DEPARTMENT OF THE INTERIOR
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TO ACCOMPANY MAP MF-1382-H

# DISTRIBUTIONS OF MOLYBDENUM, TIN, BORON, TUNGSTEN, AND GOLD IN SAMPLES OF MINUS-60-MESH (0.25-MM) STREAM SEDIMENT AND (OR) NONMAGNETIC HEAVY-MINERAL CONCENTRATE, WALKER LAKE 1° x 2° QUADRANGLE, CALIFORNIA AND NEVADA

By

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## INTRODUCTION

This report is part of a folio of maps of the Walker Lake 1° x 2° quadrangle, California and Nevada, prepared under the Conterminous United States Mineral Assessment Program. The folio includes geological, geochemical, and geophysical maps, as well as mineral resource assessment maps, which identify selected known or possible mineral-deposit environments in the quadrangle. The geochemical maps show the distributions of selected individual elements (Chaffee and others, 1988a, b, c) and the distributions of selected groups of elements (Chaffee, 1988a, b, c). Discussions accompanying the individual element maps are restricted to mineral residences of the individual elements as well as to what types of mineral deposits and environments may be represented by anomalies of a particular element. Discussions accompanying the multielement maps describe the types of mineral deposits that may be related to each element group and indicate the most favorable localities for these deposits.

This chapter of the folio shows the abundances and distributions of molybdenum, tin, boron, tungsten, and gold in 1,116 samples of minus-60-mesh (0.25-mm) stream sediment and (or) 1,005 samples of nonmagnetic heavy-mineral concentrate derived from stream sediment. Analyses for 110 stream-sediment samples and 3 concentrate samples included in this report are from samples collected and analyzed during 1967 and 1968 for the Emigrant Basin Primitive Area study (Tooker and others, 1970). The rest of the samples were collected and analyzed during 1978 and 1979, specifically for the present report. A combined tabulation of all these analyses is published as U.S. Geological Survey Open-File Report 80-881 (Chaffee and others, 1980). This same tabulation is also available on computer tape from the National Technical Information Service (McDanal and others, 1981).

## GENERAL GEOLOGY

The Walker Lake quadrangle includes parts of two major physiographic provinces: the Sierra Nevada-Cascade Mountains and the Basin and Range provinces. These two provinces have contrasting geological frameworks that reflect their different geologic histories. Because the geology of the Walker Lake quadrangle is complex, only a brief generalized summary is given here.

### Sierra Nevada-Cascade Mountains province

Most of the western one-third of the quadrangle is in the Sierra Nevada. The Sierra Nevada includes the major Sierra Nevada batholith, which is composed of plutons ranging from Permian(?) to Late Cretaceous in age (Keith and Seitz, 1981). These plutons range from alaskite to gabbro in composition, with the majority of the rocks being in the quartz monzonite to granodiorite range. This plutonic complex has intruded and metamorphosed a sequence of Paleozoic and Mesozoic rocks that comprise both clastic- and carbonate-rich sedimentary rocks as well as volcanic (and plutonic?) rocks. Overlying these older units locally are Tertiary volcanic rocks consisting of flows, breccias, and lahars, and intrusive dikes, sills, and necks. Most of these Tertiary volcanic rocks are andesitic in composition; however, rocks of rhyolitic composition are present locally. Glacial and landslide deposits are present locally in many of the valleys in the Sierra Nevada.

### Basin and Range province

Most of the eastern two-thirds of the quadrangle is in the Basin and Range physiographic province. Much of this part of the quadrangle contains thick sequences of extensively block-faulted Paleozoic and Mesozoic sedimentary rocks of widely varying compositions. Mesozoic plutons, which range in composition from alaskite to gabbro but are predominantly in the granite to granodiorite range, have intruded and locally metamorphosed the overlying sedimentary rocks. A long history of Tertiary volcanism is recorded in the eastern part of the quadrangle; thick sequences of flows, breccias, and tuffs, ranging in composition from rhyolite to basalt, are found throughout much of the area. Tertiary clastic sedimentary rocks were deposited in some areas. Tertiary and Quaternary volcanic flows, breccias, and shallow intrusive rocks, ranging in composition from rhyolite to basalt, are also present locally. Alluvial, lacustrine, and eolian sedimentary deposits are present in most of the valleys in this part of the quadrangle.

### Geologic base for the geochemical maps

A simplified geologic base map of the Walker Lake quadrangle has been used with each of the accompanying geochemical maps. A more detailed geologic map of the quadrangle is available as a separate chapter in this Walker Lake folio (Stewart and others, 1982). For purposes of discussion in this report, some of the geologic units shown on the geologic map of Stewart and others (1982) have been consolidated into three major units.

Paleozoic and Mesozoic rocks--All of the pre-Cretaceous (Paleozoic and Mesozoic) igneous and sedimentary rock units (units Pz and Mz on map) have been consolidated into this one unit. Many but not all of these rocks have been metamorphosed.

Mesozoic intrusive rocks--Plutons ranging in composition from alaskite to gabbro compose this unit (unit Mzgr on map).

Tertiary volcanic rocks--This unit is composed predominantly of flow rocks of andesitic composition, but it also includes necks and flows ranging in composition from rhyolite to basalt as well as felsic to intermediate tuffs (includes units Tt and Ta on map).

## ECONOMIC GEOLOGY

The Walker Lake quadrangle contains many mines and prospects. As a result of the complex geologic history of the area, many different mineral-deposit environments exist within the quadrangle. On the basis of geological and geochemical studies conducted for the reports in this folio, as well as on the recorded mining in the region, the commodities thought to have the greatest resource potential within the Walker Lake quadrangle are copper, lead, zinc, gold, silver, molybdenum, tungsten, and uranium. Thus, this geochemical study emphasizes those elements and element suites that may prove useful in locating areas containing (1) base and precious metals[1] and tungsten

[1]The term base metals in this report includes some or all of the elements antimony, arsenic, bismuth, cadmium, copper, lead, and zinc. The precious metals are silver and gold.

in vein or contact-metasomatic deposits, (2) copper and (or) molybdenum porphyry-type deposits, and (3) disseminated gold deposits. Studies related to uranium deposits are described elsewhere (Durham and Felmlee, 1982; Fay and Jones, 1980).

## NATURE AND SCOPE OF THE GEOCHEMICAL SAMPLING

The geochemical sampling program for the Walker Lake quadrangle was based on collecting as many as three different types of samples--rock, minus-60-mesh stream sediment, and nonmagnetic heavy-mineral concentrate derived from stream sediment--at preselected locations throughout the quadrangle. Most of the samples of alluvial material were collected from first-order (unbranched) and second-order (below the junction of two first-order) stream channels as shown on 1:62,500-scale topographic maps.

The chemical analyses of the samples of stream sediment and concentrate provide information that may be used by the evaluator to separate the background concentrations of the five elements discussed in this chapter of the folio from their anomalous concentrations. Anomalous concentrations may indicate the presence of as yet unknown mineral deposits that may be either exposed or buried. Plots of the analyses can be used to delineate those areas where samples have been found to contain anomalous concentrations of one or more elements commonly associated with ore processes.

Many anomalies shown on the accompanying maps are related to known mining activity. Some known mineral deposits are not reflected by anomalies, however, primarily because they are not close to sampled stream channels but also because not all samples collected were truly representative of the material being eroded upstream from the sample site. Because the sampling was designed and executed on a reconnaissance scale, some relatively small but exposed areas of anomalous rock may not have been detected despite proximity to sampled stream channels. Mineral deposits not exposed at the surface may not be easily detected even if part of the deposit system, such as an alteration aureole, is exposed. Additional detailed geochemical surveys would be necessary to identify and delineate specific mineralized areas.

Deposits of both placer minerals and saline, playa-associated minerals have been mined in the past in many of the alluvium-filled valleys and basins scattered throughout the Walker Lake quadrangle. The sampling program for the present study was designed primarily to evaluate areas of outcrop; thus, mineral deposits that may be present in alluvial-filled valleys and basins are excluded from consideration in this geochemical report.

## DESCRIPTION OF THE SAMPLE MEDIA

Sediment was collected from active stream channels and processed to produce the minus-60-mesh stream-sediment and the nonmagnetic heavy-mineral-concentrate samples. Unlike rock samples, which represent a restricted, essentially point source, the sediment collected at a given site is considered to represent a composite of outcrop material eroded from the entire drainage basin upstream from the collection site.

The stream-sediment samples provide information about the elements in all of the minerals present in the eroded rock materials. In contrast, the concentrate samples provide information about the elements in only a limited number of minerals. The concentrating process removes most of the quartz, feldspar, clay minerals, and highly magnetic minerals. This selective concentration of minerals commonly related to mineral deposits permits determination of some elements that are not commonly detected in stream-sediment samples by emission spectroscopy. The concentrate chemistry may also be specific for certain minerals. For example, the concentration of barium in a stream-sediment sample represents the sum of barium contained in barite plus barium contained in potassium feldspars and possibly other minerals. Because of the processing procedures used, the barium in a concentrate sample represents predominantly the single mineral barite.

## SAMPLE PREPARATION AND ANALYSIS

### Sample preparation

The stream-sediment samples were composited from active alluvium collected from several locations within a 50-ft (15-m) radius of the localities shown on the accompanying maps. Each resulting sample was air-dried and then sieved. The material passing a screen with 0.25-mm openings (a 60-mesh screen) was saved and pulverized.

The concentrate samples were processed from the same composited active alluvium material collected for the minus-60-mesh stream-sediment samples. The material was wet-panned until most of the quartz, feldspar, organic material, and clay-sized material was removed. The samples were air-dried, and the highly magnetic material was removed using a magnet. Any light material remaining in the concentrate was then separated by allowing the heavier fraction of the sample to settle through bromoform (specific gravity 2.86). The resulting heavy-mineral fraction was then separated into a magnetic and a relatively nonmagnetic fraction using a Frantz Isodynamic Separator[2] set at 0.6 amperes, with 15° forward and 15° side settings. The resulting nonmagnetic fraction was pulverized in an agate mortar.

### Sample analysis

Both stream-sediment and nonmagnetic heavy-mineral-concentrate samples were analyzed for 31 elements (Ag, As, Au, B, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, La, Mg, Mn, Mo, Nb, Ni, Pb, Sb, Sc, Sn, Sr, Th, Ti, V, W, Y, Zn, and Zr) using a six-step semiquantitative emission spectrographic method (Grimes and Marranzino, 1968). Because of the limited amount of sample material, the concentrate samples were only analyzed spectrographically. The stream-sediment samples were also analyzed for arsenic by colorimetry (Ward and others, 1963), for zinc, antimony, and gold by atomic-absorption spectrometry (Ward and others, 1969; Welsch and Chao, 1975; Meier, 1980), and for cadmium and bismuth from a single solution by atomic-absorption spectrometry (Viets, 1978). Analyses for both sample types were performed partly in the field in a mobile chemistry laboratory and partly in U.S. Geological Survey laboratories near Golden, Colo.

The spectrographic analytical values are reported as the approximate geometric midpoints (0.15, 0.2, 0.3, 0.5, 0.7, and 1.0, or appropriate powers of ten of these values) of concentration ranges whose respective boundaries are 0.12, 0.18, 0.26, 0.38, 0.56, 0.83, and 1.2 (or appropriate powers of ten of these values). In general, the precision of the spectrographic method is

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[2]The use of trade names in this report is for descriptive purposes only and does not constitute endorsement by the U.S. Geological Survey.

plus or minus one reporting value of the value given by the analyst approximately 83 percent of the time and plus or minus two reporting values of the value given by the analyst 96 percent of the time (Motooka and Grimes, 1976). A reference standard sample was analyzed with each batch of field samples to monitor the quality of the analyses.

For the six elements analyzed by colorimetry or atomic-absorption spectrometry, the reporting values vary with the element and with the concentration level for any given element. Precision for these analytical methods is commonly reported as a percent relative standard deviation and is based on replicate analyses of samples selected to provide information at different concentration levels. In general, the precision for each method tends to be lowest for those samples containing a given element at or near its lower limit of determination. For the six elements discussed in the geochemical chapters in this folio, the reported ranges of percent relative standard deviation (RSD) are as follows:

| Element | Range of percent RSD | Source of data |
|---|---|---|
| As | 0.0-48.9 | Unpublished analyses by R. H. Hill, 1981 |
| Zn | 3.4-30.2 | Ward and others, 1969, p. 21 |
| Sb | 3.7-10.7 | Welsch and Chao, 1975 |
| Au | 0.0-22.8 | Meier, 1980 |
| Cd | 3.3-18.8 | Viets, 1978 |
| Bi | 1.4-4.0 | Viets, 1978 |

As an example to use in interpreting these ranges, one might consider antimony, whose range is shown as 3.7-10.7 percent RSD. This range indicates that a reported antimony value should be within ± 10.7 percent (usually much less) of the mean value for that sample.

## EVALUATION OF THE CHEMICAL ANALYSES

Of the 37 elements determined in the stream-sediment samples, 12 elements (Ag, As, Au, Bi, Cd, Cu, Mo, Pb, Sb, Sn, W, and Zn) were selected as those most likely to be associated with hydrothermal alteration and (or) mineralization of the types known or thought to exist in the Walker Lake quadrangle. Of the 31 elements determined in the concentrate samples, 17 elements (Ag, As, Au, B, Ba, Bi, Cd, Co, Cu, Fe, Mo, Pb, Sb, Sn, Sr, W, and Zn) were selected as possibly having the same associations. This chapter of the folio shows distribution plots of the analyses for molybdenum, tin, and tungsten determined by emission spectroscopy and for gold determined by atomic-absorption spectrometry, all in the stream-sediment samples, and for gold, boron, molybdenum, tin, and tungsten determined by emission spectroscopy, in the concentrate samples.

To simplify plotting of the analytical information, all reported values for each element were assigned to a category with a symbol that could be plotted by a computer program available in the U.S. Geological Survey STATPAC system (VanTrump and Miesch, 1977). The analyses for approximately 85 to 90 percent of the samples in each element population were considered to be clearly within the background range. With the exception of tin and tungsten in stream-sediment samples and gold in concentrate samples, the rest of the analyses for each element have been placed into categories representing one or more reporting values. The reporting values and corresponding plotted symbols for each element are shown on the frequency-distribution histograms for each element (figs. 1-4).

On the basis of a study of the frequency-distribution histogram for each element population and the areal distribution of the analytical values for each element, we have selected what we feel is the best threshold value for that element. Symbols on the maps and histograms representing anomalous concentrations have been darkened, and the drainage basins upstream from these plotted symbols have been outlined on the maps. The different symbols have been plotted on each map so that a user can see the actual distributions of analytical value(s) for the samples and can therefore select a different threshold value, if desired.

The six maps (A-F) in this chapter of the folio show the distributions of five different elements in one or two sample media, and the following text includes a description of the significance of the anomalies for each element. Maps in other parts of this folio show additional single-element or multielement distributions (Chaffee, 1988a, b, c; Chaffee and others, 1988a, b, c). The single-element maps show the localities of all samples, the concentrations present for the more enriched samples, and the probable major source-rock type(s) upstream from each anomalous sample locality. The multielement maps identify specific localities that might represent favorable areas for certain types of mineral deposits containing the individual elements discussed in this chapter of the folio.

From a mineral potential standpoint, the most significant localities on maps A-F are those whose samples contain (1) more than one anomalous element, (2) concentrations for each anomalous element in the high end of the range shown on the accompanying histograms, and (or) (3) anomalies of a given element in both the stream-sediment and concentrate, where both types of samples have been analyzed for that element.

## DISCUSSION OF THE ELEMENTS

### Molybdenum

Maps A and B show the distributions of molybdenum in stream-sediment and concentrate samples. Anomalous molybdenum concentrations in both types of samples commonly are derived from the mineral molybdenite; ferrimolybdite, powellite, and (or) wulfenite may also be present locally. Molybdenum may also be present in secondary iron oxide coatings.

Within the Walker Lake quadrangle, molybdenum anomalies may locate areas containing porphyry copper or molybdenum deposits. Molybdenum anomalies may also indicate contact-metasomatic tungsten deposits.

A comparison of molybdenum concentrations in samples from drainage basins that have contrasting lithologies indicates that molybdenum concentrations are affected somewhat by rock type. Drainage basins containing exposures of felsic to intermediate plutonic rocks exhibit a generally higher background range of molybdenum concentrations than do those of most of the other rock types present in the Walker Lake quadrangle. Molybdenum anomalies are predominantly associated with these same Mesozoic intrusive units; however, much of the molybdenum in these rock units is related to normally high concentrations that are present in some localities and not to enrichment associated with mineral deposits. Anomalies associated with the Mesozoic intrusive rocks may locate molybdenum-rich stocks. A small number of molybdenum anomalies are associated with the Paleozoic and Mesozoic rocks or with the Tertiary volcanic rocks. These anomalies may indicate concealed porphyry copper or molybdenum systems, in which only the outer mineralized aureole in the host rocks is exposed, or may indicate the presence of tungsten deposits.

The outlines of the drainage basins containing anomalous samples (maps A and B) indicate that molybdenum is particularly enriched in certain parts of the Walker Lake quadrangle. Descriptions of many of these anomalous areas are given in the discussions accompanying the multielement geochemical maps (Chaffee, 1988a, b, c).

## Tin and boron

Boron and tin, but especially tin, are known to be associated with at least some types of molybdenum deposits (Westra and Keith, 1981; Boyle, 1974) and thus these two elements may be useful indicator elements for locating such deposits. Both elements may also be associated with contact-metasomatic tungsten deposits and locally with some types of base- and precious-metal deposits (Boyle, 1974).

Maps C and D show the distributions of tin in stream-sediment and concentrate samples and of boron in concentrate samples, respectively. Tin was only detected in a few of the samples collected for this study; consequently, very few analyses for this element in these samples are available for plotting. The mineral residence of tin in both concentrate and stream-sediment samples collected in the Walker Lake quadrangle is not known.

Anomalous boron concentrations in the concentrate samples probably are derived mostly from the mineral tourmaline. We speculate that anomalous boron concentrations in the stream-sediment samples are derived partly from the mineral tourmaline, and partly from hydrous, boron-rich accessory minerals, but mostly from various borate minerals that, at least in the study area, seem to have no direct association with hydrothermal mineralization. Thus, the distribution of boron in stream-sediment samples is not considered to be effective for locating hydrothermal mineral deposits in this quadrangle.

Comparisons of the concentrations of boron and tin in samples from drainage basins that have contrasting lithologies indicates these two elements are more enriched in the Mesozoic felsic plutons than in the other rock units. Samples containing anomalous concentrations of boron and tin are primarily from basins composed mostly of felsic intrusive rocks but are also found associated with both the Paleozoic and Mesozoic rocks and the Tertiary volcanic rocks.

The outlines of the drainage basins containing anomalous samples (maps C and D) indicate that tin and boron are enriched in certain parts of the Walker Lake quadrangle. Boron in particular, is enriched in a north-south zone running roughly along the boundary between the Sierra Nevada province and the Basin and Range province. Descriptions of many of these anomalous areas are given in the discussions accompanying the multielement geochemical maps (Chaffee, 1988a, b, c).

Those anomalies of molybdenum, boron, and tin associated with intrusive rocks may locate areas containing molybdenum deposits, whereas those anomalies associated with the other rock types may locate areas containing molybdenum or tungsten deposits. Those sites with anomalies of molybdenum in addition to other elements, such as tin and boron, represent the most significant sites for locating molybdenum and tungsten deposits.

## Tungsten and Gold

Maps E and F show the distributions of tungsten and gold, respectively, in samples of stream sediment and concentrate. The generally low background concentrations of these two elements in both sample media cannot be determined in the great majority of the samples by the spectrographic analytical method used in this study; consequently, very few analyses of tungsten in the stream sediment samples or of tungsten or gold in the concentrate samples are available for plotting. We generally determined gold in only those stream-sediment samples showing detectable silver. Thus, information on gold is severely limited. The distributions of arsenic and antimony (Chaffee and others, 1988b) may also be particularly useful in gold exploration. The mineral residences of tungsten and gold are not known for every locality; tungsten probably occurs mostly as scheelite or as a member of the wolframite series in either type of sample. Gold is probably present in both sample types mostly in the elemental form, but may also occur as inclusions of native gold in minerals such as pyrite or arsenopyrite.

Tungsten anomalies can be used to locate tungsten and molybdenum deposits. Gold can be used to locate precious-metal deposits and also to locate the mineralized aureoles around base-metal deposits and possibly other types of deposits.

A limited comparison of the concentrations of tungsten in samples from drainage basins that have contrasting lithologies indicates that this element is probably more enriched in the Mesozoic felsic plutons than in the other rock units. Sufficient analytical information for gold is lacking to indicate whether this element is enriched in certain rock types in the Walker Lake quadrangle. Both tungsten and gold anomalies are most commonly associated with the Paleozoic and Mesozoic rocks. Tungsten anomalies are also locally associated with the Mesozoic intrusive rocks and to a lesser extent with the Tertiary volcanic rocks. Gold anomalies are also locally associated with the Tertiary volcanic rocks.

The outlines of the drainage basins containing anomalous samples (maps E and F) indicate that tungsten and gold are enriched in certain parts of the Walker Lake quadrangle. Descriptions of many of these anomalous areas are given in the discussions accompanying the multielement geochemical maps (Chaffee, 1988a, b, c).

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