Sn skarn (14b)
	4						replacement Sn (14c)
	5						W veins (15a)
	4						Sn veins (15b)
	5						Sn greisen (15c)
	3						Cu skarn (18b)
	3t						Zn-Pb skarn (18c)
	3						porphyry Sn (20a)
	4						Sn-polymetallic veins (20b)
	2						volcanic-hosted Cu-As-Sb (22a)
	3						polymetallic veins (22c)
	5						Blackbird Co-Cu (24d)
	3						hot-spring Au-Ag (25a)
	2						Creede epithermal vein (25b)
	2						Comstock epithermal vein (25c)
	3t						carbonate-hosted Au (26a)
	3t						simple Sb (27d)
	3t						sedimentary exhalative Zn-Pb (31a)
	1t						southeast Missouri Pb-Zn (32a)

Mineral	Ore min- eral	Gangue min- eral	Host rock min- eral	Assoc- iated rock min- eral	Alter- ation min- eral	Weath- ering min- eral	Deposit type and model number
Arsenopyrite (cont.)		2 4 4 3					Kipushi Cu-Pb-Zn (32c) low-sulfide Au-quartz veins (36a) Homestake Au (36b) unconformity U (37a)
Asbestos (see chrysotile)							
Ba-silicates		4					sedimentary exhalative Zn-Pb (31a)
Barite		4 4 3 3 3 3 4m 4 3 3 5 3 3 2 1m 4 3 1m 5m 3 3 2		1m		4	carbonatite (10) polymetallic replacement (19a) replacement Mn (19b) volcanic-hosted Cu-As-Sb (22a) Au-Ag-Te veins (22b) polymetallic veins (22c) Creede epithermal vein (25b) Comstock epithermal vein (25c) Sado epithermal vein (25d) volcanogenic U (25f) epithermal Mn (25g) volcanic-hosted magnetite (25i) carbonate-hosted Au (26a) simple Sb (27d) kuroko massive sulfide (28a) Olympic Dam Cu-U-Au (29b) sandstone-hosted Pb-Zn (30a) sedimentary exhalative Zn-Pb (31a) bedded barite (31b) southeast Missouri Pb-Zn (32a) Appalachian Zn (32b) gold on flat faults (37b)
Berthierite		2t					simple Sb (27d)
Beryl		3 3t 4 5t					W veins (15a) Sn veins (15b) Sn greisen (15c) emerald veins (31c)
Biotite							Biotite is a common mineral in igneous and metamorphic rocks. carbonatite (10) low-sulfide Au-quartz veins (15d) porphyry Cu (17) porphyry Cu, skarn-related (18a) porphyry Cu-Au (20c) porphyry Cu-Mo (21a) porphyry Mo, low-F (21b) volcanic-hosted magnetite (25i)

Appendix D. Mineralogical Index--Continued

Mineral	Ore min- eral	Gangue min- eral	Host rock min- eral	Assoc- iated rock min- eral	Alter- ation min- eral	Weath- ering min- eral	Deposit type and model number
<u>Bismuth</u>							
	3t						W skarn (14a)
	4t						Sn-polymetallic veins (20b)
	2t						Kipushi Cu-Pb-Zn (32c)
	3t						low-sulfide Au-quartz veins (36a)
<u>Bismuthinite</u>							
	4t						W veins (15a)
	3t						Sn veins (15b)
	4t						Sn greisen (15c)
	3t						Cu skarn (18b)
	3t						Zn-Pb skarn (18c)
	2t						polymetallic replacement (19a)
	4t						Sn-polymetallic veins (20b)
	2t						sedimentary exhalative Zn-Pb (31a)
<u>Boehmite</u>							
	4m						bauxite, karst type (38c)
<u>Bornite</u>							
							Bornite may be a supergene, as well as hypogene, copper mineral.
	3						Noril'sk Cu-Ni-PGE (5b)
	3t						Alaskan PGE (9)
	3t						W skarn (14a)
	3t						W veins (15a)
	2						porphyry Cu (17)
	3						porphyry Cu, skarn-related (18a)
	3						Cu skarn (18b)
	3						Zn-Pb skarn (18c)
	4						porphyry Cu-Au (20c)
	3						volcanic-hosted Cu-As-Sb (22a)
	3						basaltic Cu (23)
	2						Besshi massive sulfide (24b)
	2						Creede epithermal vein (25b)
	3						epithermal quartz-alunite Au (25e)
	3t						silica-carbonate Hg (27c)
	3						kuroko massive sulfide (28a)
	5						Olympic Dam Cu-U-Au (29b)
	3t						sandstone-hosted Pb-Zn (30a)
	4						sediment-hosted Cu (30b)
	2t						sandstone U (30c)
	2						southeast Missouri Pb-Zn (32a)
	5						Kipushi Cu-Pb-Zn (32c)
	2t						gold on flat faults (37b)
<u>Brannerite</u>							
	4t						volcanogenic U (25f)
	4t						quartz pebble conglomerate Au-U (29a)
	4t						Olympic Dam Cu-U-Au (29b)
<u>Bravoite</u>							
	2t						sandstone-hosted Pb-Zn (30a)
	2t						southeast Missouri Pb-Zn (32a)
<u>Brucite</u>							
							serpentine-hosted asbestos (8d)

## Appendix D. Mineralogical Index--Continued

Mineral	Ore min- eral	Gangue min- eral	Host rock min- eral	Assoc- iated rock min- eral	Alter- ation min- eral	Weath- ering min- eral	Deposit type and model number
<u>Buddingtonite</u>		3			3		hot-spring Au-Ag (25a)
<u>Calaverite</u> (see tellurides)							
<u>Carbonates</u> (see specific carbonates below)							Carbonates are very common gangue and host-rock minerals in a wide variety of ores.
		5m			5m		Limassol Forest Co-Ni (8c)
				5m	5m		carbonatite (10)
		5m	5m				W skarn (14a)
			5m				Sn Skarn (14b)
			5m				replacement Sn (14c)
			5m				porphyry Cu, skarn-related (18a)
			5m				Cu skarn (18b)
			5m				Zn-Pb skarn (18c)
			5m				Fe skarn (18d)
		5m	5m				polymetallic replacement (19a)
		5			5		replacement Mn (19b)
		4			3		Au-Ag-Te veins (22b)
		4			3		polymetallic veins (22c)
			3				basaltic Cu (23)
4							Besshi massive sulfide (24b)
		4m					volcanogenic Mn (24c)
		4					Creede epithermal vein (25b)
		3			3		Comstock epithermal vein (25c)
5		4					Sado epithermal vein (25d)
			5				epithermal Mn (25g)
					3		carbonate-hosted Au (26a)
			3m	3m			volcanic-hosted magnetite (25i)
			5m		4		silica-carbonate Hg (27c)
							Olympic Dam Cu-U-Au (29b)
							Kipushi Cu-Pb-Zn (32c)
<u>ankerite</u>		3					carbonatite (10)
		3					polymetallic veins (22c)
		3					low-sulfide Au-quartz veins (36a)
			3m	3m			Homestake Au (36b)
<u>calcite</u>		4m					carbonatite (10)
		3m					Sn greisen (15c)
					2		porphyry Cu (17)
		4	4				replacement Mn (19b)
		4					Au-Ag-Te veins (22b)
		3			3		polymetallic veins (22c)
		4			3		basaltic Cu (23)
					2		Cyprus massive sulfide (24a)
		3					Creede epithermal vein (25b)
		4					Comstock epithermal vein (25c)
		3			3		Sado epithermal vein (25d)
					2		epithermal quartz-alunite Au (25e)
		4					epithermal Mn (25g)
		4					Almaden Hg (27b)
		4					simple Sb (27d)

Appendix D. Mineralogical Index--Continued

Mineral	Ore min- eral	Gangue min- eral	Host rock min- eral	Assoc- iated rock min- eral	Alter- ation min- eral	Weath- ering min- eral	Deposit type and model number
calcite (cont.)		3 4 4m 4 4					emerald veins (31c) sandstone-hosted Pb-Zn (30a) phosphate, upwelling type (34c) phosphate, warm-current type (34d) unconformity U (38d)
dolomite		4m 4 4 2 5 5 5m 4 4m 4m 4	3 3m 5m		4m 4 5 3 5 5m 5m 4m 4		carbonatite (10) polymetallic replacement (19a) replacement Mn (19b) Au-Ag-Te veins (22b) polymetallic veins (22c) silica-carbonate Hg (27c) sedimentary exhalative Zn-Pb (31a) emerald veins (31c) southeast Missouri Pb-Zn (32a) Appalachian Zn (32b) Kipushi Cu-Pb-Zn (32c) Superior Fe (34a) phosphate, upwelling type (34c) phosphate, warm-current type (34d) unconformity U (37b)
rhodochrosite		2 3 3 3 5m 3 4m 4 3 3 5m 3m			3		carbonatite (10) Climax Mo (16) Zn-Pb skarn (18c) polymetallic replacement (19a) replacement Mn (19b) polymetallic veins (22c) volcanogenic Mn (24c) Creede epithermal vein (25b) Comstock epithermal vein (25c) Sado epithermal vein (25d) epithermal Mn (25g) sedimentary Mn (34b)
siderite		3 3 3 2t 3m 3 3 3 3			4m 3 3 3 3 3 3 3 3 3 3m 3m		replacement Sn (14c) Sn-polymetallic veins (20b) carbonatite (10) polymetallic veins (22c) Creede epithermal vein (25b) simple Sb (27d) Algoma Fe (28b) Kipushi Cu-Pb-Zn (32c) Superior Fe (34a) phosphate, upwelling type (34c) low-sulfide Au-quartz veins (36a) Homestake Au (36b) unconformity U (37a)
Carnotite						5 3t	sandstone U (30c) phosphate, upwelling type (34c)

## Appendix D. Mineralogical Index--Continued

Mineral	Ore min- eral	Gangue min- eral	Host rock min- eral	Assoc- iated rock min- eral	Alter- ation min- eral	Weath- ering min- eral	Deposit type and model number
<u>Carrollite</u>							
	3t						Limassol Forest Co-Ni (8c)
	3t						Olympic Dam Cu-U-Au (29b)
	3t						sediment-hosted Cu (30b)
	4t						Kipushi Cu-Pb-Zn (32c)
<u>Cassiterite</u>							
	3t						W skarn (14a)
	5						Sn skarn (14b)
	5						replacement Sn (14c)
	4t						W veins (15a)
	5						Sn veins (15b)
	5						Sn greisen (15c)
	3t						Climax Mo (16)
	1t						Fe skarn (18d)
	5						porphyry Sn (20a)
	5						Sn-polymetallic veins (20b)
	5						rhyolite-hosted Sn (25h)
	1t						sedimentary exhalative Zn-Pb (31a)
<u>Celestite</u>							
		3					Au-Ag-Te veins (22b)
<u>Chalcedony</u> (includes opal)							
		4					replacement Mn (19b)
		5			5		volcanic-hosted Cu-As-Sb (22a)
		3					polymetallic veins (22c)
		5					Cyprus massive sulfide (24a)
		5m					hot-spring Au-Ag (25a)
		5m					Creede epithermal vein (25b)
		4m					Comstock epithermal vein (25c)
		4m					Sado epithermal vein (25d)
		3					epithermal quartz-alunite Au (25e)
		4m					volcanogenic U (25f)
		5					epithermal Mn (25g)
		5					rhyolite-hosted Sn (25h)
		5					hot-spring Hg (27a)
					4		silica-carbonate Hg (27c)
		2					simple Sb (27d)
<u>Chalcocite</u> and related $Cu_xS$ phases							
						5	Chalcocite and related $Cu_xS$ minerals are extremely common as supergene alterations of copper-bearing sulfides and as supergene replacements of chalcopyrite and, to a lesser extent, other primary sulfides.
	3						volcanic-hosted Cu-As-Sb (22a)
	4						basaltic Cu (23)
	2t						volcanic-hosted magnetite (25i)
	1t						simple Sb (27d)
	5						Olympic Dam Cu-U-Au (29b)



Appendix D. Mineralogical Index--Continued

Mineral	Ore min- eral	Gangue min- eral	Host rock min- eral	Assoc- iated rock min- eral	Alter- ation min- eral	Weath- ering min- eral	Deposit type and model number
<u>Chalcocite</u>							
and related							
$Cu_xS$							
phases (cont.)							
	2t						sandstone-hosted Pb-Zn (30a)
	4					4	sediment-hosted Cu (30b)
	2						southeast Missouri Pb-Zn (32a)
	4						Kipushi Cu-Pb-Zn (32c)
<u>Chalcopyrite</u>							
	5						Stillwater Ni-Cu (1)
	5t						Bushveld Cr (2a)
	5t						Merensky Reef PGE (2b)
	5						Duluth Cu-Ni-PGE (5a)
	5						Noril'sk Cu-Ni-PGE (5b)
	5						komatiitic Ni-Cu (6a)
	5t						dunitic Ni (6b)
	5						synorogenic-synvolcanic Ni-Cu (7a)
	4t						Limassol Forest Co-Ni (8c)
	3t						Alaskan PGE (9)
	5t						carbonatite (10)
	4t						W skarn (14a)
	3t						Sn skarn (14b)
	4t						replacement Sn (14c)
	5t						W veins (15a)
	4t						Sn veins (15b)
	4t						Sn greisen (15c)
	5						porphyry Cu (17)
	5						porphyry Cu, skarn-related (18a)
	5						Cu skarn (18b)
	4						Zn-Pb skarn (18c)
	4t						Fe skarn (18d)
	4t						polymetallic replacement (19a)
	3t						replacement Mn (19b)
	4t						porphyry Sn (20a)
	5						Sn-polymetallic veins (20b)
	5						porphyry Cu-Au (20c)
	5						porphyry Cu-Mo (21a)
	3t						porphyry Mo, low-F (21b)
	4						volcanic-hosted Cu-As-Sb (22a)
	4						polymetallic veins (22c)
	4						basaltic Cu (23)
	5						Cyprus massive sulfide (24a)
	5						Besshi massive sulfide (24b)
	5						Blackbird Co-Cu (24d)
	3t						hot-spring Au-Ag (25a)
	5						Creede epithermal vein (25b)
	4t						Comstock epithermal vein (25c)
	5t						Sado epithermal vein (25d)
	4						epithermal quartz-alunite Au (25e)
	3						volcanic-hosted magnetite (25i)
	4t						silica-carbonate Hg (27c)
	3t						simple Sb (27d)
	5						kuroko massive sulfide (28a)
	5						Olympic Dam Cu-U-Au (29b)
	4t						sandstone-hosted Pb-Zn (30a)
	4						sediment-hosted Cu (30b)
	3t						sandstone U (30c)

## Appendix D. Mineralogical Index--Continued

Mineral	Ore min- eral	Gangue min- eral	Host rock min- eral	Assoc- iated rock min- eral	Alter- ation min- eral	Weath- ering min- eral	Deposit type and model number
<u>Chalcopyrite (cont.)</u>							
	4t						sedimentary exhalative Zn-Pb (31a)
	4t						southeast Missouri Pb-Zn (32a)
	4						Kipushi Cu-Pb-Zn (32c)
	4t						low-sulfide Au-quartz veins (36a)
	3t						Homestake Au (36b)
	4t						unconformity U (37a)
	4t						gold on flat faults (37b)
<u>Chert</u>							
				4m			Cyprus massive sulfide (24a)
				4m			volcanogenic Mn (24c)
			4m	1m			kuroko massive sulfide (28a)
	5m		5m	5m			Algoma Fe (28b)
	4m		4m	4m			sedimentary exhalative Zn-Pb (31a)
	5m		5m				Superior Fe (34a)
			5m	5m			Homestake Au (36b)
<u>Chlorite</u>							
	3				3		Sn skarn (14b)
					4m		W veins (15a)
					4m		Sn veins (15b)
					3m		Sn greisen (15c)
	2				4		porphyry Cu (17)
				4	3		porphyry Cu, skarn-related (18a)
							Cu skarn (18b)
					3		Zn-Pb skarn (18c)
	4				4		Fe skarn (18d)
					2		polymetallic replacement (19a)
					3		porphyry Sn (20a)
					4		Sn-polymetallic veins (20b)
					4		porphyry Cu-Mo (21a)
					4		porphyry Mo, low-F (21b)
	4				4		polymetallic veins (22c)
	3				5m		Cyprus massive sulfide (24a)
		5					Besshi massive sulfide (24b)
					5m		Blackbird Co-Cu (24d)
					3		hot-spring Au-Ag (25a)
	4				4		Creede epithermal vein (25b)
	3				4		Comstock epithermal vein (25c)
	3				4		Sado epithermal vein (25d)
					3		epithermal quartz-alunite Au (25e)
					4		hot-spring Hg (27a)
					3		simple Sb (27d)
				3	4		kuroko massive sulfide (28a)
	3				5		Olympic Dam Cu-U-Au (29b)
					5		sediment-hosted Cu (30b)
					4		sedimentary exhalative Zn-Pb (31a)
	3				3		low-sulfide Au-quartz veins (36a)
	4		4	4			Homestake Au (36b)
	5				5m		unconformity U (37a)
					5m		gold on flat faults (37b)
<u>Chromite</u>							
	5m			3t			Bushveld Cr (2a)
	3			3t			Merensky Reef PGE (2b)
		4		5			dunitic Ni (6b)
	5m			5			podiform Cr (8a)

## Appendix D. Mineralogical Index--Continued

Mineral	Ore min- eral	Gangue min- eral	Host rock min- eral	Assoc- iated rock min- eral	Alter- ation min- eral	Weath- ering min- eral	Deposit type and model number
<u>Chromite</u> (cont.)	5m		3	3 5			Limassol Forest Co-Ni (8c) Alaskan PGE (9) diamond pipes (12) placer PGE-Au (39b)
		4 4					
<u>Chrysotile</u>	5 5						serpentine-hosted asbestos (8d) carbonate-hosted asbestos (18e)
<u>Cinnabar</u>	3t 5 5 5						carbonate-hosted Au (26a) hot-spring Hg (27a) Almaden Hg (27b) silica-carbonate Hg (27c)
<u>Clays</u> (see specific clays below)							Clays are very common minerals in soils and sedimentary rocks as well as in altered rocks associated with ores.
					4 3 3 3 3 5 4 4 5 4 5 3 5 5 5 3 5 4 5 4		porphyry Cu (17) porphyry Cu, skarn-related (18a) Cu skarn (18b) polymetallic replacement (19a) porphyry Sn (20a) porphyry Cu-Au (20c) porphyry Cu-Mo (21a) Mo porphyry, low-F (21b) volcanic-hosted Cu-As-Sb (22a) polymetallic veins (22c) Creede epithermal vein (25b) Comstock epithermal vein (25c) Sado epithermal vein (25d) epithermal quartz-alunite Au (25e) volcanogenic U (25f) rhyolite-hosted Sn (25h) carbonate-hosted Au (26a) simple Sb (27d) phosphate, upwelling type (34c) phosphate, warm-current type (34d)
		3 3					
		5m 5m					
ammonium- bearing					3 3 3		epithermal quartz-alunite Au (25e) carbonate-hosted Au (26a) sedimentary exhalative Zn-Pb (31a)
illite					4 4 5 4		Cyprus massive sulfide (24a) Creede epithermal vein (25b) Comstock epithermal vein (25c) carbonate-hosted Au (26a)
kaolinite and dickite							
					5m		Kaolinite is commonly formed through the reaction of sulfuric acid derived from oxidizing sulfides with felsic rocks.

## Appendix D. Mineralogical Index--Continued

Mineral	Ore min- eral	Gangue min- eral	Host rock min- eral	Assoc- iated rock min- eral	Alter- ation min- eral	Weath- ering min- eral	Deposit type and model number
kaolinite and dickite (cont.)							
					4	4	porphyry Cu (17)
					5		porphyry Cu-Au (20c)
					5		porphyry Cu-Mo (21a)
					5		volcanic-hosted Cu-As-Sb (22a)
					3		Comstock epithermal vein (25c)
		3			4		Sado epithermal vein (25d)
					5		epithermal quartz-alunite Au (25e)
					5		volcanogenic U (25f)
					5		epithermal Mn (25g)
					3		rhyolite-hosted Sn (25h)
					2		volcanic-hosted magnetite (25i)
				5	4		carbonate-hosted Au (32a)
		4t					hot-spring Hg (27a)
					3		southeast Missouri Pb-Zn (32a)
							unconformity U (37a)
montmorillonite (smectite)							
					4		Creede epithermal vein (25b)
					4		Comstock epithermal vein (25c)
					4		Sado epithermal vein (25d)
					3		epithermal quartz-alunite Au (25e)
					4		volcanogenic U (25f)
					3		rhyolite-hosted Sn (25h)
					3		carbonate-hosted Au (26a)
					2		kuroko massive sulfide (28a)
sericite							
					4		porphyry Sn (20a)
					4		Sn-polymetallic veins (20b)
					4		porphyry Cu-Mo (21a)
					4		Au-Ag-Te veins (22b)
					5		polymetallic veins (22c)
					4		Besshi massive sulfide (24b)
					4		Creede epithermal vein (25b)
					4		Comstock epithermal vein (25c)
					4		Sado epithermal vein (25d)
					3		volcanic-hosted magnetite (25i)
					4		simple Sb (27d)
					3		kuroko massive sulfide (28a)
					5		Olympic Dam Cu-U-Au (29b)
					3t		sandstone-hosted Pb-Zn (30a)
					4		unconformity U (38d)
<u>Co-bearing</u> <u>arsenides,</u> <u>sulfides</u> <u>and sulf-</u> <u>arsenides</u>							
	3t						Stillwater Ni-Cu (1)
	2t						dunitic Ni (6b)
	4t						Limassol Forest Co-Ni (8c)
	2						Cu skarn (18b)
	2						Fe skarn (18d)
	2t						Besshi massive sulfide (24b)

## Appendix D. Mineralogical Index--Continued

Mineral	Ore min- eral	Gangue min- eral	Host rock min- eral	Assoc- iated rock min- eral	Alter- ation min- eral	Weath- ering min- eral	Deposit type and model number
<u>Co-bearing arsenides, sulfides and sulf- arsenides (cont.)</u>	5 4t 3 2t 2t 4t						Blackbird Co-Cu (24d) Olympic Dam Cu-U-Au (29b) sediment-hosted Cu (30b) sedimentary exhalative Zn-Pb (31a) southeast Missouri Pb-Zn (32a) Kipushi Cu-Pb-Zn (32c)
<u>Coffinite</u>	5t 4t 5t 4t						volcanogenic U (25f) Olympic Dam Cu-U-Au (29b) sandstone U (30c) unconformity U (38d)
<u>Copper (native)</u>						3	Native copper is a common mineral in oxidized copper ores; it also occurs as a trace deuteritic mineral in some mafic rocks. basaltic Cu (23) sediment-hosted Cu (30b)
	4 3t						
<u>Cordierite</u>				2	2		kuroko massive sulfide (28a)
<u>Corundum</u>					1t 2t		porphyry Cu (17) epithermal quartz-alunite Au (25e)
<u>Covellite</u>							Covellite is a very common supergene mineral in oxidized copper ores. volcanic-hosted Cu-As-Sb (22a) epithermal quartz-alunite Au (25e) volcanic-hosted magnetite (25i) southeast Missouri Pb-Zn (32a)
	3 4 2 2t						
<u>Cubanite</u>	4 4 2 3t 3t						Duluth Cu-Ni-PGE (5a) Noril'sk Cu-Ni-PGE (5b) dunitic Ni (6b) Cyprus massive sulfide (24a) Besshi massive sulfide (24b)
<u>Diamond</u>	5tt 5tt						diamond pipes (12) diamond placers (39d)
<u>Diaspore</u>	2				2 3 3		porphyry Cu (17) volcanic-hosted Cu-As-Sb (22a) epithermal quartz-alunite Au (25e)
<u>Diopside (see pyroxenes)</u>							

## Appendix D. Mineralogical Index--Continued

Mineral	Ore min- eral	Gangue min- eral	Host rock min- eral	Assoc- iated rock min- eral	Alter- ation min- eral	Weath- ering min- eral	Deposit type and model number
<u>Dumortierite</u>					3		volcanic-hosted Cu-As-Sb (22a)
<u>Enargite-luzonite</u>							
	2t						W veins (15a)
	2t						Cu skarn (18b)
	3						polymetallic replacement (19a)
	5						volcanic-hosted Cu-As-Sb (22a)
	5						epithermal quartz-alunite Au (25e)
	1t						sedimentary exhalative Zn-Pb (31a)
	1t						southeast Missouri Pb-Zn (32a)
	2						Kipushi Cu-Pb-Zn (32c)
<u>Epidote</u>		3t			3		porphyry Cu (17)
					3		Cu skarn (18b)
		4			4		Fe skarn (18d)
		4					basaltic Cu (23)
					4		volcanic-hosted magnetite (25i)
<u>Ferrimolybdate</u>						4t	Ferrimolybdate is a common oxidation product in Mo-bearing ores.
<u>Fletcherite</u> (see sulfospinels)							
<u>Fluorite</u>							
	4						carbonatite (10)
	4t						W skarn (14a)
	4						Sn skarn (14b)
	5						replacement Sn (14c)
	4						W veins (15a)
	4				3		Sn greisen (15c)
	5				3		Climax Mo (16)
	2						Zn-Pb skarn (18c)
	3						replacement Mn (19b)
	3				3		Sn-polymetallic veins (20b)
	4						Au-Ag-Te veins (22b)
	4						polymetallic veins (22c)
	3						hot-spring Au-Ag (25a)
	3						Creede epithermal vein (25b)
	4						Comstock epithermal vein (25c)
	4						volcanogenic U (25f)
	3				3		rhyolite-hosted Sn (25h)
					2		volcanic-hosted magnetite (25i)
	3						carbonate-hosted Au (26a)
	2						simple Sb (27d)
	4t				4t		Olympic Dam Cu-U-Au (29b)
	3t						sandstone-hosted Pb-Zn (30a)
	5						emerald veins (31c)
	2t						Appalachian Zn (32b)
	3t						low-sulfide Au-quartz veins (36a)
	2t						Homestake Au (36b)
	3t						gold on flat faults (37b)

## Appendix D. Mineralogical Index--Continued

Mineral	Ore min- eral	Gangue min- eral	Host rock min- eral	Assoc- iated rock min- eral	Alter- ation min- eral	Weath- ering min- eral	Deposit type and model number
<u>Ga minerals</u>							
	2t						Kipushi Cu-Pb-Zn (32c)
<u>Gahnite</u>				3			kuroko massive sulfide (28a)
<u>Galena</u>	3t						carbonatite (10)
	2						replacement Sn (14c)
	2t						W veins (15a)
	3t						Sn veins (15b)
	3t						Sn greisen (15c)
	2t						porphyry Cu, skarn-related (18a)
	3t						Cu skarn (18b)
	5						Zn-Pb skarn (18c)
	4						polymetallic replacement (19a)
	2t						replacement Mn (19b)
	4t						Sn-polymetallic veins (20b)
	2						porphyry Cu-Mo (21a)
	4						Au-Ag-Te veins (22b)
	4						polymetallic veins (22c)
	3t						Besshi massive sulfide (24b)
	5						Creede epithermal vein (25b)
	4						Comstock epithermal vein (25c)
	4t						Sado epithermal vein (25d)
	4t						epithermal quartz-alunite Au (25e)
	4t						silica-carbonate Hg (27c)
	2t						simple Sb (27d)
	4						kuroko massive sulfide (28a)
	5						sandstone-hosted Pb-Zn (30a)
	2t						sediment-hosted Cu (30b)
	2t						sandstone U (30c)
	5						sedimentary exhalative Zn-Pb (31a)
	3t						bedded barite (31b)
	5						southeast Missouri Pb-Zn (32a)
	2t						Appalachian Zn (32b)
	3						Kipushi Cu-Pb-Zn (32c)
	4t						low-sulfide Au-quartz veins (36a)
	4t						unconformity U-Au (37a)
<u>Garnet</u>							Garnet is a common mineral in most skarns, in some regionally metamorphosed rocks, and in some igneous rocks.
almandine		3			3		W skarn (14a)
andradite		3m			4m		W skarn (14a)
					4m		Cu skarn (18b)
					4		volcanic-hosted magnetite (25i)
(Sn-bearing)					3		Sn skarn (14b)
and.-gros.-spess.					4		Zn-Pb skarn (18c)

## Appendix D. Mineralogical Index--Continued

Mineral	Ore min- eral	Gangue min- eral	Host rock min- eral	Assoc- iated rock min- eral	Alter- ation min- eral	Weath- ering min- eral	Deposit type and model number
Garnet (cont.)							
grossular- andradite		3m			5m 3 4 5		W skarn (14a) porphyry Cu, skarn-related (18a) Zn-Pb skarn (18c) Fe skarn (18d)
pyrope			5 4				diamond pipes (12) diamond placers (39d)
spessartine					3 4 3		Climax Mo (16) Zn-Pb skarn (18c) W skarn (14a) volcanogenic Mn (24c)
		3					
uvarovite			3				podiform Cr (8a)
Garnierite							
	5					5	lateritic Ni (38a)
Ge minerals							
	2t						sediment-hosted Cu (30b)
	5t						Kipushi Cu-Pb-Zn (32c)
Gold							
	3t						Alaskan PGE (9)
	4t						porphyry Cu (17)
	2t						polymetallic replacement (19a)
	4t						Sn-polymetallic veins (20b)
	5t						porphyry Cu-Au (20c)
	4t						porphyry Cu-Mo (21a)
	4t						volcanic-hosted Cu-As-Sb (22a)
	5t						polymetallic veins (22c)
	4t						Cyprus massive sulfide (24a)
	5t						hot-spring Au-Ag (25a)
	4t						Creede epithermal vein (25b)
	5t						Comstock epithermal vein (25c)
	5t						Sado epithermal vein (25d)
	5t						epithermal quartz-alunite Au (25e)
	3t						volcanogenic U (25f)
	5t						carbonate-hosted Au (26a)
	3t						simple Sb (27d)
	4t						kuroko massive sulfide (28a)
	5t						quartz pebble conglomerate Au-U (29a)
	4t						Olympic Dam Cu-U-Au (29b)
	5t						low-sulfide Au-quartz veins (36a)
	5t						Homestake Au (36b)
	3t						unconformity U-Au (37a)
	5t						gold on flat faults (37b)
	5t						placer Au-PGE (39a)
	4t						placer PGE-Au (39b)
Graphite							
	3t			3t			Merensky reef PGE (2b)
	3			3			Duluth Cu-Ni-PGE (5a)



## Appendix D. Mineralogical Index--Continued

Mineral	Ore min- eral	Gangue min- eral	Host rock min- eral	Assoc- iated rock min- eral	Alter- ation min- eral	Weath- ering min- eral	Deposit type and model number
<u>Graphite</u> (cont.)							
	3			3			synorogenic-synvolcanic Ni-Cu (7a)
	2						simple Sb (27d)
				4			kuroko massive sulfide (28a)
<u>Greenockite</u>							
						4t	Greenockite is a common trace mineral developed in the early stages of oxidation of cadmium-bearing sphalerite. Greenockite is rare as a primary mineral.
	2t						sediment-hosted Cu (30b)
<u>Gypsum</u>							
	2t						Appalachian Zn (32b)
	3						phosphate, upwelling type (34c)
			2	2			kuroko massive sulfide (28a)
<u>Halite</u>							
	3						Halite occurs as a daughter mineral in fluid inclusions from many porphyry copper and molybdenum deposits and from a few other deposits.
<u>Hematite</u>							
						5	Hematite is a common weathering product of iron minerals.
		3					Carbonatite (10)
		4				3	Sn veins (15b)
		3					porphyry Cu, skarn-related (18a)
		3					Cu skarn (18b)
		3					polymetallic veins (22c)
						3	basaltic Cu (23)
						3	volcanogenic Mn (24c)
		3					Creede epithermal vein (25b)
		4				2	Comstock epithermal vein (25c)
		5					rhyolite-hosted Sn (25h)
		1t		3			kuroko massive sulfide (28a)
	4m					5m	Algoma Fe (28b)
		5				5	Olympic Dam Cu-U-Au (29b)
				4			sediment-hosted Cu (30b)
				4			sandstone U (30c)
	5m					5m	Superior Fe (34a)
		3				3	unconformity U (37a)
		5					gold on flat faults (37b)
<u>Hematite/Goethite</u>							
						4	Hematite and goethite are common weathering products of iron-bearing sulfides. They are often grouped under the blanket term "limonite."
		4					carbonate-hosted Au (26a)
				5			hot-spring Hg (27a)
		4					phosphate, upwelling type (34c)
in ochre						4	Cyprus massive sulfide (24a)

## Appendix D. Mineralogical Index--Continued

Mineral	Ore min- eral	Gangue min- eral	Host rock min- eral	Assoc- iated rock min- eral	Alter- ation min- eral	Weath- ering min- eral	Deposit type and model number
<u>Idocrase</u>					3 2		Sn skarn (14b) porphyry Cu, skarn-related (18a)
<u>Illite</u> (see clays)							
<u>Ilmenite</u>							Ilmenite is a common accessory mineral in igneous and metamorphic rocks.
	1	3		4			Bushveld Cr (2a)
	5m	4		5			Bushveld Fe-Ti-V (3)
			5				anorthosite-Ti (7b)
		3					diamond pipes (12)
		4					replacement Sn (14c)
		4					placer Au-PGE (39a)
	5	4					placer PGE-Au (39b)
		4					shoreline placer Ti (39c)
							diamond placers (39d)
<u>Ilvaite</u>					3 3		Zn-Pb skarn (18c) Fe skarn (18d)
<u>Jarosite</u>						4	Jarosite is a common product of the supergene oxidation of iron sulfides.
					4		carbonate-hosted Au (26a)
<u>Jasperoid</u> (includes silicification in carbonate rocks)							Jasperoid here refers to massive silica replacement of pre-existing (usually carbonate) rock.
					5		polymetallic replacement (19a)
					3		polymetallic veins (22c)
					5m		hot-spring Au-Ag (25a)
					5m		silica-carbonate Hg (27c)
					5m		carbonate-hosted Au (26a)
					3m		sedimentary exhalative Zn-Pb (31a)
					3m		southeast Missouri Pb-Zn (32a)
					4m		Appalachian Zn (32b)
					3m		Kipushi Cu-Pb-Zn (32c)
<u>Kaolinite</u> (see clays)							
<u>K-feldspar</u> (also see adularia)							Potassium feldspar is a common mineral in most types of felsic igneous, metamorphic and sedimentary rocks. Several lower temperature hydrothermal deposits contain the adularia variety (separate listing).
		3			4m		W veins (15a)
		4m			5m		Climax Mo (16)
		3			4		porphyry Cu (17)
		2			3		porphyry Cu, skarn-related (18a)
		3			4		porphyry Cu-Au (20c)
		4			4		porphyry Cu-Mo (21a)
		4			4		porphyry Mo, low-F (21b)
		3					basaltic Cu (23)
					4		volcanic-hosted magnetite (25i)

## Appendix D. Mineralogical Index--Continued

Mineral	Ore min- eral	Gangue min- eral	Host rock min- eral	Assoc- iated rock min- eral	Alter- ation min- eral	Weath- ering min- eral	Deposit type and model number
<u>Leucoxene</u>		3					volcanogenic U (25f)
<u>Linneaite</u> (also see sulfospinel)							
	2t						dunitic Ni (6b)
	3t						sandstone-hosted Pb-Zn (30a)
	3t						Kipushi Cu-Pb-Zn (32c)
<u>Luzonite</u> (see enargite-luzonite)							
<u>Magnetite</u>							Magnetite is a common accessory mineral in many types of rocks.
		4		4			Bushveld Cr (2a)
	5m			5			Bushveld Fe-Ti-V (3)
		4		5			dunitic Ni (6b)
		3		4			synorogenic-synvolcanic Ni-Cu (7a)
	5						anorthosite-Ti (7b)
		3		3			podiform Cr (8a)
		3		4			Limassol Forest Co-Ni (8c)
		4					serpentine-hosted asbestos (8d)
	3m		3	4			Alaskan PGE (9)
	4m						carbonatite (10)
		3		3			W skarn (14a)
		3					Sn skarn (14b)
		3					replacement Sn (14c)
		3			2		porphyry Cu (17)
		3			3		porphyry Cu, skarn-related (18a)
		4					Cu skarn (18b)
		3					Zn-Pb skarn (18c)
	5m						Fe skarn (18d)
		3					Sn-polymetallic veins (20b)
		4			4		porphyry Cu-Au (20c)
		4					Besshi massive sulfide (24b)
		5					Blackbird Co-Cu (24d)
	5m						volcanic-hosted magnetite (25i)
		3		2			kuroko massive sulfide (28a)
	5m						Algoma Fe (28b)
					2		Olympic Dam Cu-U-Au (29b)
		2t					southeast Missouri Pb-Zn (32a)
	5m						Superior Fe (34a)
		4	4	4			Homestake Au (36b)
		5					placer Au-PGE (39a)
		5					placer PGE-Au (39b)
<u>Ti-rich</u>							
	5m						Bushveld Fe-Ti-V (3)
	5m						anorthosite Ti (7b)
	4m						Alaskan PGE (9)
<u>V-rich</u>							
	5m						Bushveld Fe-Ti-V (3)
	4m						Alaskan PGE (9)
<u>Malayaite</u>							
	2t				2		Sn skarn (14b)

## Appendix D. Mineralogical Index--Continued

Mineral	Ore min- eral	Gangue min- eral	Host rock min- eral	Assoc- iated rock min- eral	Alter- ation min- eral	Weath- ering min- eral	Deposit type and model number
<u>Marcasite</u>							
		4				4	Marcasite is common as an incipient stage in the oxidation of pyrrhotite.
		2					polymetallic replacement (19a)
		5					Cyprus massive sulfide (24a)
		2t					hot-spring Hg (27a)
		3t					simple Sb (27d)
		3					sandstone-hosted Pb-Zn (30a)
		4t					sandstone U (30c)
		4					sedimentary exhalative Zn-Pb (31a)
		4t					southeast Missouri Pb-Zn (32a)
		2					Appalachian Zn (32b)
							Kipushi Cu-Pb-Zn (32c)
<u>Melnikovite</u>							
		2t					sedimentary exhalative Zn-Pb (31a)
<u>Mercury</u> (native)							
	4t						hot-spring Hg (27a)
	4t						Almaden Hg (27b)
	4t						silica-carbonate Hg (27c)
<u>Millerite</u>							
	3t						Noril'sk Cu-Ni-PGE (5b)
	2t						sandstone-hosted Pb-Zn (30a)
	2t						sedimentary exhalative Zn-Pb (31a)
	2t						southeast Missouri Pb-Zn (32a)
<u>Mn oxides</u> <u>and silicates</u>							
				3			These are common oxidation products of manganese-bearing ores.
	5m					5m	replacement Mn (19b)
	4m						Cyprus massive sulfide (24a)
							volcanogenic Mn (24c)
						5m	sedimentary Mn (34b)
<u>Molybdenite</u>							
	4t						carbonatite (10)
	4t						W skarn (14a)
	5t						W veins (15a)
	4t						Sn veins (15b)
	5t						Sn greisen (15c)
	5						Climax Mo (16)
	4						porphyry Cu (17)
	3t						porphyry Cu, skarn-related (18a)
	3t						Cu skarn (18b)
	3t						Sn-polymetallic veins (20b)
	5t						porphyry Cu-Mo (21a)
	5t						porphyry Mo, low-F (21b)
	4t						volcanogenic U (25f)
	2t						sandstone U (30c)
	2t						sedimentary exhalative Zn-Pb (31a)
	2t						Kipushi Cu-Pb-Zn (32c)
	2t						low-sulfide Au-quartz veins (36a)
	3t						Homestake Au (36b)

## Appendix D. Mineralogical Index--Continued

Mineral	Ore min- eral	Gangue min- eral	Host rock min- eral	Assoc- iated rock min- eral	Alter- ation min- eral	Weath- ering min- eral	Deposit type and model number
<u>Muscovite</u>							
		4m		5	5m		Muscovite is a common mineral in igneous and metamorphic rocks. It also occurs as in some felsic skarns, in veins, and as the fine-grained, wallrock alteration known as sericite (see clays).
		4		4	4		Sn skarn (14b)
		3			5m		replacement Sn (14c)
		4m			5m		W veins (15a)
		2			5m		Sn veins (15b)
					4m		Sn greisen (15c)
		2m			3m		Climax Mo (16)
					4		porphyry Cu (17)
					3		porphyry Cu, skarn-related (18a)
							southeast Missouri Pb-Zn (32a)
<u>Cr-rich</u>							
					3		low-sulfide Au-quartz veins (36a)
					3		Homestake Au (36b)
<u>V-rich</u>							
		3			4		Au-Ag-Te veins (22b)
							sandstone U (30c)
<u>Ni silicates</u>							
		5				5	lateritic Ni (38a)
<u>Ni sulfides, arsenides, and sulfarsenides</u> (see also pentlandite)							
		5					dunitic Ni (6b)
		5					Limassol Forest Co-Ni (8c)
		3t					sandstone-hosted Pb-Zn (30a)
		4t					southeast Missouri Pb-Zn (32a)
		3t					unconformity U (37a)
<u>Niobium minerals</u>							
		4					carbonatite (10)
<u>Olivine</u>							
			4m				Olivine is a common mineral in mafic igneous rocks (including those associated with models 1 through 12).
<u>Organic matter</u>							
		5			5		Organic matter is found in many sedimentary and a few metamorphic rocks. The ore types noted here are those for which some relationship is probable.
		5					carbonate-hosted Au (26a)
				3			silica-carbonate Hg (27c)
							kuroko massive sulfide (28a)
			4				quartz pebble conglomerate Au-U (29a)

## Appendix D. Mineralogical Index--Continued

Mineral	Ore min- eral	Gangue min- eral	Host rock min- eral	Assoc- iated rock min- eral	Alter- ation min- eral	Weath- ering min- eral	Deposit type and model number
<u>Organic matter</u>							
		4t	4t				sandstone-hosted Pb-Zn (30a)
			4				sediment-hosted Cu (30b)
			5				sandstone U (30c)
			4	4			sedimentary exhalative Zn-Pb (31a)
		3	2				southeast Missouri Pb-Zn (32a)
		4t	4				Kipushi Cu-Pb-Zn (32c)
		2t					unconformity U-Au (37a)
<u>Orpiment</u>							
		3					volcanogenic U (25f)
		5					carbonate-hosted Au (26a)
<u>Pentlandite</u>							
	5						Stillwater Ni-Cu (1)
	4t						Bushveld Cr (2a)
	5t						Merensky Reef PGE (2b)
	5						Duluth Cu-Ni-PGE (5a)
	5						Noril'sk Cu-Ni-PGE (5b)
	5						komatiitic Ni-Cu (6a)
	5						dunitic Ni (6b)
	5						synorogenic-synvolcanic Ni-Cu (7a)
	3						Limassol Forest Co-Ni (8c)
	2t						Alaskan PGE (9)
<u>PGE minerals</u>							
	5t						Stillwater Ni-Cu (1)
	4t						Bushveld Cr (2a)
	5t						Merensky Reef PGE (2b)
	5t						Duluth Cu-Ni-PGE (5a)
	5t						Noril'sk Cu-Ni-PGE (5b)
	4t						komatiitic Ni-Cu (6a)
	3t						podiform Cr (8a)
	5t						Alaskan PGE (9)
	4t						quartz pebble conglomerate Au-U (29a)
	2t						placer Au-PGE (39a)
	5t						placer PGE-Au (39b)
<u>Phlogopite</u>							
			4				carbonatite (10)
			5				diamond pipes (12)
		4					diamond placers (39d)
<u>Phosphates</u>							
	1m	5					carbonatite (10)
	5m					5m	phosphate, upwelling type (34c)
	5m					5m	phosphate, warm-current type (34d)
<u>Plagioclase</u> (also see albite)							
			4m		1		Plagioclase feldspar is a common mineral in igneous and metamorphic rocks associated with deposit types 1 through 10.
		5			5		emerald veins (31c)

## Appendix D. Mineralogical Index--Continued

Mineral	Ore min- eral	Gangue min- eral	Host rock min- eral	Assoc- iated rock min- eral	Alter- ation min- eral	Weath- ering min- eral	Deposit type and model number
<u>Pyrite</u>							
				4			Pyrite is a very common and abundant mineral in many ore deposits and as the product of sulfidic alteration of Fe-bearing wallrocks.
				4			Duluth Cu-Ni-PGE (5a)
	3						Noril'sk Cu-Ni-PGE (5b)
	4						komatiitic Ni-Cu (6a)
	4						dunitic Ni (6b)
	3						synorogenic-synvolcanic Ni-Cu (7a)
	4						Limassol Forest Co-Ni (8c)
	4						carbonatite (10)
	3				4		W skarn (14a)
	4				3		Sn skarn (14b)
	3						replacement Sn (14c)
	4				4		W veins (15a)
	5						Sn veins (15b)
	4						Sn greisen (15c)
	4						Climax Mo (16)
	5				4		porphyry Cu (17)
	4				2		porphyry Cu, skarn-related (18a)
	5						Cu skarn (18b)
	4						Zn-Pb skarn (18c)
	4						Fe skarn (18d)
	5				3		polymetallic replacement (19a)
	4						replacement Mn (19b)
	5						porphyry Sn (20a)
	5						Sn-polymetallic veins (20b)
					3		porphyry Cu-Au (20c)
	5				5		porphyry Cu-Mo (21a)
	5				5		porphyry Mo, low-F (21b)
	5				5		volcanic-hosted Cu-As-Sb (22a)
	5				5		Au-Ag-Te veins (22b)
	5				5		polymetallic veins (22c)
			3				basaltic Cu (23)
1m	5m						Cyprus massive sulfide (24a)
	5m						Besshi massive sulfide (24b)
	5						Blackbird Co-Cu (24d)
	5						hot-spring Au-Ag (25a)
	5				5		Creede epithermal vein (25b)
	5				5		Comstock epithermal vein (25c)
	4						Sado epithermal vein (25d)
	5				5		epithermal quartz-alunite Au (25e)
	5						volcanogenic U (25f)
	2						volcanic-hosted magnetite (25i)
	5						carbonate-hosted Au (26a)
	5						hot-spring Hg (27a)
	5						silica-carbonate Hg (27c)
	4						simple Sb (27d)
	5m				5		kuroko massive sulfide (28a)
			4				quartz pebble conglomerate Au-U (29a)
	4t						sandstone-hosted Pb-Zn (30a)
	4						sediment-hosted Cu (30b)
	5						sandstone U (30c)
	4m						sedimentary exhalative Zn-Pb (31a)
	3t						bedded barite (31b)
	5						emerald veins (31c)
	5						southeast Missouri Pb-Zn (32a)

## Appendix D. Mineralogical Index--Continued

Mineral	Ore min- eral	Gangue min- eral	Host rock min- eral	Assoc- iated rock min- eral	Alter- ation min- eral	Weath- ering min- eral	Deposit type and model number
<u>Pyrite</u> (cont.)		4 5 4t 5 5 3					Appalachian Zn (32b) Kipushi Cu-Pb-Zn (32c) phosphate, upwelling type (34c) low-sulfide Au-quartz veins (36a) Homestake Au (36b) unconformity U (37a)
<u>Pyrophyllite</u>					2 2 3 2 4		porphyry Cu (17) porphyry Cu-Mo (21a) volcanic-hosted Cu-As-Sb (22a) hot-spring Au-Ag (25a) epithermal quartz-alunite Au (25e)
<u>Pyroxene</u>							Pyroxene is a common rock-forming mineral in mafic igneous rocks and in metamorphic rocks associated with some deposit types 1 through 10.
		4			5 5 5m		carbonatite (10) Cu skarn (18b) Zn-Pb skarn (18c) Fe skarn (18d) shoreline placer Ti (39c)
diopside			4				
		4m			5m 3 4m 5m 4		diamond pipes (12) W skarn (14a) porphyry Cu, skarn-related (18a) Cu skarn (18b) Fe skarn (18d) volcanic-hosted magnetite (25i)
hedenbergite		4m			5m 5m 5		W skarn (14a) Fe skarn (18d) Zn-Pb skarn (18c)
Mn-rich		2			4		Zn-Pb skarn (18c)
<u>Pyrrhotite</u>		5m 5t 5 3t 5m 5m 5m 5 5 3 4 4 4 4m		3 3			Stillwater Ni-Cu (1) Bushveld Cr (2a) Merensky Reef PGE (2b) Bushveld Fe-Ti-V (3) Duluth Cu-Ni-PGE (5a) Noril'sk Cu-Ni-PGE (5b) komatiitic Ni-Cu (6a) dunitic Ni (6b) synorogenic-synvolcanic Ni-Cu (7a) Limassol Forest Co-Ni (8c) Alaskan PGE (9) carbonatite (10) W skarn (14a) Sn skarn (14b) replacement Sn (14c)



## Appendix D. Mineralogical Index--Continued

Mineral	Ore min- eral	Gangue min- eral	Host rock min- eral	Assoc- iated rock min- eral	Alter- ation min- eral	Weath- ering min- eral	Deposit type and model number
<u>Pyrrhotite (cont.)</u>							
		3					W veins (15a)
		3					porphyry Cu, skarn-related (18a)
		3					Cu skarn (18b)
		4					Zn-Pb skarn (18c)
		4					Fe skarn (18d)
		1					polymetallic replacement (19a)
		3					porphyry Sn (20a)
		5					Sn-polymetallic veins (20b)
		3m					Cyprus massive sulfide (24a)
1m		4m					Besshi massive sulfide (24b)
		5					Blackbird Co-Cu (24d)
		3m					kuroko massive sulfide (28a)
		2t					sandstone-hosted Pb-Zn (30a)
		3m					sedimentary exhalative Zn-Pb (31a)
		1t					southeast Missouri Pb-Zn (32a)
		3					low-sulfide Au-quartz veins (36a)
		4					Homestake Au (36b)
<u>Quartz</u>							
		4m	4m	4m	3m	3m	Quartz is almost universal in hydrothermal ores and a common and abundant constituent of most rocks.
<u>Rare earth-bearing minerals</u>							
		4					carbonatite (10)
					3t		W veins (15a)
		2t					volcanogenic U (25f)
5t							Olympic Dam Cu-U-Au (29b)
		5t					emerald veins (31c)
3							shoreline placer Ti (39c)
<u>Realgar</u>							
		4					hot-spring Au-Ag (25a)
		3t					volcanogenic U (25f)
		5					carbonate-hosted Au (26a)
		1t					Homestake Au (36b)
<u>Rhodonite</u>							
					3		Climax Mo (16)
3							replacement Mn (19b)
					3		Zn-Pb skarn (18c)
4							volcanogenic Mn (24c)
<u>Rutile</u>							
		2					anorthosite Ti (7b)
							carbonatite (10)
		2					porphyry Cu (17)
					4t		porphyry Cu-Mo (21a)
					4t		Olympic Dam Cu-U-Au (29b)
					4t		emerald veins (31c)
4		5t					shoreline placer Ti (39c)
<u>Scapolite</u>							
					3		volcanic-hosted magnetite (25i)

Appendix D. Mineralogical Index--Continued

Mineral	Ore min- eral	Gangue min- eral	Host rock min- eral	Assoc- iated rock min- eral	Alter- ation min- eral	Weath- ering min- eral	Deposit type and model number
<u>Scheelite</u>							
	5						W skarn (14a)
	4t						Sn skarn (14b)
	4t						W veins (15a)
	3t						Sn veins (15b)
	2t						porphyry Cu, skarn-related (18a)
	2t						Zn-Pb skarn (18c)
	3t						Sn-polymetallic veins (20b)
	4t						porphyry Mo, low-F (21b)
	3t						simple Sb (27d)
	3t						low-sulfide Au-quartz veins (36a)
	3t						Homestake Au (36b)
<u>Selenides</u>							
	2t						hot-spring Au-Ag (25a)
	3t						Comstock epithermal vein (25c)
	2t						sandstone U (30c)
<u>Serpentine</u>							
			4m	4m			Serpentine minerals are the common products of the low-temperature metamorphism of ultramafic and mafic rocks.
					5m		serpentine-hosted asbestos (8d)
		3					carbonatite (10)
			5m				diamond pipes (12)
					5m		carbonate-hosted asbestos (18e)
			5m				silica-carbonate Hg (27c)
					2		simple Sb (27d)
<u>Silver (native)</u>							
							Native silver is a common weathering product of silver-bearing sulfide ores.
	4t						basaltic Cu (23)
	2t					3t	Creede epithermal vein (25b)
	4t						Olympic Dam Cu-U-Au (29b)
	4t						sediment-hosted Cu (30b)
<u>Silver sulfides and sulfosalts</u>							
	4t					4t	Argentite and a wide variety of silver sulfosalts are common products of the oxidation and supergene enrichment of silver-bearing sulfide ores.
	1t						porphyry Cu-Mo (21a)
	4t						porphyry Mo, low-F (21b)
	4t						polymetallic veins (22c)
	5t						Creede epithermal vein (25b)
	4t						Comstock epithermal vein (25c)
	5t						Sado epithermal vein (25d)
	5t						epithermal quartz-alunite Au (25e)
	2t						simple Sb (27d)
	4t						kuroko massive sulfide (28a)
	2t						sandstone-hosted Pb-Zn (30a)
	3t						sedimentary exhalative Zn-Pb (31a)

Appendix D. Mineralogical Index--Continued

Mineral	Ore min- eral	Gangue min- eral	Host rock min- eral	Assoc- iated rock min- eral	Alter- ation min- eral	Weath- ering min- eral	Deposit type and model number
<u>Spessartite</u>							
see Garnet							
<u>Sphalerite</u>							
	4t						carbonatite (10)
	4t						W skarn (14a)
	4t						Sn skarn (14b)
	3t						replacement Sn (14c)
	4t						W veins (15a)
	3t						Sn veins (15b)
	3t						Sn greisen (15c)
	3						porphyry Cu, skarn-related (18a)
	4						Cu skarn (18b)
	5						Zn-Pb skarn (18c)
	5						polymetallic replacement (19a)
	3t						replacement Mn (19b)
	4						porphyry Sn (20a)
	5						Sn-polymetallic veins (20b)
	3						porphyry Cu-Mo (21a)
	3						volcanic-hosted Cu-As-Sb (22a)
	3						Au-Ag-Te veins (22b)
	5						polymetallic veins (22c)
	3t						basaltic Cu (23)
	4						Cyprus massive sulfide (24a)
	5						Besshi massive sulfide (24b)
	4t						hot-spring Au-Ag (25a)
	5						Creede epithermal vein (25b)
	4						Comstock epithermal vein (25c)
	4t						Sado epithermal vein (25d)
	4t						epithermal quartz-alunite Au (25e)
	4t						silica-carbonate Hg (27c)
	3t						simple Sb (27d)
	5						Kuroko massive sulfide (28a)
	5						sandstone-hosted Pb-Zn (30a)
	3t						sediment-hosted Cu (30b)
	2t						sandstone U (30c)
	5m						sedimentary exhalative Zn-Pb (31a)
	3t						bedded barite (31b)
	5						southeast Missouri Pb-Zn (32a)
	5						Appalachian Zn (32b)
	4						Kipushi Cu-Pb-Zn (32c)
	3						Homestake Au (36b)
	3t						unconformity U-Au (37a)
<u>Sphene</u>							
		3					carbonatite (10)
					2t		porphyry Cu (17)
		5t					volcanic-hosted magnetite (25i)
<u>Spinel</u>							
		4					carbonatite (10)
<u>Stannite</u>							
	3t						replacement Sn (14c)
	4t						Sn veins (15b)
	2t						Zn-Pb skarn (18c)
	4t						porphyry Sn (20a)
	4t						Sn polymetallic veins (20b)

## Appendix D. Mineralogical Index--Continued

Mineral	Ore min- eral	Gangue min- eral	Host rock min- eral	Assoc- iated rock min- eral	Alter- ation min- eral	Weath- ering min- eral	Deposit type and model number
<u>Stibnite</u>							
	3						Au-Ag-Te veins (22b)
	3t						hot-spring Au-Ag (25a)
	2t						Creede epithermal vein (25b)
	3t						carbonate-hosted Au (26a)
	4t						silica-carbonate Hg (27c)
	5						simple Sb (27d)
	2t						Homestake Au (36b)
<u>Strontianite</u>							
	3						carbonatite (10)
<u>Sulfosalts</u>							
							The term "sulfosalts" is here used to represent all of the minerals that combine silver or base metal sulfides with As- Sb- or Bi-sulfides; enargite-luzonite and tetrahedrite-tennantite fall within this broad usage, but the Fe, Co and Ni sulfarsenides and sulfantimonides do not.
	4t						replacement Sn (14c)
	4t						W veins (15a)
	3t						Sn greisen (15c)
	3t						porphyry Cu, skarn-related (18a)
	4t						Cu skarn (18b)
	5t						polymetallic replacement (19a)
	4t						Sn-polymetallic veins (20b)
	3t						porphyry Cu-Mo (21a)
	3t						porphyry Mo, low-F (21b)
	5						volcanic-hosted Cu-As-Sb (22a)
	4t						Au-Ag-Te veins (22b)
	4t						polymetallic veins (22c)
	3t						Besshi massive sulfide (24b)
	5t						Creede epithermal vein (25b)
	5t						Comstock epithermal vein (25c)
	5t						Sado epithermal vein (25d)
	5t						epithermal quartz-alunite Au (25e)
	4t						simple Sb (27d)
	5t						kuroko massive sulfide (28a)
	4t						sandstone-hosted Pb-Zn (30a)
	4t						sedimentary exhalative Zn-Pb (31a)
	1t						southeast Missouri Pb-Zn (32a)
	5						Kipushi Cu-Pb-Zn (32c)
	3t						Homestake Au (36b)
	3t						unconformity U (37a)
<u>Sulfospinel</u>							
							(also see carrollite, linneite)
	2t						dunitic Ni (6b)
	3t						Olympic Dam Cu-U-Au (29b)
	3t						sandstone-hosted Pb-Zn (30a)
	3t						sediment-hosted Cu (30b)
	2t						southeast Missouri Pb-Zn (32a)
	3t						Kipushi Cu-Pb-Zn (32c)

## Appendix D. Mineralogical Index--Continued

Mineral	Ore min- eral	Gangue min- eral	Host rock min- eral	Assoc- iated rock min- eral	Alter- ation min- eral	Weath- ering min- eral	Deposit type and model number
<u>Sulfur</u> (native)						2t	Native sulfur is sometimes found as an intermediate stage in the oxidation of sulfide ores. epithermal quartz-alunite Au (25e) hot-spring Hg (27a)
	2	3 4			2		
<u>Sylvanite</u> (see tellurides)							
<u>Talc</u>		3					serpentine-hosted asbestos (8d)
<u>Tantalum minerals</u>	3t						carbonatite (10)
<u>Tellurides</u>	5t 3t 3t 3t 4t 2t 3t 2t 2t 2t 5t 4t 3t 4t 3t 2t						Au-Ag-Te veins (22b) hot-spring Au-Ag (25a) Creede epithermal vein (25b) Comstock epithermal vein (25c) Sado epithermal vein (25d) simple Sb (27d) low-sulfide Au-quartz veins (36a) unconformity U-Au (37a) polymetallic replacement (19a) porphyry Cu-Au (20c) Au-Ag-Te veins (22b) hot-spring Au-Ag (25a) Comstock epithermal vein (25c) Sado epithermal vein (25d) epithermal quartz-alunite Au (25e) simple Sb (27d)
<u>Tennantite- tetrahedrite</u>	3t 3t 3t 4t 4 3t 4t 4 4 3t 5t 4t 3t 4t 3t 2t 5 3t						replacement Sn (14c) W veins (15a) porphyry Cu, skarn-related (18a) Cu skarn (18b) polymetallic replacement (19a) porphyry Cu-Mo (21a) porphyry Mo, low-F (21b) volcanic-hosted Cu-As-Sb (22a) Au-Ag-Te veins (22b) polymetallic veins (22c) Besshi massive sulfide (24b) Creede epithermal vein (25b) Sado epithermal vein (25d) simple Sb (27d) kuroko massive sulfide (28a) sandstone-hosted Pb-Zn (30a) sedimentary exhalative Zn-Pb (31a) southeast Missouri Pb-Zn (32a) Kipushi Cu-Pb-Zn (32c) Homestake Au (36b)

## Appendix D. Mineralogical Index--Continued

Mineral	Ore min- eral	Gangue min- eral	Host rock min- eral	Assoc- iated rock min- eral	Alter- ation min- eral	Weath- ering min- eral	Deposit type and model number
<u>Topaz</u>	4 3 2  3			3	3 4		Sn skarn (14b) replacement Sn (14c) Sn veins (15b) Sn greisen (15c) Climax Mo (16)
<u>Tourmaline</u>		4 3 3 4 4m 2 4 4 3  5   3		3       3 3 3	3 4 4m 2 3   3 2		Sn skarn (14b) replacement Sn (14c) W veins (15a) Sn veins (15b) Sn greisen (15c) porphyry Cu (17) porphyry Sn (20a) Sn-polymetallic veins (20b) volcanic-hosted Cu-As-Sb (22a) Besshi massive sulfide (24b) Blackbird Co-Cu (24d) volcanic-hosted magnetite (25i) kuroko massive sulfide (28a) Olympic Dam Cu-U-Au (29b) sedimentary exhalative Zn-Pb (31a) Homestake Au (36b)
<u>Tungstenite</u>	2t						Kipushi Cu-Pb-Zn (32c)
<u>Ulvospinel</u>	3						anorthosite-Ti (7b)
<u>Uraninite</u>							
crystalline							
4t							quartz pebble conglomerate Au-U (29a)
5t							unconformity U (37a)
pitchblende							
5t							volcanogenic U (25f)
5t							sandstone U (30c)
5t							unconformity U (37a)
<u>V-oxides</u>							
4t						4t	sandstone U (30c)
<u>Valleriite</u>							
3t							Noril'sk Cu-Ni-PGE (5b)
2t							Besshi massive sulfide (24b)
2t							sedimentary exhalative Zn-Pb (31a)
<u>Vanadates</u>						4	sandstone U (30c)
<u>Witherite</u>		3t					bedded barite (31b)

## Appendix D. Mineralogical Index--Continued

Mineral	Ore min- eral	Gangue min- eral	Host rock min- eral	Assoc- iated rock min- eral	Alter- ation min- eral	Weath- ering min- eral	Deposit type and model number
<u>Wolframite</u>	3t						W skarn (14a)
	5						W veins (15a)
	4						Sn veins (15b)
	3						Sn greisen (15c)
	3t						Climax Mo (16)
	4						Sn-polymetallic veins (20b)
	3t						epithermal quartz-alunite Au (25e)
	2t						simple Sb (27d)
	2t						Homestake Au (36b)
<u>Wollastonite</u>					4m		W skarn (14a)
					4		porphyry Cu, skarn-related (18a)
					4		Cu skarn (18b)
<u>Zeolites</u>		4			4		basaltic Cu (23)
		5					epithermal Mn (25g)
		4					rhyolite-hosted Sn (25h)
				2	4		hot-spring Hg (27a)
		3					kuroko massive sulfide (28a)
							phosphate, warm-current type (34d)
<u>Zinnwaldite</u>		2t			2		W veins (15a)
<u>Zircon</u>		3t					anorthosite Ti (7b)
		3t					carbonatite (10)
	4t						shoreline placer Ti (39c)
<u>Zunyite</u>					3		epithermal quartz-alunite Au (25e)

# Appendix E. Index of Deposits

Name	Country	Model No	Name	Country	Model No
Aarja	OMAN	24a	Alaska	ZIMB	30b
Abbott	USCA	27c	Albert	CNQU	28a
Abdasht	IRAN	8a	Albert Lea Group	USAZ	22c
Aberfoyle	AUTS	15b	Albino	CNON	36b
Abeshiro (Sakura)	JAPN	28a	Aldermac	CNQU	28a
Abitibi	CNQU	8d	Aleksandrovskii Log	URRS	39b
Abra Negra	MXCO	25g	Aleshinka	URRS	18d
Abruzzi	ITLY	38c	Alex Hill-Mad Kiss	GUYN	36a
Abu Tartur	EGPT	34c	Alexii-Olginsky Log	URRS	39b
Abuhemsin (Abiulya)	TRKY	24c	Alice	USCA	36a
Abundancia	TRKY	24c	Alice Louise	NCAL	8a
Ace of Spades	USCA	8a	Alice Mine	USCA	8a
Acetitillar	DMRP	38c	Allan (Johnson)	USCA	8a
Achilles	NZLD	36a	Allard River	CNQU	28a
Adaevka	URRS	18d	Alleghany	USCA	36a
Adak-Lindskold	SWDN	28a	Alligator Ridge	USNV	26a
Adana-Saimbeyli	TRKY	38c	Alma (Mills) Placer	USCO	39a
Adanae (Ruby Creek)	CNBC	21b	Almaden	SPAN	27b
Adelung Creek	AUNS	39a	Almagrera-Lapilla	SPAN	28a
Adobe Canyon	USCA	8a	Almeirim	BRZL	38b
Adventure Creek	AUQL	15b	Alpha	NCAL	8a
Advocate	CNNF	8d	Alpine-Lafatsch	ASTR-ITLY-	
Aetna	USCA	27c		YUGO	32a, 32b
Affoh	GHNA	38b	Alta Hill	USCA	8a
Afterthought	USCA	28a	Altamira-Frontera	VNZL	34a, 28b
Afton	CNBC	20c	Altenberg	GRME	15c
Agalteca	HNDR	18d	Althouse	USOR	8a
Agassiz	CNMN	36b	Altindag	TRKY	8a
Agnes Waters	AUQL	39c	Alto	USCA	36a
Agnew (Perseverance)	AUWA	6b	Altoona-Elkhor-Mercury	CNBC	22c
Agnico Eagle	CNQU	36b	Alumen	MZMB	38b
Agordo-Brosso	ITLY	18b	Alyce and Blue Jay	USCA	8a
Agrokipia	CYPS	24a	Am	CNBC	17
Aguilar	AGTN	18c	Amacan	PLPN	17
Aijala	FNLD	28a	Amador City	USCA	36a
Ain Mokra	ALGR	18d	Amapa	BRZL	34a, 28b
Ain Oudrer	ALGR	18d	Amaz	CNMN	6b
Ajax (Monte Carlo)	CNBC	17	Amazon	USMT	22c
Ajax	USOR	8a	Ambatory	MDGS	38a
Ajax (Dak River)	CNBC	21b	Ambelikou	CYPS	24a
Ajo	USAZ	17	American Asbestos	USCA	8a
Akarca	TRKY	8a	American Bar	USCA	36a
Akarsen	TRKY	28a	American Fork	USUT	19a
Akashat	IRAQ	34c	Amigos	MXCO	25h
Akatani	JAPN	18d	Ammeberg	SWDN	18c
Akcabuk	TRKY	8a	Amores	CUBA	8a
Akcakilise Topkirazlar	TRKY	24c	Amphoe Phra Saeong	THLD	27d
Akenobe	JAPN	20b	Ample	CNBC	36a
Akeski	TRKY	38c	Amulet	CNQU	28a
Akinokawa (Onishi)	JAPN	24b	An-shan	CINA	34a, 28b
Akkoy	TRKY	28a	Ana Yatak-Ergani	TRKY	24a
Akkoya	TRKY	8a	Analavory	MDGS	38b
Akoluuk	TRKY	24c	Analumay	MDGS	38a
Akseki Gokceovacik	TRKY	24c	Anantagiri	INDA	38b
Aktyubinsk	URRS	34c	Anayatak-Cakmakkaya	TRKY	28a
Akulla Vastra	SWDN	28a	Anchor	AUTS	15c
Akviran	TRKY	34b	Andacolla	CILE	17
Al	AUVT	36a	Anderson Lake	CNMN	28a
Al-Hasa/Oatrana	JRDN	34c	Andhra Pradesh	INDA	34b
Alabama bauxite	USAL	38c	Andizlik	TRKY	8a
Alabama Shoot	AUVT	36a	Anduramba	AUQL	21b
Alagada	PORT	18d	Angelo	AUWA	28a



Name	Country	Model No	Name	Country	Model No
Angels-Carson	USCA	36a	Atlas	USCA	36a
Anianowsky Lojok	URRS	39b	Auerbach	URUR	18d
Animas	USCO	25b	Augusto Luis & others	CUBA	24c
Ankerite-Aunor-Delnite	CNON	36b	Aurora	USNV	25c
Ann	CNBC	17	Aurora	USOR	25f
Ann Mason	USNV	17	Aurukum	AUQL	38b
Anna Madeleine	NCAL	8a	Austin Brook	CNNB	28a
Anne	NRWY	28a	Austinvilla	USVA	32a, 32b
Ansongo	MALI	34b	Aventura	CUBA	8a
Anti Axis	USCA	8a	Avispa	CUBA	24c
Antimonial	USNV	27d	Avoca	IRLD	28a
Antimony Canyon	USUT	27d	Avsar	TRKY	8a
Antimony King	USNV	27d	Awaso	GHNA	38b
Antimony Lode	USNV	27d	Axe	CNBC	17
Antimony Mines	USMT	27d	Aya Aya	PLPN	17
Antimony Ridge	USID	27d	Ayazmant	TRKY	18d
Antler	USAZ	28a	Ayekoye	GNEA	38b
Antoine	CNBC	22c	Aznacollar	SPAN	28a
Antonio	CUBA	24c	Azul-Carajas	BRZL	34b
Apex (Del Norte Co.)	USCA	8a	B and B	USNV	27a
Apex (El Dorado Co.)	USCA	8a	B. C.	CNBC	18b
Apex Antimony	USNV	27d	B. C. Moly	CNBC	21b
Apex Mines	USUT	32c	Babcock	USOR	8a
Apiki	CYPS	24a	Babyfoot	USOR	8a
Applegate	USOR	8a	Badger	USAZ	22c
Arad	ISRL	34c	Bagacay	PLPN	28a
Araluen Valley	AUNS	39a	Bagby	USCA	36a
Aravaipa	USAZ	18c	Bagby Valley	USCA	36a
Araxa	BRZL	10	Bagdad	USAZ	17
Archer	AUTS	15c	Baghain	IRAN	18d
Arctic	USAK	28a	Bagin	TRKY	8a
Arctic Chief	CNYT	18b	Bagirsakdire	TRKY	8a
Argo	USCA	36a	Bailadila	INDA	34a, 28b
Argonaut	CNBC	18d	Bailadores	VNZL	28a
Arguillillas	MXCO	25h	Bailey	CNYT	14a
Argus Hill	AUVT	36a	Baisoara	RMNA	18d
Arie	PPNG	17	Bajo	JAPN	25d
Arinteiro	SPAN	24a	Bakerville	AUQL	15b
Arkhangelskii Log	URRS	39b	Bakhuis Mountains	SRNM	38b
Arlington	CNBC	22c	Balaklala	USCA	28a
Armour Group	USAZ	25g	Balcicakiri	TRKY	8a
Armstrong (A)	CNNB	28a	Bald Mountain	USME	28a
Arnold Hill	USNY	25i	Baldwin	USNV	27a
Arrieros	MXCO	25h	Balea-Sitaouma	MALI	38b
Arrowhead	CNQU	36b	Ballarat	AUVT	36a
Arroyo Durango	MXCO	25h	Ballynoe	IRLD	31b
As Safra	SAAR	28a	Balmat	USNY	31a
Asafo	GHNA	38b	Baltic and Revenue	USCO	22c
Asagi Zorkum	TRKY	8a	Baltimore	USMT	22c
Asakawa	JAPN	24b	Baluba	ZMBA	30b
Asbestos Hill	CNQU	8d	Bama	SPAN	24a
Asbestos Island	CNQU	8d	Bamble	NRWY	7a
Asen	SWDN	28a	Bamboutos	CMRN	38b
Ash Shizm	SAAR	28a	Ban Ban	AUQU	18c
Ashio	JAPN	20b	Bandgan	PKTN	28a
Ashland	USOR	36a	Bangam	CMRN	38b
Ashley	CNON	36b	Bankfield-Tombill	CNON	36b
Associated Chromite	USOR	8a	Bannack	USMT	39a
Asvan	TRKY	18d	Barao de Cocais-Caete	BRZL	38b
Atacocha	PERU	19a	Barbara-Surprise	AUWA	36b
Atenguillo	MXCO	25g	Barber-Larder	CNON	36b
Atlanta	USNV	26a	Barberton	SAFR	36b
Atlas	PLPN	20c	Barite (Mouse)	CNYT	31b
Atlas	USAZ	19b	Barite Mtn.	CNYT	31b

Name	Country	Model No	Name	Country	Model No
Barite Valley	SAFR	31b	Bethlehem	CNBC	21a
Barlo	PLPN	24a	Betts Cove	CNNF	24a
Baroi	INDA	31a	Bezkere-Bulurlii	TRKY	8a
Barra do Pirai	BRZL	38b	Bhaynagar	INDA	38b
Barrandum	USCA	36a	Bhimatangar	INDA	38a
Barrett	USME	28a	Bicholim	INDA	34a,28b
Barrington Lake	CNMN	28a	Bicir-Cakir	TRKY	8a
Barro Alto	BRZL	38a	Bicir-Gul	TRKY	8a
Barry Hollinger	CNON	36b	Bidgood-Modfatt-Hall	CNON	36b
Barrytown	NZLD	39c	Bidjovagge	NRWY	28a
Barvallee-Mogador	CNQU	28a	Bielgorsky Log	URRS	39b
Basay	PLPN	17	Big Badja River	AUNS	39a
Baskoy	TRKY	28a	Big Bear	USOR	8a
Basset	GRBR	15b	Big Bell	AUWA	36b
Bathurst-Norsemines	CNNT	28a	Big Ben	USMT	16
Bati	TRKY	8a	Big Bend	USCA	28a
Bati-Taban	TRKY	8a	Big Bend	USCA	8a
Batikef	TRKY	8a	Big Chief	USOR	8a
Baw Hin Khao	THLD	31b	Big Cottonwood	USUT	19a
Bawdin	BRMA	28a	Big Dipper	USCA	8a
Bayda	OMAN	24a	Big Four	USFL	34d
Bear	USNV	17	Big Four	USMT	22c
Bear Mountain	USNM	19b	Big Four	USOR	8a
Bear Valley	USCA	36a	Big Hill	USME	28a
Beat	USCA	8a	Big Horn (Yarrow Ck)	CNAL	30b
Beatson	USAK	28a	Big Mike	USNV	24a
Beaver Dam	CNNS	36a	Big Oak Flat	USCA	36a
Beceite-Fuendesplada	SPAN	38c	Big Onion	CNBC	17
Beck	USCA	18d	Big Pine Claim	USCA	8a
Bedford Hill	CNQU	28a	Big Syncline	SAFR	31a
Beersheva	ISRL	34c	Big Yank No. 1	USOR	8a
Belden	USCA	36a	Bihar	INDA	38b
Bell	CNBC	22c	Bilaspur	INDA	38b
Bell	USNV	19a	Binder No. 1	USCA	8a
Bell Allard	CNQU	28a	Bingham	USUT	17
Bell Boy-Niles-Towsley	USMT	22c	Binghampton	USAZ	28a
Bell Channel	CNQU	28a	Bingo	ZIRE	10
Bell Copper	CNBC	20c	Bintan Island	INDS	38b
Bell Molybdenum	CNBC	21b	Birch Lake	CNSK	28a
Bell and California	USCO	22c	Birch Tree	CNMN	6b
Bella Oak	USCA	27c	Birchfield	NZLD	39c
Bellacoscia	NCAL	8a	Birchfield	USNM	19b
Bellary	INDA	34a,28b	Birthday-William Fancy	AUVT	36a
Bellevue	AUWA	36b	Bisbee	USAZ	17
Bellevue	NCAL	8a	Bizmisen-Akusagi	TRKY	18d
Belokany-Laura	URRS	30a	Bjorkasen	NRWY	28a
Belvidere	USVT	8d	Bjurfors	SWDN	28a
Ben Lomond	AUQL	25f	Bjurliden	SWDN	28a
Bendigo	AUVT	36a	Bjurtrask	SWDN	28a
Bendigo	NZLD	36a	Black Bart (Great Western)	USCA	8a
Beni Douala	ALGR	18d	Black Bart Claim (Avery)	USCA	8a
Benkala	URRS	18d	Black Bart Group	USCA	8a
Benson	USNY	25i	Black Bear	USCA	36a
Benson Lake	CNBC	18b	Black Bear	USCA	8a
Benten	JAPN	25d	Black Beauty	USOR	8a
Bereket	TRKY	8a	Black Boy	USCA	36a
Berg	CNBC	21a	Black Boy	USOR	8a
Berong	PLPN	38a	Black Chrome	USCA	8a
Berry Creek	USCA	36a	Black Crow-San Juan	USNM	25g
Besimianni Log	URRS	39b	Black Cub	CNYT	18b
Bessemer	CNON	18d	Black Diablo	USNV	24c
Besshi	JAPN	24b	Black Diamond	USOR	8a
Best Chance	CNYT	18b	Black Diamond (Grey Eagle Gp.)	USCA	8a
Bethanga	AUVT	36a	Black Hawk	USNM	18c

Name	Country	Model No	Name	Country	Model No
Black Hawk	USOR	8a	Boneng Lobo	PLPN	20c
Black Lake	CNQU	8d	Bongbongan	PLPN	24a
Black Mtn.	SAFR	31a	Bonnievale	AUWA	36b
Black Otter	USOR	8a	Bonny Lake	USFL	34d
Black Range	USNM	25h	Bonsecours	NCAL	8a
Black Range-Oroya	AUWA	36b	Booker Lease	USCA	8a
Black Rock Chrome	USCA	8a	Boolarra	AUVT	38b
Black Streak	USOR	8a	Bor	YUGO	22a
Black Swan	AUWA	6b	Boss Mountain	CNBC	21b
Black Warrior	USNV	27d	Bossmo	NRWY	28a
Black Warrior	USOR	8a	Boston Group	CUBA	24c
Blackbird	USID	24d	Bosum	CNBC	22c
Blackstone	USCA	36a	Boswell River	CNYT	21b
Blairton	CNON	18d	Bothaville-Wolmaransstad	SAFR	39c
Blind River	CNON	29a	Bou Azzer	MRCO	8c
Blinman	AUSA	19b	Bou Mia	MRCO	30a
Blockhouse	CNNS	36a	Bou Sellam	MRCO	30a
Bloodwood Creek	AUQL	15b	Boulder River	USMT	39a
Bloody Canyon	USNV	27d	Boulougne-Folkston	USFL	39c
Blue Bell	CNBC	19a	Bouscadillac and others	CNON	36b
Blue Brush	USCA	8a	Bovard	USNV	25c
Blue Creek Tunnel	USCA	8a	Bowden Lake	CNMN	6b
Blue Dick	USNV	27d	Bowden Prospect	USCA	8a
Blue Grouse	CNBC	18b	Bowie Estate	USCA	8a
Blue Jay	USCA	24c	Bowser	USOR	8a
Blue Jay	USOR	27d	Boyandinskaia	URRS	39b
Blue Lead	USAK	36a	Boylen	CNQU	30a
Blue Ledge	USCA	28a	Bozkonus	TRKY	8a
Blue Moon	USCA	28a	Bozotluk-No. 551	TRKY	8a
Blue Mountain	USCA	36a	Bozshchaku	URRS	17
Blue Mountains-Oko Mountains	GUYN	38b	Br. Solomon Is.	SLMN	38a
Blue Nose	USNV	27d	Brachy	FRNC	19b
Blue Ribbon	USNV	27d	Braden	USOR	36a
Blue Ridge	PLPN	38a	Bradley	USNV	27d
Blue River	USCO	39a	Bragdor	USCA	8a
Blue Sky (Lucky Strike)	USCA	8a	Bralorne-Pioneer	CNBC	36a
Blue Star	USNV	26a	Bray-Beulah	USNV	27d
Bluebird	USAZ	17	Brejui	BRZL	14a
Bluestone	USNV	18b	Brenda	CNBC	21a
Bob	ZIMB	36b	Brenmac	USWA	17
Bobrowka River	URRS	39b	Bretz	USOR	25f
Bodennec	FRNC	28a	Bretz	USOR	27a
Bodie	USCA	25c	Bridge Hill Ridge	AUNS	39c
Boe	CNBS	38b	Briggs Creek	USOR	8a
Boiler Pit	USCA	8a	Briseida Group & others	CUBA	24c
Boleo	MXCO	23	Bristol (Jack Rabbit)	USNV	19a
Boliden	SWDN	28a	Britannia	CNBC	28a
Bolkardag	TRKY	19a	British Canadian	CNQU	8d
Bolshaya Choumika R.	URRS	39b	Broken Hill	AUNT	31a
Bolshaya Kamenouchka	URRS	39b	Broken Hill	SAFR	31a
Bolshaya Ossokina R.	URRS	39b	Broken Hills	USCA	36a
Bolshaya Prostokischenka	URRS	39b	Brookfield	CNNS	31b
Bolshaya Sosnovka	URRS	39b	Brookfield	CNNS	36a
Bolsherechensk	URRS	18d	Broulan and others	CNON	36b
Bolshoi Pokap R.	URRS	39b	Brown Scratch	USOR	8a
Bolshoi Sakciam	URRS	39b	Brownsville	AUQL	15b
Bolske-Tokmak	URRS	34b	Bruce	USAZ	28a
Bom Repouso-Cambui	BRZL	38b	Bruner	USNV	25d
Bonanza	NZLD	36a	Brunswick	CNNB	28a
Bonanza	USCA	8a	Brunswick-Altamaha	USGA	39c
Bonanza	USCO	25b	Brynor	CNBC	18d
Bonanza	CNBC	24a	Bu Craa	MRCO	34c
Bond Creek	USAK	17	Buchans	CNNF	28a
Bondurant	USCA	36a	Buckeye	USCA	24c

Name	Country	Model No	Name	Country	Model No
Buckhorn	USNV	25f	Camptonville area	USCA	8a
Buckingham	USNV	21b	Caná Brava	BRZL	8d
Bucko	CNMN	6b	Canadian Jamieson	CNON	28a
Buena Esperanza	CILE	23	Cananea	MXCO	17
Bueycito	CUBA	24c	Cananea (Capote)	MXCO	18a
Buffalo Red Lake	CNON	36b	Canariaco	PERU	17
Bugugan	TRKY	8a	Cannivan Gulch	USMT	21b
Buka	PLPN	38a	Canoe Landing	CNNB	28a
Bulacan	PLPN	18d	Cantung	CNNT	14a
Bulbula	IRAN	38c	Canyon Creek-East Fork	USCA	36a
Buller-Mokihinui	NZLD	36a	Capacmarca	PERU	18d
Bullion	USCO	22c	Cape Bougainville	AUWA	38b
Bullrun Placer	USOR	39a	Capel Shoreline	AUWA	39c
Bully Hill	USCA	28a	Capitan	USNM	18d
Bunker	USCA	8a	Captain	CNNB	28a
Burbanks	AUWA	36b	Captains Flat	AUNS	28a
Buritirama	BRZL	24c	Caracota	BLVA	27d
Burned Cabin	USOR	8a	Carawison	PLPN	24a
Burns Basin	USNV	27d	Carey/East Broughton	CNQU	8d
Burnt Hill-Knob Lake	CNQU	34a,28b	Cariboo Bell	CNBC	20c
Burra	AUSA	30b	Caribou	CNNB	28a
Bursi	NRWY	28a	Caribou	CNNS	36a
Bushveld	SAFR	2a,2b,3	Caribou-Aurum	CNBC	36a
Butilad	PLPN	17	Carleton	CNNS	36a
Butler Claims	USCA	8a	Carlin	USNV	26a
Butler, Estate Chrome	USCA	8a	Carmel	PLPN	24a
Butte	USMT	17	Carmen	CILE	18d
Butte	USNV	27a	Carmi	CNBC	21b
Buttercup Chrome	USCA	8a	Carn Brea-Tincroft	GRBR	15b
Buxton Creek	CNBC	39a	Carnation-Jennie Lind	CNBC	22c
Buyiik Gurleyen	TRKY	8a	Carnilya E.	AUWA	6a
Buyiik Karamanli	TRKY	8a	Carnilya Hill	AUWA	6a
Buyuk Yenice	TRKY	27d	Carocoles	BLVA	15b
Bwana Mkubwa	ZMBA	30b	Carolin	CNBC	36a
C.O.D.	USAZ	22c	Carolina	SAFR	39c
CC	CNBC	28a	Caroline Islands	CARL	38b
Cab	CNYT	14a	Carpenter	USAZ	17
Caño Rojo	PTRC	38a	Carpio	SPAN	28a
Cadiz	CUBA	24c	Carr Boyd	AUWA	7a
Calabogie	CNON	18d	Carr Fork	USUT	18b
Caldas	BRZL	38b	Carrock Fell	GRBR	15a
Calder-Bousquet	CNQU	36b	Carshaw-Tommy Burns	CNON	36b
Caledonia	AUVT	36a	Casa de Janos	MXCO	25g
Caledonia	CNBC	18b	Casapalca	PERU	25b
Caledonia	CUBA	8a	Casas Grandes	MXCO	25g
Caley	CNYT	8d	Cash	CNYT	17
Calico	USCA	25c	Casino	CNYT	17
California Group	USAZ	25g	Cassiar Mine	CNBC	8d
California-Hartney-Marion	CNBC	22c	Cassilis	AUVT	36a
Calistoga	USCA	25c	Cassius	HATI	18b
Calumet	USMI	23	Castillo Buitron	SPAN	28a
Calvert (Red Button)	USMT	14a	Castillode Palanco	SPAN	24c
Camaguey	CUBA	8a	Casting	USNV	18b
Camanche	USCA	39a	Castle Dome	USAZ	17
Camarasa-Oliana	SPAN	38c	Castle Island	USAK	31b
Camaratuba	BRZL	39c	Castrita	MXCO	25h
Camden Mine	USCA	8a	Castro Mine	USCA	8a
Camiglia	ITLY	18d	Castro Verde	PORT	28a
Camlica Koyee	TRKY	27d	Cataguases	BRZL	38b
Campanamah	AGTN	17	Catak	TRKY	8a
Campanario	SPAN	28a	Catak-Koraalan	TRKY	8a
Campania	ITLY	38c	Catalao	BRZL	10
Campbell	USOR	8a	Catas de las Vacas	MXCO	25h
Campbell Red Lake-Dickenson	CNON	36b	Catas el Durango	MXCO	25h

<u>Name</u>	<u>Country</u>	<u>Model No</u>	<u>Name</u>	<u>Country</u>	<u>Model No</u>
Catavi	BLVA	20a	Chibuluma West	ZMBA	30b
Catface	CNBC	17	Chicago	USCA	27c
Catheart	USMN	17	Chicago	USCA	8a
Cathroy Larder	CNON	36b	Chichagof	USAK	36a
Cathy (Walt)	CNYT	31b	Chichibu	JAPN	18d
Catolsinir	TRKY	8a	Chicote Grande	BLVA	15a
Cattle Grid	AUSA	30b	Child Harold	NCAL	8a
Cattle Springs	USCA	8a	Childs Mine	CNON	18d
Cavdarli-Komurluk	TRKY	24c	Chilisai	URRS	34c
Cave Canyon	USCA	18d	Chingola-Nchanga	ZMBA	30b
Cavyell Horse Mountain	USOR	8a	Chinkuashih	TIWN	25e
Cayirli Koy	TRKY	24c	Chintapalli-Gurtedu	INDA	38b
Cedar Creek	USOR	8a	Chisel Lake	CNMN	28a
Cehegin	SPAN	18d	Chitose	JAPN	25d
Celebration	USOR	8a	Chittering	AUWA	38b
Cenger	TRKY	8a	Chityal and others	INDA	34a,28b
Cenger-Adatepe	TRKY	8a	Chiweffe	ZIMB	34b
Cenger-Demirk	TRKY	8a	Chloride Flat	USNM	19b
Cenger-Domuza	TRKY	8a	Chloride District	USAZ	22c
Centennial	CNMN	28a	Choates	USNV	27d
Central	USCA	36a	Choghart	IRAN	25i
Central Cerbat District	USAZ	22c	Choja	JAPN	24b
Central Manitoba	CNMN	36b	Chongwe	ZMBA	30b
Central Patricia	CNON	36b	Chorolque	BLVA	20a
Central Rawdon	CNNS	36a	Christain Place	USCA	8a
Central Tennessee	USTN	32a,32b	Christmas	USAZ	18a
Cerro Blanco	MXCO	25h	Chrome Camp	USCA	8a
Cerro Bolivar	VNZL	34a,28b	Chrome Gulch	USCA	8a
Cerro Colorado	CILE	17	Chrome Hill	USCA	8a
Cerro Colorado	PANA	17	Chrome King (Josephine Co.)	USOR	8a
Cerro Gordo	USCA	19a	Chrome King (Jackson Co.)	USOR	8a
Cerro Grande	MXCO	25h	Chrome No. 3	USOR	8a
Cerro Matoso	CLBA	38a	Chrome Ridge	USOR	8a
Cerro Prieto	MXCO	25h	Chuquicamata	CILE	17
Cerro Verde	PERU	17	Chushiro	JAPN	24b
Cerro de Cobre	CLBA	18b	Cia Minera Norcro	HNDR	27d
Cerro de Mercado	MXCO	25i	Cinovec	CZCL	15c
Cervantite	USNV	27d	Cirque	CNBC	31a
Cezni	TRKY	8a	Cirque Barite	CNBC	31b
Chacarilla	BLVA	30b	Cista	CZCL	15c
Chador-Malu	IRAN	25i	Ciudad Obregon	MXCO	25g
Chagrin	NCAL	8a	Clara H	USCA	8a
Chahehgaz	IRAN	25i	Clarendon Plateau	JMCA	38c
Chalchihuites	MXCO	19a	Clary and Langford	USCA	8a
Chalcoobamba	PERU	18b	Claude Hills	AUSA	38a
Challange area	USCA	8a	Clear Springs	USFL	34d
Chambers	USOR	8a	Cleary Hill	USAK	36a
Chambiashi	ZMBA	30b	Cleopatra	USOR	8a
Champagne (Oakwood)	UNS	38b	Cleveland	AUTS	14c
Champion-New London	USAZ	22c	Cliff Roy	USNM	25g
Chang Po-Tongkeng	CINA	14c	Climax	USCO	16
Charcas	MXCO	19a	Clinton	CNQU	28a
Charco Redondo-Casualidad	CUBA	24c	Clinton Creek	CNYT	8d
Charleston placers	USSC	39c	Clover Leaf	USCA	8a
Chaucha	ECDR	17	Cluff Lake	CNSK	38d
Chavarria	MXCO	25h	Clunes Goldfield	AUVT	36a
Chavin	PERU	25b	Coal Creek	USAK	15c
Cheminis-Fernland-Omega	CNON	36b	Coalstoun	AUQL	17
Chestatee	USGA	28a	Coarsegold	USCA	36a
Chester	CNNE	28a	Coasano	USAK	27d
Chesterville	CNON	36b	Coast Copper	CNBC	18b
Chewton	AUVT	36a	Cobol	USAK	36a
Chiatura	URRS	34b	Cobriza	PERU	18b
Chibuluma	ZMBA	30b	Cobweb Diggings	AUNS	39a



Name	Country	Model No	Name	Country	Model No
Cochrane Hill	CNNS	36a	Coteje	BLVA	25f
Coco Mina	NCGA	25b	Coto	PLPN	8a
Codd Prospect	USCA	8a	Cottonwood	USNV	27d
Coeur d'Alene	USID	27d	Coulterville	USCA	36a
Coggins	USCA	8a	Country Harbour	CNNS	36a
Coimadai	AUVT	27d	Courtwright	USCA	8a
Colchester	CNNF	24a	Courtwright (Daggett)	USCA	8a
Coleman	USNV	27a	Courvan Mine	CNQU	8d
Colfax	USCA	36a	Cove District	USCA	36a
Collard Mine	USOR	8a	Cow Bay	CNNS	36a
Colombo	USCA	36a	Cow Creek Gp.	USCA	8a
Colquamarca	PERU	18d	Cowley Creek	CNYT	18b
Colquí	PERU	25b	Cox, Bolyan & Loberg	USAK	36a
Comet	USAK	36a	Craigmont	CNBC	18a
Commander	USCA	8a	Cranberry Hill	CNNS	36a
Comstock	CNBC	22c	Cranbourne	CNQU	8d
Comstock	USNV	25c	Crandon	USWI	28a
Concepcion Del Oro	MXCO	18b	Creede	USCO	25b
Conception	SPAN	28a	Crescent	USWA	24c
Confidence	USCA	36a	Creston	MXCO	21b
Conigo	CNQU	28a	Creta	USOK	30b
Connemara	ZIMB	36b	Cripple Creek	USCO	22b
Conrad Lodes	AUNW	15b	Croker Island	AUNT	38b
Consolation	NCAL	8a	Cromita	CUBA	8a
Contact	USCA	27c	Cronin	CNBC	28a
Continental	CNQU	8d	Crooked Creek	USID	39a
Continental	USNM	18a	Crouch	USOR	8a
Conyarigi	TRKY	27d	Crowell Area	USTX	30b
Coolgardie	AUWA	36b	Crown	USOR	8a
Coolgarra Dist.	AUQL	15b	Crown King	USAZ	19b
Coon Mt. Nos. 1-3	USCA	8a	Cuajone	PERU	17
Copper Basin	USAZ	17	Cubenas	CUBA	24c
Copper Basin	USNV	18a	Cubuagan	PLPN	17
Copper Canyon	USNV	18b	Cubuagan	PLPN	20c
Copper Cities	USAZ	17	Cubuklu Koyu	TRKY	24c
Copper Creek	USAZ	17	Cuchillo-Negro	USNM	18d
Copper Creek (Low Divide)	USCA	8a	Cueva de la Mora	SPAN	28a
Copper Crown	CNBC	28a	Cullaton Lake	CNNT	36b
Copper Flat	USNM	18d	Cullengoral	AUNS	39a
Copper George	AUWA	28a	Culver Bear	USCA	27c
Copper Hill	USCA	28a	Cumberland Island	USGA	39c
Copper Mountain	CNBC	17	Cummings	USCA	24c
Copper Mountain	CNBC	20c	Cupra D'Estrie	CNQU	28a
Copper Penny	USAZ	37b	Cuprus	CNMN	28a
Copper Queen	CNBC	18b	Curial-Playa Real-Pavones	CORI	24c
Copper Ridge	USTN	32b	Curtis Island	AUQL	39c
Copperhead	AUWA	36b	Cuyuna	USMN	34a,28b
Corbet	CNQU	28a	Cyclone Gap	USCA	8a
Cordero	USNV	27a	Cyclops	INDS	38a
Cordon	PLPN	17	Cynthia	GREC	19b
Cordon Estaneros	MXCO	25h	Cynthia	USOR	8a
Corduoy Creek	USID	39a	D'Analamaitso	MDGS	38b
Cork-Province	CNBC	22c	D'Ankazobe	MDGS	38b
Cornell	CNBC	18b	D-Tree	AUQL	34c
Cornwall	USPA	18d	Dabola	GNEA	38b
Cornwall Sn	GRBR	15b	Daffodil	CNON	8d
Corocoro	BLVA	30b	Dagardi	TRKY	27d
Corona	USCA	27c	Dagardi	TRKY	8a
Coronation	CNSK	28a	Dagkuplu	TRKY	8a
Cortez	USNV	19a	Daiquiri	CUBA	18d
Cortez	USNV	26a	Daisy (Aldelabron)	USCA	8a
Cosan	TRKY	8a	Dalesford	AUVT	36a
Cosmopolitan	AUWA	36b	Damascus	USCA	36a
Costerfield	AUVT	27d	Damba	ZIMB	6a

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Dammer Nissar	PKTN	18d	Djebel Guettara	ALGR	24c
Danacik	TRKY	8a	Djebel Onk	ALGR	34c
Danishment	TRKY	24c	Doe Flat	USCA	8a
Dannemora	SWDN	18d	Dogu Ezan	TRKY	8a
Danville-Hanchette	USAZ	19b	Dogu Kef	TRKY	8a
Dardanelles	CNBC	22c	Doi Pha Khan	THLD	27d
Dargo Range Dist.	AUQL	15b	Dolores	MXCO	18c
Dark Star	USOR	8a	Dolores	MXCO	25c
Darrington	USCA	8a	Dome-Paymaster-Preston	CNON	36b
Darwin	USCA	19a	Dominion Consolidated	NZLD	36a
Darwin	USNV	27d	Dominion Gulf	CNON	10
Dassoumble	IVCO	24c	Domuzburnu II	TRKY	8a
Davidson	CNON	36b	Don Jon	CNMN	28a
Davis	USMA	28a	Don Pedro	USCA	8a
Dawn Lake	CNSK	38d	Don Teodoro	MXCO	25h
Day Dawn-Main Line	AUWA	36b	Donatelli	USNV	27d
Dayton	USNV	18d	Dorothea	USOR	36a
Dcey 7	NCAL	8a	Dorothy	CNBC	17
De Santis	CNON	36b	Dorriss	USCA	8a
Debele (Kindia)	GNEA	38b	Dos Pobres	USAZ	20c
Dee	USNV	26a	Double Ed	CNBC	28a
Deep Gorge Chrome	USOR	8a	Douglas Hill	USNV	18b
Deep Gravel	USOR	39a	Dovis	IRAN	8a
Deer Isle	USME	28a	Dozier	USCA	8a
Defender	USCA	36a	Drina	YUGO	19a
Defiance	USAZ	22c	Drnis-Obrovac	YUGO	38c
Del Park-Huntly	AUWA	38b	Drumm	USNV	27d
Delamar	USID	25a	Dry Canyon	USNV	27d
Delare Prospect	USOR	8a	Dry Creek	USOR	8a
Delbridge	CNQU	28a	Dublin Gulch (GSZ)	CNYT	14a
Delta	CUBA	8a	Duchess	AUQL	34c
Delta	USCA	36a	Dudas	USNV	27d
Demarest	USCA	36a	Dugald River	AUQL	31a
Demirkapi	USNV	27d	Duke Island	USAK	9
Demirli	TRKY	8a	Dulcoath	GRBR	15b
Denali Copper	USAK	23	Duluth Complex	USMN	5a
Derekoy	TRKY	27d	Dumagami	CNQU	28a
Descoberto	BRZL	38b	Dumont	CNQU	6b
Desert	USCA	27d	Dumont Bourlamque	CNQU	28a
Despina	CNQU	28a	Duncan Lake	CNBC	31a
Detert	USCA	8a	Dungun	MDGS	18d
Detour	CNQU	28a	Dunraine	CNQU	28a
Detroit	USUT	19b	Durnovskoe	URRS	24c
Devils Elbow	CNNB	28a	Duthie	CNBC	28a
Dewey's	USCA	27c	Dy	CNYT	31a
Dexing	CINA	17	Dyce Siding	CNMN	28a
Dhalli-Rajhara	INDA	34a,28b	Dyson's (Rum Jungle)	AUNT	38d
Diamond	USCA	8a	Dzama	URRS	18d
Dickerson	USCA	8a	Dzhezhkazgan (Magakyan)	URRS	30b
Dickey and Drisbach	USCA	8a	E. Kempville	CNNS	15c
Dickstone	CNMN	28a	E. Scotia	AUWA	6a
Dikulume-Mashamba	ZIRE	30b	Eagle	CNBC	17
Dinagat	PLPN	8a	Eagle	USAK	8d
Dinagat Is.	PLPN	38a	Eagle Bluff-River Bend	USCA	36a
Dinamita	MXCO	19b	Eagle Mountain	USCA	18d
Dinero	USCA	36a	Eagle Shawmut	USCA	36a
Dirty Face	USOR	8a	Earl Smith	USCA	8a
Discovery	CNMN	6b	Early Bird	USCA	28a
Divide	USNV	25c	Early Sunrise	USOR	8a
Divinolandia de Minas	BRZL	38b	Early-Sweetwater	USCA	36a
Divrigi	TRKY	18d	East Florida (Deseret Ranch)	USFL	34d
Dixie Placer	USOR	39a	East Maui	USHI	38b
Dizon	PLPN	20c	East Ore Body	PLPN	8a
Djebel El Aziza	TUNS	19b	East Rawdon	CNNS	36a

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East Rosetta	EGPT	39c	El Porvenir (Milpo)	PERU	19a
East Sullivan	CNQU	28a	El Primero	USCA	8a
East Tennessee	USTN	32a,32b	El Profesor	MXCO	25h
East Tintic	USUT	19a	El Rincon	MXCO	25c
Eastern A&B	SYRA	34c	El Romadizo	MXCO	25h
Eaton	USNV	27d	El Romeral	CILE	25i
Eclipse No. 1	USCA	36a	El Salvador	CILE	17
Ecum Secum	CNNS	36a	El Santo Nino	MXCO	25h
Edeline	USCA	8a	El Sherana	AUNT	38d
Eden	USCA	8a	El Sherana West	AUNT	38d
Edna May	AUWA	36b	El Socavon	MXCO	25h
Eggling and Williams	USCA	8a	El Sol y La Luna	MXCO	18d
Ego	CNON	28a	El Soldado	CILE	17
Ehime	JAPN	24b	El Tarango	MXCO	25h
Ejowka	URRS	39b	El Teniente	CILE	17
Ekstromberg	SWDN	25i	El Tigre	MXCO	25b
El Abra	CILE	17	El Venado	MXCO	25h
El Abra	MXCO	25h	El Volcan-Piedra Iman	MXCO	18d
El Algarrobo	CILE	25i	El Zanzon	MXCO	25h
El Arco	MXCO	17	Elalmis	TRKY	27d
El Atascadero	MXCO	25h	Elatsite	BULG	17
El Baluarte	MXCO	25h	Elder Claim	USCA	8a
El Barroso	MXCO	25h	Elder Creek	USCA	8a
El Borrego #1	MXCO	25h	Eldirek	TRKY	8a
El Borrego #2	MXCO	25h	Electric	USNV	27d
El Calabrote	MXCO	25h	Eliza-Schroeder	USCA	36a
El Capulin	MXCO	25h	Elk Creek Claim	USCA	8a
El Cid	CUBA	8a	Elkhorn Chromite	USOR	8a
El Coloradillo	MXCO	25h	Elkhorn Creek	USMT	39a
El Corral	MXCO	25h	Ellingwood	USCA	8a
El Cristal	MXCO	25h	Elliot Lake	CNON	29a
El Cuervo	SPAN	24c	Ellis	USCA	8a
El Dorado	CILE	25i	Elliston	USMT	39a
El Dorado	MXCO	25h	Eltay	URRS	18d
El Dorado	USCA	36a	Ely	USNV	18a
El Dorado	USMT	39a	Embury Lake	CNMN	28a
El Duraznillo	MXCO	25h	Emerald-Dodger	CNBC	14a
El Durazno	MXCO	25h	Emerson	USME	28a
El Encino (La Ochoa)	MXCO	25h	Emigrant Springs	USNV	26a
El Encino (Jalisco)	MXCO	25i	Emirli	TRKY	27d
El Gotera	MXCO	25h	Emmaville	AUNS	38b
El Hamrawein	EGPT	34c	Empire Le Tac	CNQU	28a
El Huacal	MXCO	25h	Empire-Lone Star	USCA	36a
El Indio	CILE	25e	Emporer Mine	FIJI	22b
El Indio, Tadeo,			Empress	ZIMB	7a
San Antonio	MXCO	25h	Emu Creek	AUQL	15b
El Ladrillo	MXCO	25h	Emu Dist.	AUQL	15b
El Mamey	MXCO	25h	Emu-Great Eastern	AUWA	36b
El Mezquite	MXCO	25f	Endako	CNBC	21b
El Mochito	HNDR	18c	Eneabba Shoreline	AUWA	39c
El Naranjo, Buena Suerte	MXCO	25h	Enterprise	USCA	36a
El Noladero	MXCO	25h	Enterprise	USNV	27d
El Nopal (Juan Aldama)	MXCO	25h	Epoch	ZIMB	6a
El Nopal (La Ochoa)	MXCO	25h	Equity Silver	CNBC	22a
El Nopal (Nopal I and III)	MXCO	25f	Ermenis	TRKY	8a
El Pachon	AGTN	17	Errington	CNON	28a
El Pao	VNZL	34a,28b	Erzegebirge	CZCL	15c
El Pedroso	SPAN	18d	Escondida	CILE	17
El Penasco	MXCO	25h	Eskdale	AUQL	27d
El Perdido	MXCO	25h	Esmeralda	USCA	36a
El Picacho	MXCO	25h	Esperancita	CUBA	24c
El Pleito	MXCO	25h	Esperanza	CILE	17
El Polvillo	MXCO	25h	Esperanza	USCA	27c
El Portal	USCA	36a	Espiritu Santo	BLVA	27d



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Essex and Steptoe	USNV	19b	Forest Creek	USOR	39a
Estacao	CNON	28a	Forest Hill	CNNS	36a
Estacion Llanos	MXCO	25g	Forest Queen	USCA	8a
Ester Dome SE	USAK	36a	Fornas	SPAN	24a
Esterly Chrome	USOR	8a	Forrestania Group	AUWA	6b
Esther and Phyllis	USCA	8a	Fort Apache	USAZ	34a,28b
Estrella-Sopresa	CUBA	24c	Fort Gourand	MAUR	34a,28b
Estyunin	URRS	18d	Fort Green	USFL	34d
Euboea	GREC	38a	Foster	USOR	8a
Eulaminna	AUWA	28a	Foster Mountain	USCA	24c
Eureka	USCO	25b	Four Hells Mine	USCA	36a
Eureka	USNV	19a	Four Point	USOR	8a
Eustis	CNQU	28a	Four-of-July	USID	27d
Eva May	USMT	22c	Fourth Crossing	USCA	36a
Evans Head-Wooli area	AUNS	39c	Fourth of July	USCA	8a
Exmibal	GUAT	38a	Fox	CNMN	28a
Exotica	CILE	17	Francis Ormand	AUVT	36a
Experimental	USCA	36a	Franklin	USCA	36a
F Group	CNON	28a	Fraser Island	AUQL	39c
F and L Mine	USNV	27a	Fraser's	AUWA	36b
FL & DH	CNMN	28a	Freddie Wells	AUNS	28a
Fabian	USCA	24c	French	USCA	36a
Fairview	USCA	8a	French Gulch	USCA	36a
Fairview	USNV	25c	French Gulch	USCO	39a
Falconbridge	DMRP	38a	French Hill	USCA	8a
Fall Creek	USID	39a	Fretais	PORT	28a
Falun	SWDN	18c	Fria-Kimbo	GNEA	38b
Fanrouche	NCAL	8a	Friday	USOR	8a
Farewell Lake	CNMN	28a	Frieda River	PPNG	20c
Faro	CNYT	31a	Friedensville	USPA	32a,32b
Faucogney	FRNC	24c	Frotet Lake	CNQU	28a
Felicianna	USCA	36a	Fryer's Creek	AUVT	36a
Fenoarivo	MDGS	38b	Fujinokawa	JAPN	27d
Fenyoto	HUNG	38c	Fukazawa	JAPN	28a
Fiddler's Green	USCA	8a	Fuke	JAPN	25c
Fields and Stoker	USCA	8a	Fuller-Tisdale	CNON	36b
Fierro	USNM	18c	Funter Bay	USAK	7a
Fierro-Hannover	USNM	18d	Furuhaugen	NRWY	28a
Fifteen-mile Brook	CNNS	36a	Furutobe-Ainai	JAPN	28a
Fifteen-mile Stream	CNNS	36a	Fx	CNBC	31a
Fifty-five	USCA	36a	Gabretta	USCA	36a
Filon Sur-Esperanza	SPAN	28a	Gabriels Gully	NZLD	36a
Finan	USCA	8a	Gabrinus	USCA	36a
Findikli	TRKY	8a	Gachala	CLBA	31c
Fine Gold	USCA	36a	Gag Is.	INDS	38a
Finney	USCA	36a	Galaxy	CNBC	17
Fish Lake	CNBC	20c	Galena Farm and vicinity	CNBC	22c
Fisher Maiden Group	CNBC	22c	Galice North	USOR	36a
Fiskefjord	NRWY	34a,28b	Gallagher	USOR	8a
Five Pines	USCA	36a	Gallinas	USNM	18d
Fjeldgruve	NRWY	28a	Galore Creek	CNBC	20c
Flaat	NRWY	7a	Galvan	MXCO	25h
Flambeau	USWI	28a	Gambe	BRZL	38b
Flexar	CNSK	28a	Gambier Island	CNBC	21a
Flin Flon	CNMN	28a	Gamle Follidal	NRWY	28a
Flint-Martin	CNBC	22c	Ganntour	MRCO	34c
Florence	USAZ	17	Gant	HUNG	38c
Florida Canyon	USNV	26a	Gap	USPA	7a
Fond-du-Lac	CNON	38d	Gardner Mine	USOR	8a
Fongo Tongo	CMRN	38b	Garon Lake	CNQU	28a
Fonnfjell	NRWY	28a	Garpenberg Norra	SWDN	18c
Foots Creek	USOR	39a	Garpenberg Odal	SWDN	18c
Forbestown	USCA	36a	Gas Canyon	USCA	8a
Ford	USCA	36a	Gaspe	CNQU	21a

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Gaspe (Needle Mountain)	CNQU	18a	Gold Coast	FPNG	18a
Gaviao	PORT	28a	Gold Eagle-McKenzie	CNON	36b
Gavilancillos	MXCO	25h	Gold Hawk	CNON	36b
Gayna R.-Godlin L.	CNNT	32a,32b	Gold Hill	CNON	36b
Geach	USCA	8a	Gold Hill	USCO	22b
Geevor	GRBR	15b	Gold Mountain	USUT	25c
Geita	TNZN	36b	Gold Point	USCA	36a
Gelvenakko	SWDN	28a	Gold Quarry	USNV	26a
Gem	CNYT	18b	Gold Reef	USCA	36a
Gem	USCA	36a	Gold River	USCA	36a
Gem	CNBC	21b	Gold Run (Boulder Co.)	USCO	39a
Gem Olive	USCA	36a	Gold Run (Summit Co.)	USCO	39a
Gem Park	USCO	10	Goldbanks	USNV	27a
General Gallieni	NCAL	8a	Golden Age	CNQU	8d
Geol. Reser. No. 34	CNMN	6b	Golden Eagle	USCA	36a
George Copper	CNBC	28a	Golden Gate	USAZ	19b
George Lake	CNSK	30a	Golden Grove	AUWA	28a
George Prezel	USID	39a	Golden Jubilee	USCA	36a
Georgia bauxite	USCO	8c	Golden Ridge	AUWA	36b
Gerdag	TRKY	8a	Golden Rule	USID	39a
German Bar	USCA	36a	Golden-El Dorado	USCA	36a
Getchell	USNV	26a	Goldenville	CNNS	36a
Ghost Lake	CNMN	28a	Goldfield	USNV	25e
Giant King	USCA	36a	Golosh Mt.	YUGO	38a
Giant Mascot	CNBC	7a	Golos	YUGO	38a
Gibraltar	CNBC	21a	Goncolda	USOR	8a
Gibraltar	USCA	36a	Gongo Socco	BRZL	36b
Gibsonville	USCA	8a	Goodenough	CNMN	28a
Giken-Charlotta	NRWY	28a	Goodnews Bay	USAK	39b
Gill (Gill Ranch)	USCA	8a	Gora Magnitnaya	URRS	18d
Gillan	USCA	8a	Gora Vysokaya	URRS	18d
Gilliam	AUQL	14b	Coro	NCAL	38a
Gillis Prospect	USCA	8a	Gorumahisani and others	INDA	34a,28b
Gilmont	CNQU	8d	Gorunur	TRKY	8a
Giltedge	USMT	26a	Goulais	CNON	34a,28b
Gimlet-Slippery	AUWA	36b	Gove	AUNT	38b
Gingin Shoreline	AUWA	39c	Governor	USNV	27a
Giresun	TRKY	18d	Govniikbelen	TRKY	8a
Girilambone	AUNS	28a	Goynuk	TRKY	27d
Gjersvik	NRWY	28a	Gr2h	NCAL	8a
Glacier Gulch	CNBC	21b	Gran Piedra	CUBA	24c
Glacier Peak	USWA	17	Grand Victory	USCA	36a
Gladstone-Sand Queen	AUWA	36b	Grangesberg	SWDN	25i
Gladstone	USCA	36a	Granisle	CNBC	17
Gladstone Mainland	AUQL	39c	Granite Hill	USOR	36a
Glass Butte	USOR	27a	Granite King	USCA	36a
Glencoe-Woodhouse	USCA	36a	Grant	USAK	36a
Gleneindale Dist.	AUQL	15b	Grants	USNM	30c
Glib en Nam	MRCO	24c	Grass Valley	USCA	36a
Globe-Ralston	USCA	36a	Gray Boy	USOR	8a
Gloria-Elvira-Polaris	CUBA	24c	Gray Buck Gp.	USOR	8a
Glory Ho	USOR	8a	Gray Eagle	USCA	28a
Gloryana	USNM	25g	Gray Eagle	USMT	22c
Gloubokia	URRS	39b	Great Dyke	ZIMB	2a
Gocek Koyu	TRKY	24c	Great Eastern-Mt. Jackson	USCA	27c
God's Lake	CNMN	36b	Green (Americus)	USCA	8a
Gogebic	USMN	34a,28b	Green Antimony	USNV	27d
Golalan	TRKY	8a	Green Coast	CNON	28a
Golconda Fraction	USCA	8a	Green Cove Springs	USFL	39c
Gold Acres	USNV	26a	Green Excelsior	USCA	36a
Gold Bar	USNV	26a	Green Mine	USCA	8a
Gold Bug	USCA	36a	Green Ridge	USCA	8a
Gold Bug Claim	USCA	8a	Green River	USUT	39a
Gold Chariot	USCA	36a	Green's Capco Leases	USCA	8a

<u>Name</u>	<u>Country</u>	<u>Model No</u>	<u>Name</u>	<u>Country</u>	<u>Model No</u>
Greenback	USOR	36a	Hard Luck	USNV	27d
Greens Creek	USAK	28a	Hard Rock	USFL	34d
Greenvale	AUQL	38a	Hard Rock-McLeod-Cockshutt	CNON	36b
Grenville	GRBR	15b	Harkoy	TRKY	28a
Grey Eagle	USOR	27d	Harp and Sons Ranch	USCA	8a
Grey River	CNNF	15a	Harriet	CNBC	36a
Greystone	USNV	31b	Harrigan Cove	CNNS	36a
Gribble	USNV	27d	Harrison	USCA	27c
Griffin Chromite	USOR	8a	Hasaga-Howey	CNON	36b
Griffith	USNM	25g	Haskin Mountain	CNBC	21b
Groote Eylandt	AUNT	34b	Hathaway	USCA	36a
Groundhog	USNM	18c	Hatillo	DMRP	18d
Grum	CNYT	31a	Hatton	USAZ	25g
Gruvberget	SWDN	25i	Havelock Mine	SWAZ	8d
Guadalupe	MXCO	25h	Hawks Rest View	USOR	8a
Guadalupe & Calvo	MXCO	25d	Hayden Hill	USCA	25d
Guadalupe & Solis	MXCO	25i	Hayden and Hilt	USCA	8a
Guanaba Group	CUBA	24c	Haynsworth	USFL	34d
Guanacevi	MXCO	25c	Hazel	USCA	36a
Guanajuato	MXCO	25c	Heath Steele	CNNB	28a
Guillermina	CUBA	8a	Heddleston	USMT	17
Gujarat	INDA	34b	Hedley Camp	CNBC	36a
Gullbridge	CNNF	28a	Helemar	USCA	8a
Gunbasi (Akcakese)	TRKY	24c	Helen	USCA	27c
Gundie	AUNW	15b	Helvetia	USAZ	17
Gunlet-Uckopur	TRKY	8a	Henderson	USCO	16
Gunlik Basi	TRKY	8a	Hendricks No. 2	USCA	8a
Gunn Claims	USCA	8a	Hendricks-Twilight	USAZ	19b
Guntur	INDA	34a,28b	Henry Ford	USAK	36a
Gurney	CNMN	36b	Henry district	USUT	25f
Gurranda	AUNS	31b	Herberton	AUQL	15b
Gurrumba Dist.	AUQL	15b	Hercules	AUTN	28a
Guseva Gora	USSR	9	Hercules	MXCO	25i
Guttusjon	SWDN	30a	Hermada	USID	27d
Gwai River	ZIMB	30b	Herman	USCA	36a
Gwynne	USCA	36a	Herpit Yayla	TRKY	8a
HB	CNBC	31a	Herrerias	SPAN	28a
HW	CNBC	28a	Hersjo	NRWY	28a
Hacan	TRKY	28a	Hi-Yu	USAK	36a
Hagios Ioannis	GREC	38a	Hierbaniz	MXCO	25h
Hahotoe	TOGO	34c	Hierro Indio	AGTN	18d
Haikou	CINA	34c	Higashiyame	JAPN	24b
Hale-Mayabo	PLPN	17	High Dome	USCA	8a
Hales Siding	AUQL	15b	High Grade	USCA	25d
Half Chrome	USCA	8a	High Lake	CNNT	28a
Half Mile Lake (SG)	CNMN	28a	High Plateau	USCA	8a
Halimba	HUNG	38c	Highland-Trail Ridge	USFL	39c
Hall	USNV	21b	Highmont	CNBC	21a
Hall Creek	CNBC	36a	Hill-Top Chrome	USCA	8a
Halliwell	CNQU	28a	Hillgrove	AUNS	36a
Halmahera	INDS	38a	Hilton	AUQL	31a
Ham & Birney	USCA	36a	Hilton Head Island	USSC	39c
Hambone	CNMN	6b	Hinobaan	PLPN	20c
Hamme District	USNC	15a	Hirabaya	JAPN	24b
Hampton	AUQL	38b	Hiragane	JAPN	18b
Hanaoka (Doy.-Tsut.)	JAPN	28a	Hirota	JAPN	24b
Hanaoka (Mats.-Sha.)	JAPN	28a	Hirst-Chichagof	USAK	36a
Hanawa (Aket.-Osak.)	JAPN	28a	Hitachi	JAPN	24b
Hand Camp	CNNF	24a	Hitura	FNLD	6a
Hanover	USNM	18c	Hixbar	PLPN	28a
Hanscum	USOR	8a	Hodge Ranch	USCA	8a
Hanson Lake	CNSK	28a	Hoff	USCA	8a
Happy Go Lucky	USCA	8a	Hoidal	NRWY	28a
Happy Return	USNV	27d	Hokitika North	NZLD	39c

Name	Country	Model No	Name	Country	Model No
Hokitika South	NZLD	39c	Illinsky Log	URRS	39b
Holbrook and McGuire	USCA	8a	Imade & Ouchi	JAPN	24b
Hollinger and others	CNON	36b	Imanccasa	PERU	18d
Hollywood	USNV	27d	Imini	MRCO	34b
Holseman (and others)	USCA	8a	Imori	JAPN	24b
Holston (Vaughn)	USCA	8a	Imotski-Mostar	YUGO	38c
Homestake	CNBC	31a	Independence	USOR	8a
Homestake	USSD	36b	Indian Chief	CNBC	18b
Homestake-McCarty	USAK	36a	Indian Path Mine	CNNS	36a
Honeymoon Well	AUWA	6b	Infiernillo	CILE	25i
Hood River	CNNT	28a	Ingerbelle	CNBC	20c
Hope	CNBC	18b	Inguaran	MXCO	17
Horne-Quemont	CNQU	28a	Innai	JAPN	25d
Hornitos	USCA	36a	Ino	JAPN	18d
Horse Canyon	USNV	26a	Ino-Capaya	PLPN	17
Horse Praire	USMT	39a	Inskip Point	AUQL	39c
Horseshoe	AUWA	34b	Inspiration	USAZ	21a
Horseshoe	USCA	8a	Intendencia de Arauca	CLBA	38b
Horseshoe Chrome	USOR	8a	Invincible Lode	NZLD	36a
Horseshoe I	USCA	36a	Iowa Gulch	USCO	39a
Hosanger	NRWY	7a	Ipaneme	BRZL	38a
Hosokura	JAPN	25b	Irene Chromite	USOR	8a
Hostotipaquilla	MXCO	25c	Irituia	BRZL	38b
Houser & Burges	USOR	8a	Iron Duke	CNBC	18d
Howards Pass	CNYT	31a	Iron Dyke	USOR	28a
Hoyt	USNV	27d	Iron Hat	USCA	18d
Hsiangtan	CINA	34b	Iron Hill	USCO	10
Huacravilca	PERU	18d	Iron King	USAZ	28a
Huai Nai Khao	THLD	27d	Iron King	USOR	8a
Hualpai	CNBC	18d	Iron Mask	CNBC	17
Huancabamba	PERU	18d	Iron Mike	CNBC	18d
Hub	CZCL	15c	Iron Monarch-Iron Knob	AUSA	34a,28b
Hubsugul	MNGL	34c	Iron Mountain	USCA	28a
Huckleberry	CNBC	21a	Iron Mountain	USNM	14a
Hudson (Fuller Claims)	USCA	8a	Iron Mountain	USOR	8a
Hull	CNQU	18d	Iron Mountain	USNM	18d
Humbug Creek	USOR	39a	Iron Springs	USUT	18d
Hundred Dollar Gulch	USID	39a	Irsahan	TRKY	28a
Hunnan	CINA	19a	Irvine Bank	AUQL	15b
Hunter	CNQU	28a	Isaac's Harbour	CNNS	36a
Hunter Valley	USCA	36a	Isla de Pinos	CUBA	15a
Hunters Road	ZIMB	6a	Islahiye	TRKY	38c
Huntingdon	CNQU	24a	Island Copper	CNBC	17
Hutti	INDA	36b	Island Lake	CNMN	36b
Hyatt No. 1	PANA	24c	Iso-Magusi-New Insko	CNQU	28a
Hyers Island	CNMN	28a	Israil	TRKY	28a
I-Wonder	USCA	8a	Istranca	TRKY	34b
I.H.X.	USNV	27d	Isua	GRLD	34a,28b
Ichinokawa	JAPN	27d	Iszkaszentgyorgy	HUNG	38c
Iconoclast	USCA	36a	Itanhandu-Resende	BRZL	38b
Ida H.	AUWA	36b	Ithaca Peak	USAZ	17
Idaho	USID	27d	Ivanhoe-Canadian	CNBC	22c
Idaho Almaden	USID	27a	Ivov R.	URRS	39b
Idaho-Alamo Group	CNBC	22c	Iwami	JAPN	28a
Idaho-Alamo-Silver Bell	CNBC	22c	Iwato	JAPN	25e
Idaho phosphate	USID	34c	Iyo	JAPN	24b
Idfu-Qena	EGPT	34c	Izok Lake	CNNT	28a
Idikel	MRCO	24c	Izushi	JAPN	24b
Idkerberget	SWDN	25i	J.M. Meadows Group	USAZ	25g
Iide	JAPN	18b	JVB Claim	USNM	25g
Ikisulu-Gercek	TRKY	8a	Jabal Guyan	SAAR	36a
Ilave	CUBA	24c	Jabal Sayid	SAAR	28a
Iles de Los	GNEA	38b	Jabiluka	AUNT	38d
Illinois River	USOR	8a	Jack Forth	USCA	8a

<u>Name</u>	<u>Country</u>	<u>Model No</u>	<u>Name</u>	<u>Country</u>	<u>Model No</u>
Jack Sprat Gp.	USCA	8a	Kalamazoo-San Manuel	USAZ	17
Jackson	USOR	8a	Kalengwa	ZMBA	30b
Jacksonville Area	USFL	39c	Kaliapani	INDA	38a
Jacobina	BRZL	29a	Kalimantan Ni	INDS	38a
Jacupuenga	BRZL	38a	Kalkan	TRKY	18d
Jajce	YUGO	38c	Kalkanli	TRKY	28a
Jakobsbakken	NRWY	28a	Kalmakyr	URUZ	17
Jameland	CNON	28a	Kalushi (Kalulushi)	ZMBA	30b
James Bay	CNON	10	Kalvbacken	SWDN	18c
Jamestown	USCA	36a	Kam Kotia	CNON	28a
Jamirapat-Khuria	INDA	38b	Kamaishi	JAPN	18b
Jamnagar (Saurashtra)	INDA	38b	Kambaikhin central	URRS	18d
Jarrahdale	AUWA	38b	Kambaikhin east	URRS	18d
Jason	CNON	36b	Kambaikhin north	URRS	18d
Jay Bird	USOR	27d	Kambalda	AUWA	6a
Jedway	CNBC	18d	Kamegamori	JAPN	24b
Jefferson City	USTN	32b	Kamenka	URRS	39b
Jefferson Lake	USCA	8d	Kamenka R.	URRS	39b
Jeffrey Lake	CNQU	8d	Kamenskoe	URRS	34b
Jembaicumbene Creek	AUNS	39a	Kami	BLVA	15a
Jerez de los Caballeros	SPAN	18d	Kamitkita (Kominosawa)	JAPN	28a
Jerome	CNON	36b	Kamoto	ZIRE	30b
Jerome	USAZ	28a	Kansanshi	ZMBA	30b
Jerritt Canyon	USNV	26a,27d	Kanayama	JAPN	24b
Jersey Emerald	CNBC	31a	Kandira	TRKY	8a
Jerusalimsky-Priisk	URRS	39b	Kangaroo Court Mine	USCA	8a
Jib	CNBC	18d	Kanjamalai	INDA	34a,28b
Jicarilla	USNM	18d	Kankberg	SWDN	28a
Jim Bus	USOR	8a	Kanmantoo	AUSA	30b
Jo7	NCAL	24c	Kansa	INDA	38a
Joanne	CNMN	28a	Kanye	BOTS	18e
Joe Walker	USCA	36a	Kaochiao	CINA	34b
Johns	USOR	8a	Kapedhes	CYPS	24a
Johnson-Meizer	USNV	27d	Kapin	TRKY	8a
Joinville	BRZL	25i	Kapunda	AUSA	30b
Joliet	CNQU	28a	Kara Tau	URRS	34c
Jones Camp	USNM	18d	Karaculha	TRKY	8a
Jordan Creek	USID	39a	Karageban	TRKY	8a
Jose	CUBA	8a	Karamadazi	TRKY	18d
Josefina	AGTN	15a	Karamea	NZLD	39c
Josephine	USCA	8a	Karangnunggal	INDS	25g
Josephine No. 4	USOR	8a	Karani	TRKY	8a
Josselin	CNQU	28a	Karaninar	TRKY	8a
Jourawlik R.	URRS	39b	Karasivri	TRKY	8a
Joutel	CNQU	28a	Karatas	TRKY	25g
Jubilee	NZLD	36a	Karatas-Kumocak	TRKY	8a
Jubilee-New Jubilee	AUVT	36a	Karen	CNBC	21b
Judinsky-Lojok	URRS	39b	Kartalkoyu	TRKY	8a
Judy (Hicks)	USCA	8a	Kasuga	JAPN	25e
Julian	USCA	8a	Kata	PERU	25b
Julian-Banner	USCA	36a	Katherine	USAZ	25c
Juncos	CNBC	18d	Kauai	USHI	38b
June	CNBC	17	Kaunisvaara-Masugnsbyn	SWDN	18d
Jussaari	FNLD	34a,28b	Kavadarci	YUGO	38a
Jutiniou	CUBA	24c	Kavakcali	TRKY	8a
K.C.	USCA	36a	Kavakdere	TRKY	8a
Kachar	URRS	18d	Kaw Mountains	FRGN	38b
Kadzharan	URAM	17	Kawasaki	JAPN	25d
Kagit Octu	TRKY	8a	Kazadere-Kandil	TRKY	8a
Kahal de Brezina	ALGR	19b	Kedbeg Copper	URRS	18b
Kalaa Khasba	TUNS	34c	Kedtrask	SWDN	28a
Kalahandi-Koraput	INDA	38b	Keewenaw	CNYT	18b
Kalahari	SAFR	34b	Kefdag-East	TRKY	8a
Kalamaton	PLPN	17	Kelapa Kampit	INDO	15b



<u>Name</u>	<u>Country</u>	<u>Model No</u>	<u>Name</u>	<u>Country</u>	<u>Model No</u>
Kelly-Desmond	CNQU	28a	Kokkinopezoula	CYPS	24a
Kelsey	USCA	36a	Kokkinoyia	CYPS	24a
Kelsey North	USCA	36a	Kolaba-Ratnagiri	INDA	38b
Kemikli Inbasi	TRKY	8a	Kolar	INDA	36b
Kemmangundi and others	INDA	34a,28b	Kolhapur	INDA	38b
Kempfield	AUNS	31b	Kolubara-Azbest	YUGO	8d
Kemptville	CNNS	36a	Komek	TRKY	8a
Kenbridge	CNON	7a	Komurluk Koyunun	TRKY	24c
Kennecott	USNM	18c	Kondonakasi	ANGL	34c
Kennon	PLPN	20c	Konkola (Bancroft)	ZMBA	30b
Keno Hill-Galena Hill	CNYT	22c	Koolpin Creek	AUNT	38d
Kentucky-Illinois	USKN	32a,32b	Koolyanobbing	AUWA	34a,28b
Kerikeri	NZLD	38b	Koongarra	AUNT	38d
Kerr Addison	CNON	36b	Koprubasi	TRKY	28a
Kesikkopru	TRKY	18d	Koro Plateau	CHAD	38b
Ketstone-Union	USCA	28a	Korobowsky Lojok	URRS	39b
Keweenaw	USMI	23	Korucular	TRKY	24c
Key Anacon	CNNB	28a	Kosaka (Motoyama)	JAPN	28a
Key Lake (Deilmann, Gaertner)	CNSK	38d	Kosaka (Uch.-Uwa.)	JAPN	28a
Keystone	USCA	27c	Kossia R.	URRS	39b
Keystone	USCA	28a	Kossoi-Log	URRS	39b
Khans Creek	AUNS	28a	Kossorgskii Log	URRS	39b
Kheda (Kaira)	INDA	38b	Kostere	TRKY	28a
Khnaiguiyah	SAAR	28a	Kotalahti	FNLD	6a
Khneifiss	SYRA	34c	Kotchkar Mines	USSR	36a
Khushab (Sargohda)	PKTN	38b	Kotsu	JAPN	24b
Khuzdar	PKTN	31b	Kounrad	URKZ	17
Kiabakari	TNZN	36b	Koyama	JAPN	25d
Kibi	GHNA	38b	Koycegiz-Curukcu	TRKY	8a
Kidd Creek	CNON	28a	Koycegiz-Kurardi	TRKY	8a
Kieslager	ASTR	24b	Koycegiz-Orta	TRKY	8a
Kiirunavaara	SWDN	25i	Kozyrevka	URRS	18d
Kilembe	UGND	30b	Krain	CNBC	17
Kilic-Kafasi 1	TRKY	8a	Kremmel and Froelich	USCA	8a
Kilic-Kafasi 2	TRKY	8a	Kristineberg	SWDN	28a
Killag	CNNS	36a	Krivoi-Rog	URRS	34a,28b
Killifreth	GRBR	15b	Kroumovo	URRS	18d
Killingdal	NRWY	28a	Kruglogorsk	URRS	18d
Kilo-Moto	CNGO	36b	Krupka	CZCL	15b
Kimheden	SWDN	28a	Krutoi Log	URRS	39b
King Fissure	CNBC	31a	Kucuk Yenice	TRKY	27d
King Island	AUTS	14a	Kudremukh and others	INDA	34a,28b
King Solomon	USMT	22c	Kudu Asbestos Mine	ZIMB	8d
King-King	PLPN	17	Kuldoden	TRKY	8a
Kingsford	USFL	34d	Kun Ming	CINA	34c
Kingsley	USOR	8a	Kundikan-Keluskdere	TRKY	8a
Kingston	USNM	19b	Kundikan-Kelusktepe	TRKY	8a
Kinlock	SAFR	8d	Kune	JAPN	24b
Kinsley	USCA	36a	Kung-changling	CINA	34a,28b
Kinsley North	USCA	36a	Kunitomi	JAPN	28a
Kipushi	ZIRE	32c	Kupferschiefer	GRMY	30b
Kiranocak	TRKY	8a	Kure (Asikoy, Bakibaba)	TRKY	24a
Kirwin	USWY	17	Kurosawa	JAPN	28a
Kishu	JAPN	20b	Kurudere	TRKY	8a
Kisslaia-Peruonatchainik	URRS	39b	Kurzhunkul	URRS	18d
Kitlim, Severniy R.	URRS	39b	Kusalpur	INDA	34a,28b
Kittelgruvan	SWDN	28a	Kushikino-Arakawa	JAPN	25c
Kizilkaya	TRKY	28a	Kutch	INDA	38b
Kleinsorge Gp.	USCA	8a	Kutcho Creek	CNBC	28a
Kliripan	INDS	25g	Kutlular	TRKY	28a
Knoxville	USCA	27c	Kuvarshan	TRKY	28a
Koca	TRKY	8a	Kuyuluk Isletmesi	TRKY	8a
Kodiak Cub	CNYT	18b	Kuzkavak	TRKY	8a
Koff Zone	CNMN	28a	Kwanika	CNBC	17

<u>Nombre</u>	<u>Country</u>	<u>Model No</u>	<u>Nombre</u>	<u>Country</u>	<u>Model No</u>
Kylmakoski	FNLD	7a	Laguna Colorado	AGTN	25f
Kynousa	CYPS	24a	Laguna del Cuervo	MXCO	25f
La Alumbreira	AGTN	20c	Lagunazo	SPAN	28a
La Bajada	USNM	25f	Laguney	PLPN	38a
La Calanosa	SPAN	24c	Lahanos	SPAN	28a
La Caridad	MXCO	17	Lainijaur	SWDN	7a
La Caridad	CUBA	8a	Laisvall	SWDN	30a
La Carmen	MXCO	18d	Lajas	MXCO	25g
La Chapeteadá	MXCO	25h	Lake Asbestos	CNQU	8d
La Chililla	MXCO	25h	Lake Catcha	CNNS	36a
La Chinche	MXCO	25h	Lake City	USCO	25b
La Chorrera	MXCO	25h	Lake Dufault	CNQU	28a
La Cinta Corrida	MXCO	25h	Lake George	CNNB	27d
La Cocona	MXCO	25h	Lake Joanina	GREC	38a
La Colocion	MXCO	25h	Lake Valley	USNM	19b
La Cruz	MXCO	27d	Lakehurst (Glidden)	USNJ	39c
La Desparramada	MXCO	25h	Lakeshore	USAZ	18a
La Encantada	MXCO	19a	Lamb Creek	USID	39a
La Escondida	MXCO	25h	Lambert	USCA	8a
La Esperanza	MXCO	25h	Lammereck	ASTR	19b
La Estrella	MXCO	25h	Lampazos	MXCO	19a
La Florida	MXCO	17	Lamphear	USCA	36a
La Grulla	MXCO	25i	Lancefield	AUWA	36b
La Guera	MXCO	25h	Lancha	SPAN	28a
La Hormiga	MXCO	25h	LangSen	VTNM	38c
La Huacalona	MXCO	25h	Langban	SWDN	18c
La Joya	SPAN	28a	Langdal	SWDN	28a
La Joya	USCA	27c	Langley Chrome	USOR	8a
La Laguna	DMRP	18d	Langmuir 2	CNON	6a
La Leona	MXCO	25h	Langmuir 1	CNON	6a
La Leona (Sonora)	MXCO	25g	Langsele	SWDN	28a
La Libertad	MXCO	25d	Lapa Cadillac	CNQU	36b
La Libertad	USCA	27c	Lappuattnet	SWDN	7a
La Liendre	MXCO	25h	Laramie Range	USWY	7b
La Loba	MXCO	25h	Larap-Calambayungan	PLPN	18d
La Mula	MXCO	25h	Largentiere	FRNC	30a
La Noria	MXCO	25g	Las Aguilas	MXCO	25h
La Paloma	MXCO	18d	Las Amarillas	MXCO	25h
La Perla-La Negra	MXCO	25i	Las Ambollas	FRNC	19b
La Piedra Iman	MXCO	18d	Las Animas Cerro Prieto	MXCO	18d
La Plata District	USCO	22b	Las Brisas	CLBA	8d
La Polvosa	MXCO	25h	Las Cabesses	FRNC	19b
La Puntilla	MXCO	25h	Las Calaveras	MXCO	25h
La Quemada	MXCO	25h	Las Flores	MXCO	25h
La Reforma	MXCO	19a	Las Fundiciones	MXCO	25h
La Torrera	SPAN	28a	Las Marias	MXCO	25h
La Triste	MXCO	25h	Las Pegazones	MXCO	25h
La Unica	CUBA	24c	Las Perlitas	MXCO	25h
La Venadita	MXCO	25h	Las Tablas	MXCO	25h
La Verde	MXCO	17	Las Truchas	MXCO	18d
La Vibora	MXCO	25h	Las Varas-La Vaca	MXCO	25g
La Victoria	CUBA	8a	Lasail	OMAN	24a
La Victoria	MXCO	25h	Lasbela	PKTN	24c
La Vieja-El Agua	MXCO	25h	Lassic Peak	USCA	8a
La Zarza	SPAN	28a	Last Buck	USOR	8a
Lacey	USCA	8a	Last Chance	USNV	27d
Lackner Lake	CNON	10	Last Chance	USOR	8a
Ladd	USCA	24c	Laton	USCA	8a
Lady Annie	AUQL	34c	Laukunkawges	FNLD	7a
Lady Loretta	AUQL	31a	Laurium	GREC	19a
Lafayette	CNQU	8d	Lava Bed	USCA	18d
Lagnokaha	UVOL	24c	Laverton-Mt. Lucky	AUWA	24c
Lagonoy	PLPN	8a	Lawrencetown	CNNS	36a
Laguerre	CNON	36b	Le Kouif	ALGR	34c

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Leadsmith	CNBC	22c	Lonesome	USFL	34d
Lebyazhka	URRS	18d	Long Ledge Gp.	USCA	8a
Lee Creek	USNC	34c	Long Point	PLPN	38a
Legal Tender	USMT	22c	Long Tunnel	AUVT	36a
Leipsigate	CNNS	36a	Lord Nelson	AUVT	36a
Leitch-Sand River	CNON	36b	Loreto	MXCO	25h
Lena	URRS	30b	Lornex	CNBC	21a
Lenora-Twin J	CNBC	28a	Lorraine	CNBC	20c
Leoncitos	MXCO	25h	Lorraine	CNQU	7a
Lepanto	PLPN	22a	Lorraine	PLPN	24a
Letty	USCA	8a	Los Angeles	MXCO	25h
Levant	GRBR	15b	Los Arrieros	MXCO	25h
Leveaniemi	SWDN	25i	Los Borregos	MXCO	25g
Levi	SWDN	28a	Los Bronces	CILE	17
Leviathan	AUVT	36a	Los Caballos	MXCO	25h
Leviso R.	CUBA	38a	Los Campamentos	MXCO	25h
Liaoning	CINA	19a	Los Castillos	VNZL	34a, 28b
Liberty (Stanislaw Co.)	USCA	24c	Los Condores	AGTN	15a
Liberty (Siskyou Co.)	USCA	36a	Los Cuatillos	MXCO	25h
Liberty (Calaveras Co.)	USCA	8a	Los García	MXCO	25h
Liberty Bond Claim	USCA	8a	Los Lobos	MXCO	25h
Lights Creek	USCA	17	Los Mantiales	AGTN	25b
Lili	CNQU	8d	Los Pelambres	CILE	17
Lily (Ikeno)	CNBC	18b	Los Pijiguaos	VNZL	38b
Lily Creek	AUQL	34c	Los Pilares	MXCO	17
Limasol Forest	CYPS	8c	Los Pinacates	MXCO	25h
Limni	CYPS	24a	Los Puertos	MXCO	25f
Linda Marie	USOR	8a	Los Vasitos	MXCO	25i
Lingman	CNON	36b	Los Volcanes	MXCO	19b
Lingwick	CNQU	28a	Los Volcanes	MXCO	25g
Lion Den	USCA	27c	Lost Creek	USMT	14a
Lithia	USNV	27d	Lost Lake	CNMN	28a
Little Bay	CNNF	24a	Lost Lee	USOR	8a
Little Boy	USOR	8a	Lost River	USAK	14b, 15c
Little Castle Creek	USCA	8a	Lotty	USCA	8a
Little Chief	CNYT	18b	Lousal	PORT	28a
Little Hope	USCA	8a	Louvem	CNQU	28a
Little Long Lac	CNON	36b	Lovstrand	SWDN	30a
Little Nell	USMT	22c	Lowe Placer	USCO	39a
Little Rock Mine	USCA	8a	Lower Beaver Creek	USCO	39a
Little Siberia	USOR	8a	Lowland Creek	USMT	39a
Little Squaw	USAK	36a	Lowry	USNV	27d
Liverpool	USMT	22c	Lubin (Legnica-Glogow)	PLND	30b
Livitaca-Velille	PERU	18d	Lucia (Generosa)	CUBA	24c
Llallagua	BLVA	20a	Lucifer	MXCO	24c
Llano de Oro	USOR	39a	Lucky Bart	USOR	36a
Lobwa R.	URRS	39b	Lucky Boy	USCA	8a
Locarno	USCA	36a	Lucky Four	CNBC	18b
Loch Fyne	AUVT	36a	Lucky Friday	USOR	8a
Loei-Chiengkarn	THLD	18b	Lucky Girl	USCA	8a
Lofthouse	USNV	27d	Lucky Hunch	USOR	8a
Logwinska	URRS	39b	Lucky Knock	USWA	27d
Lohara and others	INDA	34a, 28b	Lucky L. & R.	USOR	8a
Lojok No. 1&2 Omoutnaia	URRS	39b	Lucky Lass	USOR	25f
Lojok at Bisserskaya	URRS	39b	Lucky Mike	CNBC	14a
Lokken	NRWY	24a	Lucky Nine Gp.	USOR	8a
Lolita	CUBA	8a	Lucky Ship	CNBC	21b
Loma de Hierro	VNZL	38a	Lucky Shot-War Baby	USAK	36a
Lomero Poyatos	SPAN	28a	Lucky Star	USOR	8a
Lomonosov	URRS	18d	Lucky Strike	USCA	8a
Lone Gravel	USCA	8a	Lucky Strike	USOR	8a
Lone Mary	USCA	36a	Lueshe	ZIRE	10
Lone Mountain	USNM	19b	Lumbay	PLPN	20c
Lone Mountain	USNV	19a	Lumwana	ZNBA	30b



<u>Name</u>	<u>Country</u>	<u>Model No</u>	<u>Name</u>	<u>Country</u>	<u>Model No</u>
Luna-Bash	PLPN	17	Manacas Group	CUBA	24c
Luossauaara	SWDN	25i	Manantenina	MDGS	38b
Lyell Goldfield	NZLD	36a	Manavalakurichi	INDA	39c
Lyndhurst	CNQU	28a	Manchester	USCA	8a
Lynn Lake	CNMN	7a	Manchester (Asarco)	USNJ	39c
Lynx	CNQU	28a	Manchester Plat.	JMCA	38c
Lynx Creek	USAZ	39a	Mandy	CNMN	28a
Lyon	USNV	18a	Manga de Lopez	MXCO	25h
Lyon Lake	CNON	28a	Mangampetta N.	INDA	31b
M and M Group	USNM	25g	Mangampetta S.	INDA	31b
Maanshan	HONG	18d	Manganese Chief	USNM	25g
Mabel	USAK	36a	Manganese Development	USAZ	25g
Mac	CNBC	18d	Mangula (Miriam)	ZIMB	30b
MacArthur	USNV	17	Mangum	USOK	30b
MacBride Lake	CNMN	28a	Manhattan	USCA	27a
MacMillan	CNYT	31a	Manibridge	CNMN	6b
Machimi	JAPN	24b	Manitou Island	CNON	10
Machkatica	YUGO	21b	Mankayan	PLPN	28a
Mackay	USCA	8a	Mansfeld	GRMY	30b
Mackey	USID	18b	Mantos Blancos	CILE	17
Mactung	CNNT	14a	Manuel	CUBA	24c
Macusani	PERU	25f	Manuel Killigrews	CNNF	34b
Madeira	USCA	8a	Manus Island	PPNG	38b
Madeni	TRKY	27d	Manzanillas	MXCO	25h
Madenkoy	TRKY	28a	Mapula	PLPN	20c
Madhya Pradesh	INDA	34b	Marais Kiki	NCAL	8a
Madrid	USCA	8a	Maralls Capro Leases	USCA	8a
Madrigal	PERU	25b	Maranboy	AUNT	15b
Madsen	CNON	36b	Marangaka	MDGS	38b
Madziwa	ZIMB	7a	Marbella	SPAN	18d
Magdalena	CUBA	24c	Marble Bar	AUWA	36b
Magdalena	USNM	19a	Marble Bay	CNBC	18b
Maggie	CNBC	17	Marbridge	CNQU	6a
Maggie Creek	USNV	26a	Marchinbar Island	AUNT	38b
Maggotty	JMCA	38c	Marcopper	PLPN	20c
Magnet Cons.	CNON	36b	Marcos	PLPN	28a
Magnet Cove	USAR	31b	Margaret	USWA	17
Maikala Range	INDA	38b	Maria Christina	CILE	19a
Main Valley of Kisslaia	URRS	39b	Maria Luisa	VNZL	34a, 28b
Mainpat	INDA	38b	Marian	PLPN	20c
Maiva	SWDN	30a	Mariana	BRZL	38b
Majdanpek	YUGO	17	Marietta	USMT	22c
Majestic-Sapphire	CNBC	22c	Mariners	AUVT	36a
Makhtesh	USRL	34c	Mariposa	USCA	36a
Makimine, Hibira	JAPN	24b	Marks & Tompson	USOR	8a
Makola	FNLD	7a	Marlborough	AUQL	38a
Malaia Koswa R.	URRS	39b	Marmoraton	CNON	18d
Malaia Prostokischenka	URRS	39b	Marquette	USMN	34a, 28b
Malaia Sosnowka	URRS	39b	Martian R.	URRS	39b
Malaiba	PLPN	28a	Martin-Bird	CNON	36b
Malden North	AUVT	36a	Martinovo	BULG	18d
Malko Trnova	BULG	18b	Martison Lake	CNON	10
MalMBERGET	SWDN	25i	Mary Jane	USCA	8a
Malmbjerg	GRLD	16	Mary Walker	USOR	8a
Malomalsky-Priisk	URRS	39b	Marysvalle	USUT	25f
Malot Pokap	URRS	39b	Marysville District	USMT	22c
Mamie	CNBC	28a	Mascot	USTN	32b
Mammoth	USAZ	19b	Masinloc	PLPN	38a
Mammoth (Kern Co.)	USCA	28a	Maslovo	URRS	18d
Mammoth (Shasta Co.)	USCA	36a	Mason Valley-Malachite	USNV	18b
Mammoth (Gunpowder)	AUQL	30b	Masonic	USCA	25e
Mammoth-St. Anthony	USAZ	22c	Matachewan Cons. & others	CNON	36b
Mamuro	JAPN	25d	Matamoros	MXCO	25g
Mamut	MDGS	20c	Matchless	NAMB	30b

Name	Country	Model No	Name	Country	Model No
Matchless West	NAMB	30b	Mic Mac	CNQU	28a
Matese-Ciocciaria	ITLY	34b	Michiquillay	PERU	17
Mathiati North	CYPS	24a	Midas	USCA	36a
Mati	PLPN	18d	Middle Fork	USWA	17
Matona-Stairs	CNON	36b	Middle Ore Body	PLPN	8a
Matt Berry	CNYT	31a	Midlothian	CNON	8d
Mattabi	CNON	28a	Midwest Lake	CNSK	38d
Mattagami Lake	CNQU	28a	Mighty Joe	USOR	8a
Maubach	GRMY	30a	Mikado	USAK	36a
Maude & Yellow Girl	AUVT	36a	Milan	USNH	28a
Maurice Bay	CNSK	38d	Milford area	USUT	14a
Mavrovouni	CYPS	24a	Millenbach	CNQU	28a
Mawchi	BRMA	15b	Miller Lake	CNNS	36a
Maxwell	USCA	8a	Milton	USCA	8a
Mayari	CUBA	38a	Milton Canyon	USNV	27d
Mayflower	USCA	8a	Mimoso do Sul	BRZL	38b
Maykhura	URTD	14a	Mina Dura	MXCO	25h
Mazagao	BRZL	38b	Mina El Sapo	CLBA	18b
Mazama	USWA	17	Mina Vieja	CLBA	18b
Mazapil	MXCO	19a	Mina del Aire	MXCO	25h
Mazidagi	TRKY	34c	Minarets	USCA	25i
Mbeya	TNZN	10	Minas Gerais	BRZL	34a,28b
McAdam	CNQU	8d	Minawa	JAPN	24b
McArthur	AUNT	31a	Mineral Butte	USAZ	17
McCaleb's Sourdough	USOR	8a	Mineral King	CNBC	31a
McCarty	USCA	8a	Mineral Park	USAZ	22c
McClean Lake	CNSK	38d	Mineville-Port Henry	USNY	25i
McConnell	CNBC	18b	Minim-Martap	CMRN	38b
McCormick	USCA	8a	Minniehaha	CNBC	22c
McDame Belle	CNBC	18c	Minto	CNBC	36a
McDermitt	USNV	27a	Minto-Tyranite	CNON	36b
McFinley	CNON	36b	Mirabel	USCA	27c
McGlaughlin	USCA	25a	Mirandag Koru	TRKY	8a
McGuffy Creek Gp.	USCA	8a	Mirandag Mevki	TRKY	8a
McMarmac	CNON	36b	Miriam	AUWA	6a
McMaster	CNNB	28a	Misima Island	PPNG	22c
McMurty	USCA	8a	Missouri Creek	USCO	39a
McWatters	CNON	6a	Mistry	CNBC	17
McWatters	CNQU	36b	Mitate	JAPN	19a
Mdilla	TUNS	34c	Mitchell Creek	USMT	39a
Meat Cove	CNNS	18c	Mitchell Plateau	AUWA	38b
Mechernich	GRMY	30a	Mitchell River	AUQL	27d
Meeker (Sonoma Chrome)	USCA	8a	Miyawa	JAPN	24b
Megara-Eleusis	GREC	38c	Mizobe	JAPN	25d
Meggen	GRMY	31a	Mizpah	USAK	36a
Meggen Barite	GRMY	31b	Mizpah	USNV	27d
Mel Barite	CNYT	31b	Mjodvattnet	SWDN	7a
Melnitschnaia	URRS	39b	Mlanje Mountain	MLWI	38b
Meme	HATI	18b	Moa Bay	CUBA	38a
Menominee	USMN	34a,28b	Moak	CNMN	6b
Menzies	AUWA	36b	Mobrun	CNQU	28a
Mercedes	CUBA	19b	Mocha	CILE	17
Mercur	USUT	26a	Mochikoshi	JAPN	25c
Merrifield	USCA	8a	Mockingbird	USOR	8a
Merrimac	USNV	27d	Mocoa	CLBA	17
Mesabi	USMN	34a,28b	Modarelli	USNV	25i
Meskala	MRCO	34c	Moengo	SRNM	38b
Metal Negro	MXCO	25h	Moffett Creek Gp.	USCA	8a
Metalline	USWA	32a,32b	Mofjell	NRWY	28a
Metcalf	USAZ	17	Mogi das Cruzes	BRZL	38b
Metlaoui	TUNS	34c	Mogollon	USNM	25c
Metsamonttu	FNLD	28a	Mogpog	PLPN	18d
Meululter	TRKY	8a	Mohave	USCA	25e
Mezcala	MXCO	25g	Mohawk Claim	USOR	8a

Name	Country	Model No	Name	Country	Model No
Mohawk-Dome View	USAK	36a	Mount Burton (Rum Jungle)	AUNT	38d
Moina	AUTS	14b	Mount Canninda	AUQL	17
Moinho	PORT	28a	Mount Chalmers	AUQL	28a
Mokambo	ZMBA	30b	Mount Ejuanema-Nsisreso	AUNS	38b
Mokanji Hills	SRLN	38b	Mount Emmons	USCO	16
Mokelumne	USCA	36a	Mount Finch (Rum Jungle)	AUNT	38d
Mokoman Lake	CNSK	28a	Mount Gaines	USCA	36a
Moladezhnoye	URRS	8d	Mount Gibson	AUWA	34a,28b
Molango	MXCO	34b	Mount Gould	AUWA	34a,28b
Molega	CNNS	36a	Mount Hale	AUWA	34a,28b
Moleon Lake	CNQU	28a	Mount Hope	USNV	16
Molitchowka	URRS	39b	Mount Hundere	CNYT	18c
Molly Gibson	CNBC	22c	Mount Isa	AUQL	31a
Monarch-Kicking Horse	CNBC	32a,32b	Mount Lyell	AUTS	28a
Monghyr	INDA	38b	Mount Morgan	AUQL	28a
Monitor	CNBC	22c	Mount Mulcahy	AUWA	28a
Moniwa	BRMA	17	Mount Nolan Dist.	AUQL	15b
Monpas	CNQU	28a	Mount Paynter	AUNS	15b
Mons Cupri	AUWA	28a	Mount Philip	AUQL	34a,28b
Montana	USMT	34c	Mount Pleasant	USCA	36a
Montaque	CNNS	36a	Mount Saddleback	AUWA	38b
Montcalm	CNON	7a	Mount Shasta	USCA	36a
Monte Carmelo	NCRG	18d	Mount Thomlinson	CNBC	21b
Montenegro-Adriana	CUBA	24c	Mount Tolman	USWA	21b
Montezuma	CNBC	22c	Mount Uniacke	CNNS	36a
Montezuma	USNV	27d	Mount Vernon	USCA	36a
Montosa	MXCO	25g	Mount Wellington	GRBR	15b
Montredon	FRNC	15a	Mountain Chief and vicinity	CNBC	22c
Moonlight	USNV	25f	Mountain Con	CNBC	22c
Moore	USCA	8a	Mountain King	USCA	36a
Moore's Flat	USCA	36a	Mountain Mines	PLPN	20c
Moorsom	PLPN	38a	Mountain Pass	USCA	10
Moose Mountain	CNON	34a,28b	Mountain Springs	USNV	31b
Moose River	CNNS	36a	Mountain View	USCA	8a
Moosehead	CNNS	36a	Mountain View Gp.	USCA	8a
Mooseland	CNNS	36a	Mousoulos-Kalavasos	CYPS	24a
Moramanga	MDGS	38a	Mowbray Creek	AUQL	15b
Mordey	CNON	28a	Moxie Pluton	USMA	7a
Morenci	USAZ	21a	Mrata	TUNS	34c
Moreton Island	AUQL	39c	Mrima	KNYA	24c
Mormon Bar	USCA	36a	Mrima Hill	KNYA	10
Morning Star	AUVT	36a	Mt. Diablo	USCA	27c
Morococha	PERU	17	Mt. Edwards	AUWA	6a
Morphine-Log	URRS	39b	Mt. Gunson	AUSA	30b
Morrachini	NCAL	8a	Mt. Keith	AUWA	6b
Morris Ravine	USCA	36a	Mt. Magnet	AUWA	36b
Morris-Kirkland	CNON	36b	Mt. Morgans	AUWA	36b
Morrison	CNBC	17	Mt. Oxide	AUQL	30b
Morro Velho	BRZL	36b	Mt. Sholl	AUWA	7a
Morro da Mina	BRZL	34b	Mt. Windarra	AUWA	6a
Morro de Engenho	BRZL	38a	MuNaly	USCA	8a
Mos	NRWY	28a	Mufulira	ZMBA	30b
Moscatelli	USCA	8a	Mugi	JAPN	27d
Moscatelli No. 2	USCA	8a	Mulcahy Prospect	USCA	8a
Moskogaissa	NRWY	28a	Mule Creek	USCA	8a
Moss Vale	AUNS	38b	Mum and Alice June Claim	USCA	8a
Mother Lode	USCA	36a,39a	Munbinea Shoreland	AUWA	39c
Mother Lode-Sunset	CNBC	18b	Munda	AUWA	6a
Motoyasu	JAPN	24b	Munesada	JAPN	18d
Moulares	TUNS	34c	Munmorah	AUNS	39c
Moulton Hill	CNQU	28a	Munro	CNON	8d
Mount Bischoff	AUTS	14c	Murguia	MXCO	25g
Mount Bulga	AUNS	28a	Murgul	TRKY	28a
Mount Bullion	USCA	36a	Muriwai	NZLD	39c

Name	Country	Model No	Name	Country	Model No
Murphy	USCA	8a	New Hosco	CNQU	28a
Murray Brook	CNNB	28a	Newfoundland Zinc	CNNF	32a,32b
Musa Danisman	TRKY	8a	Newman	USCA	8a
Musan	NKOR	34a,28b	Newton	USCA	28a
Musonoi	ZIRE	30b	Nhamunda	BRZL	38b
Musoshi	ZIRE	30b	Ni Te Ocutes	CUBA	8a
Mutum	BLVA	34a,28b	Niasman R.	URRS	39b
Muzaffarabad	PKTN	38c	Nichelini Mine	USCA	8a
Muzo	CLBA	31c	Nickel Mountain	USOR	38a
Muzzleloader (Stevens No. 1)	USCA	8a	Nickel Mountain	USOR	8a
Mwaytung	BRMA	38a	Nickel Ridge	USOR	8a
Myalla	AUNT	38b	Nicolet Asbestos	CNQU	8d
Myra Falls-Lynx	CNBC	28a	Nieves	MXCO	27d
Mystery Lake	CNMN	6b	Niggerhead	USNM	25g
Mzaita	ALGR	34c	Nii	JAPN	24b
N. Stradbroke Island	AUQL	39c	Nikolaevskoe	URRS	34b
N.L. Industries (Aurora)	USNC	39c	Nikolai-Tschoudotowsky	URRS	39b
NW Group	GUYN	38b	Nikopol	URRS	34b
Nabarlek	AUNT	38d	Niksicka Zupa	YUGO	38c
Nacimiento	USNM	30b	Nilgiri Hills	INDA	38b
Nacozari	MXCO	25g	Nimiuktuk	USAK	31b
Nagamatsu	JAPN	25d	Nimkish	CNBC	18d
Nagyegyhaza	HUNG	38c	Nimrod	AUVT	36a
Nahal-Zin	ISRL	34c	Nine Mile Brook	CNNB	28a
Naica	MXCO	19a	Niquelandia	BRZL	38a
Nakatatsu	JAPN	19a	Nishinokawa	JAPN	24b
Nakayama	JAPN	24b	Nizne-Udinskaja	URRS	34b
Nakerivaara	SWDN	25i	Noamundi-Joda-Gua etc.	INDA	34a,28b
Nalden South	AUVT	36a	Noble Electric Co.	USCA	8a
Namosi	FIJI	17	Nobles Nob	AUWA	36b
Naniango	UVOL	34b	Nogal	USNM	25b
Nanisivik	CNNT	32a,32b	Noji	JAPN	24b
Nanogawa	JAPN	24b	Nonoc	PLPN	38a
Narciso	CUBA	8a	Nonowaki	JAPN	24b
Naruyasu	JAPN	24b	Noonday	CNBC	22c
Nashville	USCA	36a	Norah	ZIMB	30b
Nasliden	SWDN	28a	Noralyn-Phosphoria	USFL	34d
Nassau Mountains	SRNM	38b	Norberg	SWDN	34a,28b
Natchez Trace State	USTN	39c	Norcross	USCA	8a
National	CNQU	8d	Nordre Gjettryggen	NRWY	28a
National	USCA	36a	Noril'sk	USSR	5b
Navan	IRLD	31a	Norita	CNQU	28a
Nawaji	JAPN	25c	Normandie/Penhale	CNQU	8d
Naybob	CNON	36b	Normetal	CNQU	28a
Neardie	AUQL	27d	Norseman-Dundas	AUWA	36b
Needle Hill	HONG	15a	North Arkansas-Ozark	USAR	32a,32b
Needle Mountain	CNCQ	18a	North Boundary	CNNB	28a
Nemogos	CNON	10	North Camden (Keer-McGee)	USTN	39c
Nepean	AUWA	6a	North Carolina phospate	USNC	34d
Nepisiguit	CNNB	28a	North Cerbat (Golconda)	USAZ	22c
Nepoui	NCAL	38a	North End, West End, Spotted Fawn	USCA8a	
Nevada King	USNV	27d	North Florida phosphate	USFL	34d
Nevada Sulphur co.	USNV	27a	North Fork	USWA	17
Nevada-Massachusetts	USNV	14a	North Fork Chrome	USCA	8a
Nevada-Scheelite	USNV	14a	North Keystone	USCA	28a
New Almaden	USCA	27c	North Mocassin	USMT	22b
New Bay Pond	CNNF	28a	North Murphy	USCA	36a
New Bendigo	AUVT	36a	North Star	CNMN	28a
New Calumet	CNQU	19a	North Star	USAK	36a
New Cuyama	USCA	34c	North Star	USOR	8a
New Era-Rowe	AUVT	36a	North Star (Red Mtn)	USCA	8a
New Frontier	PLPN	38a	North Weipa	AUQL	38b
New Hope	USCA	8a	Northair	CNBC	28a
New Hope Claim	USOR	8a	Northeast Florida	USFL	34d

<u>Name</u>	<u>Country</u>	<u>Model No</u>	<u>Name</u>	<u>Country</u>	<u>Model No</u>
Northern Anomaly	IRAN	25i	Oregon	CNBC	18b
Northern Bell-Jackson	CNBC	22c	Oregon	USAZ	19b
Northern Ireland	IRLD	38b	Oregon Bell	USOR	36a
Northumberland	USNV	26a	Oregon Chrome	USOR	8a
Northumberland barite	USNV	31b	Orendere	TRKY	27d
Norway	USOR	8a	Orient	USWA	25c
Nount Wells	AUNS	15b	Oriental	AUVT	36a
Novazza	ITLY	25f	Orijarvi	FNLD	28a
Novo Maslovo	URRS	18d	Orissa (Chatrapur)	INDA	39c
Novo Peschansk	URRS	18d	Oro Denoro (Ema)	CNBC	18b
Novoi-Log	URRS	39b	Oro Grande-Buena Vista	USCA	36a
Nueva Esperanza	CLBA	27b	Orogrande	USNM	18d
Nugget Creek (South Fork)	USID	39a	Oronta	ISRL	34c
Nuggetty	AUVT	36a	Orpit	CNON	36b
Nuqrah	SAAR	28a	Orsk	URRS	38a
Nuria	VNZL	38b	Orta Ezan	TRKY	8a
Ny Sulitjelma	NRWY	24a	Osamu Utsumi	BRZL	25f
Nyinahin	GHNA	38b	Osbourne Lake	CNMN	28a
Nyirad	HUNG	38c	Osen	NRWY	30a
Nymbool Dist.	AUQL	15b	Osgood Range	USNV	14a
Nyseter	NRWY	18c	Oshio	JAPN	28a
O'Connors	AUVT	36a	Osokino-Aleksandrovsk	URRS	18d
Oak Grove (Ethyl)	USTN	39c	Ostra Hogkulla	SWDN	28a
Oak Ridge	USCA	8a	Otjosondu	SAFR	34b
Oakleigh Creek	AUTS	15a	Otmanlar-Harpuzlu	TRKY	8a
Oamite	NAMB	30b	Otmanlar-Mesebuku	TRKY	8a
Oatman	USAZ	25c	Ottery Lode	AUNS	15b
Oberpfalz	GRMY	30a	Oturehua Field	NZLD	36a
Obi	INDS	38a	Oulad-Abdoun	MRCO	34c
Obira	JAPN	18b	Ourem	BRZL	38b
Obodranny-Lojok	USSR	39b	Ouse	AUTS	38b
Ochanocagi	TRKY	8a	Ovens	CNNS	36a
Ocna de Fier	RMNA	18d	Oviachic 1&2	MXCO	25g
Oe	JAPN	25b	Oxec	GUAT	24a
Ofelia	CUBA	8a	Oxford	USCA	8a
Offshore	USGA	34d	Oya	JAPN	36a
Ogane	JAPN	25b	P. B.	NCAL	8a
Ohguchi	JAPN	25c	P. U. P. (Zenith)	USCA	8a
Ohito	JAPN	25c	Pa-pan-ling	CINA	34a, 28b
Ok	CNBC	17	Pabineau River	CNNE	28a
Ok Tedi	PPNG	20c	Pachuca-Real del Monte	MXCO	25b
Oka	CNQU	10	Pactolus	USCO	39a
Okuki	JAPN	24b	Paddy's Flat	AUWA	36b
Old Dad Mountains	USCA	18d	Padurea Craiului	RMNA	38c
Old Diggings	USCA	36a	Page	USNV	27d
Old Waite	CNQU	28a	Pahang	MLYS	15b
Oldham	CNNS	36a	Painirova	SWDN	25i
Olinghouse	USNV	25c	Palette	AUNT	38d
Olive B.	USOR	8a	Palmer's Find	AUWA	36b
Olsen	USCA	8a	Palni Hills	INDA	38b
Olympias Chalkidiki	GREC	19a	Palo Colorado	MXCO	25h
Olympic Dam	AUSA	29b	Paloma-Gwin	USCA	36a
Omine	JAPN	24b	Pambuhan Sur	PLPN	18d
Onion Springs	USOR	8a	Pampa Norte	CILE	17
Opalite	USOR	27a	Pampachiri	PERU	18d
Ophir	USCA	36a	Panamana-An	PLPN	8a
Ophir	USCO	25b	Panasqueria	PORT	15a
Ophir	USMT	39a	Panchillo	MXCO	25h
Ophir	USUT	19a	Panguana	PPNG	20c
Ora Banda	AUWA	38a	Panguna	PPNG	17
Orange Hill	USAK	17	Panowka	URRS	39b
Orange Point	USAK	28a	Panther	USNV	27d
Orchan	CNQU	28a	Paparoa Range	NZLD	36a
Ore Drag	USNV	27d	Paracale	PLPN	18d



Name	Country	Model No	Name	Country	Model No
Paradise	USOR	8a	Picuris	USNM	39a
Paragominas	BRZL	38b	Piddig	PLPN	18d
Paramillos	AGTN	17	Pikwe	BOTS	7a
Paranam	SRNM	38b	Pilleys Island	CNNF	28a
Parish	AUNS	38b	Pillikin	USCA	8a
Park	USTN	39c	Pima-Mission	USAZ	18a
Park City	USUT	19a	Pine Bay	CNMN	28a
Park's Ranch	USCA	8a	Pine Creek	USCA	14a
Parker	USCA	8a	Pine Grove	USUT	16
Parkeson	USCA	8a	Pine Mountain Claim	USCA	8a
Parks	AUNS	17	Pine Nut	USNV	21b
Parnassus-Helikon	GREC	38c	Pine Point	CNNT	32a, 32b
Paronen	FNLD	28a	Pines	USOR	8a
Parroquio-Magistral	MXCO	18c	Pinnacles	AUQL	14b
Parys Mountain	GRBR	28a	Pinson	USNV	26a
Pashpap	PERU	17	Pintada-Stauber	USNM	30b
Passagem	BRZL	36b	Pioneer	USMT	39a
Pasto Bueno	PERU	15a	Pipe	CNMN	6b
Pasuquin	PLPN	28a	Pipestem	CNBC	36a
Patchek	URRS	39b	Piray	PLPN	28a
Pater	CNON	28a	Pirki	TRKY	24c
Patos de Minas	BRZL	34c	Piskala	TRKY	24c
Patrick	USCA	36a	Pitman (JB)	CNBC	21b
Patriquin	USCA	27c	Pito Real	MXCO	25g
Patterson	USCA	25c	Placerville	USCA	36a
Paulista	BRZL	34d	Plagia	GREC	18d
Payas	TRKY	38c	Plan de Tecolotes	MXCO	25h
Paymogo	SPAN	28a	Platies	CYPS	24a
Payne Group	CNBC	22c	Pleasant No. 1 & 2	USOR	8a
Pea Ridge	USMO	25i	Pleasant River	CNNS	36a
Pearsoll Peak	USOR	8a	Plomosas	MXCO	19a
Pecos	USNM	28a	Pluma Hidalgo	MXCO	7b
Peewan	USCA	8a	Plurhinaler	THLD	17
Peg Leg (Lambert)	USCA	8a	Poco Tiempo Quartz	USCA	8a
Pelican	USWI	28a	Pocos de Caldas	BRZL	38b
Pen-chi-hu	CINA	34a, 28b	Podbornaia	URRS	39b
Pena Colorada	MXCO	18d	Podmoskowoi-Log	URRS	39b
Penn	USCA	28a	Poerua River	NZLD	39c
Pennington Butte	USOR	8a	Point Leamington	CNNF	28a
Pennsylvania	USCO	22c	Poirier	CNQU	28a
Penobscot	USME	28a	Poison Mountain	CNBC	17
Penryn	USCA	36a	Pokrovsk	URRS	18d
Peravasa	CYPS	24a	Polar Star	USCA	27c
Perconi Ranch	USCA	8a	Polaris-Eclipse	CNNT	32a, 32b
Perda Niedda	ITLY	18d	Poludnig-Hermagor	ASTR	19b
Pergini	TRKY	8a	Pomalea	INDS	38a
Perrunal	SPAN	28a	Pontbriand	CNQU	8d
Persberg	SWDN	18d	Ponupo	CUBA	24c
Perseverance	ZIMB	6a	Ponupo de Manacal	CUBA	24c
Peschansk	URRS	18d	Pony Shoe	USCA	8a
Pestchanka R.	URRS	39b	Poodle Dog	USCA	8a
Petaquilla	PANA	17	Popowsky-Lojok	URRS	39b
Petersen Mtn.	USCA	25f	Popretschne-Log	URRS	39b
Phedinan R.-Triok	URRS	39b	Porkonen	FNLD	34a, 28b
Phelps Dodge	CNQU	28a	Poro	NCAL	38a
Phillipsburg	USMT	19b	Port Aux Moines	FRCN	28a
Phillips Lease	USNM	25g	Porter Property	USCA	8a
Phoenix	BOTS	7a	Porto Rico	CNBC	36a
Phoenix	CNBC	18b	Pot Lake	CNMN	28a
Phoenix	USCA	36a	Potosi	BLVA	20b
Piacoa	VNZL	34a, 28b	Potosi	BRZL	15c
Picacho	USCA	37b	Potosi	CUBA	8a
Picila	MXCO	18d	Potrerosillos	CILE	18a
Pickle Crow	CNON	36b	Potrero del Molino	MXCO	25h

<u>Name</u>	<u>Country</u>	<u>Model No</u>	<u>Name</u>	<u>Country</u>	<u>Model No</u>
Poum	NCAL	38a	Randall	USCA	8a
Powers	USOR	8a	Ranger	AUNT	38d
Pozo Prieto	CUBA	24c	Rankin	CNON	18d
Pratapolis	BRZL	38a	Rankin Inlet	CNNT	6a
Prater	USOR	8a	Raposos	BRZL	36b
Preble	USNV	26a	Rattlesnake Mountain	USCA	8a
Prebuz	CZCL	15c	Raul	PERU	24b
Presque Isle	USMI	30b	Ravensthorpe	AUWA	34b
Price	CNBC	28a	Ravenswood	NZLD	36a
Prickly Pear Creek	USMT	39a	Ravliden	SWDN	28a
Primer	CNBC	17	Ravlidmyran	SWDN	28a
Progreso	CUBA	24c	Ray	USAZ	21a
Prony	NCAL	38a	Ray (Tip Top)	USOR	8a
Propretschnoi	URRS	39b	Ray Gulch	CNYT	14a
Prunty	USNV	27d	Ray Spring	USOR	8a
Puerto Rico bauxite	PTRC	38c	Raymond	NCAL	24c
Pujada Pen	PLPN	38a	Razorback	AUTS	14c
Pulmoddai	SRIL	39c	Recibimiento	MXCO	18d
Punch	INDA	38c	Recsk	HUNG	18a 22a
Pyhasalmi	FNLD	28a	Red Bird	CNBC	21b
Pyramid (Mariposa Co.)	USCA	36a	Red Chris	CNBC	20c
Pyramid (Humboldt Co.)	USCA	8a	Red Crest	CNON	36b
Qala-el-Nahl	SUDN	8d	Red Dog	USAK	31a
Quartz Hill	USAK	21b	Red Elephant	USCA	27c
Quarazate	MRCO	24c	Red Hill-Red Hill Ext.	USNM	25g
Que River	AUTS	28a	Red Lake Gold Shore	CNON	36b
Quebrada Blanca	CILE	17	Red Ledge	USCA	8a
Queen Bess and vicinity	CNBC	22c	Red Mountain	USAZ	17
Queen Hill	AUTS	14c	Red Mountain	USCO	25b
Queen Victoria (Swift)	CNBC	18b	Red Mountain	USOR	8a
Queen of May	USOR	8a	Red Mountain	CNYT	21b
Queenston	CNON	36b	Red Rick	USCA	27c
Quelleveco	PERU	17	Red Slide Gp.	USCA	8a
Questa-Goat Hill	USNM	16	Red Wing	CNBC	28a
Quien-Sabe	USCA	27d	Redeyef	TUNS	34c
Quigg	USCA	8a	Redross	AUWA	6a
Quilon (Chavara)	INDA	39c	Redskin	USCA	8a
Quinto	CUBA	24c	Redstone	CNNT	23
Quixaba	BRZL	14a	Redwell	USCO	16
Qusseir	EGPT	34c	Reed	USCA	27c
R.R. Flat South	USCA	36a	Reed Lake	CNMN	28a
Rabbit Lake	CNSK	38d	Reefton Goldfield	NZLD	36a
Radiore E	CNQU	28a	Reeves	CNON	8d
Rail Lake	CNMN	28a	Reeves MacDonald	CNBC	31a
Rain	USNV	26a	Reicher Trost	PLND	36a
Rainbow	USCA	36a	Relief Canyon	USNV	26a
Rainbow	USOR	36a	Rendall-Jackson	CNNF	24a
Rainbow	USOR	8a	Renfrew	CNNS	36a
Rainy Day	USOR	8a	Renison Bell	AUTS	14c
Rajabasa	INDS	18c	Renstrom	SWDN	28a
Rajpura-Daiba	INDA	31a	Renzy	CNQU	7a
Rakkejaur	SWDN	28a	Republic	USWA	25c
Rambler-Cariboo	CNBC	22c	Rex	CNYT	8d
Rambler-Ming	CNNF	28a	Rexspar	CNBC	25f
Rammelsberg	GRMY	31a	Rhiw	GRBR	24c
Rammelsberg Barite	GRMY	31b	Rich	USCA	36a
Ramona-Loma	CUBA	38a	Rich Gulch	USCA	36a
Rampura-Agucha	INDA	31a	Rich Gulch (Virgilia)	USCA	36a
Ramsey	CNSK	28a	Richards	USCA	8a
Ramunia-Telok Ramunia	MLYS	38b	Richards Bay	SAFR	39c
Rana	NRWY	7a	Richey, U.S. & S.J.	USCA	8a
Ranch	USCA	36a	Riddle	USOR	38a
Rancherie	USOR	8a	Rieppe	NRWY	28a
Ranchi-Palamau	INDA	38b	Rim Rock and Homestake	USNV	27a

Name	Country	Model No	Name	Country	Model No
Rindge No. 1	USCA	36a	Rush Valley	USUT	19a
Ringwood	USNJ	25i	Ruth	USNV	18a
Rio	CNBC	22c	Ruttan	CNMN	28a
Rio Blanco	CILE	17	Ruwe (Mutoshi)	ZIRE	30b
Rio Challana	BLVA	39a	Ryan	USCA	36a
Rio Chimate	BLVA	39a	Ryan Group	USAK	36a
Rio Pallanga	PERU	25b	Ryllshyttan	SWDN	18c
Rio Tinto	SPAN	28a	Ryuo	JAPN	24b
Rio Tuba	PLPN	38a	Sabana Grande	DMRP	18d
Rio Tuichi (upper reach)	BLVA	39a	Sabanilla	CUBA	24c
Rio Vivi	PTRC	20c	Sabetjok	NRWY	28a
Rio Yolosano	BLVA	39a	Sablayon	PLPN	38a
Rio Yuyo	BLVA	39a	Sacaton	USAZ	17
Risliden	SWDN	7a	Sad Sack	USOR	8a
Roan Antelope (Luanshya)	ZMBA	30b	Saddle Chrome	USOR	8a
Robb Lake	CNBC	32a, 32b	Sado	JAPN	25d
Roberge Lake	CNQU	8d	Safagar	EGPT	34c
Robert E	USOR	36a	Safford (KCC)	USAZ	17
Robert Emmet	USMT	22c	Saghand	IRAN	25i
Roberts Mtns. Dist.	USNV	26a	Sagliden	SWDN	30a
Robertson	USOR	36a	Sagmo	NRWY	28a
Robt. E.	USOR	8a	Sai	JAPN	25b
Rochelois Plat.	HATI	38c	Sailor's Gully	AUVT	36a
Rock Creek	USOR	8a	Sain Bel	FRNC	28a
Rock Wren Mine	USCA	8a	Saindak	PKTN	17
Rockhole-Teages	AUNT	38d	Saindak South	PKTN	20c
Rockland	USFL	34d	Saint	USCA	8a
Rocky Turn	CNNB	28a	Saka	TRKY	8a
Rod	CNMN	28a	Sala	SWDN	18c
Rodhammeren	NRWY	28a	Salem Hills	USOR	38b
Rodkleiv	NRWY	28a	Saligny	FRNC	19b
Rokana (Nkana)	ZMBA	30b	Saline-Pulaski	USAR	38b
Romanera	SPAN	28a	Salitre	BRZL	10
Romerito	SPAN	28a	Sally Ann	USOR	8a
Rondoni	PERU	18d	Sally Malay	AUWA	7a
Rosario	HNDR	25c	Salmon River	CNNS	36a
Rose	CNBC	18d	Salsigne	FRNC	36a
Rose Claim	USCA	8a	Salt Rock	USOR	8a
Rose of Denmark	AUVT	36a	Salur	TRKY	8a
Rosebery-Read	AUTS	28a	Sam Goosly	CNBC	22a
Roseland	USVA	7b	Samar	PLPN	17
Rosethistle & Shamrock	AUVT	36a	Sambalpur	INDA	38b
Rosh Pinah	NAMB	31a	Sambas	AUVT	36a
Rosie Claim	USOR	8a	Samli	TRKY	18d
Rosita	NCRG	18b	San Antonio	PLPN	20c
Ross	CNON	36b	San Antonio	SPAN	28a
Ross	NZLD	39c	San Bernardo	MXCO	25g
Rostvangen	NRWY	28a	San Carlos	MXCO	18d
Roublewik R.	URRS	39b	San Domingos	PORT	28a
Round Bottom	USCA	8a	San Emigdio	USCA	27d
Round Mountain Au	USNV	25a	San Fabian	PLPN	20c
Round Mountain W	USNV	15a	San Francisco	MXCO	25h
Roupe	USCA	8a	San Francisco	USUT	19a
Rouyn Merger	CNQU	36b	San Giovanni Rotondo	ITLY	38c
Rowghat	INDA	34a, 28b	San Guillermo-Sierra	SPAN	28a
Royal George	AUTS	15b	San Humberto	MXCO	25h
Royal Mountain King	USCA	36a	San Juan	USAZ	17
Rua Cove	USAK	24a	San Juan de Chacna	PERU	18d
Ruby Creek	USAK	32c	San Juan de la Costa	MXCO	34c
Rudna Glava	YUGO	18d	San Juanera	MXCO	25h
Rudtjebacken	SWDN	28a	San Leone	ITLY	18d
Ruff Claim No. 32	PLPN	8a	San Manuel	USAZ	17
Rum Jungle Creek South	AUNT	38d	San Martin	ACTN	15a
Ruseifa	JRDN	34c	San Mateo	PLPN	28a



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San Miguel El Alto	MXCO	25g	Schissler Creek	USID	39a
San Pedro	SPAN	28a	Schist Lake	CNMN	28a
San Pedro	USNM	18b	Schmid	USOR	8a
San Platon	SPAN	28a	Scinto 5	AUNT	38d
San Rafael	MXCO	25h	Scotia	AUWA	6a
San Ruperto	MXCO	25h	Scott Bar	USCA	36a
San Telmo	SPAN	28a	Scott River	AUWA	39c
San Xavier	USAZ	17	Scrafford	USAK	27d
Sanchez	USAZ	17	Seraton-Pontiac-Sunset	CNBC	22c
Sand Creek	SID	39a	Se Chakhum	IRAN	25i
Sand Springs	USNV	25c	Seal Harbour	CNNS	36a
Sandford	USAK	36a	Searchlight	USNV	25c
Sanei	JAPN	25d	Sechura	PERU	34c
Sanford Lake	USNY	7b	Second Relief	CNBC	36a
Sang Dong	SKOR	14a	Sehib	TUNS	34c
Sangalwara	INDA	34a,28b	Seiad Creek (Mt. View)	USCA	8a
Sangaredi	GNEA	38b	Seiba	URRS	34b
Sankyo	JAPN	18d	Seikoshi	JAPN	25c
Sanshaw	CNON	36b	Sekioren	TRKY	8a
Santa Ana	MXCO	25g	Selco-Scott	CNQU	28a
Santa Barbara	BRZL	38b	Selebi	BOTS	7a
Santa Barbara	VNZL	34a,28b	Selimiye	TRKY	25g
Santa Barbara	PERU	27b	Selkirk	BOTS	7a
Santa Efigenia	MXCO	25h	Selukwe	ZIMB	6a
Santa Eulalia	MXCO	19a	Senor de Huarquisa	PERU	18d
Santa Fe	USNV	26a	September Morn	USCA	8a
Santa Gertrudis	MXCO	25h	Serb Creek	CNBC	21b
Santa Leonor	MXCO	25h	Sereno	BRZL	24c
Santa Lucia	MXCO	25h	Serra Negra	BRZL	10
Santa Lucia	PERU	18d	Serria do Carajas	BRZL	34a,28b
Santa Rita	USNM	18a	Sesson Mine	USCA	36a
Santa Rosa	CUBA	24c	Setting Net Lake	CNON	21b
Santa Rosa	SPAN	28a	Seven Trough	USNV	25c
Santander	PERU	19a	Severnoe	URRS	18d
Santiago Papalo	MXCO	8d	Sexton Mountain	USOR	8a
Santiago-Commonwealth-			Seydisehr	TRKY	38c
Centennial	USCO	22c	Sha	CYPS	24a
Santo Nino	PLPN	20c	Shackleton	ZIMB	30b
Santo Tomas	MXCO	17	Shade Chromite	USOR	8a
Santo Tomas	PLPN	20c	Shafer Lease	USCA	8a
Sao Domingos do Capim	BRZL	38b	Shag Rock	CNBC	25g
Sao Joao do Piaui	BRZL	38a	Shagyrkul	URRS	18d
Sao Paulo	BRZL	38b	Shahin	IRAN	8a
Santa Cruz	PLPN	38a	Shamrock	USCA	8a
Sapalskoe	URRS	24c	Shamva-Cymric Gp.	ZIMB	36b
Sar Cheshmeh	IRAN	17	Shangani	ZIMB	6a
Sarbay	URRS	18d	Shasta King	USCA	28a
Sardegna	ITLY	25g	Shasta-California	USCA	18d
Sarialan	TRKY	8a	Shediyah	JRDN	34c
Sarikaya	TRKY	8a	Sheep Ranch	USCA	36a
Saruabi	INDA	38a	Sheep Tank	USAZ	25c
Sasagatani	JAPN	18b	Shelly	USCA	8a
Sasca Montana	RMNA	18b	Shenandoah Mine	USCA	36a
Satevo	MXCO	25g	Sheppard Mine	USCA	8a
Sattelberges	ASTR	19b	Sherrin Creek	AUQL	34c
Saturday Anne	USOR	8a	Shertingdal	NRWY	30a
Saua-Toranica	YUGO	19a	Shevaroy Hills	INDA	38b
Savage River	AUTS	25i	Shihmien	CINA	8d
Savannah	USGA	34d	Shiiba, Takaragi	JAPN	24b
Savannah River	USGA	34d	Shimoga (Karnatoka)	INDA	34b
Saxberget	SWDN	18c	Shimokawa	JAPN	24b
Saysin	TRKY	8a	Shimokawa (Kouchi)	JAPN	24b
Sazare	JAPN	24b	Shinga	JAPN	24b
Schaft Creek	CNBC	17	Shinyama	JAPN	18d

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Ship Island	USMS	39c	Soho	CNBC	22c
Shirataki	JAPN	24b	Sohodol-Cimpeni	RMNA	38c
Shotgun Creek	USCA	8a	Solbec	CNQU	28a
Shuikoushan	CINA	18c	Soloviejo	SPAN	24c
Shunsby	CNON	28a	Solovyevskii Log	URRS	39b
Sicankale	TRKY	8a	Sombrerete	MXCO	19a
Sidamo	ETHP	38a	Sombreretillo	MXCO	25h
Sierra Gorda	CILE	17	Son of Gwalia	AUWA	36b
Sierra Los Organos	MXCO	25g	Soo	USAK	36a
Sierra de El Alto	MXCO	25g	Soquem	CNQU	10
Sierra de Enmedio	MXCO	25g	Sorka	URRS	18d
Sierrecilla	SPAN	28a	Soroako	INDS	38a
Sierrita-Esperanza	USAZ	21a	Sosnowka	URRS	39b
Sigua	CUBA	24c	Sosva	URRS	18d
Siirt Madenkoy	TRKY	24a	Sothman Twp.	CNON	6a
Silica Mine	USTN	39c	Sotiel	SPAN	28a
Silva-Aysen	CILE	19a	Soto	MXCO	25h
Silver Bell	USAZ	18a	Soto (Chihuahua)	MXCO	25g
Silver City	USNV	25c	Soukhoi Log	URRS	39b
Silver Cloud	USNV	27a	Soulsbyville	USCA	36a
Silver Lakes	USCA	18d	Sour Dough	USOR	8a
Silver Lease	USOR	8a	Sourdough Bay	CNMN	28a
Silver Queen	CNBC	28a	Sousa Ranch	USCA	8a
Silver Valley	AUQL	15b	South Crofty	GRBR	15b
Silvermines	IRLD	31a	South Dufault	CNQU	28a
Silverside	ZIMB	30b	South Florida phosphate	USFL	34d
Silversmith-Richmond-			South Rusty Hill	CNQU	28a
Ruth-Hope	CNBC	22c	South Sarbay	URRS	18d
Simlipal	INDA	38a	South Thomas	USCA	24c
Simmons	USCA	8a	South Uniacke	CNNS	36a
Simon	USCA	8a	South Weipa	AUQL	38b
Sims	USCA	8a	Spar Lake (Troy)	USMT	30b
Sipalay	PLPN	17	Spargoville	AUWA	6a
Sirac	TRKY	8a	Spenceville	USCA	28a
Sirigao	INDA	34a, 28b	Spinazzola	ITLY	38c
Sirkov Log	URRS	39b	Spot	USCA	8a
Six Mile	AUWA	6b	Spring Gully	AUVT	36a
Six-Mile	USOR	8a	Spring Hill	USCA	8a
Skaide	NRWY	28a	Spruce Mountain	USNV	19a
Skorovass	NRWY	24a	Spruce Point	CNMN	28a
Skouriotissa	CYPS	24a	Squirrel Hills	AUQL	31a
Skull	AUNT	38d	Srednia-Prostokischenka	URRS	39b
Skyline Mine	USCA	8a	Ssu-chia-ying	CINA	34a, 28b
Sleisbeck	AUNT	38d	St. Adrien Mtn.	CNQU	8d
Sliger	USCA	36a	St. Ann Plat.	JMCA	38c
Slocan-Sovereign	CNBC	22c	St. Anthony	USAZ	22cSt.
Smith Geitsfield	USOR	8a	Cyr	CNQU	8d
Smithfield	CNNS	30a	St. Dizier	AUTS	14c
Snake Mountain	USNV	31b	St. George	AUQL	27d
Snakehead (Jumbo)	USCA	8a	St. Honore	CNQU	10
Sneffels	USCO	25b	St. Leonards	AUTS	38b
Snowdrift	USNV	27d	St. Patrick (Camp 8)	USCA	8a
Snowshoe	USNM	18b	St. Pietro	ITLY	25g
Snowstorm	USMT	30b	Sta. Cruz	PLPN	8a
Snowstorm area	USCO	39a	Stadacona	CNQU	36b
Snowy Ridge	USCA	8a	Stafford	USCA	8a
Snowy Ridge	USOR	8a	Stall Lake	CNMN	28a
Snyder	USCA	8a	Standard	USNV	26a
Søve	NRWY	10	Standard and vicinity	CNBC	22c
Soab	CNMN	6b	Stannary Hills	AUQL	15b
Socorro-Guadalupe	MXCO	25h	Star	USUT	19a
Socrates	USCA	27c	Star Mt.-Fubilan	PPNG	20c
Sofulu	TRKY	8a	Star Mt.-Futik	PPNG	20c
Sogham	IRAN	8a	Star Mt.-Nong River	PPNG	17

<u>Name</u>	<u>Country</u>	<u>Model No</u>	<u>Name</u>	<u>Country</u>	<u>Model No</u>
Star Mt.-Olgal	PPNG	17	Surprise-Noble Five and vicinity	CNBC	22c
Stark Bee	USCA	8a	Sustut	CNBC	23
Starratt-Olsen	CNON	36b	Susu Lake	CNNT	28a
State School	USCA	8a	Sutherland	USNV	27d
Steamboat Springs	USNV	27a	Sutpinar	TRKY	8a
Stedman	USCA	25e	Sutro	USCA	28a
Steele Brook	CNQU	8d	Sutro Mine	USCA	8a
Stekenjokk	SWDN	28a	Sutter Creek	USCA	36a
Stepanoff-Log	URRS	39b	Suzanne	NCAL	8a
Stephane	NCAL	8a	Suzy Bell (Lucky Strike)	USCA	8a
Sterling Creek	USOR	39a	Svano	NRWY	24a
Sterling Lake	USNY	25i	Swardsio	SWDN	18c
Stevens-Miller	USOR	8a	Swan River	USCO	39a
Stewart	USCA	8a	Swansea	USAZ	37b
Stewart Island	CNSK	38d	Swayne	USCA	8a
Stewart May	USAR	27d	Sweetwater	USCA	8a
Stibnite	USAK	27d	Swim Lake	CNYT	31a
Stillwater	USMT	1,2a,2b	Sydvananger	NRWY	34a,28b
Stirling	CNNS	28a	Sylvanite	USOR	36a
Stockton	USAZ	22c	Syssim R.	URRS	39b
Stockton Bight	AUNS	39c	Tache Lake	CNQU	28a
Stollberg	SWDN	18c	Taco Bay	CUBA	38a
Stone & Haskins	USOR	8a	Tagpura	PLPN	17
Stonewall	USCA	36a	Taiba	SNGL	34c
Store Gulch	USOR	8a	Taio	JAPN	25c
Storeys Creek	AUTS	15a	Taisho (Nishimata)	JAPN	28a
Storie	CNBC	21b	Takahata	JAPN	25d
Stormy Group	CNYT	14a	Takanokura	JAPN	18d
Stowell	USCA	28a	Takatama	JAPN	25d
Stra Quertane	TUNS	34c	Takaura	JAPN	24b
Stralak	CNON	28a	Takeno	JAPN	25d
Strandzha	BULG	18b	Takijug Lake	CNNT	28a
Stratmat	CNNB	28a	Taknar	IRAN	28a
Strawberry	USCA	14a	Talamantes	MXCO	25g
Stray Dog	USOR	8a	Tallering Peak	AUWA	34a,28b
Stripa-Striberg	SWDN	34a,28b	Talmora Longlac	CNON	36b
Sturgeon Lake	CNON	28a	Tamborine Mountain	AUQL	38b
Suffield	CNQU	28a	Tanama	PTRC	20c
Suftlii Bor	URRS	39b	Tangier	CNNS	36a
Sugarloaf Hill	CNBC	17	Tangle Blue Divide	USCA	8a
Sukinda	INDA	38a	Tapairihua	PERU	18d
Sukulu	UGND	10	Tapira	BRZL	10
Sulat	PLPN	28a	Tapley	USME	28a
Sullivan	CNBC	31a	Taratana	CUBA	24c
Sullivan and Kahl	USCA	8a	Taritipan	INDS	24c
Sulphur Bank	USCA	27a	Tarkwa	GHNA	29a
Sultan	AUVT	36a	Tasdibi	TRKY	27d
Sulu	TRKY	8a	Tashiro	JAPN	28a
Suluiyeh	IRAN	8a	Taslica	TRKY	28a
Suluk	TRKY	8a	Tasu-Wesfrob	CNBC	18b
Sumadisa	YUGO	19a	Tawi-Tawi	PLPN	20c
Summit	USAZ	19b	Taylor	USCA	36a
Summitville	USCO	25e	Tayoltita	MXCO	25c
Sumpter Bar	USOR	39a	Taysan	PLPN	20c
Sun	CNMN	28a	Tea	CNYT	31b
Sunnyslope	USCA	8a	Teahan	CNNB	28a
Sunrise	USCA	8a	Techa	URRS	18d
Sunset	USCA	8a	Tecolote	USNM	18d
Sunshine	CNBC	28a	Tecolotes	MXCO	25h
Sunshine	USCA	8a	Tecopa	USCA	19a
Sunshine Creek	CNBC	21b	Tedi	CNBC	28a
Sunshine-Corinth	CNBC	22c	Tekneli	TRKY	8a
Surf Inlet	CNBC	36a	Tekwane	BOTS	7a
Surigao	PLPN	38a			

Name	Country	Model No	Name	Country	Model No
Telluride	USCO	25b	Topkirozlar	TRKY	24c
Tem Piute district	USNV	14a	Topock	USAZ	25g
Tenke-Fungurume	ZIRE	30b	Toquepala	PERU	17
Tennessee Chrome	USOR	8a	Toscana (Cerchiara)	ITLY	24c
Tennessee Pass	USOR	8a	Tosin	TRKY	8a
Tepebasi	TRKY	8a	Tougue	GNEA	38b
Tepustete	MXCO	18d	Toujours Gai	USCA	8a
Terano	JAPN	24b	Toura R.	URRS	39b
Terlik	TRKY	8a	Tovarnica	YUGO	18d
Terra Nova	CNNF	28a	Toyoha	JAPN	25b
Terrenates	MXCO	25g	Trail Ridge	USFL	39c
Tetyukhe	URRS	18c	Traversella	ITLY	18b
Teutonic Bore	AUWA	28a	Treadwell Mines	USAK	36a
Texada	CNBC	18d	Treasure Hill	USAZ	22c
Texas	CNNB	28a	Tregioivo	ITLY	30a
Textmont	CNON	6a	Trepca-Kopaonik	YUGO	19a
Thabazimbi	SAFR	34a,28b	Tri State	USMO-USOK	32a,32b
Thamar-Kotra	INDA	34c	Trinidad	USCA	8a
Thatcher Creek	USCA	24c	Trininty	CNQU	28a
Thetford Group	CNQU	8d	Triton	AUWA	36b
Thierry	CNON	7a	Trojan	CNBC	17
Thies	SNGL	34c	Trojan	ZIMB	6a
Thio	NCAL	38a	Trombetas	BRZL	38b
Third Portage	CNNB	28a	Troulli	CYPS	24a
Thomas	USCA	24c	Trout Bay	CNON	28a
Thompson	CNMN	6b	Trout Lake	CNBC	21b
Thompson Bousquet	CNQU	36b	Trudny-Log	URRS	39b
Thompson Creek	USID	21b	Truscott	USCA	36a
Thompson Falls	USMT	27d	Tsaitasukou	CINA	18d
Thompson Gp.	USOR	8a	Tsauch R.	URRS	39b
Thuburnic	TUNS	19b	Tschachewitaia	URRS	39b
Thurston & Hardy	USAZ	25g	Tschch R.	URRS	39b
Tiebaghi Ni	NCAL	38a	Tshinsenda	ZIRE	30b
Tiebaghi Cr	NCAL	8a	Tsuchihata	JAPN	28a
Tienpaoshan	CINA	18c	Tsumeb	NAMB	32c
Tiere	UVOL	24c	Tsumo	JAPN	18b
Tilai R.	URRS	39b	Tulameen	CNBC	39b
Tilkim-Karanlik	TRKY	8a	Tulk's Pond	CNNF	28a
Tilt Cove	CNNF	24a	Tulsequah	CNBC	28a
Timna	ISRL	34b	Tunca	TRKY	28a
Timoni	AUWA	36b	Tuncurry-Tomago area	AUNS	39c
Tin Cup Peak	USOR	10	Turfullar	TRKY	25g
Tintaya	PERU	18b	Turner-Albright	USOR	24a
Tintic	USUT	19a	Turtle Head	AUQL	38b
Tiouine	MRCO	24c	Tuscarora	USNV	25c
Tipperary Mine	NZLD	36a	Tutunculer	TRKY	24c
Tjarrojakka	SWDN	25i	Tuzlakaya	TRKY	8a
Tjokkola	SWDN	28a	Tverrfjellet	NRWY	28a
Togobomar	PLPN	8a	Twin Buttes	USAZ	18a,21a
Toi	JAPN	25c	Twin Cedars	USOR	8a
Toiyabe	USNV	26a	Twin Peaks	USCA	27c
Tokoro	JAPN	24c	Twin Valley	USOR	8a
Tolano	MXCO	25h	Tynagh	IRLD	31a
Toledo	PLPN	20c	Tybo	USNV	22c
Tolman	USID	26a	Tyrny-Auz	URRS	14a
Tom	CNYT	31a	Tyrone	USNM	21a
Tombstone	USAZ	19a	U.S. Group	USAZ	25g
Tomkin	USCA	8a	UV Industries	USNV	21b
Tomogonops	CNNB	28a	Uchi	CNON	28a
Tonkin Springs	USNV	26a	Uchi	CNON	36b
Tonkolili	SRLN	34a,28b	Uchucchaqua	PERU	18c
Tonopah	USNV	25c	Uckopru	TRKY	8a
Toombou	AUVT	36a	Udden	SWDN	28a
Toparlar-Alacik	TRKY	8a	Udokan	URRS	30b

Name	Country	Model No	Name	Country	Model No
Uinta Mtns.	USUT	34c	Vorderen Strubberges	ASTR	19b
Ulchin	SKOR	18c	Vorontsovka	URRS	18d
Uludag	TRKY	14a	Vubachikwe	ZIMB	36b
Ulukoy	TRKY	19b	Vulcan	USCA	18d
Uncle Sam	USCA	36a	Vyhne	CZCL	18d
Uncle Sam	USOR	8a	W.P.	USNV	27d
Undu	FIJI	28a	Waden Bay	CNSK	28a
Union	USNV	22c	Wafangtzu	CINA	34b
Unterlaussa	ASTR	38c	Wagasennin	JAPN	18d
Upata	VNZL	38b	Waiho River	NZLD	39c
Upper Beaver	CNON	36b	Wait (Amador Co.)	USCA	8a
Upper Bellingem	AUNS	27d	Waite (Nevada Co.)	USCA	8a
Upper Canada	CNON	36b	Waite East	CNQU	28a
Upper Mississippi Valley	USWI	32a,32b	Walibu	USCA	27a
Upper Seal Harbour	CNNS	36a	Walker	USCA	8a
Upper Silesia	PLND	32a,32b	Wall Canyon	USNV	27d
Uracum	BRZL	34b	Wall Street	USCA	27c
Uribe	USWA	31b	Wallapai District	USAZ	22c
Urkut	HUNG	34b	Wallaroo	AUWA	28a
Uruachic	MXCO	25b	Wannaway	AUWA	6a
Usinsk	URRS	34b	War Bond	USCA	8a
Utica	CNBC	22c	War Eagle	CNYT	18b
Vaddas	NRWY	28a	War Eagle-Miller	USCA	8a
Vakkerlien	NRWY	7a	Ward	CNBC	36a
Val Di Peio	ITLY	18d	Ward	USOR	8a
Valen Prospect	USOR	8a	Ward and Lyons	USCA	8a
Valenti	USCA	8a	Warm Springs, North Mocassin	USMT	22b
Valle de Manganese	CUBA	24c	Warm Springs	USMT	34c
Valle del General	CORI	38b	Waroon Shoreline	AUWA	39c
Valley Copper	CNBC	21a	Warrington	USCA	36a
Valley View	USCA	36a	Wasa Lake	CNQU	36b
Valuev	URRS	18d	Washington	MXCO	17
Vammala	FNLD	7a	Washington	USCA	36a
Vamp	CNMN	28a	Washington Camp	USAZ	18c
Vananda	CNBC	18b	Washout	USCA	8a
Vancouver Group	CNBC	22c	Waterloo	USAZ	19b
Vangorda	CNYT	31a	Watsonville	AUQL	15b
Varna	BULG	34b	Wattle Gully	AUVT	36a
Vassbo	SWDN	30a	Waverley	CNNS	36a
Vauze	CNQU	28a	Wayside	CNBC	36a
Veitsch	ASTR	19b	Weaver	USAZ	25c
Vekol	USAZ	17	Wedge	CNNB	28a
Velardepa	MXCO	19a	Weebo Bore	AUWA	6b
Verkho-Tourie	URRS	39b	Weedaroo	AUSA	31b
Vermilion	USMN	34a,28b	Weedon	CNQU	28a
Vermilion River	USMT	39a	Weipa-Andoom-Pera Head	AUQL	38b
Vermillion	CNON	28a	Weiss	TRKY	28a
Vernal	USUT	34c	Welch	USCA	24c
Vestpolltind	NRWY	34a,28b	Welch Prospect	USCA	8a
Veta Blanca	MXCO	25h	Weld Range-Wilgie Mia	AUWA	34a,28b
Viburnum	USMO	32a	Wellington	AUNS	39a
Victoria	USNV	18b	Wellington	CNBC	22c
Victory	CNBC	14a	Wenlock River	AUQL	38b
Victory No. 3	USCA	8a	West Bear	CNSK	38d
Vieille Montagne	NCAL	8a	West Chrome	USCA	8a
Vigsnes	NRWY	28a	West Gore	CNNS	27d
Violet	USOR	8a	West Jacksonville	USCA	36a
Viscaria	SWDN	28a	West Maui	USHI	38b
Viterbo-Roma	ITLY	25g	West Niggerhead	USNM	25g
Vlasenica	YUGO	38c	West Ore Body	PLPN	8a
Vogelgesang	USCA	8a	Westarm	CNMN	28a
Vogler's Cove	CNNS	36a	Western Magnesite	USCA	8a
Volcanic Peak	USNV	27d	Western Nevada	USNV	18b
Von Roi-Hewitt	CNBC	22c	Westland	NZLD	36a



<u>Name</u>	<u>Country</u>	<u>Model No</u>	<u>Name</u>	<u>Country</u>	<u>Model No</u>
Westport	NZLD	39c	Yava (Silvermine)	CNNS	30a
Wexford	CNBC	18b	Yayca Boyna	TRKY	8a
Weza	SAFR	38b	Yellow Jacket	USNM	18d
Whalesback-Little Deer	CNNF	24a	Yellow Pine	USCA	8a
Wheal Jane	GRBR	15b	Yellow Pine	USNV	19a
Wheal Kitty-Penhalls	GRGB	15b	Yellow Pine district	USID	14a
Whim Creek	AUWA	28a	Yeonhwa	SKOR	18c
White Bear	USCA	8a	Yeoval	AUNS	17
White Cedar	USCA	8a	Yerington	USNV	17
White Feather	AUWA	36b	Yermakof-Log	URRS	39b
White Feather	USCA	8a	Yeya	CUBA	24c
White King	USOR	25f	Yilmaz Ocagi	TRKY	8a
White Lake	CNMN	28a	Yoganup Shoreline	AUWA	39c
White Pine	USMI	30b	Yoichi	JAPN	28a
White Pine	USNV	19a	Yokota (Motoyama-Hama.)	JAPN	28a
White Pine Mine	USCA	8a	York Harbour	CNNF	24a
White's (Rum Jungle)	AUNT	38d	Yoshimoto	JAPN	24b
Whiteburn	CNNS	36a	Yoshino (Hisaka)	JAPN	28a
Whitlock	USCA	34d	Yoshino (Main)	JAPN	28a
Whundo	AUWA	28a	Youanmi	AUWA	36b
Wigie 3	AUWA	6a	Young	USOR	8a
Wigwam	CNBC	31a	Young's Mine	USOR	8a
Wild Cat Claim	USOR	8a	Yreka	CNBC	18b
Wildcat	PLPN	28a	Ysxjoberg	SWDN	14a
Wilder (Fish Creek)	USCA	8a	Yugashima	JAPN	25c
Wildrose Canyon	USCA	27d	Yukari Zorkum	TRKY	8a
Willecho	CNON	28a	Yulee	USFL	39c
Wilmar and others	CNON	36b	Yunus Yayla	TRKY	8a
Wilshire-Bishop	USCA	36a	Yurtlak	TRKY	8a
Wiluna-Moonlight	AUWA	36b	Yuryo	JAPN	24b
Wim	CNMN	28a	Z	CNMN	28a
Windarra	AUWA	6a	Zacate-Cerro Chino	MXCO	25g
Windfall	USNV	26a	Zaetzeff, R.	URRS	39b
Windsor	CNQU	8d	Zambales Ch	PLPN	8a
Windy	CNBC	28a	Zanitzza	MXCO	18d
Windy Point	USOR	8a	Zarikan	IRAN	18d
Wine Harbour	CNNS	36a	Zawar	INDA	31a
Wingelinn-Daisy	AUWA	38a	Zawarmala	INDA	31a
Winters	USCA	25d	Zeballos	CNBC	18d
Wintrop	CNBC	22c	Zeida	MRCO	30a
Witswatersrand	SAFR	29a	Zeila	USCA	36a
Wolf Creek	USCA	8a	Zemlianoi-Mostik Log	URRS	39b
Wolf Creek area	USCA	8a	Zerfing Ranch	USCA	8a
Wombat Creek	AUNS	39a	Zimapan	MXCO	19a
Wonder	USOR	8a	Zimparalik	TRKY	8a
Wonder Gp.	USOR	8a	Zindani	GREC	8d
Wonderful-Elkhorn	CNBC	22c	Zip	CNBC	18b, 18
Woodcutters	AUNT	31a	Zonguldak	TRKY	38c
Woodlawn	AUQL	28a	Zortman Landusky	USMT	22b
Woodsreef Mine	AUNS	8d			
Woody Woody	AUWA	24c			
Wyoming	USWY	34c			
Wyssim R.	URRS	39b			
Xihuashan	CINA	15a			
Yahualica	MXCO	25g			
Yakobi Island	USAK	7a			
Yanahara	JAPN	24b			
Yanchiachangtze	CINA	18c			
Yandera	PPNG	17			
Yanikara	TRKY	8a			
Yankee Hill	USCA	36a			
Yaprakli	TRKY	8a			
Yatani	JAPN	25b			
Yava	CNNT	28a			









