BULLETIN 65

# Metallogenic Provinces of the Southwestern United States and Northern Mexico

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1959

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**NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY**
**CAMPUS STATION SOCORRO, NEW MEXICO**

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# *Abstract*

Some of the metallogenic provinces of the southwestern United States and northern Mexico are defined by the geographic distribution of sulfophile trace elements in more than 500 samples of chalcopyrite and sphalerite from 172 mining districts.

Maps that show the geographic distribution of tin, silver, and the "combined metal content" in chalcopyrite, and of silver and the "combined metal content" in sphalerite, reveal three major belts of high trace-element content in the Southwest. These belts, which are here called the Eastern, Central, and Western metallogenic belts, are consistent in trend and position with a beltlike distribution of the major ore deposits of copper, gold, silver, and other metals. However, the deposits of a given metal tend to be concentrated in certain segments of the metallogenic belts; consequently, the metallogenic provinces, in the ordinary sense, are merely component parts of the larger beltlike features.

The metallogenic belts also are generally consistent in position and trend with the major tectonic features, although they do not appear to be closely related in time. Hence, it is suggested that both the metallogenic belts and the major tectonic features are the effects of a more fundamental cause, which perhaps is a combination of compositional heterogeneities and associated physical discontinuities in the deep-seated source regions of the ores.

# Introduction

This paper[1] embodies, in part, the results of an investigation of the geographic distribution of trace or minor elements in two hypogene sulfide minerals, chalcopyrite and sphalerite. The investigation was undertaken mainly in an attempt to define quantitatively some metallogenic provinces in the southwestern United States, as a knowledge of these features is of considerable value in the search for new ore deposits and in the formulation of sound theories on the origin of ore deposits and associated geologic features. Especial emphasis is placed on a discussion of the results of the work, and an effort has been made to restrict speculation on the origin of the features that are described, for in the present state of knowledge gross speculation would serve little constructive purpose.

The concept of metallogenic provinces appears to have been first described by De Launay and Urbain (1910), although Spurr (1902, 1905) previously had applied the terms "metalliferous provinces" and "metallographic provinces" to a similar concept. De Launay (1913) regarded a metallogenic province as a region of the earth that is characterized by mineral deposits which belong to a specific metallogenic epoch or combination of epochs and to a specific tectonic setting, whereas Spurr (1902, p. 336) visualized a metallographic province as a region that is "characterized by special combinations or amounts of the rarer, especially the commercially valuable metals." Spurr recognized, moreover, that within a metallographic province thus defined there may be deposits which represent several metallogenic epochs.

Lindgren (1933) applied the terms "minerogenetic provinces" and "metallogenetic provinces" to a concept that appears to be very similar to De Launay's, whereas Bateman (1950, p. 319) has used the term "metallogenetic provinces" in referring to "certain regions characterized by relatively abundant mineralization dominantly of one type."

Recently, Turneaure (1955) has presented a comprehensive review and summary of ideas on metallogenic provinces. However, neither he, Bateman, nor other contemporary investigators of the subject appear to make a distinction in the application of the terms metallographic, metallogenetic, and metallogenic. Consequently, the term metallogenetic (or metallogenic) province commonly is applied to the feature that Spurr called a metallographic province, although a demonstrable genetic relationship is not generally implied. Therefore, the term metallogenic province is used throughout this paper, in part to effect harmony with current usage and in part because evidence is presented that suggests certain genetic relationships.

[1] Contribution No. 869, Division of the Geological Sciences, California Institute of Technology.

Although there are numerous discussions in the literature concerning metallogenic provinces, in terms of groups of ore deposits or mining districts that possess some feature in common, very few have resulted in concrete expressions, such as maps of the provinces. Spurr (1923) was one of the first to attempt such an expression in the publication of maps (p. 459-462) that show the "Great Silver Channel." He concluded that all the silver deposits along this "channel" have a common genetic element; namely, a compositional similarity in terms of source. Moreover, this source, which differs compositionally from adjacent regions, has a configuration that corresponds to the configuration of the "channel." About 10 years later, Butler (1933, p. 233) published a map which indicates that the important mining districts of the western United States tend to be concentrated around the margins of the Colorado and Columbia Plateaus. This distribution previously had prompted Butler (1930) to suggest a possible genetic relationship between the ore deposits and these "positive" tectonic elements. More recently, Billingsley and Locke (1941, p. 52) have published a map of the orogenic belts of the United States and have attempted to show that the more important ore deposits tend to cluster around intersections of these orogenic belts (the "cross-roads") and other tectonic features that extend to great depths. Also, Kerr (1946) has outlined three "tungsten arcs" in the western United States, based on the geographic distribution of tungsten deposits, and finds certain features in the deposits of one "arc" that in general serve to distinguish them from the deposits in the other "arcs."

The foregoing summary of ideas concerning metallogenic provinces is not intended as a comprehensive survey of the literature on the subject, but as an illustration of the fact that although the basic concepts have been in existence for nearly half a century, our knowledge of metallogenic provinces consists mainly of generalizations based on qualitative studies. Few, if any, quantitative studies heretofore have been aimed specifically at the definition of metallogenic provinces, although some trace-element studies indirectly have provided much evidence that bears on the problem.

The existence of a distinct geographic distribution of trace elements in certain primary sulfide minerals was recognized very early by De Launay and Urbain (1910), but little emphasis was placed on the geographic or province aspect of the distribution until Stoiber (1940, p. 513, 518) pointed out that:

> A closer similarity in composition of sphalerite from a single metallogenetic group of deposits than from deposits of a single temperature group suggests a further correlation between minor element content and the geology of sphalerite occurrence.
>
> Sphalerite from the same metallogenetic group of deposits contains similar kinds and amounts of constituents but the composition of sphalerite from each region is distinctive.

This concept of a metallogenic group that is characterized by a distinctive trace-element content in sphalerite was enlarged upon by Warren and Thompson (1945, p. 334):

> Metallogenetic provinces or zones are of primary importance in establishing the minor element content of sphalerite. Within a metallogenetic province or zone, the temperature and type of deposit in which the sphalerite occurs are important, but not determining factors.
>
> There appears to be a tendency for each mining camp in Western Canada to exhibit a characteristic assemblage of minor elements. This tendency is reflected in part by the minor elements which appear in sphalerite. There are several instances of one or more mines situated on the same, or intimately related lodes, exhibiting a striking similarity in their minor element content. However, in view of the fact that sufficient collaborative results are not yet available, no final conclusions relative to most of these minor areas may yet be made. Nevertheless, further work may profitably be carried on in this field: there is every indication that detailed studies will show that each important orebody has a characteristic mineral assemblage and, furthermore, a characteristic minor element distribution in those minerals.

It is clear, then, that the concept of metallogenic provinces that are defined by the trace- or minor-element content of hypogene sulfide minerals has been held previously. In fact, Warren and Thompson (1945, fig. 1) outlined a beltlike tin province in eastern British Columbia that is defined by tin as a trace element in sphalerite. Although the data on which this map is based might be regarded as somewhat meager, the map nevertheless represents the first depiction of a metallogenic province that is based on quantitative information. Moreover, the position, trend, and general dimensions of this tin belt are consistent with the findings of the present study.

Schroll (1950, 1951) has shown that in Europe the trace-element content of sphalerite and galena from the Alpine region reflects certain geological conditions and hence exhibits a provincial distribution. Recently, Goldschmidt (1954, p. 92-93) has discussed the problems connected with the uneven distribution of certain elements, notably tin, and has noted that:

> The absence of workable tin deposits in large regions of the earth, which are also characterized by the scarcity of even small amounts of tin minerals, seems also to be followed by a scarcity of tin as a "trace element" as indicated by spectroscopic observations on magmatic rocks.

It has been known for a long time that workable deposits of some metals, especially tin, are not evenly distributed throughout the earth, and now it is suggested that there is a close correlation of tin deposits with tin as a trace element in the minerals of igneous rocks. Further development of this idea leads to the conclusion that metallogenic provinces, in this case tin provinces, could be defined by the trace elements in minerals that are genetically connected with the tin deposits. Thus, although the present work was begun 2 years before the appearance of Goldschmidt's book, it nevertheless was predicated on the assumption that a relationship exists between the distribution of metals in workable deposits and the distribution of the same or chemically similar metals as trace elements in hypogene minerals.

It is noteworthy that the relationship is postulated only for "the same or chemically similar" elements, for there appears to be no a priori reason to suspect that the chemically dissimilar elements would possess consistent genetic relationships. These studies, therefore, are confined to the sulfophile (or chalcophile) elements; more specifically, they are confined to those sulfophile elements whose spectrographic sensitivities permit their detection in a majority of the samples.

The establishment of the validity of the assumption that a relationship exists between the distributions of metalliferous deposits and sulfophile trace elements was an essential first step in these investigations. To this end, a fairly comprehensive preliminary study was made of the region that includes Arizona and adjacent parts of southwestern New Mexico and northern Sonora. This area was selected primarily because it includes the so-called Arizona Copper Province, one of the most widely recognized metallogenic provinces in North America. Other factors that influenced the selection are the accessibility of the region and the ready availability of samples of hypogene sulfide minerals, especially chalcopyrite.

Inasmuch as the results of this preliminary study indicated that the area includes parts of three metallogenic provinces instead of one, as was supposed previously, it was considered desirable to include a larger area in the study, in order to define as much of the provinces as possible. Consequently, the region outside Arizona, as shown in Plates 1-5, was studied largely in reconnaissance fashion; the definition of the provinces in this large region, therefore, is correspondingly less reliable. The data, however, are considered sufficient to establish the general positions and trends of the beltlike provinces as they are shown in Plates 1-5, although their precise dimensions and detailed configurations are somewhat conjectural. The geographic coverage of samples is by no means complete, and it is hoped that further work will provide information on the areas where data are now meager or lacking.

Initially, attention was confined to the distribution of trace elements in chalcopyrite, as it is the most abundant and widespread hypogene ore mineral of copper in the Southwest. However, as the region under investigation was enlarged, areas were included from which suitable samples of chalcopyrite were not readily available, although other hypogene sulfides, such as sphalerite, could be obtained. Consequently, sphalerite eventually was included in the study, with the hope that its trace-element content would be sufficiently similar to that of chalcopyrite to permit its use in some areas where chalcopyrite is unavailable. Despite the fact that definite relationships exist between the two minerals with respect to trace-element distributions, the relationships unfortunately are not precise enough to permit prediction of the amounts of trace elements contained in chalcopyrite from a knowledge of their contents in sphalerite. Therefore, sphalerite was investigated with the same objectives in mind as for chalcopyrite, but as an independent system.

# *Acknowledgments*

The study of metallogenic provinces was proposed by Dr. J. A. Noble, of the California Institute of Technology; throughout the work, he has contributed greatly by way of encouragement, frequent discussions, and helpful criticism. Dr. R. H. Jahns has offered many valuable suggestions and criticisms in the preparation of the manuscript. Much benefit has been derived from discussions of the problem with Mr. Julian Feiss, of the Kennecott Copper Corp.

The spectrographic work was done by the writer under the direction of Mr. A. A. Chodos, and the polished sections were prepared by Mr. R. von Huene. Miss S. Young kindly made the statistical computations presented in Tables 3 and 4, although the method of statistical analysis was selected by the writer.

The writer gratefully acknowledges the support he has received through fellowship grants from the Kennecott Copper Corp. during the academic years 1952-55. Laboratory facilities and several hundred polished sections were provided by the California Institute of Technology.

Many of the ore specimens that were utilized in this work were generously provided by Dr. B. S. Butler, University of Arizona; Dr. E. D. Wilson, Arizona Bureau of Mines; Dr. Eugene Callaghan and staff, New Mexico Bureau of Mines and Mineral Resources; Dr. T. H. Kuhn, Colorado School of Mines; Dr. B. F. Stringham, University of Utah; Dr. V. E. Scheid, University of Nevada; and Dr. C. S. Hurlbut, Harvard University. Many other individuals have also contributed ore specimens to this study.

The writer is grateful for the many courtesies extended by officials of the following mining companies: the Cananea Consolidated Copper Co., Cananea, Sonora; the Potosi Mining Co., Santa Eulalia, Chihuahua; the Inspiration Consolidated Copper Co., Miami, Arizona; the Kennecott Copper Corp., at Ray, Arizona, Ruth, Nevada, and Santa Rita, New Mexico; the Magma Copper Co., San Manuel, Arizona; the Miami Copper Co., Miami, Arizona; and the Phelps Dodge Corp., at Ajo, Bisbee, Jerome, and Morenci, Arizona.

The New Mexico Bureau of Mines and Mineral Resources financed the publication of the completed study.

# *Sampling and Analytical Methods*

## SAMPLING METHODS

The determination of the variations in the trace-element content of chalcopyrite within an ore deposit, within a mining district, and between mining districts is an essential preliminary in the establishment of the validity of the trace-element approach in defining metallogenic provinces. Consequently, samples were collected from several of the large copper deposits of the Southwest, a special effort being made to obtain fresh material from widely separated parts of the deposits. However, once these preliminary determinations indicated that the most profitable course lay in the gross enlargement of the area to be studied, samples from every available source were utilized. The adoption of this procedure introduces a great deal of uncertainty into the reliability of the results, although an estimate of the effect can be obtained from a comparison of the "within district" variances in Tables 3 and 4.

The samples for spectrochemical analysis were obtained as drill cuttings from the surfaces of polished sections under the metallographic microscope. The drilling equipment consists of a laboratory-model dental machine fitted with S. S. White No. 2 "Carbide" dental burrs. These burrs are approximately 1 mm in diameter and are therefore suit-able for the sampling of relatively small areas of the polished section. The chief advantages of this method over the commonly employed method of "handpicking clean-looking" fragments under a binocular microscope are that intimate mineral intergrowths can be detected and avoided, and possible contamination by other minerals can be evaluated more easily.

The possibility that contamination occurs in the preparation of the polished sections and in the drilling process was tested by analyzing two samples that were taken from the same part of a specimen by two different methods. One sample (JER-36HSP) was chipped with a diamond-tipped probe from an unprepared surface. No other minerals could be seen in the specimen under the binocular microscope. A second sample (JER-36) was obtained by the regular drilling procedure from a polished section of the same part of the specimen, after the first sample was obtained. It is evident from the analyses of these samples presented below that the preparation of the polished sections and the drilling process do not introduce any systematic contamination effects.

TESTS FOR CONTAMINATION IN THE PREPARATION OF SAMPLES
(In parts per million)

| SAMPLE NO. | Ag | As | Bi | Cd | Co | Ge | In | Mn | Mo | Ni | Sb | Sn | Te |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JER-36HSP | 30 | — | 30 | — | 4 | — | 100 | 30 | — | — | — | 300 | — |
| JER-36 | 30 | — | 30 | — | — | — | 100 | 20 | — | — | — | 100 | — |

## ANALYTICAL METHODS

The trace-element contents of chalcopyrite and sphalerite were determined spectrographically on a Jarrel-Ash 21-foot Wadsworth mounted grating-type instrument. The instrumental conditions and analytical procedures are described elsewhere (Chodos and Burnham, 1954), and the details need not be repeated here.

The use of standard methods of spectrochemical analysis did not yield satisfactory results with small samples, owing to the high iron content of chalcopyrite. Therefore, a special method was developed that involves a two-stage arcing of the sample mixture; in this way the profuse and interfering iron spectrum is effectively separated from the spectra of the elements that are of most interest. The sample mixture consists of 25 percent chalcopyrite, 37.5 percent quartz, 30 percent zinc oxide, and 7.5 percent sodium carbonate.

The method yields results that are reproducible to one significant figure, with a standard deviation of about 25 percent. It requires the use of only 5 mg of chalcopyrite in each electrode charge; hence, it was possible to make duplicate analyses of 95 percent of the samples. Moreover, the 5-mg sample is sufficiently large to yield sensitivities that are satisfactory for most elements of interest, as shown in Figure 1.

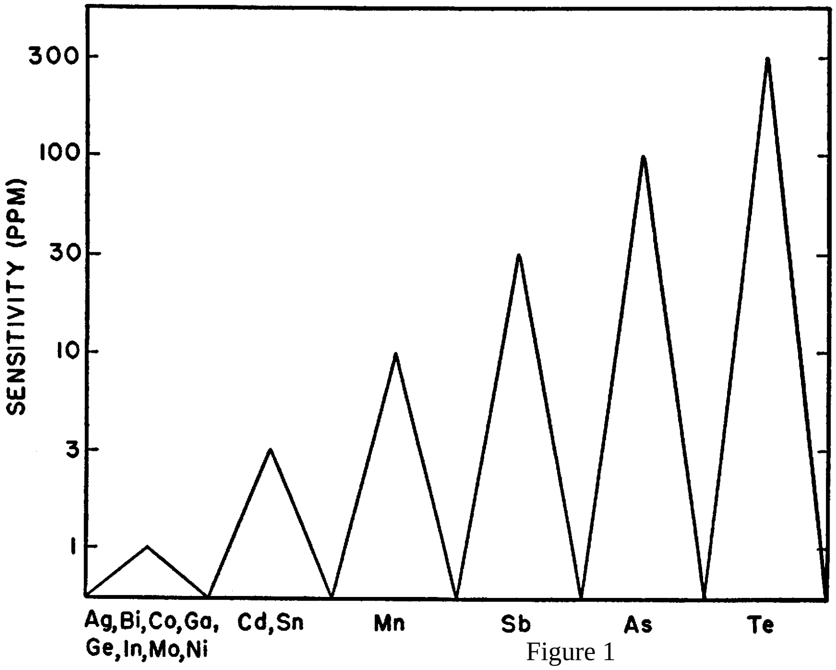

Figure 1

MAXIMUM SPECTROGRAPHIC SENSITIVITIES OF THE ELEMENTS IN CHALCOPYRITE

Essentially the same method, with only slight modification, was used for the analysis of sphalerite. The principal difference consists of the addition of cupric oxide to the sample mixture to give a bulk composition of 25 percent sphalerite, 37.5 percent quartz, 18.8 percent zinc oxide, 7.5 percent sodium carbonate, and 11.2 percent cupric oxide. The lower iron content of sphalerite as compared with chalcopyrite, permits an increase in the amount of light transmitted to the slit from 40 percent to 64 percent; this results in a slightly increased sensitivity for some elements, notably cadmium, as shown in Figure 2. The reproducibility of the sphalerite analyses is essentially the same as for the chalcopyrite analyses.

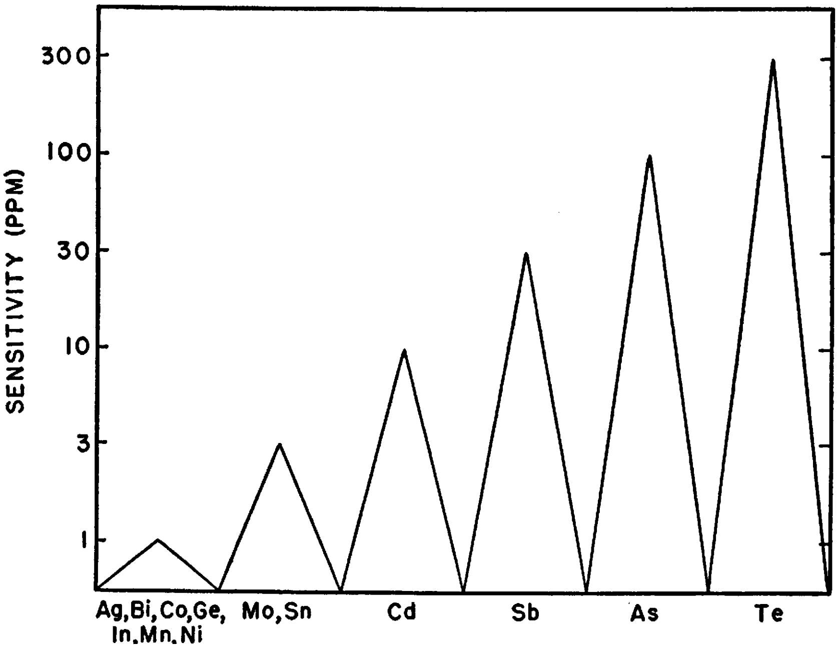

Figure 2
MAXIMUM SPECTROGRAPHIC SENSITIVITIES OF THE ELEMENTS IN SPHALERITE

# Analytical Data

The elements of particular interest in these studies are the sulfophile elements: antimony, arsenic, bismuth, cadmium, cobalt, copper, gallium, germanium, gold, indium, iron, lead, mercury, molybdenum, nickel, selenium, silver, sulfur, tellurium, thallium, tin, and zinc. How-ever, inasmuch as copper, iron, lead, sulfur, and zinc are major constituents of the ores, they are generally unsuitable as trace-element indicators. Also, the relatively poor spectrographic sensitivities of antimony, arsenic, gold, mercury, selenium, and tellurium preclude their detection in the majority of samples; hence, they also are generally unsuitable.

Each sample of chalcopyrite was analyzed for antimony, arsenic, bismuth, cadmium, cobalt, germanium, indium, molybdenum, nickel, silver, tellurium, and tin, but because tellurium was found in only one sample (N-116, 800 ppm), it has been omitted from Table 1. In addition, gallium, gold, selenium, and thallium were sought in each sample but not found.

Each sample of sphalerite was analyzed for the same elements as chalcopyrite, plus gallium and thallium. Tellurium was found also in only one sample of sphalerite (ARI-58, 300 ppm); so it has been omitted from Table 2. Gold and selenium also were sought in sphalerite but not found.

The analyses in Tables 1 and 2 are grouped according to the mining districts from which the samples were obtained. The data thus grouped are averaged, and these district averages form the basis for the maps of Plates 1-5. All the data that are represented in Plates 1-5 are contained in Tables 1 and 2, and 95 percent of the entries in these tables are aver-ages of duplicate determinations. The remaining 5 percent of the entries are single determinations, owing to insufficient amount of material.

A short dash (—) in the tables indicates that the element was not detected in either analysis of the sample. A "less than" symbol (<) in the silver analyses indicates that silver was detected, but in amounts less than 1 part per million, the lower limit of the standards. A "greater than" symbol (>) indicates that the element is present in such large amounts that the analysis line is too dense to measure accurately with a microphotometer (less than 2 percent transmission). A query (?) indicates one of two things: Either slight contamination from the preceding sample during weighing is suspected, or a potentially interfering element is present in abnormally high concentrations.

# *Mode of Occurrence of Trace Elements in Chalcopyrite and Sphalerite*

The two most widely recognized modes of occurrence of "impurities" in minerals, as noted by Fleischer (1955) and others, are as "trace minerals" and as atomic substituents for the major component elements in regular lattice positions. A third mode of occurrence, not as widely recognized as the other two, is as individual atoms or small groups of atoms in lattice defects of the host mineral.

The "trace minerals" occur as separate mineral phases, commonly of microscopic size, that are included within the crystal of the host mineral and are likely to have an appreciable effect upon the apparent trace-element content of the mineral. The effect of these "trace minerals" on the data in Tables 1 and 2 has been minimized by drilling the samples from polished sections under a microscope.

Impurities that occur in atomic substitution for the major constituents of the host mineral are likely to exhibit a more consistent distribution and hence to provide more information on the factors involved in the formation of the mineral deposits. Consequently, they are the real object of these investigations, as well as of most other investigations of the trace-element content of minerals.

The occurrence of individual atoms or small groups of atoms in lattice defects of the host mineral obviously would be greatly affected by the number and nature of such defects. The sphalerite examined in this study is notably rich in microscopic defects as compared with chalcopyrite; this may account in part for the greater variability of some elements, such as tin, in this mineral.

Many of the polished sections used in this study yielded samples of both chalcopyrite and sphalerite. A comparison of the trace-element content of these sample pairs provides much information on the distribution of trace elements between coexisting phases. These distributional relationships, a discussion of which will be published elsewhere, indicate that many elements exhibit a definite and consistent preference for one or the other of the two minerals. Such a consistent preference is difficult to explain unless it is assumed that the host mineral exercises a controlling influence. Thus, it is suggested that these elements occur largely in atomic substitution for the major constituents of chalcopyrite and sphalerite.

TABLE 1. TRACE ELEMENTS IN CHALCOPYRITE
(In parts per million)

| Dist. No. | Sample No. | Locality | Ag | As | Bi | Cd | Co | Ge | In | Mn | Mo | Ni | Sb | Sn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ARIZONA | | | | | | | | | | | | |
| 1 | | Wallapai district | | | | | | | | | | | | |
| | CHL-11 | Keystone mine | 900 | - | 100 | - | - | - | 200 | 90 | - | - | - | 200 |
| 2 | | Cedar Valley district | | | | | | | | | | | | |
| | AN-1 | Antler mine | 40 | - | 70 | - | 3 | - | 10 | 40 | 4 | - | - | 500 |
| | CW-1 | Copper World mine | 100 | - | - | - | - | 5 | 4 | 10 | 90 | 5 | - | 600 |
| | CW-2 | do. | 100 | - | - | - | - | - | 4 | 5 | 300 | 3 | - | 600 |
| | BOR-1 | Boriana mine | 600 | - | - | 50 | - | - | 80 | 7 | - | 20 | - | 2000 |
| | BOR-2 | do. | 700 | - | - | 30 | 2 | - | 50 | 70 | - | 20 | - | 1000 |
| | BOR-3 | do. | 1000 | - | - | 80 | - | - | 80 | 20 | - | 5 | - | 700 |
| 3 | | Eureka district | | | | | | | | | | | | |
| | BAG-4 | Bagdad | <1 | - | - | - | - | - | 4 | 1 | - | - | - | 60 |
| | BAG-21 | Bagdad pit | 3 | - | - | - | 1 | - | 1 | 1 | - | - | - | 70 |
| | BAG-22 | do. | 6 | - | - | - | 1 | - | 10 | - | 500 | - | - | 80 |
| | BAG-23 | Old Dick mine | 30 | - | - | - | - | - | - | 50 | 20 | - | - | 8 |
| | BAG-25 | Copper King mine | 20 | - | - | - | - | - | 20 | 200 | - | - | - | 2000 |
| 4 | | Verde district | | | | | | | | | | | | |
| | JER-30 | United Verde mine | 10 | - | - | - | - | - | 30 | 40 | - | 10 | - | 50 |
| | JER-32 | do. | 50 | - | - | - | 20 | - | 70 | 20 | 30 | - | - | 200 |
| | JER-33 | do. | 50 | - | - | - | - | - | 200 | 40 | - | 20 | - | 200 |
| | JER-34 | do. | 40 | - | - | - | - | - | 300 | 70 | - | - | - | 300 |
| | JER-35 | do. | 70 | - | - | - | - | - | 60 | 100 | - | - | - | 100 |
| | JER-36 | do. | 30 | - | 30 | - | - | - | 100 | 20 | - | - | - | 100 |

TABLE 1. TRACE ELEMENTS IN CHALCOPYRITE (continued)

| Dist. No. | Sample No. | Locality | Ag | As | Bi | Cd | Co | Ge | In | Mn | Mo | Ni | Sb | Sn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | | Peck district | | | | | | | | | | | | |
| | ARI-98 | Crown King mine | 4000 | 300 | 3 | 20 | 2 | - | 5 | 20 | - | 5 | - | 100 |
| 6 | | Bradshaw district | | | | | | | | | | | | |
| | ARI-99 | Money Metals mine | 600 | 300 | - | 100 | 40 | - | 10 | 1 | - | 4 | - | 30 |
| 7 | | Minnehaha district | | | | | | | | | | | | |
| | ARI-103A | 12 mi SW. of Mayer | 20 | - | - | - | - | - | 6 | - | - | - | - | - |
| 8 | | Swansea district | | | | | | | | | | | | |
| | ARI-66 | Swansea | 3 | - | - | - | 2 | - | 2 | - | 5 | - | - | - |
| | ARI-67 | do. | 1 | - | - | - | 8 | - | 3 | - | - | - | - | - |
| 9 | | Green Valley district | | | | | | | | | | | | |
| | MAZ-15 | E. foot of N. Peak, Mazatzal Mtns. | 2000 | 20000 | 2000 | 400 | - | - | 200 | 20 | 30 | | >10000 | 8000 |
| 10 | | Miami district | | | | | | | | | | | | |
| | MIA-12 | Inspiration shaft | 40 | - | - | - | 2 | - | - | 1 | 3 | 40 | - | 200 |
| | MIA-13 | Live Oak pit | 50 | - | - | - | 3 | - | - | - | 1000 | 30 | - | 90 |
| | MIA-14 | Inspiration mine | 40 | - | - | - | - | - | - | - | 30 | - | - | 200 |
| 11 | | Globe district | | | | | | | | | | | | |
| | OD-3 | Old Dominion mine | 10 | - | - | - | 2 | - | 7 | 3 | 5 | 5 | - | 200 |
| 12 | | Summit district | | | | | | | | | | | | |
| | MIA-4 | Castle Dome mine | 70 | - | - | - | - | - | - | 4 | 6 | - | - | 4 |
| | MIA-6 | do. | 100 | - | - | - | 60 | - | - | 6 | 6 | 9 | - | 100 |
| 13 | | Pioneer district | | | | | | | | | | | | |
| | MAG-27 | Magma mine | 8 | - | 8 | - | 2 | - | 8 | 600 | 3 | 6 | - | 10 |
| | MAG-32 | do. | 100 | 1000 | 900 | - | 6 | 6 | 3 | 8 | 7 | 20 | 100 | 70 |
| | MAG-46 | do. | 30 | 6000 | 500 | - | 3 | - | 3 | 2 | - | - | 100 | 20 |

TABLE 1. TRACE ELEMENTS IN CHALCOPYRITE (continued)

| Dist. No. | Sample No. | Locality | Ag | As | Bi | Cd | Co | Ge | In | Mn | Mo | Ni | Sb | Sn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13 | (cont.) | Pioneer district | | | | | | | | | | | | |
| | MAG-76 | Magma mine | 10 | - | 20 | - | - | - | 20 | 20 | - | - | - | 30 |
| 14 | | Copper Mountain district | | | | | | | | | | | | |
| | MCI-9 | Arizona Central mine | 50 | - | - | 40 | - | - | - | - | - | - | - | 3 |
| 15 | | Mineral Creek district | | | | | | | | | | | | |
| | RAY-12 | Ray pit | 70 | - | 20 | - | - | - | 9 | 10 | 100 | - | - | 30 |
| | RAY-14 | do. | 40 | - | - | - | 2 | - | 30 | 200 | - | - | - | 20 |
| | RAY-15 | Ray (surface) | 50 | - | - | - | - | - | 10 | 10 | - | - | - | 20 |
| | RAY-16 | Ray, No. 4 well | 50 | - | 8 | - | - | - | 50 | 20 | - | - | - | 80 |
| 16 | | Banner district | | | | | | | | | | | | |
| | CHR-3 | Christmas mine | 10 | - | - | - | 20 | - | 10 | 400 | 60 | 40 | - | 30 |
| 17 | | Stanley district | | | | | | | | | | | | |
| | ARI-113 | Unnamed prospect | 2 | - | 200 | - | 4 | - | - | 60 | 200 | 70 | - | 10 |
| | ARI-114 | do. | <1 | - | 60 | - | 1 | - | - | 200 | 20 | 100? | - | - |
| 18 | | Bunker Hill district | | | | | | | | | | | | |
| | CHA-1 | Childs-Aldwinkle mine | 3 | 2000 | - | - | 3 | - | - | - | 5 | 6 | - | 100 |
| | CHA-10 | do. | 9 | - | 400 | - | - | - | 3 | 3 | 6 | - | - | 20 |
| | CHA-12 | do. | 5 | - | - | - | - | - | - | - | 4 | - | - | 30 |
| | CHA-27 | do. | <1 | - | - | - | 30 | - | - | 30 | 5 | 3 | - | - |
| | CHA-40 | do. | 2 | - | - | - | 6 | - | 7 | 1 | 4 | - | - | 200 |
| 19 | | Mammoth, San Manuel district | | | | | | | | | | | | |
| | SM-7 | San Manuel mine | 30 | - | - | - | - | - | - | 300 | - | - | - | 30 |
| | SM-8 | do. | 20 | - | - | - | 4 | - | - | - | 8 | 3 | - | 30 |

TABLE 1. TRACE ELEMENTS IN CHALCOPYRITE (continued)

| Dist. No. | Sample No. | Locality | Ag | As | Bi | Cd | Co | Ge | In | Mn | Mo | Ni | Sb | Sn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | | Silver Bell district | | | | | | | | | | | | |
| | AT-1 | Atlas mine | 50 | - | 40 | - | 10 | - | 10 | 10 | - | 10 | - | - |
| | AT-2 | do. | 60 | - | 20 | 80 | 50 | - | 30 | 400 | 80 | 20 | - | 20 |
| | AT-3 | do. | 200 | - | 30 | - | 30 | - | 10 | 30 | 9 | 70 | - | - |
| | AT-4 | do. | 100 | - | 10 | - | 20 | - | 10 | 7 | - | 8 | - | - |
| 21 | | Ajo district | | | | | | | | | | | | |
| | AJ-36 | New Cornelia mine | 40 | - | - | - | 6 | - | - | 1 | - | - | - | 40 |
| | AJ-37 | do. | 40 | - | - | - | 50 | - | - | - | - | - | - | 4 |
| | AJ-38 | do. | 40 | - | - | - | - | - | - | 6 | - | - | - | 8 |
| | AJ-40 | do. | 50 | - | 20 | - | 7 | - | 7 | 2 | - | - | - | 5 |
| | AJ-41 | do. | 100 | - | - | - | 2 | - | - | 100 | 7 | - | - | 40 |
| 22 | | Gunsight district | | | | | | | | | | | | |
| | CM-1 | Copper Mtn. mine | 200 | 400 | 500 | - | 70 | - | 7 | 4 | - | 7 | - | 10 |
| 23 | | Amole district | | | | | | | | | | | | |
| | ARI-108A | Mile Wide mine | 6 | - | 30 | - | - | - | 9 | 100 | 10 | - | - | - |
| 24 | | Cochise district | | | | | | | | | | | | |
| | JO-1 + 2 | Johnson camp | 6 | - | 5 | - | 9 | - | 20 | 500 | 20 | 30 | - | 20 |
| 27 | | Pima district | | | | | | | | | | | | |
| | PIM-2 | San Xavier Ext. mine | 60 | - | 50 | - | 6 | - | - | 6 | 3 | 4 | - | - |
| | PIM-3 | Pima mine | 400 | 2000 | 30 | - | 100 | - | 70 | 20 | 400 | 20 | - | 70 |
| | PIM-4 | do. | 40 | - | 20 | - | 30 | - | 100 | 300 | 10 | 5 | - | 40 |
| | PIM-6 | do. | 60 | - | 6 | - | 30 | - | 50 | 200 | - | 6 | - | 50 |
| 28 | | Helvetia district | | | | | | | | | | | | |
| | ARI-107 | McClary's mine | 400 | - | 9 | - | 200 | - | 20 | - | 100 | 10 | - | 200 |
| | ARI-110 | Exile and King mine | 200 | - | - | - | 10 | - | 30 | 500 | 20 | 3 | - | 40 |

TABLE 1. TRACE ELEMENTS IN CHALCOPYRITE (continued)

| Dist. No. | Sample No. | Locality | Ag | As | Bi | Cd | Co | Ge | In | Mn | Mo | Ni | Sb | Sn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 33 | | Warren district | | | | | | | | | | | | |
| | BI-52 | Junction shaft | 40 | - | 20 | - | - | - | 400 | 80 | - | 20 | - | 200 |
| | BI-53 | do. | 70 | - | 20 | - | - | - | 400 | 300 | 10 | - | - | 200 |
| | BI-54 | do. | 30 | - | - | - | - | - | 400 | 30 | - | - | - | 100 |
| | BI-56 | Campbell shaft | 60 | - | - | - | - | - | 1000 | 90 | 10 | - | - | 200 |
| 35 | | Patagonia, Duquesne district | | | | | | | | | | | | |
| | ARI-85 | Santa Nino mine | 60 | - | 9 | - | 20 | - | - | 20 | 600 | - | - | 40 |
| | SN-1 | do. | 40 | - | - | - | 40 | - | 70 | 20 | - | 20 | - | 40 |
| | SN-4 | do. | 100 | - | - | - | - | - | 10 | 2 | - | - | - | 50 |
| | ARI-108B | Morning Glory mine | 30 | - | - | - | - | - | 80 | 700 | - | - | - | 30 |
| | | CALIFORNIA | | | | | | | | | | | | |
| 36 | | Afterthought district | | | | | | | | | | | | |
| | AFT-3 | Afterthought mine | 1 | 400 | - | 10 | 4 | 2 | - | 2 | - | 20 | - | - |
| 37 | | Lights Canyon district | | | | | | | | | | | | |
| | SUP-13 | Superior mine | 1000 | - | - | - | 2 | - | 9 | 600 | - | - | - | 20 |
| 38 | | Nevada City district | | | | | | | | | | | | |
| | IMM-56 | Idaho Maryland mine | <1 | - | - | 200 | 1 | - | 3 | - | - | 6 | - | - |
| 40 | | Fairplay district | | | | | | | | | | | | |
| | C-229 | Consumnes mine | 40 | - | 100 | - | 1 | - | - | 2 | - | 10 | - | 20 |
| 41 | | Pine Creek district | | | | | | | | | | | | |
| | C-220 | Pine Creek | <1 | 500 | 3 | - | - | - | 3 | 10 | - | - | - | 70 |
| 44 | | Argus Range | | | | | | | | | | | | |
| | MS-17 | Mtn. Springs Canyon | 100 | - | 4 | 40 | 2 | - | 1 | 7 | - | - | - | - |

TABLE 1. TRACE ELEMENTS IN CHALCOPYRITE (continued)

| Dist. No. | Sample No. | Locality | Ag | As | Bi | Cd | Co | Ge | In | Mn | Mo | Ni | Sb | Sn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 45 | | Woody district | | | | | | | | | | | | |
| | C-257 | Greenback mine | 20 | - | - | - | 20 | - | 10 | - | - | 70 | - | 100 |
| 47 | | Cima district | | | | | | | | | | | | |
| | C-151 | Evening Star mine | 30 | - | - | 70 | - | - | 400 | 6 | - | 10 | - | 1000 |
| 48 | | Ord district | | | | | | | | | | | | |
| | C-256 | Painsville mine | 7 | - | 4 | - | 3 | - | 10 | 30 | - | 10 | - | - |
| 50 | | Tujunga district | | | | | | | | | | | | |
| | C-263 | Pacoima Canyon | 2000 | - | - | 60 | 8 | - | 9 | 30 | - | 10 | - | 30 |
| 51 | | Crestmore district | | | | | | | | | | | | |
| | C-261 | Crestmore mine | 800 | - | 300 | 10 | 1 | - | 20 | - | - | 200 | - | 40 |
| 52 | | Julian district | | | | | | | | | | | | |
| | C-260 | Friday mine | 3 | - | - | - | 100 | - | - | 20 | - | >1000 | - | 10 |
| 53 | | Cargo Muchacho district | | | | | | | | | | | | |
| | CMU-29 | Cargo Muchacho | 1000 | - | 1 | 20 | - | - | 20 | 300 | - | - | 100 | - |
| | | COLORADO | | | | | | | | | | | | |
| 54 | | Ward district | | | | | | | | | | | | |
| | COL-102 | Albion mine | 3000 | 5000 | - | 20 | 1 | - | 2 | 600 | 90 | 9 | 500 | 50 |
| 55 | | Kremmling district | | | | | | | | | | | | |
| | COL-80 | Kremmling | 30 | 100 | 40 | - | - | - | 5 | - | - | - | - | - |
| | COL-81 | do. | 70 | 300 | - | - | - | - | - | 3 | - | - | 600 | - |
| 56 | | Central City district | | | | | | | | | | | | |
| | COL-100 | Bobtail incline | 30 | 700 | 100 | - | - | - | 200 | 9 | 10 | - | - | 100 |
| 57 | | Idaho Springs district | | | | | | | | | | | | |
| | COL-94 | Plutus mine | 80 | 100 | - | - | - | - | 200 | - | - | 7 | - | 7 |
| | COL-95 | Bride mine | 2000 | 8000 | - | 90 | 2 | - | 3 | 20 | 20 | - | 9000 | 20 |

TABLE 1. TRACE ELEMENTS IN CHALCOPYRITE (continued)

| Dist. No. | Sample No. | Locality | Ag | As | Bi | Cd | Co | Ge | In | Mn | Mo | Ni | Sb | Sn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 58 | | Griffith district | | | | | | | | | | | | |
| | COL-91 | Georgetown | 2000 | 1000 | 9 | - | <1 | - | 200 | - | 10 | 20 | 1000 | - |
| 60 | | Red Cliff district | | | | | | | | | | | | |
| | COL-106 | Gilman | 70 | - | - | - | - | - | 40 | 2 | - | 4 | - | 2000 |
| | COL-107 | Rocky Pt. horizon | 200 | - | - | - | 1 | 40 | 200 | 2 | - | - | - | 900 |
| 62 | | Fremont Pass district | | | | | | | | | | | | |
| | CL-14 | Climax Molybdenum mine | 60 | - | 9 | - | 50 | - | 200 | 700 | 10 | 5 | - | 800 |
| 65 | | Roaring Fork district | | | | | | | | | | | | |
| | COL-101 | Aspen | 200 | - | - | - | 10 | - | 10 | 2000 | 70 | 9 | - | - |
| 67 | | Cebolla district | | | | | | | | | | | | |
| | COL-83 | Red Top mine | 70 | 2000 | - | - | 6 | - | 60 | 1 | - | - | - | 2000 |
| 69 | | Uncompahgre district | | | | | | | | | | | | |
| | OU-1 | Des Ouray ore chute | 1000 | 9000 | 80 | 30 | - | - | 7 | 200 | - | - | 800 | 40 |
| | OU-2 | Benack tunnel | 500 | - | 5 | 300 | - | - | 40 | 600 | 8 | - | 300 | 200 |
| 70 | | Sneffels district | | | | | | | | | | | | |
| | COL-113 | Camp Bird mine | 7 | - | 20 | 7 | 7 | - | 6 | 50 | - | - | - | - |
| 72 | | Iron Springs district | | | | | | | | | | | | |
| | COL-108 | Alta mine | 300 | - | 1000 | 80 | 1 | 20 | ? | 8000 | - | 5 | - | - |
| 74 | | Animas district | | | | | | | | | | | | |
| | COL-110 | Green Mtn. mine | 200 | - | 2 | 600 | 10 | - | 2 | 100 | - | 6 | - | - |
| 75 | | Pioneer district | | | | | | | | | | | | |
| | COL-104 | Blackhawk mine | 30 | - | 200 | 20 | 1 | - | 300 | 50 | - | 4 | - | 2000 |
| | | NEW MEXICO. | | | | | | | | | | | | |
| 76 | | Willow Creek district | | | | | | | | | | | | |
| | PEC-2 | Pecos mine | 50 | - | - | 30 | - | - | 2 | 20 | - | 20 | - | 4 |

TABLE 1. TRACE ELEMENTS IN CHALCOPYRITE (continued)

| Dist. No. | Sample No. | Locality | Ag | As | Bi | Cd | Co | Ge | In | Mn | Mo | Ni | Sb | Sn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 76 | (cont.) | Willow Creek district | | | | | | | | | | | | |
| | PEC-3 | Pecos mine | 20 | - | - | - | - | - | 2 | - | - | 4 | - | 8 |
| 78 | | San Pedro district | | | | | | | | | | | | |
| | NM-60 | San Pedro district | 400 | - | 10 | - | 2 | - | 7 | 200 | 20 | 40 | - | - |
| | NM-69 | San Pedro mine | 200 | - | 5 | 20 | 70 | - | 7 | 8 | - | 500 | - | - |
| 79 | | Magdalena district | | | | | | | | | | | | |
| | MG-1 | Magdalena district | 600 | - | 2000 | 40 | - | - | 3 | 20 | - | - | - | - |
| 80 | | Nogal district | | | | | | | | | | | | |
| | NM-74 | Tommy LeMay claim | 9 | - | - | 200 | 1 | - | - | 3 | - | 50 | - | - |
| | NM-75 | do. | 60 | - | - | - | <1 | - | - | 200 | - | 5 | - | - |
| 82 | | Hermosa district | | | | | | | | | | | | |
| | HE-5 | Nana mine | 2000 | - | - | 30 | - | - | - | 40 | 6 | - | 600 | 4 |
| | HE-6 | do. | 20000 | - | - | 50 | 4 | - | - | 200 | 400 | 10 | 500 | - |
| 83 | | Fierro-Hanover district | | | | | | | | | | | | |
| | BH-14 | Black Hawk Cons. mines | 20 | - | 20 | - | 10 | - | - | 200 | - | 4 | - | - |
| | OS-1 | Oswaldo No. 1 mine | 100 | - | - | - | 6 | - | - | 400 | - | - | - | - |
| 84 | | Steeple Rock district | | | | | | | | | | | | |
| | NM-25 | Carlisle mine | 9 | - | - | - | - | - | - | - | - | - | - | - |
| | NM-70 | do. | 200 | - | - | 500 | 2 | - | - | 30 | - | - | - | 4 |
| | NM-71 | Gold-Silver mine | 70 | - | - | 10 | - | - | - | 20 | - | - | - | 3 |
| 85 | | Santa Rita district | | | | | | | | | | | | |
| | G-3 | Groundhog mine | 40 | - | - | - | 3 | - | 10 | 7 | 3 | 9 | - | - |
| | G-4 | do. | 20 | - | - | - | 4 | - | - | 10 | - | 3 | - | - |
| | G-6 | do. | 20 | - | - | - | - | - | - | 6 | 4 | 2 | - | - |

TABLE 1. TRACE ELEMENTS IN CHALCOPYRITE (continued)

| Dist. No. | Sample No. | Locality | Ag | As | Bi | Cd | Co | Ge | In | Mn | Mo | Ni | Sb | Sn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 85 | (cont.) | Santa Rita district | | | | | | | | | | | | |
| | G-11 | Groundhog mine | 100 | - | 60 | - | 20 | - | 2 | 300 | - | - | - | 8 |
| | SR-15 | Ivanhoe lease | 1000 | - | - | 100 | 20 | - | - | 100 | - | - | - | - |
| | SR-16 | Chino mine | 40 | - | - | - | 20 | - | - | 400 | 4 | 6 | - | 6 |
| | SR-17 | do. | 1 | - | - | - | 1 | - | 2 | 10 | 4 | 6 | - | 30 |
| 88 | | Orogrande district | | | | | | | | | | | | |
| | NM-79 | Jim mine | 20 | - | 4 | - | - | - | 10 | 40 | - | 3 | - | - |
| | NM-80 | Lucky mine | 40 | - | - | - | 5 | - | 10 | 30 | 20 | 30 | - | 5 |
| 89 | | Organ district | | | | | | | | | | | | |
| | NM-57 | Stevenson Bennett mine | 90 | - | - | - | - | - | 7 | 2 | - | 10 | - | - |
| 90 | | Lordsburg district | | | | | | | | | | | | |
| | CAM-11 | 85 mine | 300 | - | 600 | - | - | - | 20 | - | 8 | - | - | - |
| | CAM-21 | do. | 200 | - | 20 | - | - | - | 10 | 200 | - | 6 | - | 8 |
| | CAM-22 | do. | 60 | - | - | - | - | - | 10 | - | - | - | - | - |
| | CAM-24 | do. | 5 | - | 40 | - | - | - | 8 | 10 | - | 60 | - | - |
| | CAM-25 | do. | 7 | - | 10 | - | - | - | 30 | 6 | 2 | - | - | 6 |
| | CAM-27 | do. | 80 | - | - | - | - | - | 10 | 2 | - | 6 | - | - |
| | NM-30 | do. | 70 | - | - | - | 3 | - | 10 | 100 | - | 4 | - | - |
| | NM-28 | Banner mine | 100 | - | 7 | - | - | - | 2 | 5 | 4 | 20 | - | - |
| | NM-32 | do. | 50 | - | - | - | - | - | 3 | - | 4 | 3 | - | - |
| | NM-62 | Lordsburg district | 20 | - | - | - | - | - | 8 | - | - | - | - | - |
| 91 | | Eureka district | | | | | | | | | | | | |
| | NM-76 | Little Hatchet Mtns. | 90 | - | 90 | - | 2 | - | 2 | 200 | - | 30 | - | - |
| | NM-77 | do. | 90 | - | 600 | 20 | 1 | - | 50 | 4 | 10 | 8 | - | - |

TABLE 1. TRACE ELEMENTS IN CHALCOPYRITE (continued)

| Dist. No. | Sample No. | Locality | Ag | As | Bi | Cd | Co | Ge | In | Mn | Mo | Ni | Sb | Sn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | NEVADA | | | | | | | | | | | | |
| 92 | | Mountain City district | | | | | | | | | | | | |
| | N-168 | Mtn. City copper | 6 | - | 5 | - | 20 | - | - | 20 | 30 | 8 | - | 30 |
| 93 | | Jackson Creek district | | | | | | | | | | | | |
| | N-159 | Humboldt King claims | 2 | - | 8 | - | 80 | 2 | - | 1 | - | 90 | - | - |
| 94 | | Tuscarora district | | | | | | | | | | | | |
| | N-86 | Independence mine | 400 | - | - | 70 | 1 | - | 3 | 5 | - | - | 300 | 40 |
| 98 | | Safford district | | | | | | | | | | | | |
| | N-138 | Safford district | 700 | 1000 | - | - | 50 | - | 1 | 100 | 20 | 100 | - | 6 |
| | N-140 | do. | 3000 | - | - | 100 | 3 | - | 5 | 2000 | - | 3 | - | - |
| 99 | | Railroad district | | | | | | | | | | | | |
| | N-142 | Railroad district | 100 | - | 10 | 300 | 10 | - | 10 | 3000 | - | 9 | - | 400 |
| 102 | | Bullion district | | | | | | | | | | | | |
| | N-148 | Elder Creek | 1000 | 200 | 3 | 200 | 80 | - | 8 | 20 | - | 200 | - | 200 |
| 103 | | Dolly Varden district | | | | | | | | | | | | |
| | N-162 | Victoria mine | 100 | - | - | - | 10 | - | 4 | 3 | - | 80 | - | - |
| | N-163 | do. | 200 | - | - | - | 4 | - | 5 | 2 | - | 50 | - | 8 |
| 110 | | Reese River district | | | | | | | | | | | | |
| | N-146 | Austin | 100 | 600 | - | - | 2 | 7 | 2 | 200 | - | - | - | 200 |
| 112 | | Comstock district | | | | | | | | | | | | |
| | COM-1 | Comstock district | 4000 | - | - | - | - | - | - | 30 | - | - | - | - |
| | VI-1 | Cons. California and Virginia mine | 2000 | - | - | 10 | - | - | - | 40 | 70 | - | - | - |
| 113 | | Ely district | | | | | | | | | | | | |
| | ELY-13 | Emma-Nevada mine | 20 | - | - | - | 300 | - | - | 7 | - | 8 | - | 100 |

TABLE 1. TRACE ELEMENTS IN CHALCOPYRITE (continued)

| Dist. No. | Sample No. | Locality | Ag | As | Bi | Cd | Co | Ge | In | Mn | Mo | Ni | Sb | Sn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 113 | (cont.) | Ely district | | | | | | | | | | | | |
| | ELY-18 | Ruth mine | 70 | - | - | - | 40 | - | - | 200 | - | 7 | - | 20 |
| | ELY-19 | do. | 70 | - | - | - | 70 | - | - | 100 | - | 40 | - | 30 |
| | ELY-23 | Morris mine | 50 | - | - | - | 2 | - | - | 10 | 10 | 7 | - | 40 |
| | ELY-24 | do. | 50 | - | - | - | 2 | - | - | 5 | 3 | 7 | - | 30 |
| 115 | | Buckskin district | | | | | | | | | | | | |
| | N-128 | Buckskin district | 500 | - | 3 | 20 | 7 | - | 5 | 70 | - | 6 | - | 8 |
| 116 | | Yerington district | | | | | | | | | | | | |
| | YER-2 | Yerington Copper Co. | <1 | - | 2 | - | - | - | 2 | 2 | - | - | - | - |
| | YER-4 | Ludwig mine | 30 | - | - | - | 5 | 3 | - | 1 | - | 400 | - | - |
| | YER-5 | Mason Valley mines | 2 | - | - | - | 100 | - | - | 7 | - | 100 | - | - |
| 117 | | Gardnerville district | | | | | | | | | | | | |
| | N-154 | Ruby Hill mine | 100 | - | - | 80 | - | - | 2 | 30 | - | 10 | - | 40 |
| | N-157 | do. | 60 | - | - | 20 | 3 | - | - | 10 | 6 | - | - | 10 |
| | N-158 | do. | 50 | - | - | 10 | 6 | - | - | 20 | 5 | - | - | 40 |
| 120 | | Santa Fe district | | | | | | | | | | | | |
| | N-87 | 8 mi N. of Luning | 200 | 200 | - | 10 | 200 | - | 10 | 10 | - | - | - | 10 |
| | N-97 | Emma mine | 100 | - | 7 | 10 | 100 | - | 4 | 90 | 10 | 40 | - | 30 |
| | N-100 | Champion mine | 30 | - | - | 30 | - | - | 1 | 300 | 40 | - | - | 6 |
| 123 | | Silver Star district | | | | | | | | | | | | |
| | N-95 | Gold Range district | 90 | - | 30 | 60 | 1 | - | 10 | 1 | - | - | - | 5 |
| 125 | | Tonopah district | | | | | | | | | | | | |
| | TON-78 | Montana Tonopah mine | 20 | - | - | - | - | - | - | - | - | - | - | 8 |
| | TON-79 | do. | 2000 | - | 20 | - | - | 2 | - | 6 | - | - | - | 80 |
| | TON-85 | MacNamara mine | 2000 | - | - | - | - | 5 | - | 6 | - | - | 300 | - |

TABLE 1. TRACE ELEMENTS IN CHALCOPYRITE (continued)

| Dist. No. | Sample No. | Locality | Ag | As | Bi | Cd | Co | Ge | In | Mn | Mo | Ni | Sb | Sn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 126 | | Jack Rabbit district | | | | | | | | | | | | |
| | N-114 | Bristol district | 300 | - | - | - | - | - | - | 20 | 2 | - | - | 6 |
| 129 | | Tem Piute district | | | | | | | | | | | | |
| | N-164 | Lincoln mine | 100 | - | - | 20 | - | - | 3 | 400 | - | 10 | - | 100 |
| 130 | | Bullfrog district | | | | | | | | | | | | |
| | N-160 | Beatty | 40 | - | - | - | - | - | <1 | <1 | - | - | - | - |
| | N-161 | do. | 60 | - | - | - | 40 | - | 20 | 2 | - | 200 | - | 40 |
| 131 | | Copper King district | | | | | | | | | | | | |
| | KW-1 | Key West mine | 10 | - | - | - | - | - | 5 | 7 | - | 300 | - | 7 |
| | KW-3 | do. | 20 | 100 | 4 | - | - | - | - | 7 | - | 70 | - | 6 |
| 133 | | Eldorado district | | | | | | | | | | | | |
| | N-116 | Callahan & Averal property | 3000 | 400 | 600 | - | 40 | - | - | 200 | 2 | 200 | - | - |
| | | UTAH | | | | | | | | | | | | |
| 135 | | Uinta district | | | | | | | | | | | | |
| | PC-12 | New Park mine | 500 | - | - | - | - | - | 1 | 4 | - | - | - | - |
| | PC-16 | do. | 500 | - | 500 | - | - | - | 70 | 40 | - | - | - | - |
| | PC-17 | do. | 100 | - | 20 | - | - | - | 50 | 3 | - | - | - | - |
| 136 | | Bingham district | | | | | | | | | | | | |
| | BIN-7 | Utah Apex mine | 30 | - | 8 | 7 | - | - | 50 | 70 | - | - | - | 200 |
| | BIN-8 | Highland Boy mine | 200 | - | 2000 | 20 | - | - | 100 | 300 | - | - | - | 900 |
| | BIN-12 | Utah Apex mine | 200 | - | 200 | - | - | - | 40 | 20 | - | - | - | 400 |
| | BIN-14 | Bingham mine (pit) | 100 | - | 20 | - | 10 | - | 6 | 8 | - | 20 | - | 40 |
| 137 | | American Fork district | | | | | | | | | | | | |
| | UT-31 | Silver Wave Min. Co. | 20 | - | - | - | 7 | - | 1 | 80 | 60 | - | - | 10 |

TABLE 1. TRACE ELEMENTS IN CHALCOPYRITE (continued)

| Dist. No. | Sample No. | Locality | Ag | As | Bi | Cd | Co | Ge | In | Mn | Mo | Ni | Sb | Sn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 137 | (cont.) | American Fork district | | | | | | | | | | | | |
| | UT-41 | American Fork district | 20 | - | - | - | - | - | 30 | - | - | 30 | - | 80 |
| 138 | | Ophir district | | | | | | | | | | | | |
| | UT-42 | Hidden Treasure mine | 800 | - | - | 100 | 5 | 3 | - | 200 | - | 20 | - | 100 |
| 139 | | Gold Hill district | | | | | | | | | | | | |
| | UT-45A | Gold Hill | 200 | - | - | - | 6 | - | 20 | 2 | 80 | - | - | 40 |
| 141 | | San Rafael district | | | | | | | | | | | | |
| | UT-38 | Lucky Strike mine | 1 | 4000 | - | 100 | 3000 | 200 | - | - | 300 | 1000 | - | - |
| 142 | | Frisco district | | | | | | | | | | | | |
| | UT-43 | O.K. mine | 10 | - | 20 | - | 1 | - | 2 | - | - | - | - | 7 |
| 143 | | White Canyon district | | | | | | | | | | | | |
| | UT-44 | Happy Jack mine | 200 | 700 | - | - | 300 | 20 | - | 400 | 90 | 100 | - | - |
| | | MONTANA | | | | | | | | | | | | |
| 172 | | Butte district | | | | | | | | | | | | |
| | BU-36 | Mountain Con mine | 30 | 4000 | 40 | - | - | 40 | 1 | 3 | - | - | 800 | 50 |
| | BU-45 | do. | 200 | - | 100 | - | - | 4 | - | 4 | - | - | - | - |
| | | MEXICO | | | | | | | | | | | | |
| | | CHIHUAHUA | | | | | | | | | | | | |
| 145 | | Temosachic, Guerrero district | | | | | | | | | | | | |
| | CA-7 | Calera mine | 400 | - | - | 30 | 4 | - | 2 | 500 | 10 | - | - | - |
| 146 | | Magistral, Iturbide district | | | | | | | | | | | | |
| | MEX-47 | Magistral mine | 20 | - | - | - | 90 | - | 9 | <1 | - | 60 | - | - |

TABLE 1 TRACE ELEMENTS IN CHALCOPYRITE (continued)

| Dist. No. | Sample No. | Locality | Ag | As | Bi | Cd | Co | Ge | In | Mn | Mo | Ni | Sb | Sn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 147 | | San Diego, Iturbide district | | | | | | | | | | | | |
| | SE-94 | San Antonio mine | 200 | - | - | 40 | 1 | - | 1 | 400 | - | - | - | 5000 |
| | SE-95 | do. | 50 | - | - | 30 | 1 | - | 1 | 300 | - | 5 | - | 5000 |
| 149 | | Guerrero, Guerrero district | | | | | | | | | | | | |
| | MEX-48 | Guadalupe mine | 30 | - | 30 | - | 20 | - | 7 | 4 | - | 10 | - | - |
| 152 | | Los Reyes, Jimenez district | | | | | | | | | | | | |
| | MEX-45 | Los Reyes mine | 60 | - | - | - | 100 | - | 10 | 1 | - | 50 | - | - |
| 153 | | El Parral, Hidalgo district | | | | | | | | | | | | |
| | PAR-3 | Parral unit | 200 | - | - | 30 | 30 | - | - | 2 | - | 3 | 200 | - |
| 154 | | Alisos, Andres del Rio district | | | | | | | | | | | | |
| | MEX-35 | El Carmen mine | <1 | - | - | - | - | - | 2 | 1 | - | - | - | - |
| | MEX-36 | do. | <1 | - | - | - | - | - | 3 | 1 | - | - | - | - |
| | | DURANGO | | | | | | | | | | | | |
| 159 | | Reina de Cobre, Cuencame district | | | | | | | | | | | | |
| | VEL-1 | Reina de Cobre mine | 60 | 200 | - | 30 | 400 | - | - | 50 | - | 30 | - | 8 |
| | VEL-2 | do. | 200 | 100 | - | 20 | 90 | - | <1 | 60 | - | 30 | - | 9 |
| 160 | | San Lucas, San Juan del Rio district | | | | | | | | | | | | |
| | MEX-37 | Santa Cruz mine | 60 | - | - | - | - | - | 200 | 1 | - | 4 | 500 | - |

TABLE 1. TRACE ELEMENTS IN CHALCOPYRITE (continued)

| Dist. No. | Sample No. | Locality | Ag | As | Bi | Cd | Co | Ge | In | Mn | Mo | Ni | Sb | Sn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 160 | (cont.) | San Lucas, San Juan del Rio district | | | | | | | | | | | | |
| | MEX-38 | Santa Cruz mine | 100 | - | - | - | - | - | 100 | 1 | - | 6 | 300 | - |
| | MEX-39 | do. | 600 | - | 1000 | 50 | - | - | 200 | 300 | - | 7 | 2000 | - |
| 162 | | Tayoltita, San Dimas district | | | | | | | | | | | | |
| | TAY-1 | Tayoltita | 50 | - | - | 20 | 4 | - | 50 | 10 | - | 4 | - | 300 |
| | | SAN LUIS POTOSI | | | | | | | | | | | | |
| 163 | | Matehuala, Catorce district | | | | | | | | | | | | |
| | MAT-1 | Dolores unit | 60 | - | 50 | 200 | 30 | - | 60 | 20 | - | 10 | - | 1000 |
| | MAT-2 | do. | 60 | - | 5 | 300 | 10 | - | 20 | 100 | - | - | - | 2000 |
| | | SONORA | | | | | | | | | | | | |
| 165 | | Cananea, Arispe district | | | | | | | | | | | | |
| | CN-20 | Puertocitos open cut | 40 | - | - | - | - | - | - | 10 | 3 | - | - | - |
| | CN-33 | Colorado mine | 60 | - | 4 | - | 4 | - | - | 2 | 20 | 20 | - | 20 |
| | CN-35 | do. | 40 | - | 50 | - | 3 | - | - | 20 | - | 20 | - | 10 |
| | CN-37 | do. | 20 | - | 20 | - | 20 | - | - | 2 | - | - | - | 50 |
| | CN-38 | Cananea Duluth mine | 90 | - | 90 | - | 2 | - | - | 60 | - | - | - | 4 |
| 166 | | Nacozari, Arispe district | | | | | | | | | | | | |
| | NAC-6 | Pilares mine | 50 | - | - | - | - | - | 70 | 5 | 40 | - | - | 90 |
| | NAC-7 | do. | 40 | - | - | - | - | - | 80 | - | 20 | - | - | 40 |
| | NAC-9 | do. | 70 | - | - | - | - | - | 80 | - | 30 | - | - | 50 |
| | NAC-18 | do. | 9 | - | - | - | - | - | 40 | 10 | 20 | - | - | 200 |

TABLE 1. TRACE ELEMENTS IN CHALCOPYRITE (continued)

| Dist. No. | Sample No. | Locality | Ag | As | Bi | Cd | Co | Ge | In | Mn | Mo | Ni | Sb | Sn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 167 | | Santa Domingo, Arispe district | | | | | | | | | | | | |
| | NAC-21 | Santa Domingo mine | 7 | - | - | - | 1 | - | 20 | 600 | - | 4 | - | 80 |
| 168 | | Santa Barbara, Hermosillo district | | | | | | | | | | | | |
| | MEX-29 | Alaska mine | <1 | - | 2000 | - | - | 3 | 10 | 800 | - | - | - | 20 |
| | MEX-30 | do. | 2 | - | 4 | - | - | 2 | 10 | 200 | - | - | - | 10 |
| | MEX-31 | do. | 6 | - | 2 | - | - | - | 6 | 50 | - | - | - | 6 |
| 169 | | San Javier, Hermosillo district | | | | | | | | | | | | |
| | MEX-26 | Cerro Verde prop. | <1 | - | 4 | - | - | - | 4 | 900 | - | - | - | 30 |
| | | ZACATECAS | | | | | | | | | | | | |
| 170 | | Sain Alto, Sombrerete district | | | | | | | | | | | | |
| | MEX-52 | San Martin mine | 2000 | 200 | 10 | 100 | 9 | - | 1 | 100 | - | 30 | 300 | 2000 |
| 171 | | Sombrerete, Sombrerete district | | | | | | | | | | | | |
| | MEX-49 | Tocayos mine | 2000 | - | - | 40 | 1 | - | - | <1 | - | - | 7000 | 60 |

TABLE 2. TRACE ELEMENTS IN SPHALERITE (In parts per million)

| Dist. No. | Sample No. | Locality | Ag | As | Bi | Cd | Co | Ga | Ge | In | Mn | Mo | Ni | Sb | Sn | Tl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ARIZONA | | | | | | | | | | | | | | |
| 1 | | Wallapai district | | | | | | | | | | | | | | |
| | CHL-10 | Towne mine | 200 | - | 10 | 5000 | 10 | 6 | - | 200 | 900 | - | - | - | - | - |
| | CHL-11 | Keystone mine | 200 | - | 3 | 2000 | 4 | 10 | - | 600 | 2000 | - | - | - | - | - |
| 2 | | Cedar Valley district | | | | | | | | | | | | | | |
| | CW-1 | Copper World mine | 8 | - | 2 | 2000 | 5 | 20 | 2 | 10 | 400 | - | - | - | 10 | - |
| 3 | | Eureka district | | | | | | | | | | | | | | |
| | BAG-24 | Copper Queen mine | 1 | - | - | 2000 | 40 | 20 | 20 | - | 400 | 10 | - | - | 30 | - |
| | BAG-28 | do. | <1 | 100 | - | 2000 | 10 | 10 | 7 | 3 | 200 | 6 | - | - | 100 | - |
| | BAG-29 | Copper King mine | 2 | 200 | - | 3000 | 30 | 20 | 3 | 5 | 500 | - | - | - | 200 | - |
| 4 | | Verde district | | | | | | | | | | | | | | |
| | JER-37 | United Verde mine | 40 | 800 | - | 5000 | 40 | 200 | 90 | 300 | 200 | - | 10 | - | 1000 | - |
| | JER-361 | do. | 4 | - | - | 4000 | 10 | 90 | - | 200 | 700 | 50 | - | - | 800 | - |
| 5 | | Peck district | | | | | | | | | | | | | | |
| | ARI-98 | Crown King mine | 100 | - | - | 3000 | 200 | 20 | - | 40 | 1000 | - | - | - | 10 | - |
| 6 | | Bradshaw district | | | | | | | | | | | | | | |
| | ARI-99 | Money Metals mine | 20 | - | 6 | 5000 | 400 | 9 | - | 200 | 800 | - | - | - | - | - |
| 12 | | Summit district | | | | | | | | | | | | | | |
| | MIA-4 | Castle Dome mine | 20 | - | - | 3000 | 80 | - | - | 50 | 400 | 20 | 8 | - | 8 | - |
| | MIA-6 | do. | 20 | - | - | 4000 | - | - | - | 20 | 800 | - | - | - | - | - |
| 13 | | Pioneer district | | | | | | | | | | | | | | |
| | MAG-27 | Magma mine | 300 | - | 9 | 3000 | 10 | - | - | 100 | 2000 | - | 10 | - | 10 | - |
| | MAG-75 | do. | 300 | - | 100 | 2000 | 5 | 200 | 8 | 300 | 2000 | - | - | - | 9 | - |
| 14 | | Copper Mtn. district | | | | | | | | | | | | | | |
| | MCL-9 | Arizona Central mine | 90 | - | 2 | 20000 | 30 | 9 | - | - | 200 | - | - | - | - | - |

TABLE 2. TRACE ELEMENTS IN SPHALERITE (continued)

| Dist. No. | Sample No. | Locality | Ag | As | Bi | Cd | Co | Ga | Ge | In | Mn | Mo | Ni | Sb | Sn | Tl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 19 | | Mammoth, Tiger, San Manuel district | | | | | | | | | | | | | | |
| | MAM-6 | Mammoth mine | 200 | - | 4 | 4000 | - | 50 | - | - | 50 | - | - | 200 | 500 | - |
| | MAM-9 | do. | 40 | - | 1 | 8000 | 60 | 10 | - | 20 | 600 | - | - | - | - | - |
| | MAM-11 | do. | 40 | - | 2 | 9000 | 20 | 6 | - | - | 300 | - | - | - | - | - |
| 20 | | Silver Bell district | | | | | | | | | | | | | | |
| | ARI-104 | Stump mine | 2 | - | 3 | 6000 | 200 | - | - | - | 100 | - | - | - | - | - |
| | AT-1 | Atlas mine | 10 | - | 70 | 4000 | 800 | 2 | - | 80 | 2000 | - | 70 | - | - | - |
| | AT-5 | do. | 2 | - | 3 | 4000 | 400 | 8 | - | 200 | 2000 | - | 80 | - | - | - |
| | AT-6 | do. | 2 | - | 100 | 4000 | 400 | - | - | 70 | 2000 | - | 40 | - | - | - |
| | AT-7 | do. | 4 | - | 3 | 3000 | 300 | - | - | 40 | 5000 | - | 50 | - | - | - |
| 25 | | Dragoon district | | | | | | | | | | | | | | |
| | AB-1 | Abril mine | 100 | - | 4000 | 3000 | 200 | - | - | - | 3000 | - | 20 | - | - | - |
| | AB-2 | do. | 30 | - | 500 | 4000 | 300 | - | - | - | 1000 | - | 30 | - | - | - |
| | ARI-100 | Senecia mine | 2 | - | 30 | 4000 | 10 | - | - | 50 | 4000 | - | - | - | - | - |
| | SJ-1 | San Juan mine | 20 | - | 50 | 5000 | 200 | 10 | - | 20 | 2000 | 2 | 3 | - | - | - |
| | SJ-2 | do. | 200 | - | 2000 | 4000 | 200 | - | - | 10 | 1000 | 20 | - | - | - | - |
| | SJ-3 | do. | 3 | - | 10 | 4000 | 100 | - | - | - | 2000 | - | 3 | - | - | - |
| 26 | | California district | | | | | | | | | | | | | | |
| | ARI-112 | Hilltop mine | 3 | - | - | 4000 | 10 | 30 | - | - | 1000 | 200 | 3 | - | 8 | - |
| 27 | | Pima district | | | | | | | | | | | | | | |
| | PIM-2 | San Xavier Ext. mine | 30 | - | - | 5000 | 300 | - | - | 40 | 3000 | - | 10 | - | - | - |
| | PIM-7 | do. | 2 | - | - | 3000 | 60 | - | - | - | 3000 | - | - | - | - | - |
| | PIM-8 | do. | 20 | - | 80 | 3000 | 100 | - | - | 10 | 2000 | - | 3 | - | 4 | - |

TABLE 2. TRACE ELEMENTS IN SPHALERITE (continued)

| Dist. No. | Sample No. | Locality | Ag | As | Bi | Cd | Co | Ga | Ge | In | Mn | Mo | Ni | Sb | Sn | Tl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 29 | | Tombstone district | | | | | | | | | | | | | | |
| | TB-12 | Ingersoll mine | 200 | - | 1 | 5000 | - | 200 | 3 | 2 | 40000 | - | - | 90 | 40 | - |
| | TB-14 | Silver Thread mine | 300 | 2000 | - | 5000 | 100 | 20 | - | - | 20000 | 7 | 20 | 400 | - | - |
| | TB-15 | Toughnut mine | 1 | - | 10 | 6000 | 60 | - | - | - | 1000 | - | - | - | - | - |
| 30 | | Tyndall district | | | | | | | | | | | | | | |
| | TY-1 | Tyndall district | 20 | - | 5 | 3000 | 400 | 20 | - | - | 1000 | - | - | - | 20 | - |
| | TY-2 | do. | 200 | - | 400 | 3000 | 300 | 2 | - | - | 2000 | - | - | - | 6 | - |
| 31 | | Harshaw district | | | | | | | | | | | | | | |
| | ARI-106 | Trench mine | 30 | - | - | 4000 | - | 30 | 20 | - | 30 | - | - | - | - | - |
| 32 | | Oro Blanco district | | | | | | | | | | | | | | |
| | MON-2 | Montana mine | 300 | - | - | 8000 | 50 | - | - | 3 | 2000 | - | - | 100 | - | - |
| | MON-3 | do. | 60 | - | - | 9000 | 30 | - | - | - | 500 | - | - | 60 | - | - |
| 33 | | Warren district | | | | | | | | | | | | | | |
| | BI-58 | Sacramento mine | 30 | - | 100 | 4000 | - | 9 | - | 100 | 2000 | - | - | - | 20 | - |
| | BI-59 | Junction mine | 3 | - | 2 | 3000 | - | 2 | - | 10 | 3000 | - | - | - | - | - |
| | BI-60 | Bisbee | 5 | - | - | 5000 | 20 | - | - | 200 | 30 | - | - | - | - | - |
| 34 | | Hereford district | | | | | | | | | | | | | | |
| | ARI-115 | Hereford | 7 | - | - | 10000 | 30 | - | - | - | 80 | - | 20 | 200 | - | - |
| 35 | | Patagonia, Duquesne district | | | | | | | | | | | | | | |
| | ARI-105 | Duquesne mine | <1 | - | - | 3000 | 100 | - | - | 30 | 6000 | - | - | - | - | - |
| | | CALIFORNIA | | | | | | | | | | | | | | |
| 39 | | Ophir district | | | | | | | | | | | | | | |
| | C-153 | Hathaway mine | 900 | - | - | 9000 | 7 | - | - | 9 | 40 | - | 7 | - | - | - |

TABLE 2. TRACE ELEMENTS IN SPHALERITE (continued)

| Dist. No. | Sample No. | Locality | Ag | As | Bi | Cd | Co | Ga | Ge | In | Mn | Mo | Ni | Sb | Sn | Tl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 42 | | Cerro Gordo district | | | | | | | | | | | | | | |
| | C-171 | Estelle mine | 90 | - | - | 6000 | - | 200 | 40 | 20 | 500 | - | 5 | - | 30 | - |
| 43 | | Darwin district | | | | | | | | | | | | | | |
| | DA-13 | Thompson tunnel | 20 | - | - | 7000 | 10 | 70 | - | 20 | 6000 | - | 10 | - | 30 | - |
| | DA-20 | Defiance mine | 50 | - | 4 | 6000 | 5 | 200 | - | 40 | 3000 | - | 10 | - | 200 | - |
| 46 | | Saratoga district | | | | | | | | | | | | | | |
| | C-258 | Shoshone mine | 200 | - | - | 4000 | 3 | 20 | - | 40 | 100 | - | - | 90 | 100 | - |
| | C-259 | do. | 70 | - | - | 4000 | - | 6 | - | 200 | 90 | - | - | 50 | 90 | - |
| 49 | | Oro Grande district | | | | | | | | | | | | | | |
| | AD-14 | Adelanto district | <1 | - | - | 5000 | 20 | 30 | - | 20 | 5000 | - | - | - | - | - |
| 51 | | Crestmore district | | | | | | | | | | | | | | |
| | C-175 | Crestmore mine | 3 | 3000 | - | 10000 | - | - | - | 9 | 1000 | 2 | - | - | - | - |
| | C-261 | do. | 50 | - | 20 | 10000 | 50 | 10 | - | 70 | 200 | - | 10 | - | 60 | - |
| | | COLORADO | | | | | | | | | | | | | | |
| 54 | | Ward district | | | | | | | | | | | | | | |
| | COL-102 | Albion mine | 300 | 700 | - | 2000 | - | 4 | - | 20 | 3000 | 20 | - | - | 5 | - |
| 55 | | Kremmling district | | | | | | | | | | | | | | |
| | COL-80 | Kremmling | 900 | - | 1000 | 3000 | - | 30 | - | 90 | 50 | - | - | - | - | - |
| | COL-81 | do. | 10 | - | 4 | 3000 | - | 20 | - | 100 | 60 | - | - | - | - | - |
| 57 | | Idaho Springs district | | | | | | | | | | | | | | |
| | COL-95 | Bride mine | 400 | 1000 | - | 6000 | - | 60 | 50 | 20 | 2000 | - | - | 2000 | 6 | - |
| | COL-96 | do. | 100 | 600 | - | 6000 | 7 | 30 | 8 | 100 | 3000 | - | - | - | 6 | - |
| 58 | | Griffith district | | | | | | | | | | | | | | |
| | COL-92 | Silver Plume mine | 60 | - | - | 5000 | 70 | 5 | - | - | 200 | 3 | - | - | - | - |
| | COL-93 | Molini tunnel | <1 | - | - | 4000 | 90 | - | - | 10 | 400 | - | 20 | - | - | - |

TABLE 2. TRACE ELEMENTS IN SPHALERITE (continued)

| Dist. No. | Sample No. | Locality | Ag | As | Bi | Cd | Co | Ga | Ge | In | Mn | Mo | Ni | Sb | Sn | Tl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 58 | (cont.) | Griffith district | | | | | | | | | | | | | | |
| | COL-117 | Jo Reynolds vein | 200 | - | - | 4000 | - | - | - | - | 100 | - | - | - | 20 | - |
| 59 | | Montezuma district | | | | | | | | | | | | | | |
| | COL-111 | Fisherman vein | 80 | - | - | 4000 | 10 | 60 | 20 | - | 200 | - | - | - | 20 | - |
| 60 | | Red Cliff district | | | | | | | | | | | | | | |
| | COL-105 | Gilman | 40 | - | - | 4000 | - | 80 | - | 50 | 500 | - | - | - | 1000 | - |
| 61 | | Tenmile district | | | | | | | | | | | | | | |
| | COL-82 | Sheep mountain | 400 | - | - | 5000 | - | 30 | - | 80 | 700 | - | - | - | 30 | - |
| 63 | | Leadville district | | | | | | | | | | | | | | |
| | COL-85 | Little Ellen hill | 100 | - | 10 | 5000 | 20 | - | - | 200 | 2000 | 5 | 8 | - | 10 | - |
| | COL-86 | do. | 30 | - | - | 4000 | - | - | - | 40 | 1000 | 3 | - | - | 8 | - |
| 64 | | Buckskin district | | | | | | | | | | | | | | |
| | COL-115 | Russia mine | 2000 | - | - | 6000 | 30 | - | - | - | 300 | 3 | - | 2000 | - | - |
| | COL-116 | do. | 7000 | - | - | 7000 | 30 | - | - | - | 40 | 8 | - | 300 ? | - | - |
| 66 | | Elk Mtn. district | | | | | | | | | | | | | | |
| | COL-84 | Crested Butte district | 200 | - | - | 7000 | 200 | 8 | - | 300 | 2000 | - | - | - | 10 | - |
| 68 | | Kerber Creek district | | | | | | | | | | | | | | |
| | COL-88 | Blue Moon lode | 200 | - | - | 7000 | - | 400 | 50 | 300 | 2000 | - | - | - | - | 20 |
| | COL-90 | Pawley mine | 100 | - | - | 6000 | - | 300 | 40 | 60 | 800 | - | - | - | - | 40 |
| 69 | | Uncompahgre district | | | | | | | | | | | | | | |
| | OU-2 | Benack tunnel | 50 | - | 3 | 3000 | 3 | 10 | - | 100 | 600 | 4 | - | - | 50 | - |
| | OU-3 | do. | 60 | - | - | 3000 | 6 | 9 | - | - | 400 | - | - | - | 7 | - |
| 70 | | Sneffels district | | | | | | | | | | | | | | |
| | COL-113 | Camp Bird mine | 7 | - | 5 | 5000 | 100 | - | - | 60 | 900 | - | - | - | - | - |

TABLE 2. TRACE ELEMENTS IN SPHALERITE (continued)

| Dist. No. | Sample No. | Locality | Ag | As | Bi | Cd | Co | Ga | Ge | In | Mn | Mo | Ni | Sb | Sn | Tl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 71 | | Eureka district | | | | | | | | | | | | | | |
| | COL-118 | Sunnyside mine | 40 | - | 4 | 4000 | - | - | - | 20 | 3000 | - | - | - | 2 | - |
| 72 | | Iron Springs district | | | | | | | | | | | | | | |
| | COL-109 | Alta mine | 300 | - | 20 | 4000 | 6 | 9 | - | - | 2000 | - | - | 400 | 4 | - |
| 73 | | Creede district | | | | | | | | | | | | | | |
| | COL-114 | Amethyst mine | 3 | - | - | 8000 | 90 | - | - | - | 200 | - | - | - | - | - |
| 74 | | Animas district | | | | | | | | | | | | | | |
| | COL-110 | Green Mtn. mine | 500 | - | 5 | 8000 | 60 | 4 | - | 9 | 1000 | 7 | - | 100 | - | - |
| 75 | | Pioneer district | | | | | | | | | | | | | | |
| | COL-103 | Enterprise mine | 100 | - | - | 9000 | - | 20 | - | - | 3000 | - | - | - | 5 | - |
| | | NEW MEXICO | | | | | | | | | | | | | | |
| 76 | | Willow Creek district | | | | | | | | | | | | | | |
| | NM-58 | Willow Creek district | 800 | - | 100 | 3000 | 9 | 100 | - | 10 | 400 | 2 | 2 | 500 | 40 | - |
| 77 | | Cerrillos district | | | | | | | | | | | | | | |
| | NM-65 | Cerrillos district | 9 | - | - | 5000 | 40 | 30 | - | 20 | 50 | - | - | - | 4 | - |
| | NM-66 | Pennsylvania mine | 3 | - | - | 3000 | - | 10 | 3 | - | 3000 | - | - | - | - | - |
| 79 | | Magdalena district | | | | | | | | | | | | | | |
| | MG-1 | Magdalena district | 200 | - | 500 | 4000 | 30 | - | - | 60 | 600 | - | - | - | - | - |
| | MG-2 | do. | 20 | - | 100 | 4000 | 100 | - | - | 50 | 800 | - | - | - | - | - |
| | MG-3 | do. | 60 | - | - | 5000 | 4 | - | - | - | 2000 | - | - | - | - | - |
| 80 | | Nogal district | | | | | | | | | | | | | | |
| | NM-74 | Tommy LeMay claim | 40 | - | - | 10000 | 30 | 4 | - | - | 60 | - | 40 | - | 2 | - |
| 81 | | Mogollon district | | | | | | | | | | | | | | |
| | NM-67 | Mogollon district | 30 | - | - | 3000 | 7 | - | - | - | 3000 | - | - | - | - | - |

TABLE 2. TRACE ELEMENTS IN SPHALERITE (continued)

| Dist. No. | Sample No. | Locality | Ag | As | Bi | Cd | Co | Ga | Ge | In | Mn | Mo | Ni | Sb | Sn | Tl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 81 | (cont.) | Mogollon district | | | | | | | | | | | | | | |
| | NM-68 | Mogollon district | 20 | - | 300 | 1000 | 200 | - | - | 8 | 2000 | - | 300 | - | - | - |
| 82 | | Hermosa district | | | | | | | | | | | | | | |
| | HE-1 | Day tunnel | 30 | - | - | 5000 | 60 | - | - | - | 70 | 5 | - | - | - | - |
| | HE-3 | do. | 30 | - | - | 5000 | 30 | 2 | - | - | 200 | 10 | - | - | 200 | - |
| | HE-5 | Nana mine | 1000 | - | 1 | 5000 | 40 | 20 | - | - | 300 | - | - | - | 5 | - |
| 83 | | Fierro-Hanover district | | | | | | | | | | | | | | |
| | BH-6 | Black Hawk mine | 200 | - | 80 | 2000 | 100 | - | - | 30 | 4000 | - | 8 | - | - | - |
| | BH-9 | do. | 30 | - | 80 | 2000 | 200 | - | - | 30 | 2000 | - | 20 | - | - | - |
| | HAN-5 | N. J. Zinc Co. mine | 50 | - | 3 | 2000 | 20 | - | - | 20 | 2000 | - | - | - | - | - |
| | HAN-6 | do. | 80 | - | 3 | 2000 | 60 | - | - | - | 600 | - | 7 | - | - | - |
| | HAN-16 | do. | 50 | - | 4 | 1000 | 40 | - | - | 30 | 3000 | - | - | - | - | - |
| | HAN-19 | Surface outcrop | 90 | - | 50 | 4000 | - | - | - | 100 | 7000 | - | - | - | - | - |
| | HAN-20 | Empire Zinc mine | 2 | - | 2 | 2000 | 30 | - | - | - | 20000 | - | 1 | - | 100 | - |
| | NM-54 | Shingle Canyon mine | 400 | - | 7 | 2000 | 10 | - | - | 200 | 4000 | - | 20 | - | - | - |
| | NM-55 | do. | 20 | - | 40 | 3000 | 40 | 10 | - | 200 | 400 | - | - | - | 20 | - |
| | OS-1 | Oswaldo No. 1 mine | 70 | - | 60 | 2000 | 100 | - | - | 40 | 2000 | - | - | - | - | - |
| | PEW-8 | Pewabic mine | 20 | - | 4 | 1000 | 300 | 20 | - | 60 | 1000 | 30 | 20 | - | - | - |
| | PEW-9 | do. | 40 | - | 2 | 2000 | 200 | 10 | - | 60 | 2000 | - | 10 | - | - | - |
| | PEW-12 | do. | 30 | - | 3 | 2000 | 200 | - | - | 60 | 1000 | - | 20 | - | - | - |
| | PEW-13 | do. | 200 | - | 700 | 1000 | 200 | - | - | 50 | 3000 | - | 9 | - | - | - |
| 84 | | Steeple Rock district | | | | | | | | | | | | | | |
| | NM-25 | Carlisle mine | 20 | - | 2 | 20000 | 100 | 8 | - | - | 300 | - | - | - | 7 | - |
| | NM-70 | do. | 300 | - | - | 7000 | 50 | 9 | - | - | 500 | - | - | - | 20 | - |

TABLE 2. TRACE ELEMENTS IN SPHALERITE (continued)

| Dist. No. | Sample No. | Locality | Ag | As | Bi | Cd | Co | Ga | Ge | In | Mn | Mo | Ni | Sb | Sn | Tl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 85 | | Santa Rita district | | | | | | | | | | | | | | |
| | G-3 | Groundhog mine | 30 | - | 2 | 4000 | 7 | - | - | - | 300 | - | - | - | - | - |
| | G-4 | do. | 200 | - | 2 | 2000 | 60 | - | - | 100 | 2000 | - | 5 | - | - | - |
| | G-11 | do. | 100 | - | 40 | 800 | 60 | - | - | 20 | 2000 | - | - | - | - | - |
| | G-18 | do. | 70 | - | 7 | 3000 | 30 | - | - | - | 2000 | - | - | - | - | - |
| | OS-2 | Oswaldo No. 2 mine | 100 | - | 4 | 3000 | 6 | - | - | 30 | 500 | - | - | - | 10 | - |
| | OS-4 | do. | 90 | - | 8 | 3000 | 5 | - | - | 100 | 1000 | - | - | - | 8 | - |
| | SR-15 | Ivanhoe lease | 100 | - | 20 | 3000 | 60 | - | - | 20 | 1000 | - | - | - | - | - |
| 86 | | Burro Mtn's. district | | | | | | | | | | | | | | |
| | NM-59 | Little Burro Mtns. | 500 | 200 | - | 4000 | 60 | 5 | - | - | 300 | - | - | 40 | 20 | - |
| 87 | | Cooks Peak district | | | | | | | | | | | | | | |
| | NM-63 | Cooks Peak district | 80 | - | - | 4000 | - | - | - | 20 | 600 | 5 | - | - | - | - |
| | NM-64 | do. | 20 | - | - | 3000 | - | - | - | 100 | 300 | 7 | - | - | 90 | - |
| 89 | | Organ district | | | | | | | | | | | | | | |
| | ORG-2 | Merrimac mine | 20 | - | 200 | 1000 | 200 | - | - | 8 | 2000 | - | 30 | - | - | - |
| | ORG-4 | do. | 60 | - | >4000 | 1000 | 100 | 2 | - | 7 | 1000 | - | 20 | 20 | 10 | - |
| 90 | | Lordsburg district | | | | | | | | | | | | | | |
| | CAM-23 | 85 mine | 30 | - | - | 4000 | 80 | - | - | - | 100 | - | - | - | - | - |
| | CAM-26 | do. | 4 | - | - | 6000 | 20 | 10 | - | 10 | 40 | - | - | - | - | - |
| | | NEVADA | | | | | | | | | | | | | | |
| 95 | | Donnelly district | | | | | | | | | | | | | | |
| | N-111 | Comrade mine | 10 | - | - | 5000 | 8 | 8 | - | 10 | 1000 | - | 4 | 200 | 40 ? | - |
| 96 | | Sierra district | | | | | | | | | | | | | | |
| | N-124 | Dun Glen mine | 200 | - | 50 | 8000 | - | 3 | - | 40 | 70 | - | - | 400 | - | - |

TABLE 2. TRACE ELEMENTS IN SPHALERITE (continued)

| Dist. No. | Sample No. | Locality | Ag | As | Bi | Cd | Co | Ga | Ge | In | Mn | Mo | Ni | Sb | Sn | Tl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 97 | | Imlay district | | | | | | | | | | | | | | |
| | N-125 | Nr. Betty LaVerne mine | 100 | - | 30 | 5000 | - | - | - | 100 | 600 | - | - | >7000 | - | - |
| 98 | | Safford district | | | | | | | | | | | | | | |
| | N-140 | Safford district | 200 | - | 10 | 4000 | 90 | - | - | - | 2000 | 3 | 4 | - | - | - |
| 100 | | Lewis district | | | | | | | | | | | | | | |
| | N-93 | Eagle mine | 4000 | 300 | 4 | 7000 | - | 20 | - | 30 | 7000 | - | - | >7000 | 20 | - |
| 101 | | Kennedy district | | | | | | | | | | | | | | |
| | N-121 | Kennedy district | 20 | - | - | 7000 | - | 20 | - | 10 | 4000 | - | - | 50 | - | - |
| | N-155 | do. | 100 | 6000 | - | 6000 | 5 | 50 | - | 20 | 2000 | - | - | 200 | - | - |
| 102 | | Bullion district | | | | | | | | | | | | | | |
| | N-143 | Julius mine | 8000 | 300 | 90 | 3000 | - | 7 | - | 30 | 200 | 20 | - | 20000 | 5 | - |
| | N-147 | Buckingham Mina Consolidated mines | 500 | 200 | 7 | 7000 | - | 90 | - | 30 | 10000 | - | - | 1000 | 2000 | - |
| | N-149 | Gray Eagle mine | 400 | 20000 | 6 | 7000 | 6 | 30 | - | 30 | 3000 | - | - | 2000 | - | - |
| 104 | | Mineral Hill district | | | | | | | | | | | | | | |
| | MH-2 | Mineral Hill mine | 500 | - | - | 3000 | - | 20 | 300 | - | 200 | - | 3 | - | - | - |
| | MH-3 | do. | 300 | 200 | - | 2000 | - | 40 | >500 | - | 300 | - | - | - | - | - |
| | MH-4 | do. | 300 | - | - | 3000 | - | 40 | 300 | - | 70 | - | - | - | 8 | 20 |
| 105 | | Pyramid district | | | | | | | | | | | | | | |
| | PYR-1 | Frank Blandin claims | 600 | 700 | 2 | 4000 | - | 40 | 80 | 80 | 300 | - | - | 2000 | 10 | - |
| | PYR-2 | do. | 100 | 200 | 6 | 4000 | - | 100 | 6 | 20 | 70 | 30 | - | 1000 | 2 | - |
| | PYR-3 | do. | 900 | 300 | 2 | 7000 | - | 20 | 20 | 10 | 30 | - | 4 | 2000 | - | - |

TABLE 2. TRACE ELEMENTS IN SPHALERITE (continued)

| Dist. No. | Sample No. | Locality | Ag | As | Bi | Cd | Co | Ga | Ge | In | Mn | Mo | Ni | Sb | Sn | Tl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 106 | | Roberts district | | | | | | | | | | | | | | |
| | N-139 | Jameson, Fletcher, and Carletti prop. | 100 | 900 | 2 | 4000 | - | 300 | 1000 | - | 70 | - | - | - | 40 | 100 |
| 107 | | Cherry Creek district | | | | | | | | | | | | | | |
| | N-126 | Cherry Creek district | 70 | - | - | 6000 | 60 | 10 | - | - | 2000 | - | 3 | - | 300 | - |
| | N-129 | Star mine | 900 | - | - | 6000 | 20 | - | - | - | 2000 | - | - | 400 | 70 | - |
| 108 | | Wedekind district | | | | | | | | | | | | | | |
| | WED-1 | Wedekind district | 1 | - | 1 | 5000 | - | 30 | 3 | 2 | 2000 | - | - | - | 3 | - |
| | WED-2 | do. | 40 | - | - | 8000 | - | 60 | - | 10 | 1000 | - | - | - | - | - |
| 109 | | Peavine district | | | | | | | | | | | | | | |
| | N-156 | Votero Zinc mine | 4 | - | - | 5000 | 9 | 100 | 200 | - | 40 | - | - | - | - | - |
| 111 | | Eureka district | | | | | | | | | | | | | | |
| | EU-1 | Albion mine | 700 | - | - | 6000 | 6 | 30 | - | 100 | 2000 | - | 1 | 800 | 100 | - |
| 114 | | Antelope district | | | | | | | | | | | | | | |
| | N-141 | Keystone lode | 200 | - | - | 3000 | 90 | - | 7 | 6 | 3000 | 2 | 10 | - | - | - |
| 117 | | Gardnerville district | | | | | | | | | | | | | | |
| | N-158 | Ruby Hill mine | 200 | - | - | 8000 | 100 | 10 | 80 | 7 | 80 | - | 10 | - | 4 | - |
| 118 | | Duckwater district | | | | | | | | | | | | | | |
| | N-85 | Duckwater | 1 | - | - | 6000 | - | 8 | - | - | 700 | - | - | - | - | - |
| 119 | | Garfield district | | | | | | | | | | | | | | |
| | N-131 | West of Luning | 500 | - | 3000 | 7000 | 7 | 9 | - | 40 | 2000 | 80 | - | - | - | - |
| | N-135 | Mabel mine | 70 | - | 20 | 9000 | 5 | 10 | - | 5 | 100 | - | - | - | - | - |
| 121 | | Cedar Mtn. district | | | | | | | | | | | | | | |
| | SIM-2 | Simon mine | 40 | 100 | 100 | 9000 | 400 | - | - | 40 | 2000 | - | 30 | - | - | - |

TABLE 2. TRACE ELEMENTS IN SPHALERITE (continued)

| Dist. No. | Sample No. | Locality | Ag | As | Bi | Cd | Co | Ga | Ge | In | Mn | Mo | Ni | Sb | Sn | Tl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 121 | (cont.) | Cedar Mtn. district | | | | | | | | | | | | | | |
| | SIM-7 | Simon (mina) | 400 | - | 10 | 4000 | 100 | 4 | - | - | 4000 | - | 4 | 100 | 4 | - |
| | SIM-8 | do. | 100 | - | 1 | 4000 | 200 | 1 | - | - | 6000 | - | 3 | 20 | 3 | - |
| 122 | | Belmont district | | | | | | | | | | | | | | |
| | BEL-3 | Belmont | 1000 | - | 9 | 4000 | - | 10 | - | 20 | 400 | - | 4 | 2000 | - | - |
| 124 | | Tybo district | | | | | | | | | | | | | | |
| | N-152 | Tybo | 30 | 300 | - | 5000 | - | - | - | 80 | 1000 | - | - | - | - | - |
| 127 | | Pioche district | | | | | | | | | | | | | | |
| | N-21 | Comb. Metals mine | 60 | - | - | 4000 | - | 60 | 20 | 30 | 500 | - | 7 | - | 300 | - |
| | PIO-2 | do. | 200 | 200 | - | 6000 | 10 | 90 | >100 | 40 | 500 | - | 8 | - | 300 | - |
| | PIO-9 | Pioche | 90 | 100 | - | 5000 | - | 80 | 300 | - | 400 | - | 9 | - | 600 | - |
| | PIO-12 | Black Ledge, Pioche mines | 300 | 200 | 8 | 3000 | - | 8 | 500 | - | 90 | 20 | 10 | 20 | 3 | - |
| 128 | | Goldfield district | | | | | | | | | | | | | | |
| | GFD-37 | White Rock shaft | 400 | 200 | 70 | 9000 | - | 500 | 70 | 700 | 20 | - | - | 1000 | - | - |
| 129 | | Tem Piute district | | | | | | | | | | | | | | |
| | N-165 | Lincoln mine | <1 | - | - | 4000 | 10 | - | - | 100 | 5000 | - | 6 | - | - | - |
| | N-166 | do. | 1 | - | - | 3000 | 20 | - | 6 | 80 | 9000 | - | 10 | - | - | - |
| 132 | | Yellow Pine district | | | | | | | | | | | | | | |
| | GS-34 | Potosi mine | 600 | 700 | 1 | 10000 | - | 4 | 700 | - | - | - | 8 | 200 | - | - |
| | GS-43 | do. | 700 | 100 | 1 | 6000 | - | 4 | 600 | - | - | - | 6 | 40 | - | - |
| | GS-44 | do. | 500 | 300 | 2 | 7000 | 6 | 30 | 700 | - | - | 200 | 10 | - | 6 | - |
| | GS-45 | do. | 100 | 400 | 1 | 8000 | 3 | 10 | 700 | - | - | 30 | 30 | 300 | - | - |

TABLE 2. TRACE ELEMENTS IN SPHALERITE (continued)

| Dist. No. | Sample No. | Locality | Ag | As | Bi | Cd | Co | Ga | Ge | In | Mn | Mo | Ni | Sb | Sn | Tl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | UTAH | | | | | | | | | | | | | | |
| 134 | | Big Cottonwood district | | | | | | | | | | | | | | |
| | UT-46 | Cottonwood Canyon | 50 | 1000 | 3 | 6000 | - | >700 | 40 | 10 | 4000 | - | 6 | 60 | 3 | - |
| 135 | | Uinta district | | | | | | | | | | | | | | |
| | PC-1 | Ontario mine | 2 | - | - | 6000 | - | 10 | - | - | 7000 | - | - | - | 100 | - |
| | PC-3 | Daly-Judge mine | 6 | - | - | 5000 | - | 20 | - | - | 2000 | - | - | - | - | - |
| | PC-10 | do. | 40 | - | - | 7000 | 7 | 50 | - | 20 | 3000 | - | - | 100 | - | - |
| | PC-12 | New Park mine | 30 | - | - | 10000 | - | 10 | - | 30 | 2000 | - | - | - | - | - |
| | PC-13 | do. | 5 | - | - | 8000 | - | - | - | - | 1000 | - | - | - | 10 | - |
| | PC-16 | do. | 4 | - | - | 10000 | - | - | - | 30 | 700 | - | - | - | - | - |
| | PC-28 | Ontario mine | 1 | - | - | 5000 | - | 7 | - | 20 | 100 | - | - | - | 100 | - |
| | PC-34 | do. | 1 | - | - | 5000 | - | 9 | - | 20 | 500 | - | - | - | 60 | - |
| 136 | | Bingham district | | | | | | | | | | | | | | |
| | BIN-9 | Lark mine | <1 | - | - | 6000 | - | 40 | - | - | 5000 | - | - | - | 5 | - |
| | BIN-11 | Butterfield mine | 5 | - | - | 4000 | 4 | 60 | - | 20 | 500 | 3 | - | 200 | 20 | - |
| 138 | | Ophir district | | | | | | | | | | | | | | |
| | UT-37 | Ophir district | 20 | - | - | 10000 | 30 | 20 | - | 200 | 4000 | - | - | - | - | - |
| | UT-42 | Hidden Treasure mine | 60 | - | 2 | 7000 | 8 | 8 | - | - | 4000 | - | - | - | 20 | - |
| 140 | | Tintic district | | | | | | | | | | | | | | |
| | EUR-46 | North Lilly mine | 20 | 600 | - | 6000 | - | 1 | 6 | 5 | 80 | - | - | 40 | 3 | 10 |
| | UT-29 | Chief Cons. mines | 600 | 200 | 2 | 8000 | 8 | >400 | 30 | 80 | 90 | - | - | 2000 | - | - |
| 142 | | Frisco district | | | | | | | | | | | | | | |
| | UT-1 | Lincoln mine | 40 | - | - | 5000 | - | - | - | 200 | 900 | - | - | - | - | - |

TABLE 2. TRACE ELEMENTS IN SPHALERITE (continued)

| Dist. No. | Sample No. | Locality | Ag | As | Bi | Cd | Co | Ga | Ge | In | Mn | Mo | Ni | Sb | Sn | Tl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 142 | (cont.) | Frisco district | | | | | | | | | | | | | | |
| | UT-14 | Lincoln mine | 30 | - | - | 3000 | - | - | - | 500 | 1000 | 300 | - | - | - | - |
| | UT-33 | Milford | 30 | - | 60 | 5000 | 100 | 4 | - | 60 | 7000 | - | - | - | 3 | - |
| | | <u>MEXICO</u> | | | | | | | | | | | | | | |
| | | BAJA CALIFORNIA | | | | | | | | | | | | | | |
| 144 | | El Triunfo, San Antonio district | | | | | | | | | | | | | | |
| | MEX-32 | Humboldt mine | 400 | - | - | 6000 | - | 100 | - | 200 | 200 | - | - | 3000 | 4000 | - |
| | | CHIHUAHUA | | | | | | | | | | | | | | |
| 147 | | San Diego, Iturbide district | | | | | | | | | | | | | | |
| | SE-94 | San Antonio mine | 10 | - | - | 4000 | 20 | - | - | - | 2000 | - | - | - | 4 | - |
| | SE-95 | do. | 60 | - | 8 | 4000 | 10 | - | - | - | 3000 | - | - | - | 20 | - |
| 148 | | Santa Eulalia, Iturbide district | | | | | | | | | | | | | | |
| | SE-96 | Potosi mine | 10 | - | - | 9000 | - | 20 | - | 8 | 4000 | - | - | - | - | - |
| | SE-98 | Santo Domingo mine | 20 | - | - | 5000 | 10 | 20 | - | 10 | 3000 | - | - | - | - | - |
| 149 | | Guerrero, Guerrero district | | | | | | | | | | | | | | |
| | CA-4 | Calera mine | 80 | - | - | 5000 | 100 | - | - | - | 2000 | 20 | - | 50 | - | - |
| 150 | | Meoqui, Camargo district | | | | | | | | | | | | | | |
| | MEX-28 | Las Plomosas mine | 100 | - | - | 3000 | - | 30 | 100 | - | 700 | - | - | - | 9 | - |
| | MEX-33 | do. | 40 | - | - | 3000 | - | 10 | 200 | - | 200 | - | - | - | - | - |
| 151 | | Naica, Camargo district | | | | | | | | | | | | | | |
| | MEX-53 | Naica | 200 | - | - | 7000 | 50 | - | - | 5 | 6000 | - | - | - | 10 | - |

TABLE 2. TRACE ELEMENTS IN SPHALERITE (continued)

| Dist. No. | Sample No. | Locality | Ag | As | Bi | Cd | Co | Ga | Ge | In | Mn | Mo | Ni | Sb | Sn | Tl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 151 | (cont.) | Naica, Camargo district | | | | | | | | | | | | | | |
| | MEX-54 | Naica | 200 | - | 30 | 8000 | 70 | - | - | 9 | 5000 | 10 | - | - | - | - |
| 152 | | Los Reyes, Jimenez district | | | | | | | | | | | | | | |
| | MEX-46 | Josefina y Anexas mine | 200 | - | - | 5000 | 30 | - | - | 100 | 3000 | - | - | - | - | - |
| 153 | | El Parral, Hidalgo district | | | | | | | | | | | | | | |
| | PAR-1 | Parral unit | 500 | - | - | 8000 | 200 | 8 | - | - | 1000 | - | - | 400 | - | - |
| | PAR-2 | do. | 3000 | 200 | - | 4000 | 70 | 9 | - | - | 1000 | 4 | - | 1000 | 200 | - |
| | PAR-4 | do. | 80 | - | - | 7000 | 100 | 10 | - | - | 3000 | 1 | - | - | - | - |
| 155 | | Santa Barbara, Hidalgo district | | | | | | | | | | | | | | |
| | SAF-1 | San Francisco del Oro | 100 | - | - | 9000 | 200 | 8 | - | - | 1000 | - | 5 | - | - | - |
| | SAN-1 | Hidalgo vein | 30 | 1000 | 5 | 4000 | 70 | - | 5? | - | 1000 | - | - | - | - | - |
| | SAN-3 | La Paz vein | 40 | - | - | 5000 | 200 | 20 | - | 6 | 2000 | 3 | 1 | - | - | - |
| | | DURANGO | | | | | | | | | | | | | | |
| 156 | | Penoles, Mapimi district | | | | | | | | | | | | | | |
| | OJ-37 | Ojuela mine | 200 | - | - | 6000 | - | - | - | 30 | 6000 | - | - | 300 | 10 | - |
| | OJ-40 | do. | 10 | - | - | 10000 | - | 9 | - | 10 | 3000 | - | - | - | - | - |
| 157 | | Las Vacas, Nombre de Dios district | | | | | | | | | | | | | | |
| | MEX-44 | La Fortuna mine | 700 | - | - | 8000 | 5 | 10 | - | 8 | 300 | - | - | 1000 | - | - |

TABLE 2. TRACE ELEMENTS IN SPHALERITE (continued)

| Dist. No. | Sample No. | Locality | Ag | As | Bi | Cd | Co | Ga | Ge | In | Mn | Mo | Ni | Sb | Sn | Tl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 158 | | Teneras, Cuencame district | | | | | | | | | | | | | | |
| | VEL-3 | Teneras mine | 300 | 900 | - | 8000 | 10 | 50 | - | - | 2000 | - | - | 4000 | 40 | - |
| | VEL-4 | do. | 30 | - | - | 8000 | 8 | 60 | - | - | 1000 | - | - | 400 | 20 | - |
| 159 | | Reina de Cobre, Cuencame district | | | | | | | | | | | | | | |
| | VEL-1 | Reina de Cobre mine | 6 | - | - | 3000 | 600 | 7 | - | 10 | 2000 | - | 20 | - | - | - |
| | VEL-2 | do. | 20 | - | - | 4000 | 600 | 2 | - | 20 | 2000 | - | 20 | - | - | - |
| 160 | | San Lucas, San Juan del Rio district | | | | | | | | | | | | | | |
| | MEX-40 | Santa Cruz mine | 7 | - | 3 | 8000 | - | - | - | 5 | 1000 | - | - | - | 20 | - |
| | MEX-41 | do. | 700 | - | - | 8000 | 5 | 10 | - | 8 | 300 | - | - | 1000 | - | - |
| 161 | | Panuco de Coronado, San Juan del Rio district | | | | | | | | | | | | | | |
| | MEX-42 | Guadalupe Victoria | 800 | 3000 | - | 9000 | 200 | - | - | 30 | 3000 | - | - | 3000 | 10 | - |
| | MEX-43 | do. | 200 | 200 | - | 9000 | 20 | - | - | 40 | 3000 | - | - | 3000 | 8 | - |
| | | SAN LUIS POTOSI | | | | | | | | | | | | | | |
| 164 | | Charcas, Venado district | | | | | | | | | | | | | | |
| | MEX-34 | Charcas | 90 | - | - | 10000 | - | - | - | - | 3000 | - | - | 60 | 10 | - |
| | | SONORA | | | | | | | | | | | | | | |
| 165 | | Cananea, Arispe district | | | | | | | | | | | | | | |
| | CN-38 | Cananea Duluth mine | 200 | - | 100 | 2000 | 300 | 10 | - | 80 | 5000 | - | 6 | - | - | - |

TABLE 2. TRACE ELEMENTS IN SPHALERITE (continued)

| Dist. No. | Sample No. | Locality | Ag | As | Bi | Cd | Co | Ga | Ge | In | Mn | Mo | Ni | Sb | Sn | Tl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 165 | (cont.) | Cananea, Arispe district | | | | | | | | | | | | | | |
| | CN-39 | Cananea Duluthmine | 100 | 400 | 30 | 2000 | 200 | - | - | 50 | 700 | 30 | 10 | 500 | 7 | - |
| | CN-40 | Democrata mine | 70 | 200 | 70 | 2000 | 400 | - | - | 100 | 1000 | - | 10 | - | - | - |
| 166 | | Nacozari, Arispe district | | | | | | | | | | | | | | |
| | ELT-3 | El Tigre mine | 200 | - | - | 10000 | - | 300 | - | 300 | 2000 | - | - | 300 | 200 | - |
| | ELT-7 | do. | 70 | - | - | 5000 | 7 | 100 | - | - | 6000 | - | - | 200 | 20 | - |
| | ELT-8 | do. | 200 | - | - | 9000 | - | 100 | - | 300 | 3000 | - | - | 500 | 300 | - |
| | | ZACATECAS | | | | | | | | | | | | | | |
| 170 | | Sain Alto, Sombrerete district | | | | | | | | | | | | | | |
| | MEX-52 | San Martin mine | 300 | - | 8 | 4000 | - | - | - | - | 600 | - | - | - | 40 | - |
| 171 | | Sombrerete, Sombrerete district | | | | | | | | | | | | | | |
| | MEX-50 | Tocayos mine | 200 | - | - | 10000 | 5 | - | - | 4 | 800 | 70 | 10 | 300 | 10 | - |
| | MEX-51 | do. | 20 | - | - | 10000 | - | - | - | 3 | 900 | 3 | - | - | 100 | - |

# *Effects of Conditions of Formation on the Trace-Element Content of Chalcopyrite and Sphalerite*

Attempts to associate certain minor and trace' elements, or certain concentrations of elements, with particular types of ore deposits have been one of the chief objectives in nearly all the studies on the distribution of minor and trace elements in sulfide minerals since the very early work of De Launay and Urbain (1910). Except for this earliest work, in which more emphasis was placed on depth of formation, the general tendency has been to relate the minor and trace-element content of certain sulfides, especially sphalerite, to the temperature type of deposit, mostly in terms of the Lindgren classification.

The results of all this previous work have been summarized concisely by Fleischer (1955). The essence of this summary apparently is that several factors affect the trace-element content of sulfide minerals. Among these factors are: (1) Temperature and pressure of formation, (2) the nature of the wall rocks, (3) "regional factors," and perhaps related to this, (4) the amount of the elements present in the ore-forming solutions. It is widely recognized that the amount of the elements present in the ore-forming solutions generally is a determining factor in the trace-element content of sulfides, although Fleischer (1955, p. 975) believes "that the available data support many of the generalizations that have been made linking the concentrations of minor elements with temperature of formation or other factors." However, he also acknowledges that a "regional trend" may have a greater effect "than the generally observed trend due to temperature of formation."

This "generally observed trend" apparently alludes mainly to the fact that sphalerite from the presumed low-temperature deposits of the Mississippi Valley province and from European deposits of Mississippi Valley type are relatively rich in germanium. It is unlikely, however, that the deposits in these two regions are representative of low-temperature deposits the world over. In fact, the evidence presented in Table 2 does not support the premise that sphalerite from epithermal deposits is richest in germanium. Nor does it appear that the overall trace-element content of either sphalerite or chalcopyrite is in general closely related to the type of deposit in which the mineral occurs. This could mean that the deposits included in this study are not properly classified, or that the trace-element content of sphalerite is not sensitive to temperature differences such as are presumed to exist between epithermal and mesothermal conditions, or that the classification has relatively little temperature significance as far as the majority of Cordilleran sulfide ore deposits are concerned. All these explanations appear meritorious; thus any attempt here to classify the deposits listed in Tables 1 and 2 is unwarranted.

Many deposits are placed in one or another (sometimes more than one) temperature category of the Lindgren classification on the basis of their mineral composition, and their mineral composition reflects largely their bulk chemical composition. Inasmuch, therefore, as the trace elements are controlled by the same processes that control the major component elements of the ores, it is probable that the chemical history, including the composition of the source material, is fully as important as the so-called temperature type of deposit in determining the trace-element content of the hypogene sulfide minerals.

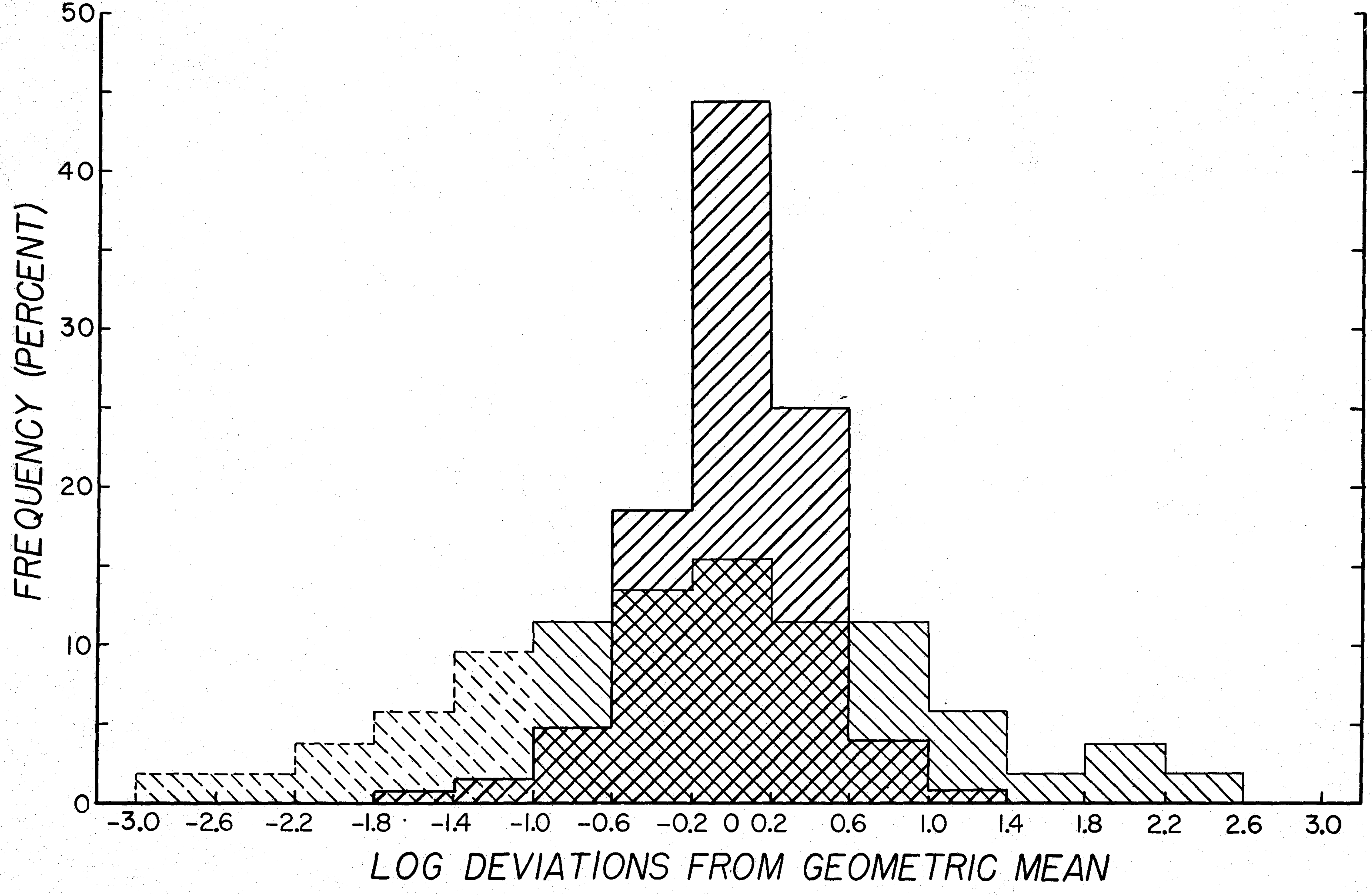

Figure 3

Frequency histograms of the logarithmic deviations from the geometric-mean tin content of chalcopyrite within each mining district (heavy lines) and among all the mining districts (light lines)

Dashed light lines indicate assumed distribution of deviations of the district means that lie below the spectrographic sensitivity (3 ppm).

# *Geographic Distribution of Trace Elements in Chalcopyrite*

Perhaps it would be desirable, before proceeding to a detailed discussion of the elements, to present additional evidence for the existence of a well-defined geographic distribution of trace elements in chalcopyrite and sphalerite. This can be done on a statistical basis by comparing the variation of the sample means for a given element about the district means, with the variation of the district means about the grand mean for the entire region. That is, a definite geographic distribution is more firmly established if it can be shown that the variance about the grand mean is significantly greater than the variance about the district means. In practice, the approach is to adopt the hypothesis that the variances are equal and then to test this hypothesis at a predetermined level of significance.

An assumption that underlies the simpler tests of the hypothesis of equal variance is that the deviations from the mean are normally distributed, but for most practical purposes it is sufficient that the frequency-distribution curve have a symmetrical bell shape. The assumption of "normality" for deviations from the arithmetic-mean tin content of chalcoprite appears to be invalid, owing to a strong positive skewness of the frequency-distribution curve. However, the deviations of the logarithms of the tin content from the geometric mean appear to approximate closely a normal distribution, as shown in Figure 3. Therefore, the hypothesis of equal variance is tested on the assumption that the deviations of the logarithms of the concentrations from the geometric mean are approximately normally distributed.[2]

The analysis of the data in Table 1 for the tin content of chalcopyrite is summarized in Table 3. A comparison of the computed variance

TABLE 3. ANALYSIS OF VARIANCE OF TIN IN CHALCOPYRITE

| SOURCE OF VARIATION | SUM OF SQUARES | DEGREES OF FREEDOM | $S^2$ | F |
|---|---|---|---|---|
| Among all mining districts | 157.17 | 53 | 2.966 | 14.92 †† |
| Within each mining district | 23.06 | 116 | 0.199 | |

$F_{0.99}$ (40, 120) = 1.76 (Dixon and Massey, 1951, p. 312)

[2] Ahrens (1954) and others have suggested that variations in the trace-element content of igneous rocks and minerals closely approximate a lognormal distribution. This has been questioned (Chayes, 1954) on the ground that other types of distribution might fit the data equally well. However, considerations based on the distribution law indicate that the variations in the trace-element content of a given mineral should tend to be logarithmic functions (c « exp µ/RT, where c is the molar concentration and µ is the chemical potential in the standard state).

ratio (F) with the critical variance ratio at the .01 level of significance indicates that the hypothesis of equal variance must be rejected. Hence, it is concluded that the variations in the tin content of chalcopyrite from district to district are greater than the variations within each mining district. This same conclusion is surmised readily from a comparison of the frequency histograms in Figure 3.

The frequency histogram shown in heavy lines represents the distribution of the logarithms of the tin concentrations about the means for each of the mining districts, and the histogram shown in light lines represents the distribution of the district geometric means about the grand mean for all the mining districts in the sample.

It should be emphasized that all available data have been utilized in the foregoing analysis; i.e., every mining district that is represented in Table 1 by more than one spectrochemical analysis is included in the statistical analysis. Although this procedure furnishes the most accurate statistical information concerning the data utilized in the construction of Plate 1, it does not permit a precise evaluation of the variance that actually exists within each of the mining districts. The reasons are that much material was utilized in the present studies about which nothing is known firsthand, and hence some of which is likely to be labeled incorrectly; and the data are grouped into arbitrary geographic units, the mining districts, the sizes of which are greatly different in different regions.

An estimate of the effect that these and other factors might have on the within-district variance can be obtained by a comparison of the variance of a group of samples, the sources of which are known, with the variance of all the data. Thus, an analysis of variance was made of the tin content of chalcopyrite that was collected by the writer or obtained firsthand from the collector. This analysis is summarized in Table 4, and a comparison with Table 3 reveals that the within-district variance of the reliable data is less than half the within-district variance of all the data. It also is evident from the variance ratio (F) in Table 4 that if the sampling is completely reliable and the geographic unit is the mine or relatively small group of mines, the significance of the differences in "district" averages would appear to be even greater than Table 3 indicates.

TABLE 4. ANALYSIS OF VARIANCE OF TIN IN SELECTED SAMPLES OF CHALCOPYRITE

| SOURCE OF VARIATION | SUM OF SQUARES | DEGREES OF FREEDOM | $S^2$ | F |
|---|---|---|---|---|
| Among selected mining districts | 43.27 | 17 | 2.545 | 24.44 |
| Within each selected mining district | 3.40 | 35 | 0.097 | |

$F_{0.99}$ (15, 30) = 2.70 (Dixon and Massey, 1951, p. 312)

## TIN

A pronounced regional distribution of tin in chalcopyrite was recognized early in the present studies; as a result, considerable emphasis has been placed on it. In fact, the realization that tin, perhaps more than any other metal, is concentrated into certain regions of the earth's crust has led to the use of its distribution, as shown in Plate 1, as a model in the construction of other maps that represent distributions which are not so well defined. Conversely, the distributions of other elements, notably silver, have been used to work out some of the details of the tin distribution. For example, without knowledge of the silver distribution, it would have been about as reasonable to continue the Western belt for tin southward, west of district 52 in California.

A very remarkable feature of the distribution of tin, and of other elements as well, is the occurrence of three main belts of relatively high trace-element content in the western United States. These three belts are hereinafter referred to as the Eastern, Central, and Western belts.

Perhaps a note of caution should be expressed here with respect to the interpretation of the beltlike patterns for tin and other elements shown in Plates 1-5. Although there is abundant evidence to indicate that the positions, trends, and approximate widths of the belts are as shown on the maps, some of the details may require alteration when more complete sample coverage is obtained. The main reason for presenting all the data is to permit one to judge for himself the validity of the features shown on the maps. Attention also should be brought here to the logarithmic nature of the pattern intervals in Plates 1-5. This is in keeping with the evidence presented above in support of the thesis that trace elements in minerals appear to be distributed "log-normally." Thus, the darkest pattern on the maps represents concentrations approximately 1,000 times greater than those represented by the lightest pattern.

Another notable feature of the tin distribution in Plate 1 is the continuity of the Central belt. This is in contrast to the Eastern belt, which is very strongly expressed along most of the Colorado mineral belt, but which apparently does not continue through southern New Mexico. However, the tin deposits of the Taylor Creek district, New Mexico, about 60 miles north of district 83, may be significant in connection with the southward extension of the tin-rich belt from Colorado.

The Eastern tin belt is practically severed by a tin-poor area in the San Juan region of southwestern Colorado, and a similar feature occurs in the heart of the Western belt in north-central Nevada (district 98). Although the cause of this phenomenon is not known, the fact that all the deposits which exhibit the anomaly occur in thick piles of tuffaceous volcanic rocks is perhaps significant. Moreover, many of the volcanic rocks in north-central Nevada are notably cassiterite bearing. It appears possible that the higher oxidizing environment of these rocks promotes the early separation of tin from the sulfide-bearing solutions and its fixation in cassiterite. erhaps a similar explanation applies to the behavior of indium, which shows essentially the same anomalies. Tin exhibits a well-defined geographic distribution not only as a trace element in chalcopyrite, but as economically important deposits as well. This distribution of tin has been known for many years, and the problems connected with it have been summarized recently by Goldschmidt (1954, p. 392-393) as follows:

> A difficult problem in the geochemistry of tin is the question, whether or not tin is distributed evenly in corresponding rocks of different regions of the globe. The data available seem to indicate that there are important regional variations. It was observed long ago, and probably even known to prehistoric man, that an obviously regional concentration existed, but the average amount of tin in ordinary magmatic rocks seems also to show regional variations. The scarcity of tin deposits in the enormous region stretching from the northern Urals to near the North American west coast is certainly not due to the absence of such magmatic rocks as are commonly followed by tin deposits in "tin regions."
>
> Tin is not the only metal which is subject to such regional concentrations and deficiencies. Tungsten in this respect is very closely associated with tin in the same type of deposits. Molybdenum also is subject to regional variations, but these seem to be independent of those of tin and tungsten or even reciprocal to them, as in Norway, where tin and tungsten are practically absent while workable molybdenum deposits are found associated with granites of very different geological ages from early Precambrian to Permian.

The reciprocal relation of molybdenum to tin and tungsten that Goldschmidt suggests is not supported by the present studies, at least not on the trace-element level. A majority of the molybdenum-bearing chalcopyrite deposits, as well as the more important molybdenite de-posits, occur within or very close to the tin belts as they are defined in Plate 1. In fact, tin has been a byproduct in the recovery of molybdenum at the Climax mine in Colorado (district 62).

## SILVER

The relatively common occurrence and great range in concentration of silver in chalcopyrite combine to produce a relatively well defined geographic distribution, as shown in Plate 2. However, owing to the danger of contamination by silver-bearing minerals, a question arises as to the meaningfulness of some of the high concentrations reported in Table 1. Consequently, no attempt has been made to distinguish on the map the geographic distribution of silver contents in excess of 100 ppm. The area in central Nevada between districts 99, 110, 125, and 130 on one side, and districts 103, 113, and 129 on the other, for lack of information, is covered on the map with the 30- to 100-ppm pattern.

A feature of Plate 2 that is of particular interest is the fairly direct relationship between the silver content of chalcopyrite and the regional productivity of silver (cf. pl. 6). Deserving of mention in this connection are the Comstock district (112) in western Nevada, the Colorado mineral belt, and many deposits in Chihuahua, Durango, Zacatecas, San Luis Potosi, etc.

## COBALT

Maps showing the geographic distribution of cobalt, indium, and nickel were prepared but have been omitted from this presentation mainly because the distributional patterns are the same as for tin and silver in most essential respects. They are represented, moreover, more effectively in their aggregate as the "combined metal content of chalcopyrite" in Plate 3.

Some features of the distribution of cobalt in chalcopyrite that are not apparent in Plate 3 are: (1) The weakness of the Central belt, especially in Arizona; (2) a possible branch in the Western belt in north-western Nevada, extending northward through district 93; (3) the weakness of the Eastern belt in New Mexico; and (4) the occurrence of relatively large amounts of cobalt in the pitchblende-bearing ores of southeastern Utah (districts 141[3] and 143).

The weakness of the Central belt is noteworthy, as this belt is especially rich in copper (cf. pl. 7). The weakness of the Eastern belt in New Mexico also is of interest inasmuch as this belt is strongly expressed to the south in Chihuahua and Durango. The fork in the Western belt is problematical, for it is based on very scanty data.

The association of cobalt with uranium, which apparently is worldwide, leads to interesting speculation regarding the cobalt-rich Eastern belt in Mexico. It should be pointed out, however, that although nearly all pitchblende- or uraninite-rich ores are cobaltiferous, not all cobalt-rich ores are uraniferous.

It is conceivable that chalcopyrite is subject to enrichment or impoverishment in cobalt, as well as some other elements, depending upon certain paragenetic factors. That is, the presence of abundant pyrite, the lattice of which will accept much larger amounts of cobalt, could cause the chalcopyrite to become impoverished in this element. However, Gavelin and Gabrielson (1947) found no such effect in the pyrite and chalcopyrite from the same specimen. Thus, if pyrite contains a higher than average amount of cobalt, the chalcopyrite generally contains a higher than average amount also. The evidence indicates, more-over, that the same principle applies to the trace-element content of sulfides in general—a reflection perhaps of the sequential deposition (and replacement) of sulfide minerals.

## NICKEL

The geographic distribution of nickel in chalcopyrite has several features in common with the distribution of cobalt, as might be ex-

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[3] The cobalt content reported for district 141 might be too high, owing to possible contamination by cobaltite that is present in the polished section.

pected from the chemical similarities of the two metals. Thus, the Colorado Plateau uranium deposits are nickeliferous as well as cobaltiferous. Also, the Western belt for nickel is strongly expressed, especially in southern California, and there is a suggestion of a fork in this belt in northwestern Nevada. The low nickel content of the copper-rich Central belt in Arizona constitutes another resemblance to the distribution of cobalt.

### INDIUM

One of the more noteworthy features of the distribution of indium in chalcopyrite is the relatively strong expression of the Central belt, in contrast with cobalt and nickel. The northeast-trending Colorado mineral belt also is strongly expressed, except for the deposits of the San Juan volcanic region, but the rest of the Eastern belt and the Western belt are very weakly expressed.

The low indium content of the deposits in the San Juan volcanic rocks, as compared with the deposits in older rocks on either side, already has been mentioned in connection with the similar distribution of tin. This association of indium with tin appears to be general and has been noted by several workers (Borovick and Prokopenko, 1939; Brewer and Baker, 1936; Fleischer and Harder, 1946). Thus, there are few deposits of chalcopyrite that are indium rich and tin poor, although there are many deposits that are tin rich and indium poor.

### OTHER TRACE ELEMENTS

No attempt has been made to define quantitatively the geographic distribution of antimony, arsenic, bismuth, cadmium, germanium, manganese, and molybdenum in chalcopyrite, mainly because most of these are not sufficiently widespread in spectrographically detectable quantities. Manganese, although sufficiently widespread, is highly erratic in its behavior even within a single mine or district. Consequently, it does not exhibit a consistent geographic distribution.

An examination of Table 1 reveals that larger amounts of antimony are associated with above average concentrations of silver in chalcopyrite, although not all silver-rich chalcopyrite is antimony bearing. Hence, the map that shows the distribution of silver in chalcopyrite (pl. 2) defines in a general way the areas in which larger amounts of antimony occur.

The geographic distribution of arsenic in chalcopyrite is more difficult to determine than the distribution of antimony, because the spectrographic sensitivity for arsenic is poorer than for antimony, and arsenic does not appear to be closely associated with any of the other elements sought. That arsenic and antimony differ in their behavior with respect to silver is indicated by the rarity of argentian tennantite as compared with argentian tetrahedrite (freibergite). Gold commonly is regarded as an associate of arsenic, but owing to relatively poor spectrographic sensitivity as compared with its abundance in sulfides, gold was detected in only a few samples of chalcopyrite. Consequently, very little information in this connection has been obtained in these studies.

The bismuth content of chalcopyrite is highly erratic even within a single deposit; consequently, its geographic distribution is not well defined. In general, the Central belt in Arizona and adjacent parts of Sonora appears to be enriched in bismuth, but elsewhere along the belts shown in Plate 3, bismuth is sporadically distributed.

Owing to the common association of sphalerite with chalcopyrite and to the fact that sphalerite contains essentially all the cadmium in the average base-metal ores, the data in Table 1 on the cadmium content of chalcopyrite are not very reliable. Therefore, any attempt to define the geographic distribution of cadmium in chalcopyrite on the basis of the present data is unwarranted.

Germanium is rare as a spectrographically detectable trace element in the chalcopyrite of the Southwest. The only really noteworthy occurrences are in the uranium deposits of the Colorado Plateau (districts 141 and 143) and at Butte, Montana.

The manganese content of chalcopyrite is highly erratic, as mentioned above. This behavior perhaps reflects the more oxyphile or lithophile nature of manganese, as many of the variations might result from contamination of the hydrothermal fluids by manganese-bearing wall rocks.

Molybdenum is similar to manganese in its erratic behavior within many mining districts. In general, it appears that the molybdenum con-tent of chalcopyrite is greater along the Central belt in Arizona (pl. 3) than in any other region, except perhaps the region that includes the two Colorado PIateau uranium deposits (districts 141 and 143). It is noteworthy that the chalcopyrite from the molybdenite-rich Climax and Childs-Aldwinkle deposits (districts 62 and 18 respectively) is not molybdenum rich.

## COMBINED METAL CONTENT

A comparison of the maps in Plates 1 and 2 and the data for cobalt, indium, and nickel in Table 1 reveals a close relationship between the positions and trends of the belts of greater than average trace-element content. This implies a fairly high degree of correlation in occurrence among the metals, at least among the five metals represented. In order that the distributional relationships might be visualized more readily, the district average cobalt, indium, nickel, silver, and tin contents of chalcopyrite have been combined as the logarithms of their products, and the distribution of the quantities thus obtained is shown in Plate 3. The individual metal contents are combined in this manner in order to reduce the effect of unusually high concentrations of a particular metal that otherwise would dominate the combined metal content.

It should be emphasized that the belts shown in Plate 3 represent an aggregate effect, as the axes of the individual belts do not everywhere coincide. However, in many places, as in central Arizona, they very nearly coincide. This indicates that although the degree of correlation in occurrence among the five metals is relatively high, it is by no means perfect. If another group of metals had been combined in similar fashion, the axes of the aggregate belts doubtless would not coincide exactly with those shown in Plate 3, although they would be essentially parallel in trend. However, the important fact here is that the belts for each of the five metals overlap to such an extent that their aggregate effect results in a very well defined geographic distribution of the combined metal content of chalcopyrite.

Although the distribution of trace elements in chalcopyrite is unknown in the region of central Mexico south of the patterned area in Plate 3, the distribution of metalliferous deposits suggests that the continuation of the belt shown would be mainly in a south-southeasterly direction; also, there is a vague suggestion that the Western belt eventually joins this main belt, perhaps in the State of Queretaro.

Another fork in the main belt occurs in Zacatecas (pl. 3), the north-eastern branch becoming the Eastern belt and the southwestern branch continuing as the Central belt. In the vicinity of the junction, each of the five metals makes a significant contribution to the combined metal content. In the northeastern branch, cobalt, nickel, and silver are the main contributors, and indium and tin are relatively unimportant, whereas in the southwestern branch, indium, silver, and tin are most important, and cobalt and nickel are nearly absent. However, as the Eastern belt is traced northward into Colorado, it is no longer characterized by cobalt, nickel, and silver, but by indium, silver, and tin, as in the Central belt in Zacatecas.

The compositional characteristics of the Central belt remain much the same from Zacatecas to south-central Nevada, but from Nevada northeastward the indium content of chalcopyrite decreases and is compensated by an increase in nickel and, to a less extent, cobalt. The tin, as well as the silver, persists, however, and is the most characteristic feature of the Central belt.

The extension of the Western belt southward from southern Arizona is conjectural. Presumably it is the belt that joins the main belt in Queretaro, and very probably it is silver rich. The combined metal content of chalcopyrite in the Western belt in southern Arizona consists largely of cobalt, silver, and tin. Nickel also becomes important in southern California. In central California the Western belt branches, but the main branch, to which the name Western belt still applies, continues northeastward through Nevada. The western branch, which is rich in silver and tin, courses northward into northern California.

# *Geographic Distribution of Trace Elements in Sphalerite*

The geographic distribution of trace elements generally is not as well defined in sphalerite as in chalcopyrite; hence, sphalerite is not as suitable a geographic indicator as chalcopyrite. The principal reason for the behavior of sphalerite in this respect is that tin, the mainstay of the trace-element distribution in chalcopyrite, exhibits an erratic distribution in sphalerite. Moreover, cadmium, which in sphalerite should be the counterpart of tin from the standpoint of uniformity of content within each district, is not very suitable as a geographic indicator be-cause the total range in its concentrations is only about tenfold, not great enough to produce a well-defined geographic distribution in many large regions. Cadmium might be suitable, however, if a more precise method of analysis were employed. In view of these disadvantages, less emphasis is placed on sphalerite as an indicator of the geographic distribution of trace elements than is placed on chalcopyrite. Moreover, largely owing to this lighter emphasis, only the maps that show the distribution of silver and the "combined metal content of sphalerite" are presented here (pl. 4 and 5).

## SILVER

The geographic distribution of silver in sphalerite (pl. 4) is very similar to the distribution of silver in chalcopyrite (pl. 2), although generally it is more irregular. These irregularities result in a distributional pattern in Colorado that, in addition to being unusual, suggests that the silver-rich belt which coincides with the northeastern part of the Colorado mineral belt branches southwestward into two belts. The southeastern branch presumably extends southward as the Eastern belt into New Mexico. The northwestern branch continues southwestward along the Colorado mineral belt, perhaps into northeastern Arizona, where it presumably turns back southeastward and joins the Eastern belt again in southwestern New Mexico.

The genetic significance of the great width of the Western belt in Nevada is not clear, but its economic significance is well attested by the amount of silver that has been produced from this region. Also, the distributional relationships of silver in sphalerite in western Chihuahua, northeastern Sonora, and southeastern Arizona are not clear, and the interpretations indicated for this region in Plate 4 should be regarded as tentative.

## COBALT

The geographic distributions of cobalt, gallium, germanium, and indium are shown in their aggregate effect in Plate 5. The individual maps for each of these metals have been omitted, as little information in addition to that contained in Plate 5 could be obtained from them.

The distribution of cobalt in sphalerite resembles in several respects its distribution in chalcopyrite, although there are some notable differences. The near lack of cobalt in chalcopyrite from the Central belt in Arizona contrasts with the well-developed belt for cobalt in sphalerite. Also, chalcopyrite gives little indication of an Eastern belt, whereas sphalerite from this region exhibits a pronounced distribution.

## GALLIUM

The gallium content of sphalerite exhibits a fairly well defined geographic distribution, although there are some complicating local irregularities. Some of these irregularities perhaps could be due to contamination by gallium-bearing aluminous wall rocks, but the magnitude of this effect probably would be small. The relatively high concentrations of gallium in sphalerite from the Central belt in Utah and the Western belt in Nevada are especially noteworthy. Also, there is a strong indication of a northwestward trending belt in Colorado, whereas there is little indication of a northeast trend parallel to the Colorado mineral belt.

## GERMANIUM

The most striking features of the geographic distribution of germanium in sphalerite are the relatively high concentrations in the Central and Western belts in Nevada and the general scarcity elsewhere in the Southwest. This is in contrast to the general abundance of germanium in sphalerite throughout much of the Mississippi Valley region.

## INDIUM

The geographic distribution of indium in sphalerite is somewhat more erratic than that of the other four elements represented in Plate 5, and also more erratic than that of the indium in chalcopyrite. Indium resembles tin in this respect, as tin exhibits a highly consistent distribution in chalcopyrite but an erratic distribution in sphalerite. Moreover, the definite association of indium with tin in chalcopyrite finds no counterpart in sphalerite, as many of the indium-bearing samples of sphalerite are not tin bearing.

The Eastern belt in New Mexico provides a good illustration of the poor correlation in the indium contents of sphalerite and chalcopyrite. Indium in sphalerite is distributed in a well-defined belt, whereas indium is virtually absent from the chalcopyrite of this region. Similarly, sphalerite from the Central belt in Nevada is indium rich, whereas the chalcopyrite is indium poor.

## OTHER TRACE ELEMENTS

The cadmium content of sphalerite is remarkably uniform within a given district, as indicated in Table 2, and on this account might be expected to exhibit a well-defined geographic distribution. However, the total range in the cadmium content of sphalerite from the Southwest is only about tenfold, whereas the total range in the tin content of chalcopyrite, for example, is more than a thousandfold. Consequently, there is a great deal of uncertainty as to the significance of small differences in cadmium content among mining districts throughout large regions.

On the other hand, in some regions where the range in cadmium content is from about 1,000 to 10,000 ppm, as in southern Arizona and southwestern New Mexico, the distribution is well defined and consistent with the trends in the distributions of the other trace elements. The very narrow range in the cadmium content of sphalerite throughout the Southwest probably indicates that owing to the close chemical similarity of cadmium to zinc, the processes that concentrate zinc in sulfide bodies cannot differentiate it from cadmium.

The behavior of antimony, arsenic, and bismuth in sphalerite is much the same as in chalcopyrite. Thus, antimony-rich sphalerite also generally is silver rich, the arsenic content of sphalerite appears to bear no close relation to the content of any other element, and the bismuth content is highly erratic.

The average manganese content of sphalerite is several times that of chalcopyrite, but the characteristics of manganese behavior in the geographic sense are very similar in the two minerals. It is possible, as noted previously, that the erratic behavior of manganese is related to its more oxyphile character and its greater abundance in the gangue and wall rocks of the sulfide deposits.

Molybdenum resembles manganese in its erratic behavior in sphalerite, but, unlike manganese, it is slightly enriched in chalcopyrite as compared with sphalerite. The erratic behavior of molybdenum in sphalerite and chalcopyrite perhaps reflects a lack of tendency for molybdenum to enter the structures of these minerals, except perhaps in defects.

Thallium was not detected in any chalcopyrite and occurs in the sphalerite from only four of the mining districts included in this study; hence, little can be said about its geographic distribution. However, all the thallium-bearing sphalerite analyzed also is germanium bearing. Inasmuch as germanium is not a common trace constituent of sphalerite in the Southwest, the association suggests that perhaps the geographic distribution of thallium is closely related to that of germanium.

The erratic behavior of tin in the sphalerite from a given district stands in contrast to its behavior in chalcopyrite; consequently, no attempt has been made to represent its geographic distribution in sphalerite on a map. Despite the erratic behavior, however, most of the samples of sphalerite that contain appreciable amounts of tin are from the tin-rich belts shown in Plate 1. Moreover, the indications of a definite geographic distribution of tin in sphalerite are strong enough to have enabled Warren and Thompson (1945, fig. 1) to outline a tin belt in British Columbia.

## COMBINED METAL CONTENT

The geographic distribution of the combined metal content of sphalerite is shown in Plate 5. The component elements are cobalt, gallium, germanium, indium, and silver, and these are combined to form the log-product concentration in the manner described for the corresponding combined metal content of chalcopyrite. In view of the many irregularities in the distributions of the component metals, it is somewhat surprising that as consistent a distributional pattern as shown in Plate 5 was obtained.

The essential features of the distribution of the combined metal content of sphalerite are very similar to those for the corresponding distribution for chalcopyrite. That is, there are three main belts, the Eastern, Central, and Western belts, and a subsidiary west branch of the Western belt in California. However, owing to the smaller geographic coverage of sphalerite samples, the features and interrelation-ships of each of the belts are not as well known.

Cobalt and silver are the main contributors to the Eastern belt in north-central Mexico and New Mexico, although in the latter area indium becomes increasingly important. All the elements except germanium are important in the Eastern belt in Colorado, where, in contrast to chalcopyrite, the main trend appears to be northwesterly. Again, all but germanium are important contributors to the Central belt from south of the international boundary to the Nevada border. From southern Nevada northeastward, germanium is an important contributor, and cobalt becomes unimportant. In the portion of the Western belt that is known, only indium is relatively unimportant.

# *Comparison of the Combined Metal Contents of Chalcopyrite and Sphalerite*

A comparison of the geographic distribution of the combined metal contents of chalcopyrite and sphalerite reveals striking general similarities. Throughout the Southwest, exclusive of Colorado, the belts defined by the combined metal contents in the two minerals either are essentially coincident or closely parallel. The significance of this empirical relationship appears to be that the seven metals represented in the two maps, and probably the sulfophile metals in general, are very closely related in the sulfide ore deposits of the Southwest.

Although the trends of the Central and Western belts in Nevada are essentially parallel for both minerals, the axes of the belts for chalcopyrite lie about 50 miles northwest of the corresponding axes for sphalerite. In Colorado, on the other hand, there appears to be an inter-section of the Eastern belts for the two minerals. The Eastern belt for chalcopyrite is very nearly parallel to the northeast-trending Colorado mineral belt. The Eastern belt for sphalerite, however, appears to cross the Colorado mineral belt with a northwesterly trend, although a weak northeast trend along the mineral belt also is evident.

The belts do not everywhere coincide, apparently because the positions of the belts for each of the component metals are not exactly the same, and of the seven metals that are represented on the two maps only three are common to both. The belts of the remaining four elements, two in each mineral, are sufficiently different in their positions, then, to cause a shift in the positions of the belts for the combined metal contents. However, had the four elements, or a certain combination of pairs, been chemically more similar, the evidence suggests that the belts for the combined metal contents in the two minerals would have been nearly coincident. For example, the belts for the two chemically similar elements, gallium and germanium, are essentially coincident, whereas the belts for nickel and tin are far from coincident.

Perhaps a relationship such as that just postulated is largely responsible for the irregular distribution of indium in sphalerite, for in some respects indium is similar to gallium and in others it is similar to tin. Thus, in regions where the belts for tin and gallium do not coincide, as in southern Nevada, the distribution of indium might tend to resemble that of tin in one area and to resemble that of gallium in another.

# *Metallogenic Provinces*

The foregoing discussion has been concerned primarily with the geographic distribution of trace elements in two primary sulfide minerals, chalcopyrite and sphalerite. Considered from a more general point of view, the metals that have been investigated also are trace elements in the ore deposits and in the earth's crust, and as such do not differ in most essential respects from the other metals, such as copper, gold, lead, tungsten, and zinc, which also are trace elements in the earth's crust. Hence, it might be expected that whatever processes have operated to produce a geographic distribution of one chemically heterogeneous group of sulfophile elements very probably have produced a similar geographic distribution of another group of sulfophile elements. That such a relationship exists between the two groups of metals is demonstrated by silver, which is a member of both groups.

## SILVER PROVINCES

Silver as a trace element in chalcopyrite and sphalerite has been shown to possess a well-defined geographic distribution. Moreover, a comparison of Plates 2 and 4 with Plate 6,[4] which shows the distribution of ore deposits in which silver is an important constituent of the ores, reveals that all the major silver-producing districts lie within the belts defined in Plates 2 and 4. Therefore, the distribution of silver as an economically important constituent of the ores is consistent with the distribution of silver as a trace constituent of two common sulfide minerals. Furthermore, inasmuch as the distribution of silver is consistent with the distribution of all the other trace elements investigated, there is good reason to expect that the distribution of the sulfophile elements in general would be consistent with the distribution of these trace elements.

A further comparison of Plate 6 with Plates 2-5 reveals that the silver deposits are not uniformly distributed along the belts defined by the trace elements, but tend to be concentrated into certain segments of the belts. This phenomenon is analogous to the variations observed in the concentrations of a particular trace element along the axes of the belts, or to the resulting changes in the relative importance of that element along the belts of the combined metal contents. However, the higher concentrations of silver as a trace element in chalcopyrite and sphalerite generally extend for greater distances along the belts than do the- corresponding silver-rich deposits. Therefore, there might be a distinction between the metallogenic province in the trace-element sense and the metallogenic province in the economic sense, although the trace-element province generally includes the economic or production province.

[4] Plates 6-8 were adapted from maps made by Dr. J. A. Noble in 1954.

Unfortunately, copper, gold, lead, tungsten, and zinc cannot be treated in a manner similar to silver, because no data are available on their distribution as trace elements in the sulfide minerals of the South-west. However, by analogy with such chemically diverse elements as cobalt, gallium, germanium, indium, nickel, and tin, all of which bear a consistent distributional relationship to silver, there is good reason to expect that the distribution of deposits of copper, gold, lead, tungsten, and zinc also would be consistent with the distribution of silver deposits.

## COPPER PROVINCES

All the major copper deposits, as well as a majority of the minor ones, can be seen in Plate 7 to lie within belts that are consistent in trend and position with the belts defined by the trace-element distribution, especially the combined metal content of chalcopyrite (pl. 3). Furthermore, copper provinces can be defined within these belts. For example, two and possibly three copper metallogenic provinces occur within the Central belt: one that is centered in Arizona and extends southward into Sonora; another that extends from eastern Nevada into north-central Utah; and, by extrapolation, possibly a third that includes Butte, Montana.

There are two clearly recognizable copper provinces in the Western belt and its western subsidiary branch. One of these provinces includes the western branch in California and adjacent parts of the main Western belt in Nevada. This province also might extend northeastward across Nevada to the Idaho boundary, although it is weakly developed throughout most of its length in Nevada. The other copper province in the Western belt lies in southern Arizona and adjacent parts of Sonora.

The Eastern belt contains only one prominent copper province, which extends northwestward through southwestern New Mexico into Arizona, and there disappears beneath the volcanic rocks of the Colorado Plateau. In addition, a very weakly developed copper province appears to be centered in central Colorado and to extend northward into Wyoming. Although this province is relatively insignificant from the standpoint of copper production, it is of especial interest here as it does not appear to reflect the northeast trend of the Colorado mineral belt.

## GOLD PROVINCES

The distribution of gold deposits is even better defined than the distribution of copper deposits, as shown in Plate 8. In general, the distribution of gold deposits most closely resembles the distribution of silver as a trace element in chalcopyrite and sphalerite (pl. 2 and 4); consequently, it reflects the distribution of silver deposits as well (pl. 6). However, the gold provinces do not necessarily coincide with the silver provinces. For example, the most prominent gold province extends along the Western belt from southern California to northern Nevada, and northwestward along the western subsidiary branch as far as south-ern Oregon.

Perhaps the second most prominent gold province is the one that lies in the Eastern belt in central and southwestern Colorado. Gold, unlike copper, strongly reflects the Colorado mineral belt; but, like copper, it also reflects a north-south trend through Colorado.

Gold also differs from copper in the relative weakness of the gold provinces in the Central belt. A weakly developed gold province lies in northwestern Utah and perhaps extends into southeastern Nevada, but probably it does not join another weakly developed gold province that is centered in Arizona. Perhaps a third very weakly developed gold province in the Central belt includes Butte, Montana, if extrapolation of the Central belt northward from Utah is warranted. The regional relationships of the gold deposits of the Black Hills, South Dakota, are not yet understood.

## LEAD PROVINCES

The distribution of lead deposits in the western United States most closely resembles the distribution of the combined metal content of sphalerite (pl. 5). The economically most important lead metallogenic province in the Cordilleran region extends from northern Idaho north-ward into British Columbia. The belt in which this province lies is largely conjectural, but from the work of Warren and 'Thompson (1945), together with extrapolations from the present work, it is suggested that the three main belts that are distinguished in the Southwest join in Idaho and Montana to form a single major belt that trends generally northwestward through the region included in this lead province.

Lead metallogenic provinces occur in all three of the main belts in the southwestern United States, but the province in the Western belt that extends from eastern California into northeastern Nevada is relatively unimportant economically. In the Central belt there are two lead provinces, one that extends from northwestern Arizona northwestward into Nevada and thence northeastward into northern Utah, and another that extends from southeastern Arizona southward for an unknown distance into Sonora. The lead deposits in the Eastern belt in New Mexico probably belong to the same province as the lead deposits in Colorado. Moreover, this lead province probably extends southward through Chihuahua into Durango and perhaps somewhat farther.

## ZINC PROVINCES

Inasmuch as there are only about 25 zinc deposits in the western United States, it is difficult to define zinc metallogenic provinces with much assurance. It is clear, however, that nearly all the zinc deposits lie within the three main belts, especially those defined by the combined metal content of sphalerite (pl. 5). It appears that there are only three important zinc provinces in the western United States: one that extends from the vicinity of Butte, Montana, northwestward into northernmost Idaho and southern British Columbia; another that extends along the Central belt from north-central Utah to southern Arizona and perhaps into Sonora; and a third, in the Eastern belt, that apparently extends from Colorado southward through New Mexico into Chihuahua. A noteworthy feature of the distribution is the relatively rare occurrence of zinc deposits in the Western belt; in this respect, zinc bears a close resemblance to lead.

## TUNGSTEN PROVINCES

In describing the distribution of tungsten deposits in the western United States, Kerr (1946) recognizes three "tungsten arcs" that are de-fined by the distribution of tungsten deposits and known occurrences of tungsten minerals. A comparison of Plates 3 and 5 with Kerr's Figure 1 (p. 4) indicates that the three "tungsten arcs" correspond very closely to the three main belts defined in this study, especially the belts for the combined metal content of chalcopyrite.

Doubtless the most prominent tungsten metallogenic province in the western United States lies in the Western belt (Kerr's "western arc") and extends from southern California into northern Nevada. Second in importance are the much smaller provinces in the Central belt (Kerr's "central arc"), one of which lies in southern Arizona and extends into Sonora. Another, or perhaps merely a northwestward extension of the southern Arizona province, lies in western Arizona and adjacent parts of California. A third province in the Central belt extends northeast-ward through southeastern Nevada. A single tungsten-rich district in Colorado, the Boulder district, justifies the recognition of a tungsten province in the Eastern belt (Kerr's "eastern arc") that extends from the Boulder district southwestward along the Colorado mineral belt.

## SUMMARY

The evidence presented in the foregoing pages clearly indicates that there is a definite and consistent relationship between the distribution of certain metals as economically important constituents of ore deposits, and the distribution of the same or similar metals as trace elements in the sulfide minerals chalcopyrite and sphalerite. More specifically, this relationship consists of the repeated occurrence of three main belts in the Southwest that, although not everywhere coincident for each of the metals, are nevertheless generally closely parallel in trend. However, within each of these three main belts, the distribution of metalliferous deposits, as well as the trace elements, is not uniform, and this nonuniformity has given rise to relatively well defined metallogenic provinces.

Each of the three metallogenic belts, which correspond to the three main belts defined by the distribution of trace elements in the sulfides, can be distinguished, as a whole, by the predominant metals produced from it. Thus, the Western belt may be regarded as a gold-silver-copper belt, the Central belt as a copper-silver-gold belt, and the Eastern belt as a silver-gold-copper belt.

A distinction such as this suggests a crude zonal arrangement of the metals. For example, the Central metallogenic belt is distinctive for its high copper content, whereas the gold-rich provinces lie on either side in the Western and Eastern metallogenic belts. However, lead and zinc appear to be less abundant, whereas tungsten is more abundant, in the Western belt than in the other two belts.

It is not known to what extent these relationships are real or the result of over-generalization; the evidence indicates that they are real. However, it is probable that features such as the zonal arrangement are fortuitous and merely reflect overall similarities on the one hand, and differences on the other, of the processes of concentration in the source materials in each of the metallogenic belts.

# *Metallogenic Belts and Provinces in Relation to Other Geologic Features*

In describing the "Great Silver Channel," which he visualized as a very narrow, long, straight silver metallogenic province, Spurr (1923, p. 463) says:

> Along this line in North and South America occur most of the celebrated mines in the world, like the Comstock, Tonopah, Santa Eulalia, Guanajuato, Pachuca, Cerro de Pasco, and Potosi. This wonderful straight line slashes clean across mountain ranges and other geologic structures, and continues its course independent of them. This is shown in Nevada, where it cuts at an angle of nearly 45° across the trend of the north-south-trending desert ranges. In Mexico, it shows an utter disregard of the main geologic features and mountain chains—starting in northern Sonora west of the main range, or Sierra Madre, it cuts diagonally across this onto the central Mexican Plateau, with its short desert ranges; and in the south of Mexico, its unswerving course carries it back across the Sierra Madre again, for this range curves much like the west coast line.

In addition to the "Great Silver Channel," Spurr recognized several other shorter channels, some of which are nearly at right angles to the "Great Silver Channel." These features led him (p. 483) to postulate:

> The data which I have above outlined are, of course, sketchy, but do indicate the existence in North America of two sets of intersecting straight belts or channels of silver (with other metals), running respectively northeast and northwest. These channels correspond rudely in trend to the skeletal geometrical framework of the continent; and the major channel, which is of world proportions, parallels rudely the eastern side of the Pacific.
>
> Here, then, is a discovery of prime scientific and commercial importance. This channel system is marked by a continuity or rather a chain system (like beads on a wire) of consanguineous magma occurrences and also consanguineous ore occurrences. In part—in large part—both magma and ore chains have no evident relation to the major belts of folding and faulting of the rocks, and therefore appear to belong to a zone below the zone of surface wrinkling and breaking.

A comparison of Spurr's data (fig. 74, p. 459, and fig. 75, p. 460) with Plates 1-8 of the present paper, especially Plates 3 and 5, reveals that the deposits which Spurr visualized as constituting a single metallogenic belt or "channel" actually occur in three different metallogenic belts that are by no means straight lines. Furthermore, instead of two sets of belts, one trending northwest and the other northeast, there appears to be only one set, which has variable trends.

The purpose of pointing out these discrepancies is not so much to emphasize the disagreement, but to indicate that Spurr's conclusion of the independence of the metallogenic belts from other major geologic features may not be valid, if the belts actually have the forms shown in Plates 3 and 5 instead of the oversimplified straight lines that Spurr has drawn. In fact, a comparison of these latter maps with the Tectonic Map of the United States (1944) reveals some remarkably close relationships between the metallogenic belts and the tectonic trends.

Thus, northward from north-central Mexico, where a strong east-west tectonic trend is reflected in an east-west trend in the metallogenic belts, the Central and Eastern metallogenic belts are nearly parallel to the tectonic trends. The Western belt, however, does not appear to bear as close a relationship to the tectonic trends as do the Central and Eastern belts. For example, there appears to be a considerable divergence in the two trend axes in southwestern Arizona. Furthermore, although there is a general parallelism of trends in southern California, north-ward the trends again diverge, so that the Western belt appears to bear a crosscutting relationship to the axis of elongation of the Sierra Nevada batholith. However, in view of the branching nature of the Western belt in this part of California, the divergence in trends might be more apparent than real. Northeastward through Nevada there is a weak but discernible tectonic belt that is closely parallel in trend to the Western metallogenic belt.

Another feature of the Western metallogenic belt in the United States that serves to distinguish it from the Central and Eastern belts is its association with exposed batholithic intrusives. In the north, it assuredly passes through the heart of the Idaho batholith. Southwest-ward through Nevada, it is associated with granitic intrusives that perhaps are related to the Sierra Nevada batholith (Ferguson, 1944). The association with Sierra Nevada-type intrusives persists southward through California, and in southern California the Western metallogenic belt trends diagonally across the northern exposed part of the Southern California batholith. This relationship may be more significant in view of the statement by Larsen et al. (1954) that the three batholiths just mentioned are essentially of the same age (approximately 100 million years).

There is indication, then, that the main extension of the Sierra Nevada batholith might be northeastward through Nevada, perhaps to a junction with the Idaho batholith, and that the northwest trend into northern California is merely a branch, analogous to the branch in the Western metallogenic belt. An interpretation such as this would provide not only a more consistent tectonic picture and relationship to the metallogenic belts, but would be compatible with the position of the boundary between the so-called "Paleozoic-Mesozoic-Cenozoic" orogenic belt and the "Cretaceous-Cenozoic" orogenic belt very near the eastern margin of the Western metallogenic belt, as shown by Eardley (1951, pl. 1). However, in view of the age relations that recently have been indicated, the distinction between "Mesozoic" (Nevadan?) and "Cretaceous" might not be valid.

Billingsley and Locke (1941) also have discussed apparent relation-ships between the distribution of some of the more important mining districts of the western United States and various structural features. In general, there is fairly good agreement between the trends and positions of several of the "orogenic belts" shown by Billingsley and Locke (1941, fig. 13, p. 52-53) and the metallogenic belts defined here. This is particularly true of the belts in New Mexico, southern Arizona, central Nevada, and Utah. However, the present study, as well as the information available on the Tectonic Map of the United States (1944), which was published subsequent to Billingsley and Locke's work, does not indicate the existence of the "Walker line," which the latter authors visualize as extending northwestward through southwestern Nevada. Instead, the so-called "Walker line" in Arizona actually appears to bend around the western margin of the Colorado Plateau and to continue north-northeastward through Utah as Billingsley and Locke's "Early Tertiary" orogenic belt.

The uncertainty connected with the existence of the "Walker line" in Nevada leads to further uncertainties concerning the significance of "superimposed orogenic movements or of intersecting lines of successive motion, or of persistent deep seated breaks" (op. cit., p. 58) in determining the loci of the "clusters" of "ore deposits of upper magnitudes," for there are no "upper magnitude" ore deposits near the intersection of the Tertiary orogenic belt and the "Walker line" in southern Nevada or northwestern Arizona. Furthermore, it is doubtful that many mining districts could be found in the North American Cordillera that would not possess one or more of the three determining features required by Billingsley and Locke.

Despite these objections, however, many of the orogenic belts established by Billingsley and Locke doubtless are real and are of consider-able importance in connection with the metallogenic belts. In fact, some of the trend lines, taken in conjunction with the more prominent of those shown on the Tectonic Map, lead to interesting speculation on the extensions of the metallogenic belts defined in the present study. For example, the west branch of the Western belt in California might be extended northward into Oregon and thence northeastward across Oregon to a junction with the main belt in Idaho. Furthermore, the Western belt appears to join the Central belt in central Idaho to form the "Main belt." This relationship also is suggested from a consideration of the distribution of the ore deposits alone.

Billingsley and Locke (1941) distinguish three orogenic epochs in the western United States since the Precambrian. The earliest of these epochs, the "final Paleozoic," characterizes the orogenic belt in Oregon (the west branch of the Western belt?). The orogenic belt that corresponds to the main Western metallogenic belt is presumed to be early Cretaceous; and the youngest orogenic belt, which corresponds to the Central metallogenic belt, is supposed to be early Tertiary. Although these age distinctions may be valid for the orogenic belts, they do not appear to be valid for the corresponding metallogenic belts, for there are as many as four different epochs of mineralization represented within any one of them.

# Conclusions

It was stated at the outset that the main purpose of these investigations was to define some metallogenic provinces in the southwestern United States. That a certain measure of success in this endeavor has been achieved can be seen by a comparison of Plates 1-8. Thus, it appears that in their aggregate the metallogenic provinces form three major beltlike features in the Southwest that are consistent in trend and position with the major tectonic features. Moreover, the metallogenic provinces for a specific metal or group of metals, as determined by the regional productivity, appear to be beltlike features of smaller extent that lie within, and are essentially defined by, the major metallogenic belts. The ends of a given province along a metallogenic belt are not sharply defined, however; as a result, there appears to be no good argument against the possibility of enlargement of the provinces in these directions.

It also was stated at the outset that an effort has been made to restrain gross speculation on the origin of the features described, as such speculation is not warranted in the present state of knowledge. However, these investigations provide certain lines of evidence that bear directly on the origin of the metallogenic belts and that must be included in any acceptable explanation of them. Especially noteworthy in this connection are the following facts: (1) The metallogenic belts are of vast extent; (2) they are largely unrelated in time to the associated tectonic features; (3) relatively small segments of them contain deposits that represent as many as four widely separated metallogenic epochs, and (4) they are not uniquely associated with a particular kind of intrusive or wall rock, for the same kinds of rocks occur both within and outside the belts.

The conclusion that appears to be most compatible with the fore-going facts is that the metallogenic belts are of deep-seated origin. This view already has been summarized by Spurr (1923, p. 444), as follows:

> The phenomenon on which I have just touched, of metallographic provinces characterizing certain zones, belts, limited areas, or even spots on the earth, and that independently in large measure of the distribution of granites, diorite, or diabases, rhyolites, andesites, or basalts (although closely associated in general with belts of igneous activity and crustal disturbance), can hardly be explained except by postulating a highly individualized distribution of the metals in that portion of the earth beneath or at the base of those rocks which are exposed to our view by erosion, or beneath what we conveniently though perhaps inaccurately term the crust.

An alternative to the deep-seated origin involves a hypothetical genetic connection between the ore deposits and geosynclinal sediments. Specifically, it involves the postulate that the ores are concentrated into the deposits from the surrounding sedimentary rocks, which, by the nature of the processes of their formation, are abnormally rich in certain metals. Although this hypothesis does not appear to be compatible with the fact that the same kinds of rocks occur both within and outside the belts, it must be acknowledged that there is a close correspondence of the metallogenic belts with the geosynclinal belts. However, a spatial association, and perhaps a genetic connection, does not necessarily imply a specific cause-and-effect relationship.

If, on the other hand, the abnormally high metal content of the sedimentary rocks does not reflect the nature of the processes of their formation, but merely the composition of the source materials of the sediments, the origin of the beltlike features no longer lies in the geosynclinal sediments but in their source materials. Hence, the weight of evidence does not appear to favor a shallow-seated origin of the metallogenic belts within the geosynclinal sediments.

Although it is conceivable that the metallogenic belts could have originated by the repeated occurrence of a more or less unique process of concentration within each belt but not outside it, it appears more probable that they merely reflect beltlike compositional heterogeneities in the ore source materials that have existed since early in the history of the earth. Accordingly, the ores derived from these source materials would reflect their nature regardless of the metallogenic epoch in which a particular deposit was formed. Of course, in order to explain the origin of the heterogeneities, it is necessary to postulate that at some stage in the early history of the earth, certain processes operated within beltlike regions to concentrate a metal or assemblage of metals, and did not operate, at least not to as great an extent, outside the beltlike regions. The important advantage of this hypothesis is that it does not necessitate the recurrence within a belt of the same process or set of processes at several widely separated intervals of geologic time.

Despite the relatively close parallelism of the tectonic or orogenic belts and the metallogenic belts, neither is regarded as the cause or the effect of the other, but both the gross tectonic features and the metallogenic belts are more probably the effect of some more fundamental cause. Moreover, this more fundamental cause probably is not the postulated deep-seated compositional heterogeneities alone, but a combination of compositional heterogeneities and closely associated physical discontinuities, both of which may have arisen during the same events of early earth history.

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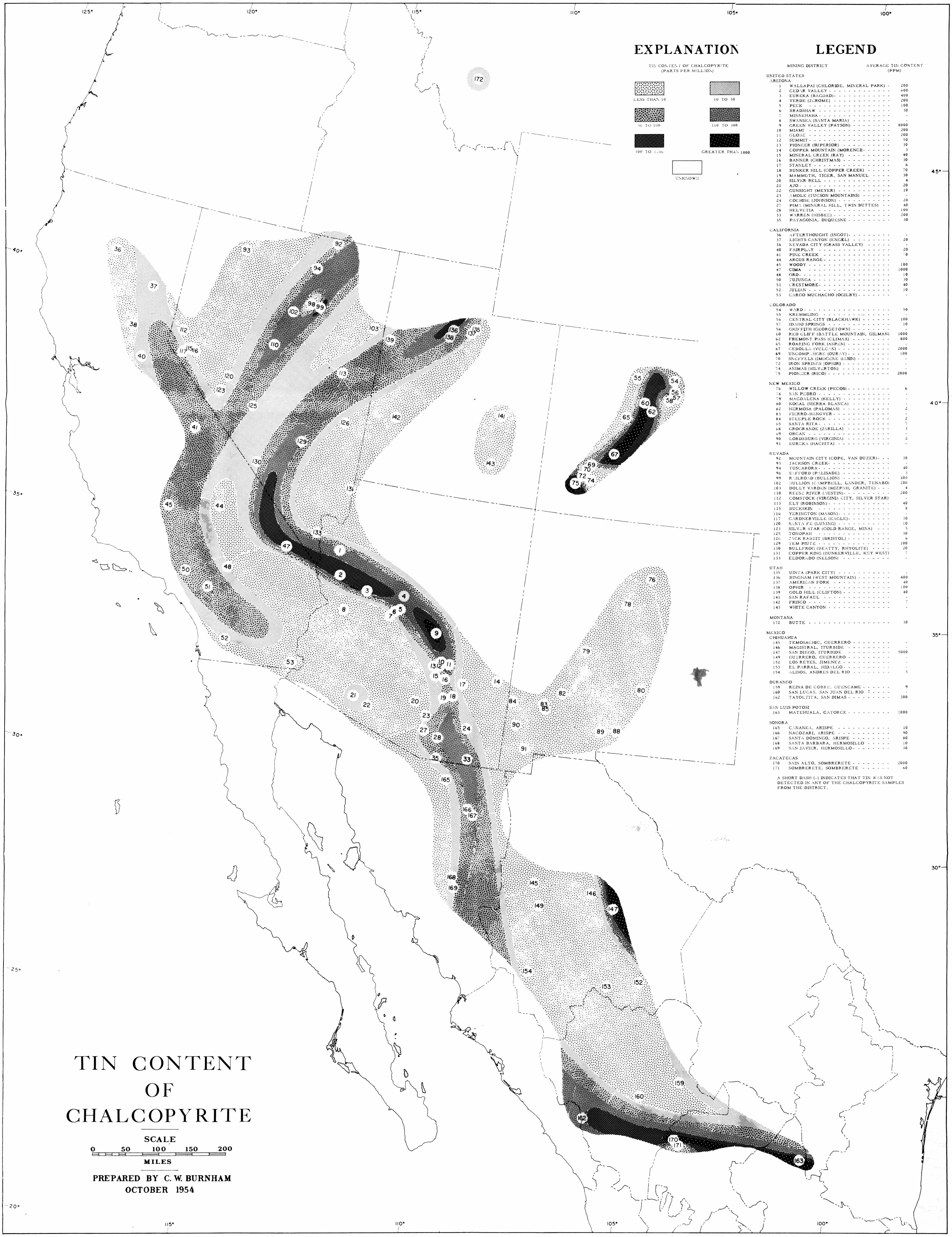


## EXPLANATION

TIN CONTENT OF CHALCOPYRITE
(PARTS PER MILLION)

- ░ LESS THAN 10
- ░ 10 TO 30
- ▒ 30 TO 100
- ▒ 100 TO 300
- ▓ 300 TO 1000
- ■ GREATER THAN 1000
- ☐ UNKNOWN

## LEGEND

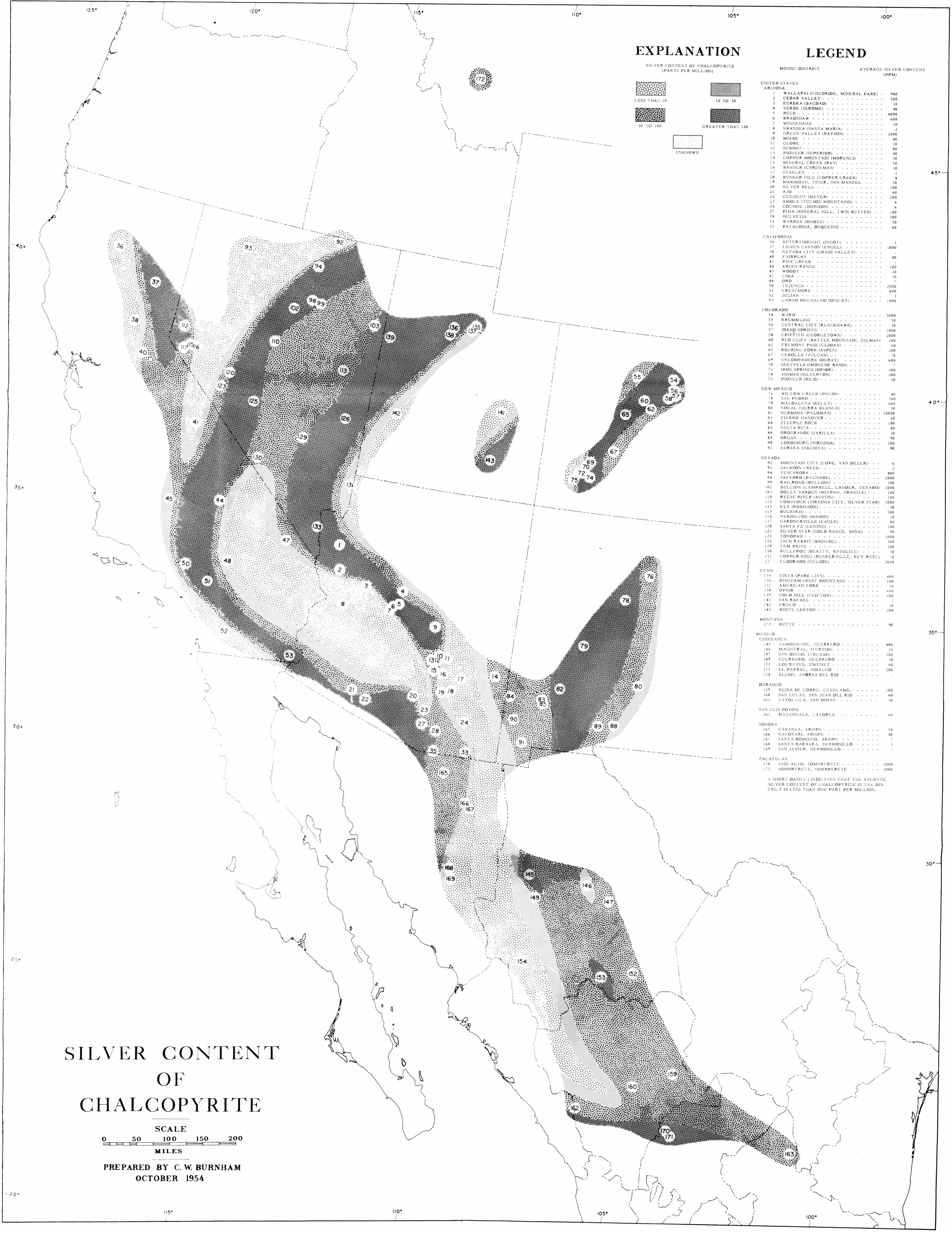
| | MINING DISTRICT | AVERAGE TIN CONTENT (PPM) |
|---|---|---|
| | UNITED STATES | |
| | ARIZONA | |
| 1 | WALLAPAI (CHLORIDE, MINERAL PARK) | 200 |
| 2 | CEDAR VALLEY | 800 |
| 3 | EUREKA (BAGDAD) | 400 |
| 4 | VERDE (JEROME) | 200 |
| 5 | PECK | 100 |
| 6 | BRADSHAW | 30 |
| 7 | MINNEHAHA | - |
| 8 | SWANSEA (SANTA MARIA) | - |
| 9 | GREEN VALLEY (PAYSON) | 8000 |
| 10 | MIAMI | 200 |
| 11 | GLOBE | 200 |
| 12 | SUMMIT | 50 |
| 13 | PIONEER (SUPERIOR) | 30 |
| 14 | COPPER MOUNTAIN (MORENCI) | 3 |
| 15 | MINERAL CREEK (RAY) | 40 |
| 16 | BANNER (CHRISTMAS) | 30 |
| 17 | STANLEY | 6 |
| 18 | BUNKER HILL (COPPER CREEK) | 70 |
| 19 | MAMMOTH, TIGER, SAN MANUEL | 30 |
| 20 | SILVER BELL | 4 |
| 21 | AJO | 20 |
| 22 | GUNSIGHT (MEYER) | 10 |
| 23 | AMOLE (TUCSON MOUNTAINS) | - |
| 24 | COCHISE (JOHNSON) | 20 |
| 27 | PIMA (MINERAL HILL, TWIN BUTTES) | 40 |
| 28 | HELVETIA | 100 |
| 33 | WARREN (BISBEE) | 200 |
| 35 | PATAGONIA, DUQUESNE | 30 |
| | CALIFORNIA | |
| 36 | AFTERTHOUGHT (INGOT) | - |
| 37 | LIGHTS CANYON (ENGEL) | 20 |
| 38 | NEVADA CITY (GRASS VALLEY) | - |
| 40 | FAIRPLAY | 20 |
| 41 | PINE CREEK | 70 |
| 44 | ARGUS RANGE | - |
| 45 | WOODY | 100 |
| 47 | CIMA | 1000 |
| 48 | ORD | 10 |
| 50 | TUJUNGA | 30 |
| 51 | CRESTMORE | 40 |
| 52 | JULIAN | 10 |
| 53 | CARGO MUCHACHO (OGILBY) | - |
| | COLORADO | |
| 54 | WARD | 50 |
| 55 | KREMMLING | - |
| 56 | CENTRAL CITY (BLACKHAWK) | 100 |
| 57 | IDAHO SPRINGS | 10 |
| 58 | GRIFFITH (GEORGETOWN) | - |
| 60 | RED CLIFF (BATTLE MOUNTAIN, GILMAN) | 1000 |
| 62 | FREMONT PASS (CLIMAX) | 800 |
| 65 | ROARING FORK (ASPEN) | - |
| 67 | CEBOLLA (VULCAN) | 2000 |
| 69 | UNCOMPAHGRE (OURAY) | 100 |
| 70 | SNEFFELS (IMOGENE BASIN) | - |
| 72 | IRON SPRINGS (OPHIR) | - |
| 74 | ANIMAS (SILVERTON) | - |
| 75 | PIONEER (RICO) | 2000 |
| | NEW MEXICO | |
| 76 | WILLOW CREEK (PECOS) | 6 |
| 78 | SAN PEDRO | - |
| 79 | MAGDALENA (KELLY) | - |
| 80 | NOGAL (SIERRA BLANCA) | - |
| 82 | HERMOSA (PALOMAS) | 2 |
| 83 | FIERRO-HANOVER | - |
| 84 | STEEPLE ROCK | 2 |
| 85 | SANTA RITA | 7 |
| 88 | OROGRANDE (JARILLA) | 3 |
| 89 | ORGAN | - |
| 90 | LORDSBURG (VIRGINIA) | 2 |
| 91 | EUREKA (HACHITA) | - |
| | NEVADA | |
| 92 | MOUNTAIN CITY (COPE, VAN DUZER) | 30 |
| 93 | JACKSON CREEK | - |
| 94 | TUSCARORA | 40 |
| 98 | SAFFORD (PALISADE) | 3 |
| 99 | RAILROAD (BULLION) | 400 |
| 102 | BULLION (CAMPBELL, LANDER, TENABO) | 200 |
| 103 | DOLLY VARDEN (MIZPAH, GRANITE) | 4 |
| 110 | REESE RIVER (AUSTIN) | 200 |
| 112 | COMSTOCK (VIRGINIA CITY, SILVER STAR) | - |
| 113 | ELY (ROBINSON) | 40 |
| 115 | BUCKSKIN | 8 |
| 116 | YERINGTON (MASON) | - |
| 117 | GARDNERVILLE (EAGLE) | 30 |
| 120 | SANTA FE (LUNING) | 10 |
| 123 | SILVER STAR (GOLD RANGE, MINA) | 5 |
| 125 | TONOPAH | 30 |
| 126 | JACK RABBIT (BRISTOL) | 6 |
| 129 | TEM PIUTE | 100 |
| 130 | BULLFROG (BEATTY, RHYOLITE) | 20 |
| 131 | COPPER KING (BUNKERVILLE, KEY WEST) | 7 |
| 133 | ELDORADO (NELSON) | - |
| | UTAH | |
| 135 | UINTA (PARK CITY) | - |
| 136 | BINGHAM (WEST MOUNTAIN) | 400 |
| 137 | AMERICAN FORK | 40 |
| 138 | OPHIR | 100 |
| 139 | GOLD HILL (CLIFTON) | 40 |
| 141 | SAN RAFAEL | - |
| 142 | FRISCO | 7 |
| 143 | WHITE CANYON | - |
| | MONTANA | |
| 172 | BUTTE | 30 |
| | MEXICO | |
| | CHIHUAHUA | |
| 145 | TEMOSACHIC, GUERRERO | - |
| 146 | MAGISTRAL, ITURBIDE | - |
| 147 | SAN DIEGO, ITURBIDE | 5000 |
| 149 | GUERRERO, GUERRERO | - |
| 152 | LOS REYES, JIMENEZ | - |
| 153 | EL PARRAL, HIDALGO | - |
| 154 | ALISOS, ANDRES DEL RIO | 5 |
| | DURANGO | |
| 159 | REINA DE COBRE, CUENCAME | 9 |
| 160 | SAN LUCAS, SAN JUAN DEL RIO | - |
| 162 | TAYOLTITA, SAN DIMAS | 300 |
| | SAN LUIS POTOSI | |
| 163 | MATEHUALA, CATORCE | 1000 |
| | SONORA | |
| 165 | CANANEA, ARISPE | 10 |
| 166 | NACOZARI, ARISPE | 90 |
| 167 | SANTA DOMINGO, ARISPE | 80 |
| 168 | SANTA BARBARA, HERMOSILLO | 10 |
| 169 | SAN JAVIER, HERMOSILLO | 30 |
| | ZACATECAS | |
| 170 | SAIN ALTO, SOMBRERETE | 2000 |
| 171 | SOMBRERETE, SOMBRERETE | 60 |

A SHORT DASH (-) INDICATES THAT TIN WAS NOT DETECTED IN ANY OF THE CHALCOPYRITE SAMPLES FROM THE DISTRICT.

# TIN CONTENT
# OF
# CHALCOPYRITE

SCALE
0 50 100 150 200
MILES

PREPARED BY C. W. BURNHAM
OCTOBER 1954



## EXPLANATION

SILVER CONTENT OF CHALCOPYRITE
(PARTS PER MILLION)

- ▨ LESS THAN 10
- ▨ 10 TO 30
- ▨ 30 TO 100
- ▨ GREATER THAN 100
- ☐ UNKNOWN

## LEGEND

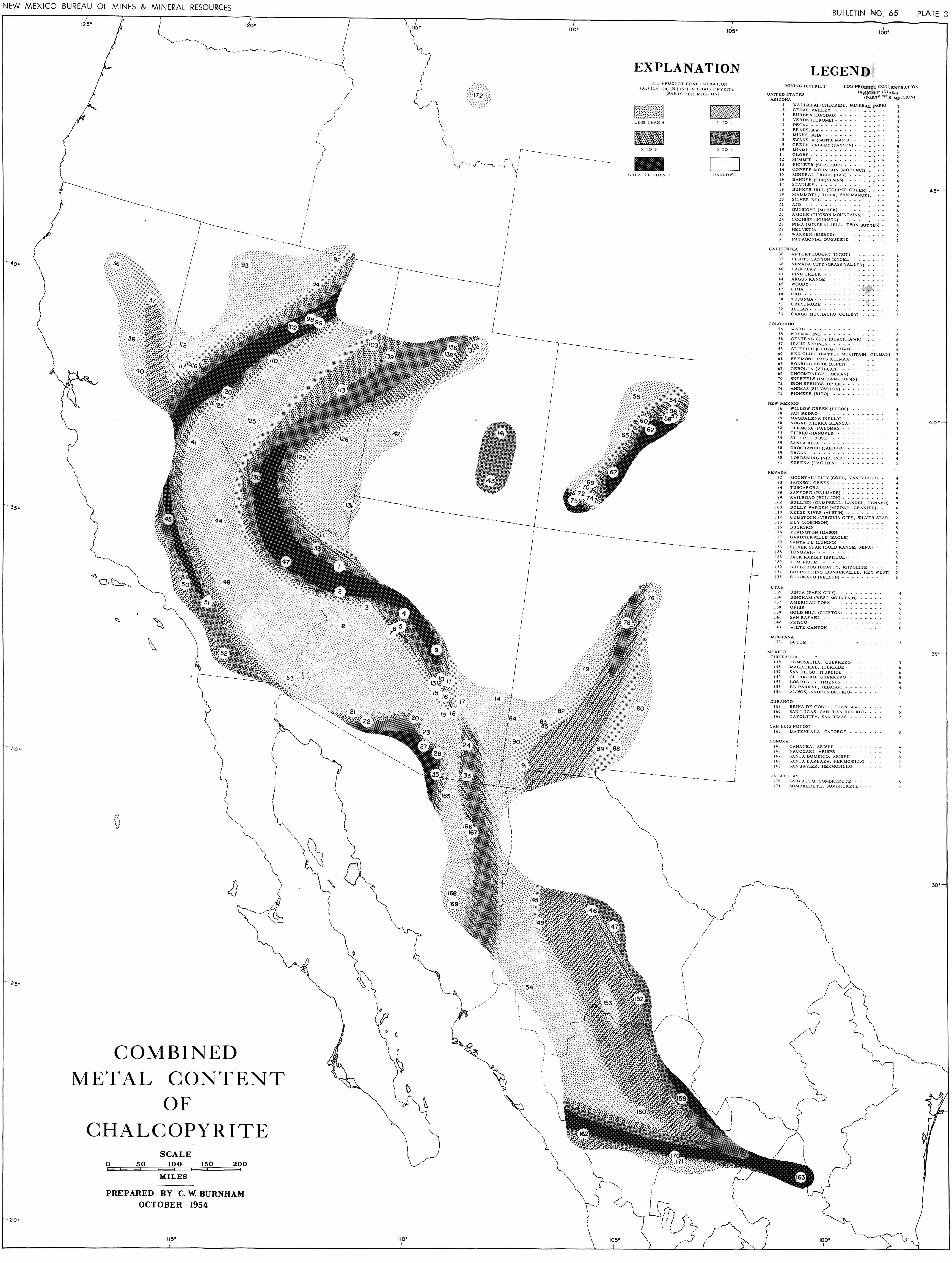
| | MINING DISTRICT | AVERAGE SILVER CONTENT (PPM) |
|---|---|---|
| UNITED STATES | | |
| ARIZONA | | |
| 1 | WALLAPAI (CHLORIDE, MINERAL PARK) | 900 |
| 2 | CEDAR VALLEY | 500 |
| 3 | EUREKA (BAGDAD) | 10 |
| 4 | VERDE (JEROME) | 40 |
| 5 | PECK | 4000 |
| 6 | BRADSHAW | 600 |
| 7 | MINNEHAHA | 20 |
| 8 | SWANSEA (SANTA MARIA) | 2 |
| 9 | GREEN VALLEY (PAYSON) | 2000 |
| 10 | MIAMI | 40 |
| 11 | GLOBE | 10 |
| 12 | SUMMIT | 80 |
| 13 | PIONEER (SUPERIOR) | 40 |
| 14 | COPPER MOUNTAIN (MORENCI) | 50 |
| 15 | MINERAL CREEK (RAY) | 50 |
| 16 | BANNER (CHRISTMAS) | 10 |
| 17 | STANLEY | 1 |
| 18 | BUNKER HILL (COPPER CREEK) | 4 |
| 19 | MAMMOTH, TIGER, SAN MANUEL | 20 |
| 20 | SILVER BELL | 100 |
| 21 | AJO | 60 |
| 22 | GUNSIGHT (MEYER) | 200 |
| 23 | AMOLE (TUCSON MOUNTAINS) | 6 |
| 24 | COCHISE (JOHNSON) | 6 |
| 27 | PIMA (MINERAL HILL, TWIN BUTTES) | 100 |
| 28 | HELVETIA | 300 |
| 33 | WARREN (BISBEE) | 50 |
| 35 | PATAGONIA, DUQUESNE | 60 |
| CALIFORNIA | | |
| 36 | AFTERTHOUGHT (INGOT) | 1 |
| 37 | LIGHTS CANYON (ENGEL) | 1000 |
| 38 | NEVADA CITY (GRASS VALLEY) | - |
| 40 | FAIRPLAY | 40 |
| 41 | PINE CREEK | - |
| 44 | ARGUS RANGE | 100 |
| 45 | WOODY | 20 |
| 47 | CIMA | 30 |
| 48 | ORD | 7 |
| 50 | TUJUNGA | 2000 |
| 51 | CRESTMORE | 800 |
| 52 | JULIAN | 3 |
| 53 | CARGO MUCHACHO (OGILBY) | 1000 |
| COLORADO | | |
| 54 | WARD | 3000 |
| 55 | KREMMLING | 50 |
| 56 | CENTRAL CITY (BLACKHAWK) | 30 |
| 57 | IDAHO SPRINGS | 1000 |
| 58 | GRIFFITH (GEORGETOWN) | 2000 |
| 60 | RED CLIFF (BATTLE MOUNTAIN, GILMAN) | 100 |
| 62 | FREMONT PASS (CLIMAX) | 60 |
| 65 | ROARING FORK (ASPEN) | 200 |
| 67 | CEBOLLA (VULCAN) | 70 |
| 69 | UNCOMPAHGRE (OURAY) | 800 |
| 70 | SNEFFELS (IMOGENE BASIN) | 7 |
| 72 | IRON SPRINGS (OPHIR) | 300 |
| 74 | ANIMAS (SILVERTON) | 200 |
| 75 | PIONEER (RICO) | 30 |
| NEW MEXICO | | |
| 76 | WILLOW CREEK (PECOS) | 40 |
| 78 | SAN PEDRO | 300 |
| 79 | MAGDALENA (KELLY) | 600 |
| 80 | NOGAL (SIERRA BLANCA) | 30 |
| 82 | HERMOSA (PALOMAS) | 10000 |
| 83 | FIERRO-HANOVER | 60 |
| 84 | STEEPLE ROCK | 100 |
| 85 | SANTA RITA | 40 |
| 88 | OROGRANDE (JARILLA) | 30 |
| 89 | ORGAN | 90 |
| 90 | LORDSBURG (VIRGINIA) | 100 |
| 91 | EUREKA (HACHITA) | 90 |
| NEVADA | | |
| 92 | MOUNTAIN CITY (COPE, VAN DUZER) | 6 |
| 93 | JACKSON CREEK | 2 |
| 94 | TUSCARORA | 400 |
| 98 | SAFFORD (PALISADE) | 2000 |
| 99 | RAILROAD (BULLION) | 100 |
| 102 | BULLION (CAMPBELL, LANDER, TENABO) | 1000 |
| 103 | DOLLY VARDEN (MIZPAH, GRANITE) | 100 |
| 110 | REESE RIVER (AUSTIN) | 100 |
| 112 | COMSTOCK (VIRGINIA CITY, SILVER STAR) | 3000 |
| 113 | ELY (ROBINSON) | 50 |
| 115 | BUCKSKIN | 500 |
| 116 | YERINGTON (MASON) | 10 |
| 117 | GARDNERVILLE (EAGLE) | 80 |
| 120 | SANTA FE (LUNING) | 100 |
| 123 | SILVER STAR (GOLD RANGE, MINA) | 90 |
| 125 | TONOPAH | 1000 |
| 126 | JACK RABBIT (BRISTOL) | 300 |
| 129 | TEM PIUTE | 100 |
| 130 | BULLFROG (BEATTY, RHYOLITE) | 50 |
| 131 | COPPER KING (BUNKERVILLE, KEY WEST) | 10 |
| 13 | ELDORADO (NELSON) | 3000 |
| UTAH | | |
| 135 | UINTA (PARK CITY) | 400 |
| 136 | BINGHAM (WEST MOUNTAIN) | 100 |
| 137 | AMERICAN FORK | 20 |
| 138 | OPHIR | 800 |
| 139 | GOLD HILL (CLIFTON) | 200 |
| 141 | SAN RAFAEL | 1 |
| 142 | FRISCO | 10 |
| 143 | WHITE CANYON | 200 |
| MONTANA | | |
| 172 | BUTTE | 90 |
| MEXICO | | |
| CHIHUAHUA | | |
| 145 | TEMOSACHIC, GUERRERO | 400 |
| 146 | MAGISTRAL, ITURBIDE | 20 |
| 147 | SAN DIEGO, ITRUBIDE | 100 |
| 149 | GUERRERO, GUERRERO | 30 |
| 152 | LOS REYES, JIMENEZ | 60 |
| 153 | EL PARRAL, HIDALGO | 200 |
| 154 | ALISOS, ANDRES DEL RIO | - |
| DURANGO | | |
| 159 | REINA DE COBRE, CUENCAME | 100 |
| 160 | SAN LUCAS, SAN JUAN DEL RIO | 80 |
| 162 | TAYOLTITA, SAN DIMAS | 50 |
| SAN LUIS POTOSI | | |
| 163 | MATEHUALA, CATORCE | 60 |
| SONORA | | |
| 165 | CANANEA, ARISPE | 50 |
| 166 | NACOZARI, ARISPE | 40 |
| 167 | SANTA DOMINGO, ARISPE | 7 |
| 168 | SANTA BARBARA, HERMOSILLO | 3 |
| 169 | SAN JAVIER, HERMOSILLO | - |
| ZACATECAS | | |
| 170 | SAIN ALTO, SOMBRERETE | 2000 |
| 171 | SOMBRERETE, SOMBRERETE | 2000 |

A SHORT DASH (-) INDICATES THAT THE AVERAGE SILVER CONTENT OF CHALCOPYRITE IN THE DISTRICT IS LESS THAN ONE PART PER MILLION.

# SILVER CONTENT OF CHALCOPYRITE

SCALE
0 50 100 150 200
MILES

PREPARED BY C. W. BURNHAM
OCTOBER 1954



# EXPLANATION

LOG PRODUCT CONCENTRATION
(Ag) (Co) (In) (Ni) (Sn) IN CHALCOPYRITE
(PARTS PER MILLION)

- ▨ LESS THAN 4
- ▨ 4 TO 5
- ▨ 5 TO 6
- ▨ 6 TO 7
- ■ GREATER THAN 7
- □ UNKNOWN

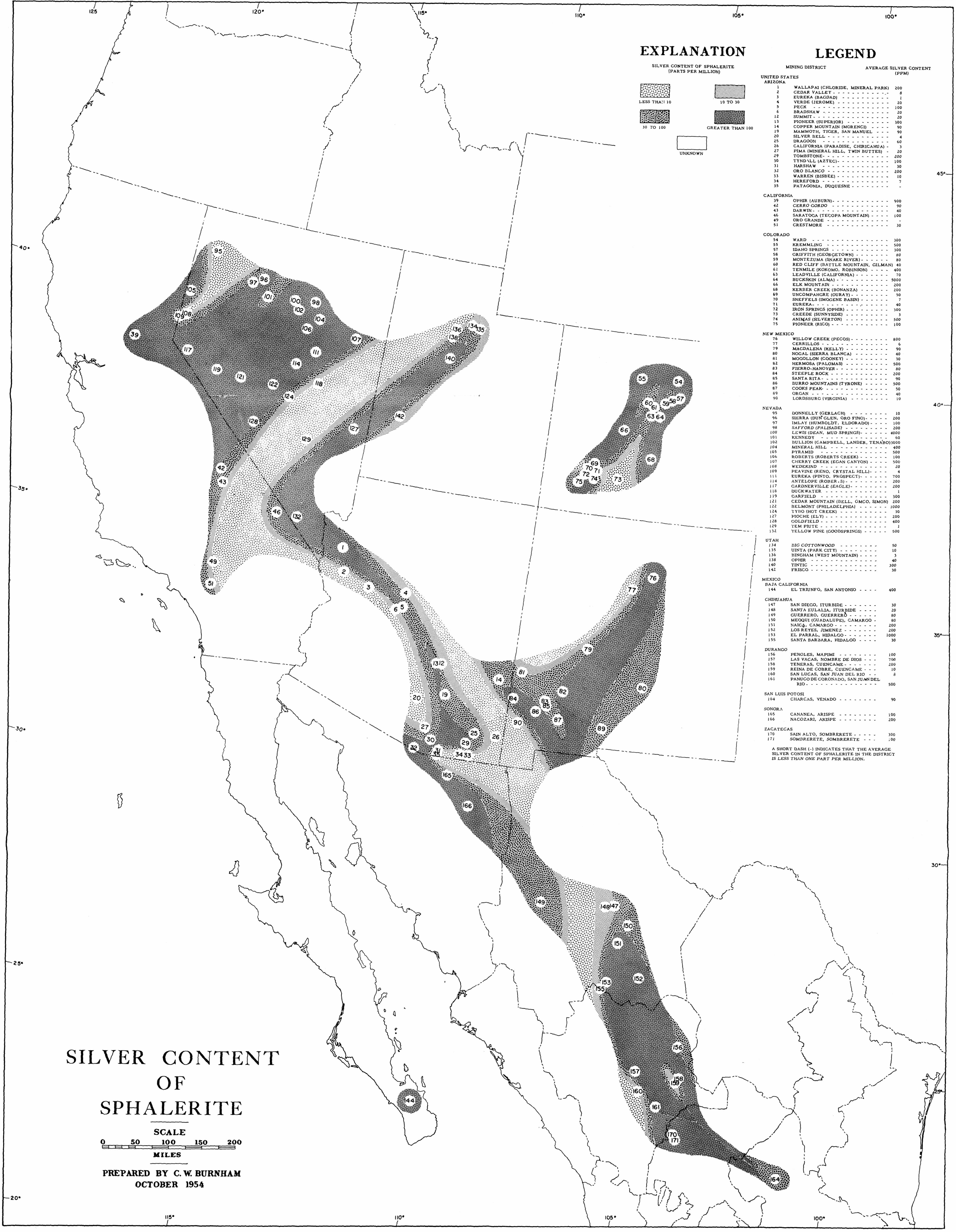
# LEGEND

| | MINING DISTRICT | LOG PRODUCT CONCENTRATION (Ag)(Co)(In)(Ni)(Sn) (PARTS PER MILLION) |
|---|---|---|
| UNITED STATES | | |
| ARIZONA | | |
| 1 | WALLAPAI (CHLORIDE, MINERAL PARK) | 7 |
| 2 | CEDAR VALLEY | 8 |
| 3 | EUREKA (BAGDAD) | 4 |
| 4 | VERDE (JEROME) | 7 |
| 5 | PECK | 6 |
| 6 | BRADSHAW | 7 |
| 7 | MINNEHAHA | 2 |
| 8 | SWANSEA (SANTA MARIA) | 1 |
| 9 | GREEN VALLEY (PAYSON) | 8 |
| 10 | MIAMI | 5 |
| 11 | GLOBE | 5 |
| 12 | SUMMIT | 6 |
| 13 | PIONEER (SUPERIOR) | 5 |
| 14 | COPPER MOUNTAIN (MORENCI) | 2 |
| 15 | MINERAL CREEK (RAY) | 5 |
| 16 | BANNER (CHRISTMAS) | 6 |
| 17 | STANLEY | 3 |
| 18 | BUNKER HILL (COPPER CREEK) | 4 |
| 19 | MAMMOTH, TIGER, SAN MANUEL | 3 |
| 20 | SILVER BELL | 6 |
| 21 | AJO | 4 |
| 22 | GUNSIGHT (MEYER) | 6 |
| 23 | AMOLE (TUCSON MOUNTAINS) | 2 |
| 24 | COCHISE (JOHNSON) | 6 |
| 27 | PIMA (MINERAL HILL, TWIN BUTTES) | 8 |
| 28 | HELVETIA | 8 |
| 33 | WARREN (BISBEE) | 7 |
| 35 | PATAGONIA, DUQUESNE | 7 |
| CALIFORNIA | | |
| 36 | AFTERTHOUGHT (INGOT) | 2 |
| 37 | LIGHTS CANYON (ENGEL) | 5 |
| 38 | NEVADA CITY (GRASS VALLEY) | 1 |
| 40 | FAIRPLAY | 4 |
| 41 | PINE CREEK | 2 |
| 44 | ARGUS RANGE | 2 |
| 45 | WOODY | 7 |
| 47 | CIMA | 8 |
| 48 | ORD | 4 |
| 50 | TUJUNGA | 6 |
| 51 | CRESTMORE | 7 |
| 52 | JULIAN | 6 |
| 53 | CARGO MUCHACHO (OGILBY) | 3 |
| COLORADO | | |
| 54 | WARD | 5 |
| 55 | KREMMLING | 2 |
| 56 | CENTRAL CITY (BLACKHAWK) | 6 |
| 57 | IDAHO SPRINGS | 6 |
| 58 | GRIFFITH (GEORGETOWN) | 6 |
| 60 | RED CLIFF (BATTLE MOUNTAIN, GILMAN) | 7 |
| 62 | FREMONT PASS (CLIMAX) | 9 |
| 65 | ROARING FORK (ASPEN) | 4 |
| 67 | CEBOLLA (VULCAN) | 8 |
| 69 | UNCOMPAHGRE (OURAY) | 5 |
| 70 | SNEFFELS (IMOGENE BASIN) | 2 |
| 72 | IRON SPRINGS (OPHIR) | 3 |
| 74 | ANIMAS (SILVERTON) | 4 |
| 75 | PIONEER (RICO) | 8 |
| NEW MEXICO | | |
| 76 | WILLOW CREEK (PECOS) | 4 |
| 78 | SAN PEDRO | 7 |
| 79 | MAGDALENA (KELLY) | 2 |
| 80 | NOGAL (SIERRA BLANCA) | 3 |
| 82 | HERMOSA (PALOMAS) | 3 |
| 83 | FIERRO-HANOVER | 3 |
| 84 | STEEPLE ROCK | 2 |
| 85 | SANTA RITA | 4 |
| 88 | OROGRANDE (JARILLA) | 4 |
| 89 | ORGAN | 4 |
| 90 | LORDSBURG (VIRGINIA) | 4 |
| 91 | EUREKA (HACHITA) | 5 |
| NEVADA | | |
| 92 | MOUNTAIN CITY (COPE, VAN DUZER) | 4 |
| 93 | JACKSON CREEK | 4 |
| 94 | TUSCARORA | 4 |
| 98 | SAFFORD (PALISADE) | 6 |
| 99 | RAILROAD (BULLION) | 8 |
| 102 | BULLION (CAMPBELL, LANDER, TENABO) | 9 |
| 103 | DOLLY VARDEN (MIZPAH, GRANITE) | 6 |
| 110 | REESE RIVER (AUSTIN) | 5 |
| 112 | COMSTOCK (VIRGINIA CITY, SILVER STAR) | 2 |
| 113 | ELY (ROBINSON) | 6 |
| 115 | BUCKSKIN | 5 |
| 116 | YERINGTON (MASON) | 5 |
| 117 | GARDNERVILLE (EAGLE) | 4 |
| 120 | SANTA FE (LUNING) | 7 |
| 123 | SILVER STAR (GOLD RANGE, MINA) | 4 |
| 125 | TONOPAH | 3 |
| 126 | JACK RABBIT (BRISTOL) | 3 |
| 129 | TEM PIUTE | 5 |
| 130 | BULLFROG (BEATTY, RHYOLITE) | 7 |
| 131 | COPPER KING (BUNKERVILLE, KEY WEST) | 5 |
| 133 | ELDORADO (NELSON) | 6 |
| UTAH | | |
| 135 | UINTA (PARK CITY) | 4 |
| 136 | BINGHAM (WEST MOUNTAIN) | 7 |
| 137 | AMERICAN FORK | 6 |
| 138 | OPHIR | 6 |
| 139 | GOLD HILL (CLIFTON) | 6 |
| 141 | SAN RAFAEL | 6 |
| 142 | FRISCO | 2 |
| 143 | WHITE CANYON | 6 |
| MONTANA | | |
| 172 | BUTTE | 3 |
| MEXICO | | |
| CHIHUAHUA | | |
| 145 | TEMOSACHIC, GUERRERO | 3 |
| 146 | MAGISTRAL, ITURBIDE | 6 |
| 147 | SAN DIEGO, ITURBIDE | 6 |
| 149 | GUERRERO, GUERRERO | 5 |
| 152 | LOS REYES, JIMENEZ | 6 |
| 153 | EL PARRAL, HIDALGO | 4 |
| 154 | ALISOS, ANDRES DEL RIO | 1 |
| DURANGO | | |
| 159 | REINA DE COBRE, CUENCAME | 7 |
| 160 | SAN LUCAS, SAN JUAN DEL RIO | 5 |
| 162 | TAYOLTITA, SAN DIMAS | 7 |
| SAN LUIS POTOSI | | |
| 163 | MATEHUALA, CATORCE | 8 |
| SONORA | | |
| 165 | CANANEA, ARISPE | 4 |
| 166 | NACOZARI, ARISPE | 5 |
| 167 | SANTA DOMINGO, ARISPE | 5 |
| 168 | SANTA BARBARA, HERMOSILLO | 2 |
| 169 | SAN JAVIER, HERMOSILLO | 2 |
| ZACATECAS | | |
| 170 | SAIN ALTO, SOMBRERETE | 8 |
| 171 | SOMBRERETE, SOMBRERETE | 4 |

# COMBINED METAL CONTENT OF CHALCOPYRITE

SCALE
0 50 100 150 200
MILES

PREPARED BY C. W. BURNHAM
OCTOBER 1954



# SILVER CONTENT OF SPHALERITE

SCALE

0 50 100 150 200

MILES

PREPARED BY C. W. BURNHAM
OCTOBER 1954

## EXPLANATION

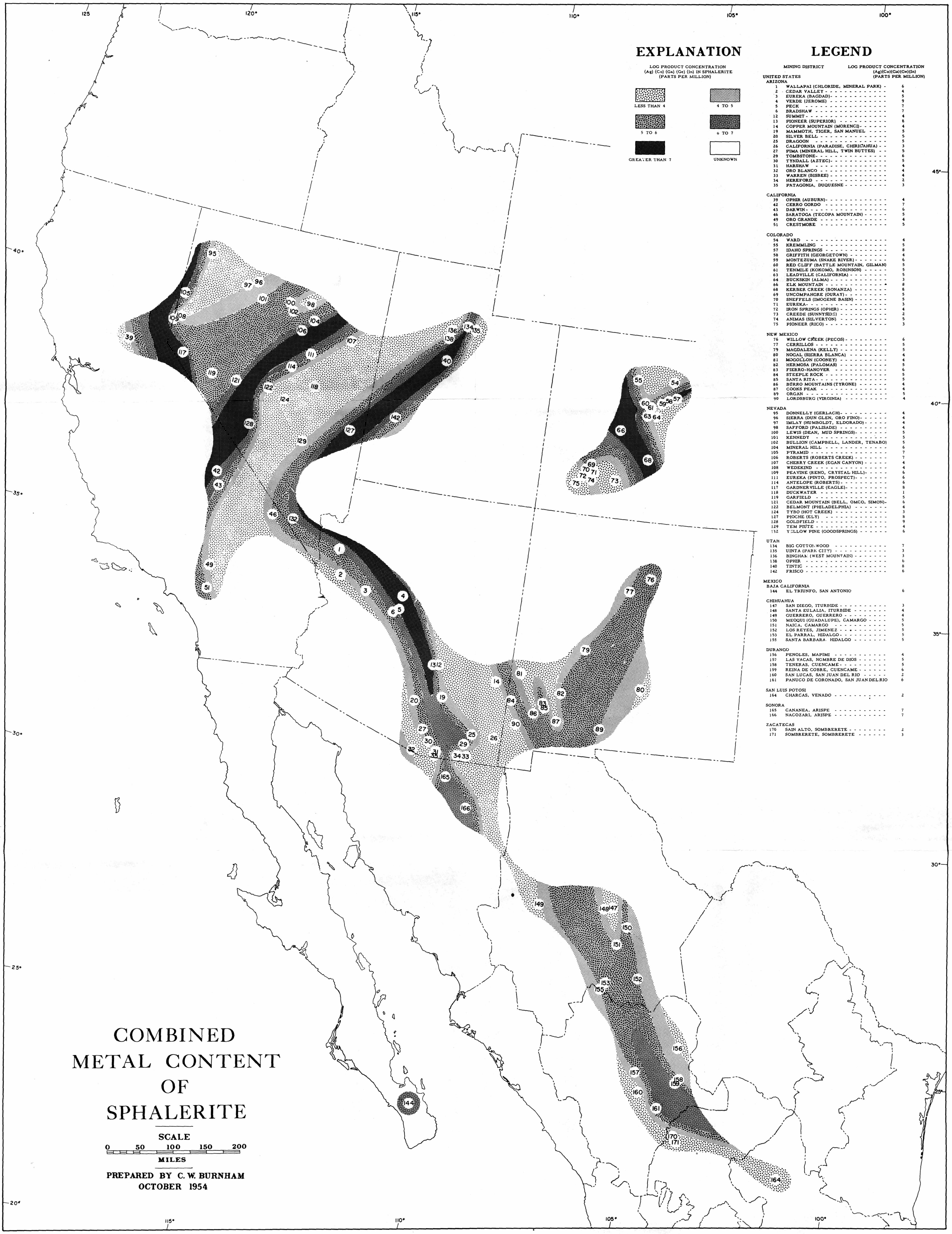
SILVER CONTENT OF SPHALERITE
(PARTS PER MILLION)

| | |
|---|---|
| ░ LESS THAN 10 | ▒ 10 TO 30 |
| ▓ 30 TO 100 | █ GREATER THAN 100 |
| ☐ UNKNOWN | |

## LEGEND

| | MINING DISTRICT | AVERAGE SILVER CONTENT (PPM) |
|---|---|---|
| | UNITED STATES | |
| | ARIZONA | |
| 1 | WALLAPAI (CHLORIDE, MINERAL PARK) | 200 |
| 2 | CEDAR VALLEY | 8 |
| 3 | EUREKA (BAGDAD) | 1 |
| 4 | VERDE (JEROME) | 20 |
| 5 | PECK | 100 |
| 6 | BRADSHAW | 20 |
| 12 | SUMMIT | 20 |
| 13 | PIONEER (SUPERIOR) | 300 |
| 14 | COPPER MOUNTAIN (MORENCI) | 90 |
| 19 | MAMMOTH, TIGER, SAN MANUEL | 90 |
| 20 | SILVER BELL | 4 |
| 25 | DRAGOON | 60 |
| 26 | CALIFORNIA (PARADISE, CHIRICAHUA) | 3 |
| 27 | PIMA (MINERAL HILL, TWIN BUTTES) | 20 |
| 29 | *TOMBSTONE* | 200 |
| 30 | TYNDALL (AZTEC) | 100 |
| 31 | HARSHAW | 30 |
| 32 | ORO BLANCO | 200 |
| 33 | WARREN (BISBEE) | 10 |
| 34 | HEREFORD | 7 |
| 35 | PATAGONIA, DUQUESNE | - |
| | CALIFORNIA | |
| 39 | OPHIR (AUBURN) | 900 |
| 42 | *CERRO GORDO* | 90 |
| 43 | DARWIN | 40 |
| 46 | SARATOGA (TECOPA MOUNTAIN) | 100 |
| 49 | ORO GRANDE | - |
| 51 | CRESTMORE | 30 |
| | COLORADO | |
| 54 | WARD | 300 |
| 55 | KREMMLING | 500 |
| 57 | IDAHO SPRINGS | 300 |
| 58 | GRIFFITH (GEORGETOWN) | 80 |
| 59 | MONTEZUMA (SNAKE RIVER) | 80 |
| 60 | RED CLIFF (BATTLE MOUNTAIN, GILMAN) | 40 |
| 61 | TENMILE (KOKOMO, ROBINSON) | 400 |
| 63 | LEADVILLE (CALIFORNIA) | 70 |
| 64 | BUCKSKIN (ALMA) | 5000 |
| 66 | ELK MOUNTAIN | 200 |
| 68 | KERBER CREEK (BONANZA) | 200 |
| 69 | UNCOMPAHGRE (OURAY) | 50 |
| 70 | SNEFFELS (IMOGENE BASIN) | 7 |
| 71 | EUREKA | 40 |
| 72 | IRON SPRINGS (OPHIR) | 300 |
| 73 | CREEDE (SUNNYSIDE) | 3 |
| 74 | *ANIMAS (SILVERTON)* | 500 |
| 75 | PIONEER (RICO) | 100 |
| | *NEW MEXICO* | |
| 76 | WILLOW CREEK (PECOS) | 800 |
| 77 | CERRILLOS | 6 |
| 79 | *MAGDALENA (KELLY)* | 90 |
| 80 | NOGAL (SIERRA BLANCA) | 40 |
| 81 | MOGOLLON (COONEY) | 30 |
| 82 | HERMOSA (PALOMAS) | 500 |
| 83 | *FIERRO-HANOVER* | 80 |
| 84 | STEEPLE ROCK | 200 |
| 85 | SANTA RITA | 90 |
| 86 | BURRO MOUNTAINS (TYRONE) | 500 |
| 87 | COOKS PEAK | 50 |
| 89 | ORGAN | 40 |
| 90 | LORDSBURG (VIRGINIA) | 10 |
| | NEVADA | |
| 95 | DONNELLY (GERLACH) | 10 |
| 96 | SIERRA (DUN GLEN, ORO FINO) | 200 |
| 97 | IMLAY (HUMBOLDT, ELDORADO) | 100 |
| 98 | *SAFFORD (PALISADE)* | 200 |
| 100 | *LEWIS (DEAN, MUD SPRINGS)* | 4000 |
| 101 | KENNEDY | 60 |
| 102 | BULLION (CAMPBELL, LANDER, TENABO) | 3000 |
| 104 | *MINERAL HILL* | 400 |
| 105 | PYRAMID | 500 |
| 106 | ROBERTS (ROBERTS CREEK) | 100 |
| 107 | CHERRY CREEK (EGAN CANYON) | 500 |
| 108 | *WEDEKIND* | 20 |
| 109 | PEAVINE (RENO, CRYSTAL HILL) | 4 |
| 111 | EUREKA (PINTO, PROSPECT) | 700 |
| 114 | *ANTELOPE (ROBERTS)* | 200 |
| 117 | *GARDNERVILLE (EAGLE)* | 200 |
| 118 | DUCKWATER | 1 |
| 119 | GARFIELD | 300 |
| 121 | CEDAR MOUNTAIN (BELL, OMCO, SIMON) | 200 |
| 122 | BELMONT *(PHILADELPHIA)* | 1000 |
| 124 | TYBO (HOT CREEK) | 30 |
| 127 | PIOCHE (ELY) | 200 |
| 128 | GOLDFIELD | 400 |
| 129 | TEM PIUTE | 1 |
| 132 | YELLOW PINE (GOODSPRINGS) | 500 |
| | UTAH | |
| 134 | *BIG COTTONWOOD* | 50 |
| 135 | UINTA (PARK CITY) | 10 |
| 136 | BINGHAM (WEST MOUNTAIN) | 3 |
| 138 | OPHIR | 40 |
| 140 | TINTIC | 300 |
| 142 | FRISCO | 30 |
| | MEXICO | |
| | BAJA CALIFORNIA | |
| 144 | EL TRIUNFO, SAN ANTONIO | 400 |
| | CHIHUAHUA | |
| 147 | SAN DIEGO, ITURBIDE | 30 |
| 148 | SANTA EULALIA, ITURBIDE | 20 |
| 149 | GUERRERO, GUERRERO | 80 |
| 150 | MEOQUI (GUADALUPE), CAMARGO | 80 |
| 151 | NAICA, CAMARGO | 200 |
| 152 | LOS REYES, JIMENEZ | 200 |
| 153 | EL PARRAL, HIDALGO | 1000 |
| 155 | SANTA BARBARA, HIDALGO | 30 |
| | DURANGO | |
| 156 | PENOLES, MAPIMI | 100 |
| 157 | LAS VACAS, NOMBRE DE DIOS | 700 |
| 158 | TENERAS, CUENCAME | 200 |
| 159 | REINA DE COBRE, CUENCAME | 10 |
| 160 | SAN LUCAS, SAN JUAN DEL RIO | 8 |
| 161 | PANUCO DE CORONADO, SAN JUAN DEL RIO | 500 |
| | SAN LUIS POTOSI | |
| 164 | CHARCAS, VENADO | 90 |
| | SONORA | |
| 165 | CANANEA, ARISPE | 100 |
| 166 | NACOZARI, ARISPE | 200 |
| | ZACATECAS | |
| 170 | SAIN ALTO, SOMBRERETE | 300 |
| 171 | *SOMBRERETE, SOMBRERETE* | 100 |

A SHORT DASH (-) INDICATES THAT THE AVERAGE SILVER CONTENT OF SPHALERITE IN THE DISTRICT *IS LESS THAN ONE PART PER MILLION.*



# COMBINED METAL CONTENT OF SPHALERITE

SCALE

PREPARED BY C. W. BURNHAM
OCTOBER 1954

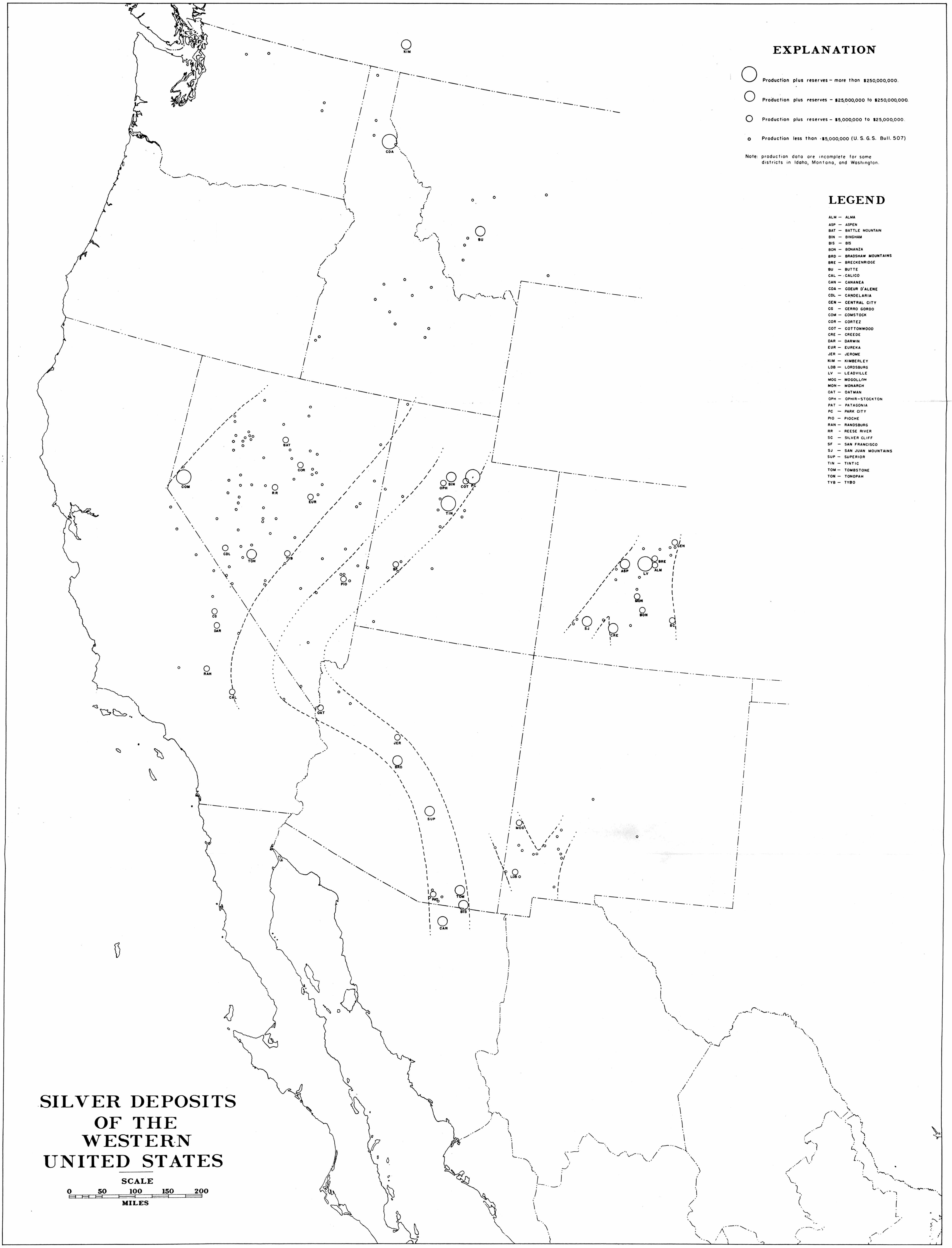
## EXPLANATION

LOG PRODUCT CONCENTRATION
(Ag) (Co) (Ga) (Ge) (In) IN SPHALERITE
(PARTS PER MILLION)

- ░ LESS THAN 4
- ▒ 4 TO 5
- ▨ 5 TO 6
- ▓ 6 TO 7
- ■ GREATER THAN 7
- □ UNKNOWN

## LEGEND

| | MINING DISTRICT | LOG PRODUCT CONCENTRATION (Ag)(Co)(Ga)(Ge)(In) (PARTS PER MILLION) |
|---|---|---|
| UNITED STATES | | |
| ARIZONA | | |
| 1 | WALLAPAI (CHLORIDE, MINERAL PARK) | 6 |
| 2 | CEDAR VALLEY | 4 |
| 3 | EUREKA (BAGDAD) | 5 |
| 4 | VERDE (JEROME) | 9 |
| 5 | PECK | 7 |
| 6 | BRADSHAW | 7 |
| 12 | SUMMIT | 4 |
| 13 | PIONEER (SUPERIOR) | 8 |
| 14 | COPPER MOUNTAIN (MORENCI) | 4 |
| 19 | MAMMOTH, TIGER, SAN MANUEL | 5 |
| 20 | SILVER BELL | 5 |
| 25 | DRAGOON | 5 |
| 26 | CALIFORNIA (PARADISE, CHIRICAHUA) | 3 |
| 27 | PIMA (MINERAL HILL, TWIN BUTTES) | 5 |
| 29 | TOMBSTONE | 6 |
| 30 | TYNDALL (AZTEC) | 5 |
| 31 | HARSHAW | 4 |
| 32 | ORO BLANCO | 4 |
| 33 | WARREN (BISBEE) | 4 |
| 34 | HEREFORD | 2 |
| 35 | PATAGONIA, DUQUESNE | 3 |
| CALIFORNIA | | |
| 39 | OPHIR (AUBURN) | 4 |
| 42 | CERRO GORDO | 7 |
| 43 | DARWIN | 6 |
| 46 | SARATOGA (TECOPA MOUNTAIN) | 5 |
| 49 | ORO GRANDE | 4 |
| 51 | CRESTMORE | 5 |
| COLORADO | | |
| 54 | WARD | 4 |
| 55 | KREMMLING | 5 |
| 57 | IDAHO SPRINGS | 8 |
| 58 | GRIFFITH (GEORGETOWN) | 4 |
| 59 | MONTEZUMA (SNAKE RIVER) | 6 |
| 60 | RED CLIFF (BATTLE MOUNTAIN, GILMAN) | 5 |
| 61 | TENMILE (KOKOMO, ROBINSON) | 5 |
| 63 | LEADVILLE (CALIFORNIA) | 5 |
| 64 | BUCKSKIN (ALMA) | 3 |
| 66 | ELK MOUNTAIN | 8 |
| 68 | KERBER CREEK (BONANZA) | 8 |
| 69 | UNCOMPAHGRE (OURAY) | 5 |
| 70 | SNEFFELS (IMOGENE BASIN) | 5 |
| 71 | EUREKA | 3 |
| 72 | IRON SPRINGS (OPHIR) | 4 |
| 73 | CREEDE (SUNNYSIDE) | 2 |
| 74 | ANIMAS (SILVERTON) | 5 |
| 75 | PIONEER (RICO) | 3 |
| NEW MEXICO | | |
| 76 | WILLOW CREEK (PECOS) | 6 |
| 77 | CERRILLOS | 5 |
| 79 | MAGDALENA (KELLY) | 5 |
| 80 | NOGAL (SIERRA BLANCA) | 4 |
| 81 | MOGOLLON (COONEY) | 4 |
| 82 | HERMOSA (PALOMAS) | 5 |
| 83 | FIERRO-HANOVER | 6 |
| 84 | STEEPLE ROCK | 5 |
| 85 | SANTA RITA | 5 |
| 86 | BURRO MOUNTAINS (TYRONE) | 4 |
| 87 | COOKS PEAK | 4 |
| 89 | ORGAN | 5 |
| 90 | LORDSBURG (VIRGINIA) | 4 |
| NEVADA | | |
| 95 | DONNELLY (GERLACH) | 4 |
| 96 | SIERRA (DUN GLEN, ORO FINO) | 4 |
| 97 | IMLAY (HUMBOLDT, ELDORADO) | 4 |
| 98 | SAFFORD (PALISADE) | 4 |
| 100 | LEWIS (DEAN, MUD SPRINGS) | 5 |
| 101 | KENNEDY | 5 |
| 102 | BULLION (CAMPBELL, LANDER, TENABO) | 5 |
| 104 | MINERAL HILL | 6 |
| 105 | PYRAMID | 7 |
| 106 | ROBERTS (ROBERTS CREEK) | 7 |
| 107 | CHERRY CREEK (EGAN CANYON) | 4 |
| 108 | WEDEKIND | 4 |
| 109 | PEAVINE (RENO, CRYSTAL HILL) | 6 |
| 111 | EUREKA (PINTO, PROSPECT) | 6 |
| 114 | ANTELOPE (ROBERTS) | 6 |
| 117 | GARDNERVILLE (EAGLE) | 8 |
| 118 | DUCKWATER | 1 |
| 119 | GARFIELD | 5 |
| 121 | CEDAR MOUNTAIN (BELL, OMCO, SIMON) | 6 |
| 122 | BELMONT (PHILADELPHIA) | 4 |
| 124 | TYBO (HOT CREEK) | 3 |
| 127 | PIOCHE (ELY) | 8 |
| 128 | GOLDFIELD | 9 |
| 129 | TEM PIUTE | 4 |
| 132 | YELLOW PINE (GOODSPRINGS) | 6 |
| UTAH | | |
| 134 | BIG COTTONWOOD | 7 |
| 135 | UINTA (PARK CITY) | 3 |
| 136 | BINGHAM (WEST MOUNTAIN) | 3 |
| 138 | OPHIR | 6 |
| 140 | TINTIC | 8 |
| 142 | FRISCO | 6 |
| MEXICO | | |
| BAJA CALIFORNIA | | |
| 144 | EL TRIUNFO, SAN ANTONIO | 6 |
| CHIHUAHUA | | |
| 147 | SAN DIEGO, ITURBIDE | 3 |
| 148 | SANTA EULALIA, ITURBIDE | 4 |
| 149 | GUERRERO, GUERRERO | 4 |
| 150 | MEOQUI (GUADALUPE), CAMARGO | 5 |
| 151 | NAICA, CAMARGO | 5 |
| 152 | LOS REYES, JIMENEZ | 5 |
| 153 | EL PARRAL, HIDALGO | 5 |
| 155 | SANTA BARBARA, HIDALGO | 5 |
| DURANGO | | |
| 156 | PENOLES, MAPIMI | 4 |
| 157 | LAS VACAS, NOMBRE DE DIOS | 5 |
| 158 | TENERAS, CUENCAME | 5 |
| 159 | REINA DE COBRE, CUENCAME | 6 |
| 160 | SAN LUCAS, SAN JUAN DEL RIO | 2 |
| 161 | PANUCO DE CORONADO, SAN JUAN DEL RIO | 6 |
| SAN LUIS POTOSI | | |
| 164 | CHARCAS, VENADO | 2 |
| SONORA | | |
| 165 | CANANEA, ARISPE | 7 |
| 166 | NACOZARI, ARISPE | 7 |
| ZACATECAS | | |
| 170 | SAIN ALTO, SOMBRERETE | 2 |
| 171 | SOMBRERETE, SOMBRERETE | 3 |



## EXPLANATION

◯ Production plus reserves – more than $250,000,000.

○ Production plus reserves – $25,000,000 to $250,000,000.

○ Production plus reserves – $5,000,000 to $25,000,000.

∘ Production less than $5,000,000 (U. S. G. S. Bull. 507)

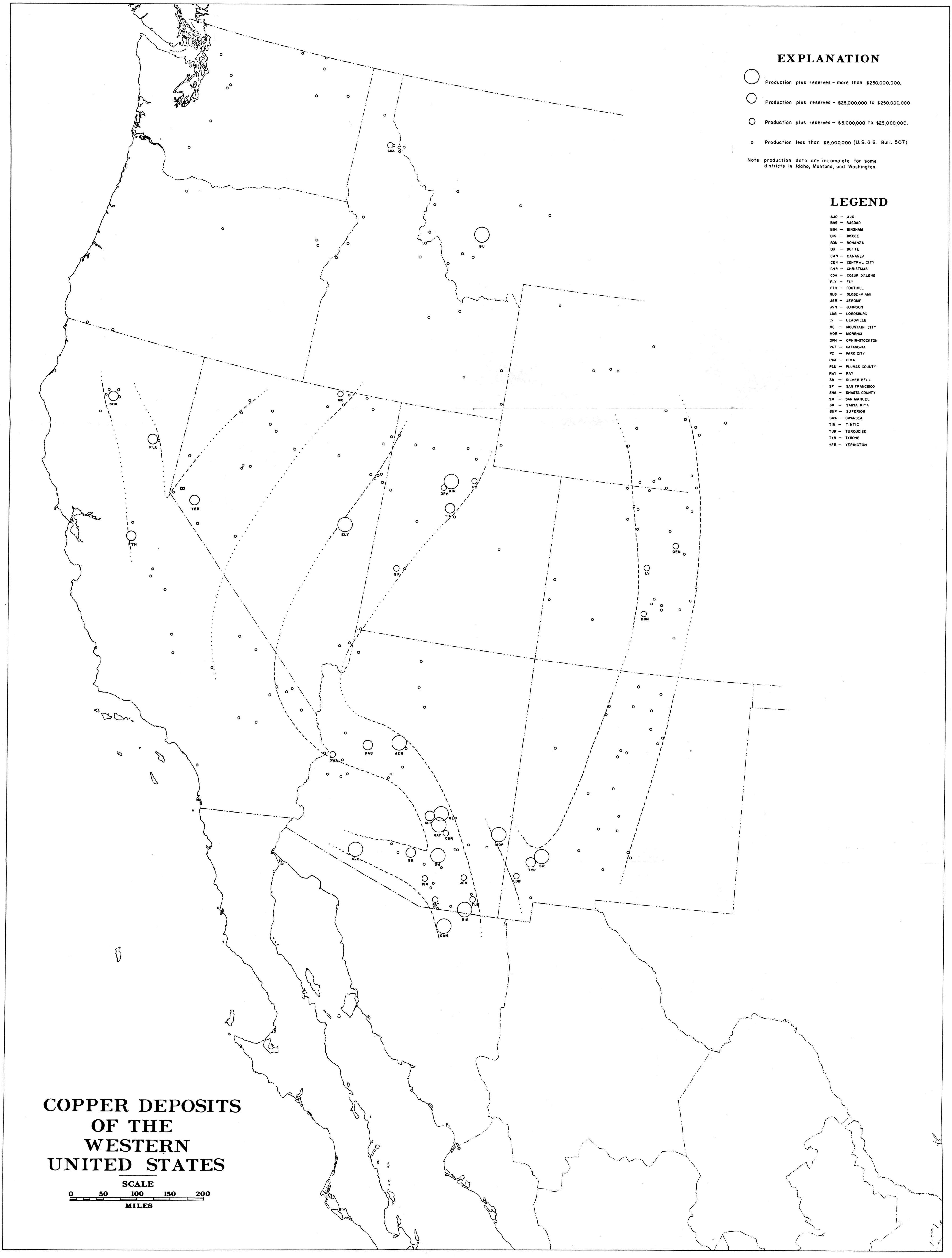
Note: production data are incomplete for some districts in Idaho, Montana, and Washington.

## LEGEND

ALM — ALMA
ASP — ASPEN
BAT — BATTLE MOUNTAIN
BIN — BINGHAM
BIS — BIS
BON — BONANZA
BRD — BRADSHAW MOUNTAINS
BRE — BRECKENRIDGE
BU — BUTTE
CAL — CALICO
CAN — CANANEA
CDA — COEUR D'ALENE
CDL — CANDELARIA
CEN — CENTRAL CITY
CG — CERRO GORDO
COM — COMSTOCK
COR — CORTEZ
COT — COTTONWOOD
CRE — CREEDE
DAR — DARWIN
EUR — EUREKA
JER — JEROME
KIM — KIMBERLEY
LDB — LORDSBURG
LV — LEADVILLE
MOG — MOGOLLON
MON — MONARCH
OAT — OATMAN
OPH — OPHIR-STOCKTON
PAT — PATAGONIA
PC — PARK CITY
PIO — PIOCHE
RAN — RANDSBURG
RR - REESE RIVER
SC — SILVER CLIFF
SF — SAN FRANCISCO
SJ — SAN JUAN MOUNTAINS
SUP — SUPERIOR
TIN — TINTIC
TOM — TOMBSTONE
TON — TONOPAH
TYB — TYBO

# SILVER DEPOSITS OF THE WESTERN UNITED STATES

SCALE
0 50 100 150 200
MILES



## EXPLANATION

◯ Production plus reserves – more than $250,000,000.

○ Production plus reserves – $25,000,000 to $250,000,000.

○ Production plus reserves – $5,000,000 to $25,000,000.

° Production less than $5,000,000 (U. S. G. S. Bull. 507)

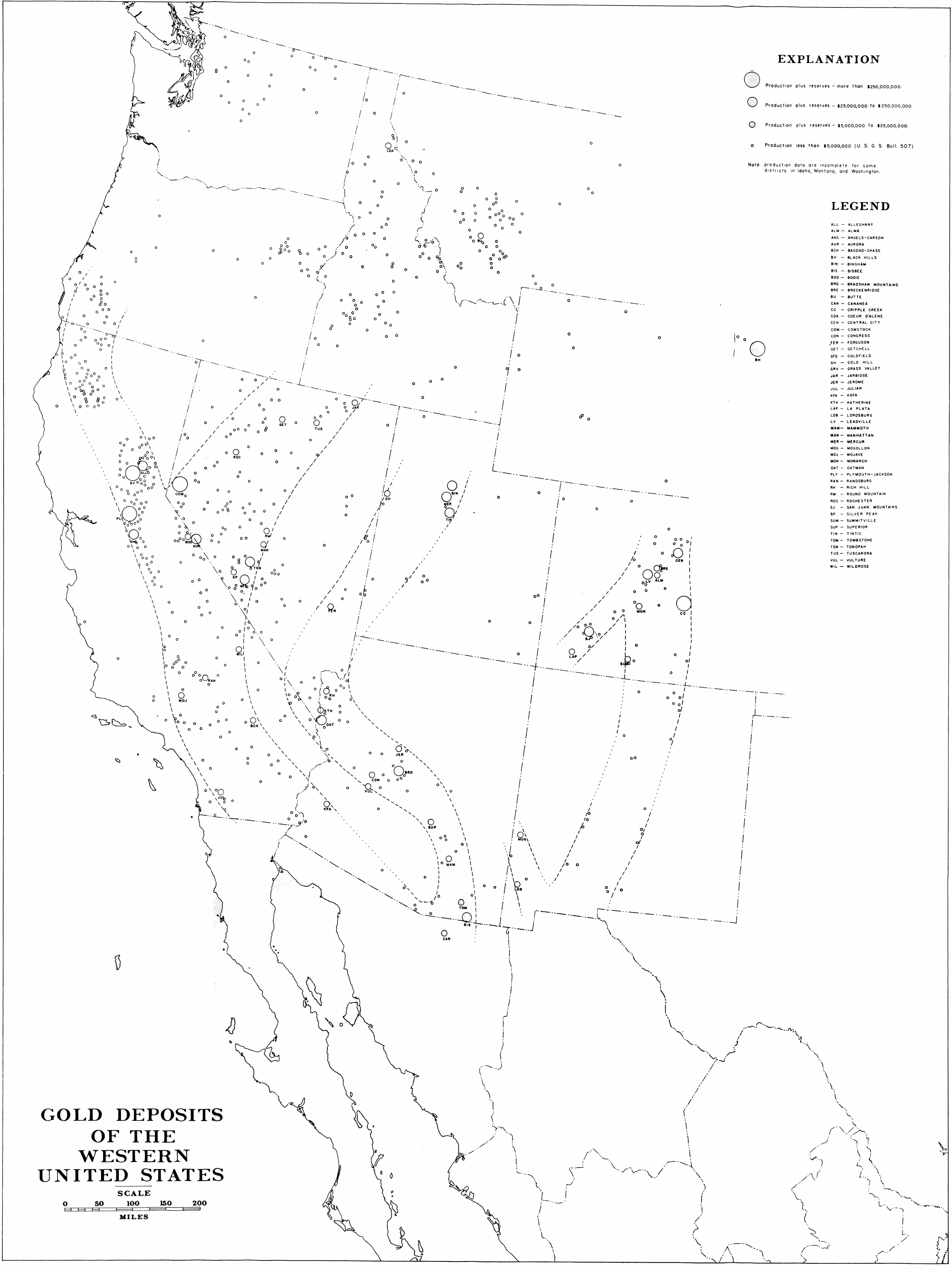
Note: production data are incomplete for some districts in Idaho, Montana, and Washington.

## LEGEND

AJO – AJO
BAG – BAGDAD
BIN – BINGHAM
BIS – BISBEE
BON – BONANZA
BU – BUTTE
CAN – CANANEA
CEN – CENTRAL CITY
CHR – CHRISTMAS
CDA – COEUR D'ALENE
ELY – ELY
FTH – FOOTHILL
GLB – GLOBE-MIAMI
JER – JEROME
JSN – JOHNSON
LDB – LORDSBURG
LV – LEADVILLE
MC – MOUNTAIN CITY
MOR – MORENCI
OPH – OPHIR-STOCKTON
PAT – PATAGONIA
PC – PARK CITY
PIM – PIMA
PLU – PLUMAS COUNTY
RAY – RAY
SB – SILVER BELL
SF – SAN FRANCISCO
SHA – SHASTA COUNTY
SM – SAN MANUEL
SR – SANTA RITA
SUP – SUPERIOR
SWA – SWANSEA
TIN – TINTIC
TUR – TURQUOISE
TYR – TYRONE
YER – YERINGTON

# COPPER DEPOSITS OF THE WESTERN UNITED STATES

SCALE
0 50 100 150 200
MILES



## EXPLANATION

◯ Production plus reserves – more than $250,000,000.

○ Production plus reserves – $25,000,000 to $250,000,000

○ Production plus reserves – $5,000,000 to $25,000,000.

∘ Production less than $5,000,000 (U. S. G. S. Bull. 507)

Note: production data are incomplete for some districts in Idaho, Montana, and Washington.

## LEGEND

ALL — ALLEGHANY
ALM — ALMA
ANG — ANGELS-CARSON
AUR — AURORA
BCH — BAGDAD-CHASE
BH — BLACK HILLS
BIN — BINGHAM
BIS — BISBEE
BOD — BODIE
BRD — BRADSHAW MOUNTAINS
BRE — BRECKENRIDGE
BU — BUTTE
CAN — CANANEA
CC — CRIPPLE CREEK
CDA — COEUR D'ALENE
CEN — CENTRAL CITY
COM — COMSTOCK
CON — CONGRESS
FER — FERGUSON
GET — GETCHELL
GFD — GOLDFIELD
GH — GOLD HILL
GRV — GRASS VALLEY
JAR — JARBIDGE
JER — JEROME
JUL — JULIAN
KFA — KOFA
KTH — KATHERINE
LAP — LA PLATA
LDB — LORDSBURG
LV — LEADVILLE
MAM — MAMMOTH
MAN — MANHATTAN
MER — MERCUR
MOG — MOGOLLON
MOJ — MOJAVE
MON — MONARCH
OAT — OATMAN
PLY — PLYMOUTH-JACKSON
RAN — RANDSBURG
RH — RICH HILL
RM — ROUND MOUNTAIN
ROC — ROCHESTER
SJ — SAN JUAN MOUNTAINS
SP — SILVER PEAK
SUM — SUMMITVILLE
SUP — SUPERIOR
TIN — TINTIC
TOM — TOMBSTONE
TON — TONOPAH
TUS — TUSCARORA
VUL — VULTURE
WIL — WILDROSE

# GOLD DEPOSITS OF THE WESTERN UNITED STATES

SCALE
0 50 100 150 200
MILES