DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
MONTANA BUREAU OF MINES AND GEOLOGY

TO ACCOMPANY MAP I-1509
CHAPTERS B-D

APPLICATION OF GEOCHEMICAL DATA TO THE MINERAL RESOURCE APPRAISAL OF THE WALLACE 1° x 2° QUADRANGLE, MONTANA AND IDAHO

By D. L. Leach

INTRODUCTION

The Wallace 1° x 2° quadrangle folio includes a series of mineral resource appraisal maps prepared under the Conterminous United States Mineral Resource Assessment Program (CUSMAP). Also included in this folio are a variety of maps that present geochemical, geological, and geophysical data that were used to arrive at the mineral resource appraisal for the quadrangle. The geochemical maps, compiled from data collected by the U.S. Geological Survey in the Wallace quadrangle from 1978 through 1981, show the distribution and abundance of related elements and delineate areas with anomalous concentrations. The geochemical survey consisted of the collection and analysis of 1,229 samples of stream sediment and 1,080 samples of nonmagnetic heavy-mineral concentrates.

A complete tabulation of the geochemical data used in the Wallace CUSMAP study is available on computer tape from the National Technical Information Service (McDanal and others, 1982). The data are also available, together with various statistical estimates, in U.S. Geological Survey Open-File Report 82-494 (Leach and others, 1982). Maps showing the distribution and abundance of many of the data are shown in many U.S. Geological Survey reports (Leach and Goldfarb, 1986; Leach and others, 1983 a, b, c, d, e, f; Leach and Hopkins, 1986 a and b; Leach and Domenico, 1985 and 1986).

GEOGRAPHY

The Wallace 1° x 2° quadrangle area is in northwest Montana and the panhandle of northern Idaho. The area includes parts of the St. Joe, Lolo, and Coeur d'Alene National Forests. The Flathead Indian Reservation, located in the eastern part of the quadrangle was not included in this study. Much of the Wallace 1° x 2° quadrangle area consists of deeply dissected mountains of the Bitterroot Range, which extends on both sides of the Idado-Montana state line. The area is mostly characterized by moderate relief, but, in places, is as much as 1000 m. Major river drainages include the Clark Fork, St. Joe, Thompson, Coeur d'Alene, and St. Regis Rivers.

GEOLOGY

Most of the area is underlain by Middle Proterozoic rocks of the Belt Supergroup in what is referred to as the Precambrian Belt basin of the northwestern United States and adjacent parts of Canada. The thickness of the Belt section in parts of the Wallace 1° x 2° quadrangle may exceed 20,600 m (Harrison, 1972, p. 1219). The rocks comprising the Belt Supergroup consist largely of fine-grained clastic rock—quartzites, siltites, and argillites. The Belt rocks have been metamorphosed to greenschist facies regionally and to amphibolite facies locally near areas of intrusive rock. The rocks are generally monotonous in appearance, because of their fine grain size and drab colors. More detailed discussions about Belt basin rocks may be found in Harrison and Grimes (1970) and Harrison (1972).

Structurally the rocks in the Wallace 1° x 2° quadrangle area are highly faulted and fractured. Perhaps the most strongly deformed area is the northwest-trending Lewis and Clark line, which is a wide crustal flaw that has existed probably since the Middle Proterozoic. The highly faulted and fractured ground, characteristic of the Wallace 1° x 2° quadrangle, contains a series of mafic to felsic intrusive bodies that include Precambrian and Tertiary mafic dikes and sills and Cretaceous and Tertiary felsic plutons. In a regional sense, the Cretaceous and Tertiary intrusive bodies are outliers of the Idaho batholith, which is about 25 km to the south of the quadrangle, and of the batholithic terrane of eastern Washington and northern Idaho, which is about 45 km northwest of the quadrangle.

KNOWN AND PROBABLE TYPES OF MINERAL DEPOSITS

The mineral resource assessment of the Wallace quadrangle is based upon several mineral resource (nongenetic) models for each type of known or probable metallic mineral resource in the quadrangle. The models are derived from observed characteristics of ore deposits inside the Wallace quadrangle or, if there are no known occurrences inside the quadrangle, from characteristics of deposits as nearby as possible. Each of these models is described in brief here and in detail in the mineral resource appraisal reports of the Wallace CUSMAP folio.

MESOTHERMAL BASE- AND PRECIOUS-METAL VEINS

The mesothermal vein category includes the famed Coeur d'Alene district as well as numerous vein occurrences located over a wide area in the quadrangle. We have combined all the vein occurrences into a single model because we could not establish any geochemical differences between the veins in the Coeur d'Alene district and those widespread through the quadrangle.

By local usage, the Coeur d'Alene district includes an area about 26 miles long and 9 miles wide, centered more or less around the town of Osburn, Idaho. The Wallace quadrangle contains the eastern part of the district. A larger area referred to as the greater Coeur d'Alene mineral belt extends along the Lewis and Clark line from Coeur d'Alene, Idaho, on the west, to Superior, Mont., on the east. Within the Wallace quadrangle, it includes the area between Wallace, Idaho, and Superior, Mont.

The lead-zinc-silver-copper ore deposits in the Coeur d'Alene district occur as fissure-filled veins and replacement ore bodies. Principal ore minerals are galena, sphalerite, tetrahedrite, and chalcopyrite. Parts of the district appear to be zoned as indicated by the common occurrence of copper sulfides on the eastern end, through predominantly lead-zinc-silver sulfides and sulfosalts, to zinc and lead sulfides on the western end. Stibnite tends to be most abundant in veins that are in a crude outer zone around the district. Outside the district, but within the greater Coeur d'Alene mineral belt, small areas of replacement or fissure-filled veins may be dominated by lead, gold, or antimony. Outside the Coeur d'Alene district and the greater Coeur d'Alene mineral belt, veins of this deposit type are mostly fissure fillings but include some replacement ore zones. They commonly occur near exposed felsic plutons or in areas of positive magnetic anomalies. Primary ore minerals are galena, sphalerite, bornite, and chalcopyrite accompanied by varying amounts of gold or silver.

Host rocks for mesothermal veins are formations of the Belt Supergroup—mostly the Prichard,Burke, Revette, and St. Regis Formations, although some veins occur in the stratigraphically higher Wallace Formation. Present production from active mines in the Coeur d'Alene district are in veins located in quartzite and siltite units in the Revette and St. Regis Formations.

STRATABOUND COPPER-SILVER

Stratabound copper-silver occurrences have been found in almost all the Belt formations, excluding the Prichard, Bonner, and Pilcher Formations. These occurrences are generally small, and the copper-silver grade is highly variable from location to location. Ore occurrences known to date occur northwest of the Wallace quadrangle boundary in quartzites of the Revett Formation. The sulfides are dominately bornite, chalcocite, and digenite with lesser amounts of chalcopyrite, tetrahedrite, and covellite. Galena, however, is an important constituent in some of the occurrences in the Revett Formation.

SULLIVAN-TYPE LEAD-ZINC

Sullivan-type stratabound lead-zinc deposits have not been identified to date within the Wallace quadrangle. However, some of the geologic characteristics of the Sullivan deposit occur in the lower Prichard Formation—which is stratigraphically equivalent to the host formation (Middle Proterozoic Aldridge) of the Sullivan deposit. The principal minerals of the Sullivan mine are galena, sphalerite, pyrite, and pyrrhotite. Minor constituents include chalcopyrite, arsenopyrite, magnetite, tourmaline, cassiterite, boulangerite, jamesonite, and tetrahedrite.

EPITHERMAL SILVER

Epithermal high-grade silver deposits are associated with a small Tertiary volcanic center in the northeastern part of the Wallace quadrangle. Veins and pockets of primary ore occur in fumerole holes and tubes, and at contacts between porphyry plugs and their host rocks.

STOCKWORK-PORPHYRY MOLYBDENUM-TUNGSTEN

The single known occurrence of a stockwork-porphyry molybdenum-tungsten deposit in the Wallace quadrangle is near Liver Peak, approximately 15 mi north of the mouth of the Thompson River. The deposit is associated with a buried intrusive body, which is indicated by a prominent positive aeromagnetic anomaly.

PLACER GOLD

Placer gold has been found in many areas of the Wallace quadrangle in stream sediments of old (Tertiary and Pleistocene) as well as modern (Holocene) drainages or other valley-fill deposits. The most abundant prospects and dredging operations have been along present stream courses in second- or third-order tributaries to principal rivers such as the Clark Fork, St. Regis, and Coeur d'Alene Rivers. Minor amounts of gold have been reported from higher level terranes along principal rivers.

SAMPLING PLAN

Most sample sites were chosen on small-order drainages, generally first- or second-order drainages. Sampling sites were selected at a minimum density of one site per cell, with the cell being an area of approximately 4 sq mi. Some cells may not contain a sample site because of factors such as lack of small-order stream drainage or inaccessibility. Some cells may contain more than one sample site because of resampling for various reasons.

We generally avoided sampling streams that contain mines within the stream catchment area, which explains the lack of sample sites within the most active part of the Coeur d'Alene district. However, a large amount of geochemical data from the district, based on soil and rock sampling, has been published by Gott and Cathrall (1980). The numerous prospects and mines scattered throughout the Wallace quadrangle undoubtedly have contaminated a small number of samples even though we attempted to avoid such contamination. Many of the potentially contaminated samples are near the mines and smelter activity in the Coeur d'Alene district. A limited number of samples were collected from selected stream drainages that contain exposures of mineralized rocks that represent the various types of mineral resources known in the quadrangle. The data from these samples were used to characterize the suite of elements associated with each known mineral resource type. In addition, a detailed geochemical study was conducted near a stratabound copper-silver occurrence in the Cabinet Mountains Wilderness, north of the quadrangle boundary (Cazes and others, 1981; Cazes, 1981).

STREAM SEDIMENTS

The standard sediment sample was composited from at least five subsamples taken along a 10-m stretch of the active stream channel using a polyethylene or aluminum scoop. After drying, the composited sample was sieved using a stainless steel minus-80-mesh (180-μm opening)screen. The material passing through the minus-80-mesh screen was pulverized to less than 100 mesh for analysis. In the discussion that follows, the term "stream sediment" refers to the minus-80-mesh fraction.

HEAVY-MINERAL CONCENTRATES

A heavy-mineral concentrate sample was collected at most sites using a standard gold pan. Heavy-mineral concentrates were not collected from some sites because of the near absence of heavy minerals in some stream sediments. Commonly, 3-4 kg of composited sediment were collected to yield the desired 30-60 g of concentrate. At the laboratory, the sample was air dried, and the highly magnetic material (that is, magnetite or ilmenite) was removed by an electromagnet. Light-weight material in the concentrate was then separated by allowing the heavier fraction to settle through bromoform (specific gravity 2.8). The resulting heavy-mineral fraction was then separated into a nonmagnetic and magnetic fraction using a Frantz Isodynamic Separator[1] at a setting of 0.6 ampere, with 15° forward and 15° side settings. The nonmagnetic fraction was pulverized in an agate mortar before analysis.

ANALYTICAL PROCEDURES

SEMIQUANTITATIVE EMISSION SPECTROGRAPHY

Each stream sediment and nonmagnetic heavy-mineral concentrate sample was analyzed semiquantitatively for 31 elements using an optical emission spectrograph, according to the method outlined by Grimes and Marranzino (1968).

ATOMIC-ABSORPTION SPECTROMETRY

Each stream sediment was analyzed by atomic-absorption spectrometry for total metal concentration of silver, bismuth, cadmium, copper, lead, antimony, and zinc to obtain lower detection limits than available by emission spectrographic methods. This suite of elements was selected because they are important constituents of most of the mineral resource types in the quadrangle. Atomic-absorption spectrometry was also used to determine weak hydrochloric partially extractable concentrations of the mentioned elements except cadmium in each sample of stream sediment. The weak acid extraction dissolves the loosely-bound metals associated with clays and surface coatings on iron-manganese oxides. The extraction also dissolves the majority of secondary minerals such as sulfates, carbonates, and oxides, stable under oxidizing conditions, but will not significantly dissolve most sulfide minerals. This method was used to enhance potential hydromorphic anomalies that may be present in sediment dominated by mineralogically mature Belt sediments.

The partially extractable digestion method, similar to the method described by Viets and others (1979), uses a 3.6-N hydrochloric-acid solution containing 20 percent ascorbic acid and 10 percent potassium iodide in contact with the sample for 30 minutes at room temperature. The metals that have gone into solution are then selectively extracted into an organic phase composed of Aliquat-336 (tricaprylymethylammonium chloride) and methyl-isobutyl ketone. The elements are then determined from the organic phase by atomic-absorption spectroscopy. Total metal concentrations are determined by digestion of the sample in a solution of hydrofluoric and nitric acids followed by extraction into the Aliquat-336 and methyl-isobutyl-ketone phase and then analyzed by atomic-absorption spectrometry.

MINERAL RESOURCE ASSESSMENT AND APPRAISAL OF GEOCHEMICAL ANOMALIES

For each of the mineral resource models, a suite of elements that best characterize the most common geochemical signatures has been established by detailed studies at known mineral occurrences and from information available from review of publications. The geochemical signatures for these various types are given in table 1. In addition, we have developed criteria to identify a range in favorability for each geochemical signature, and we have assigned favorability scores to the criteria that form subdivisions within each. The point scores range from 0 through positive numbers that were deliberately kept low for each geochemical signature. Thus a few broad subdivisions could be used for classifying the reconnaissance data. Many finer categories, though desirable, would require more detailed information than was available in the quadrangle.

The geochemical favorability scores for subareas of the quadrangle were combined with favorability scores from other kinds of diagnostic data using a matrix diagram (fig. 1) that shows increasing levels of confidence and favorability; the combination of these elements establishes a measure of probability for the occurrence of an ore deposit. A more detailed discussion of the procedures used for resource appraisal of the Wallace quadrangle is presented by Harrison and others (1986).

MESOTHERMAL BASE- AND PRECIOUS-METAL VEINS

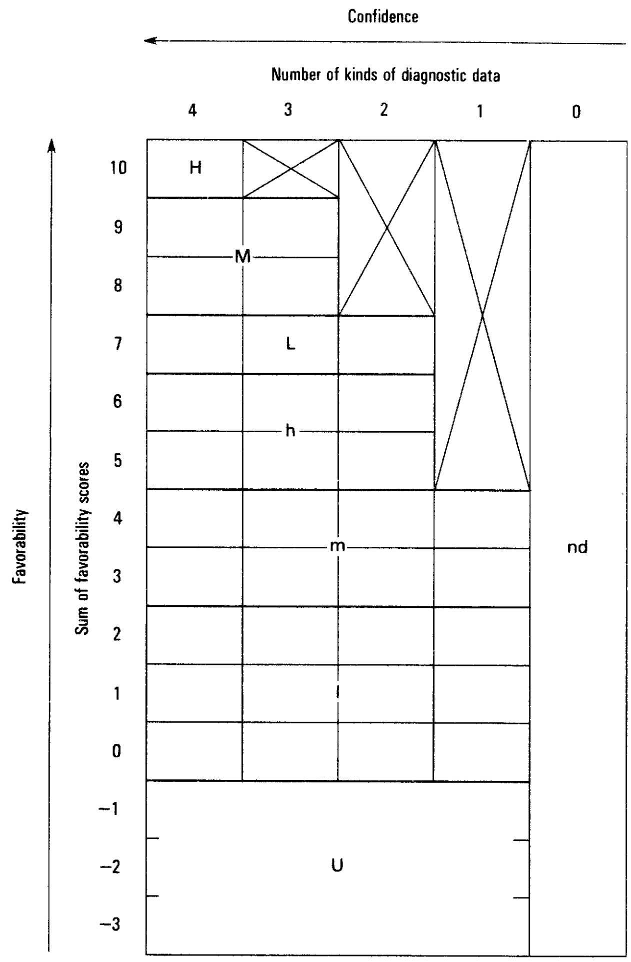
The mesothermal veins may range in composition from simple lead-zinc or copper ores, through those that also contain gold and silver, to highly complex veins where antimony, arsenic, nickel, cadmium, cobalt, iron, and barium may also be significant components of the ores. The wide variety of ore minerals present is responsible in part for the complex geochemical signature observed. Nearly all possible combinations of anomalous silver, arsenic, bismuth, cadmium, copper, lead, antimony, and zinc are observed in samples of stream sediments and heavy-mineral concentrates near known occurrences of mesothermal veins.

One of the difficulties in evaluating the favorability for mesothermal veins at this reconnaissance scale is that some of the mineralogically simple veins may yield a simple geochemical signature that shows only anomalous amounts of one or two elements. A simple suite of anomalous elements may also be derived from other types of mineral occurrences, such as stratabound copper-silver (may show Cu ± Ag ± Pb), or epithermal silver (may show Ag ± Zn), or stockwork-porphyry molybdenum-tungsten (may show Ag ± Cu ± Zn), or Sullivan-type occurrences (may show Pb ± Zn). However, it is unusual for any of these other occurrences to show consistently all four elements; whereas samples from areas of known mesothermal veins tend to contain all four or relatively high amounts of at least three. In addition to having a complex geochemical signature, mesothermal veins commonly contain antimony as an important constituent. Therefore, the procedure used to assign levels of favorability to subareas of the quadrangle was based upon a measure of the number of signature elements present in anomalous concentrates, with an emphasis on antimony.

Table 1.—*Elements which may be present in anomalous concentrations for the mineral resource occurrence models for the Wallace 1° x 2° folio*

[Underscored elements were used as signature elements for the particular resource type.]

Mineral-resource type	Total metal in stream sediments	Partially extractable metal in stream sediments	Nonmagnetic heavy-mineral concentrate
Mesothermal veins	Ag, Cu, Cd, Pb, Sb, Zn, minor Bi, Mo, Mn	Ag, Cu, Cd, Pb, Sb, Zn	Ag, As, Cu, Pb, Sb, Zn, minor Cd, Bi, Mo Mo
Stratbound copper-silver	Ag, Cu, minor Bi, Mo, Hg, Zn, Pb	Ag, Cu, minor Pb	Ag, Cu, minor Pb
Sullivan-type stratabound lead-zinc	Pb, Zn, minor Ag, Sb, Cu	Pb, Zn	Pb, Zn
Stockwork porphyry molybdenum-tungsten	Ag, Bi, Cd, Cu, Zn	Ag, Bi, Cu, Zn	Bi, Mo, Sn, W
Epithermal high-grade silver	Ag, Zn, minor Cd	Zn	None detected
Placer gold	None detected	None detected	Au, minor Ag



Probability of ore deposit occurrence
H, highly diagnostic
M, moderately diagnostic
L, slightly diagnostic
h, highly suggestive
m, moderately suggestive
l, slightly suggestive
nd, no diagnostic data
U, unfavorable

Favorability characteristics	Range of favorability scores
Geologic	−2 to +4
Geochemical	0 to +3
Geophysical	−1 to +2
Known mineral occurrences	0 to +1
Total range	−3 to +10

Figure 1.—Example of a confidence-favorability diagram (from Harrison and others, 1986)

In an effort to quantify the complex geochemical signature of mesothermal veins, a detailed four-step procedure was used to identify areas that have some level of geochemical favorability for mesothermal veins. This procedure was described in detail by Leach (1982 and 1986) and is briefly summarized here. The first step of the procedure identified areas of the quadrangle that ranked in the top 25th percentile for the sum of the ranks of Pb + Zn + Cu + Ag and Pb + Zn in samples of stream sediments. The second step of the procedure identified favorable areas of the quadrangle from the distribution of samples of nonmagnetic heavy-mineral concentrates with anomalous concentrations of lead, zinc, copper, silver, arsenic, and antimony. The third step identified favorable areas of the quadrangle on the basis of the relative enrichment of partially extractable antimony in samples of stream sediment. Finally, the favorable areas identified in the first three steps were integrated into a single map showing the geochemical favorability for mesothermal base- and precious-metal veins (Leach, 1982).

STRATABOUND COPPER-SILVER

The geochemical signature of samples that may be related to stratabound copper-silver is anomalous concentrations of copper or silver with lead as a permissible addition. Sample sites with anomalous concentrations of zinc, cadmium, antimony, bismuth, or arsenic in samples of stream sediment or heavy-mineral concentrates were not included as sites with a stratabound-type geochemical signature. We recognize that these elements may rarely be present in anomalous concentrations in some stratabound occurrences; however, they are characteristic of other mineral resource types in the Wallace quadrangle. The simple geochemical signature, copper or silver ± lead, and the absence of other anomalous metal concentrations are consistent with the data from a detailed geochemical study made near a stratabound copper-silver occurrence in the Cabinet Mountains Wilderness (Cazes and others, 1981), north of the quadrangle boundary. This study showed that total metal concentrations of copper and silver in samples of stream sediment were generally anomalous whereas the partially extractable metal and heavy-mineral concentrates generally contained either anomalous copper or silver. The distribution of anomalous lead was more erratic than either copper or silver. The geochemical favorability scores shown below range from 0 to +3.

Favorability score	Geochemical signature
+3	Anomalous copper and silver ± lead in stream sediment, anomalous extractable copper ± silver or lead in stream sediments, anomalous copper ± silver or lead in heavy-mineral concentrates
+2	Anomalous copper or silver ± lead in stream sediments, anomalous copper ± silver or lead in heavy-mineral concentrates, or anomalous partially extractable concentrations in stream sediments
+1	Anomalous copper or silver in a single data set
0	No copper or silver in any data set

SULLIVAN-TYPE LEAD-ZINC

For the Wallace quadrangle, samples of the Prichard Formation and samples of stream sediment that contain anomalous concentrations of zinc and(or) lead and that are underlain by the Prichard Formation have some potential for Sullivan-type mineral occurrences. Other anomalous elements that are permissible in this occurrence model, in addition to lead and zinc, include antimony silver, copper, and cadmium. We recognize that this suite of elements may also be produced from mesothermal vein systems—therefore, the geochemical signature is permissible for both occurrence models. The favorability scores and the criteria used for the Sullivan-type stratabound lead-zinc occurrence model are given below:

Favorability score	Geochemical signature
+2	Anomalous totally or partially extractable concentrations of lead and zinc in samples of stream sediment
+1	Anomalous totally or partially extractable concentrations of lead or zinc in samples of stream sediment
0	No anomalous totally or partially extractable concentrations of lead or zinc in samples of stream sediment

EPITHERMAL SILVER

Samples of stream sediment from this area are characterized by anomalous total metal concentrations of zinc and silver; anomalous concentrations of cadmium and molybdenum may also be present. Partially extractable metal concentrations in samples of stream sediment and metal concentrations of the nonmagnetic heavy-mineral concentrates are not anomalous in this area. Therefore, only the total metal concentration of zinc and silver were used as the geochemical signature for this deposit type. A favorability score of +1 was assigned to areas near the Tertiary volcanic crater that contain anomalous concentrations of either zinc or silver.

STOCKWORK-PORPHYRY MOLYBDENUM-TUNGSTEN

Samples of stream sediment in this area are characterized by anomalous totally and partially extractable concentrations of bismuth, silver, copper, zinc, and cadmium. Notably absent from this suite are antimony and lead. However, this suite of elements includes those characteristic of other deposit types—particulary the many occurrences of mesothermal veins in the quadrangle. Therefore, the most reliable geochemical signature for this deposit type is anomalous concentrations of bismuth, tungsten, and molybdenum in the heavy-mineral concentrates. Tin was included with bismuth, tungsten, and molybdenum in assigning geochemical favorability for this deposit type because it is commonly associated with the highly differentiated intrusives characteristic of the Liver Peak stock. The geochemical favorability scores and the criteria for this deposit type are given below:

Favorability score	Geochemical signature
±3	Anomalous concentrations of tungsten, molybdenum and bismuth in samples of nonmagnetic heavy-mineral concentrates. Tin may be present.
+2	Two of the above three elements ± tin in sample of nonmagnetic heavy-mineral concentrates
+1	Tin plus one of the three elements shown for the +3 category (tungsten, molybdenum or bismuth) in sample of nonmagnetic heavy mineral concentrates
0	Single-element anomaly of either tungsten, molybdenum, bismuth or tin

PLACER GOLD

Detectable gold in samples of nonmagnetic heavy-mineral concentrates was used to assign geochemical favorability to stream drainages for silver gold. A favorable score of +1 was assigned to the 14 locations that contained detectable gold.

[1]Any use of trade names is for descriptive purposes only and does not imply endorsement by the U.S. Geological Survey.

REFERENCES

Cazes, D. K., 1981, Geochemical analyses of stream sediment and heavy-mineral concentrates collected near a stratabound Cu-Ag occurrence in the Cabinet Mountains Wilderness, Montana: Moscow, University of Idaho, M.S. thesis, 120 p.

Cazes, D. K., Domenico, J. A., Hopkins, D. M., and Leach, D. L., 1981, Geochemical analyses of stream sediment and heavy-mineral concentrates collected near a stratabound Cu-Ag occurrence in the Cabinet Mountains Wilderness, Montana: U.S. Geological Survey Open-File Report 81-665, 11 p.

Gott, G. B., and Cathrall, J. B., 1980, Geochemical exploration studies in the Coeur d'Alene district, Idaho and Montana: U.S. Geological Survey Professional Paper 1116, 62 p.

Grimes, D. J., and Marranzino, A. P., 1968, Direct current arc and alternating-current spark emission spectrographic field methods for the semiquantitative analysis of geologic materials: U.S. Geological Survey Circular 591, 6 p.

Harrison, J. E., 1972, Precambrian Belt basin of northwestern United States: Its geometry, sedimentation, and copper occurrences: Geological Society of America Bulletin, v. 83, p. 1215-1240.

Harrison, J. E., and Grimes, D. J., 1970, Mineralogy and geochemistry of some belt rocks, Montana and Idaho: U.S. Geological Survey Bulletin 1312-0, 49 p.

Harrison, J. E., Leach, D. L., and Kleinkopf, M. D., 1986, Resource appraisal maps for mesothermal base- and precious-metal veins in the Wallace 1° x 2° quadrangle, Montana and Idaho: U.S. Geological Survey Miscellaneous Investigations Series Map I-1509-I.

Leach, D. L., 1982, Geochemical favorability for mesothermal veins in the Wallace 1° x 2° quadrangle, Montana and Idaho: U.S. Geological Survey Open-File Report 82-577.

________1986, Geochemical favorability for mesothermal base- and precious-metal veins in the Wallace 1° x 2° quadrangle, Montana and Idaho: U.S. Geological Survey Miscellaneous Field Studies Map MF-1354-C.

Leach, D. L., and Domenico, J. A., 1985, Distribution of samples of nonmagnetic heavy-mineral concentrates having anomalous concentrations of tungsten, bismuth, tin, and molybdenum from the Wallace 1° x 2° quadrangle, Montana and Idaho: U.S. Geological Survey Open-File Report 85-700, 7 p.

________1986, Geochemical map showing distribution of samples of nonmagnetic heavy-mineral concentrates that contain anomalous concentrations of antimony, arsenic, copper, lead, silver, and zinc in the Wallace 1° x 2° quadrangle, Montana and Idaho: U.S. Geological Survey Miscellaneous Investigations Series Map I-1509-B.

Leach, D. L., Domenico, J. A., Hopkins, D. M., Dawson, H. E., and Goldfarb, R. J., 1982, Data report and statistical summary for samples of stream sediment and nonmagnetic heavy-mineral concentrates from the Wallace 1° x 2° quadrangle, Montana and Idaho: U.S. Geological Survey Open-File Report 82-494.

Leach, D. L., and Goldfarb, R. J., 1986, Maps showing the distribution of sum of the ranks concentrations of lead, zinc, copper, and silver and lead and zinc in samples of stream sediment from the Wallace 1° x 2° quadrangle, Montana and Idaho: U.S. Geological Survey Miscellaneous Field Studies Map MF-1354-D.

Leach, D. L., and Hopkins, D. M., 1986a, Geochemical map showing distribution of stream-sediment samples that contain anomalous concentrations of antimony, bismuth, cadmium, copper, lead, silver, and zinc in the Wallace 1° x 2° quadrangle, Montana and Idaho: U.S. Geological Survey Miscellaneous Investigations Series Map I-1509-C.

________1986b, Geochemical map showing distribution of stream-sediment samples that contain anomalous concentrations of partially-extractable antimony, bismuth, copper, lead, silver, and zinc in the Wallace 1° x 2° quadrangle, Montana and Idaho: U.S. Geological Survey Miscellaneous Investigations Series Map I-1509-D.

Leach, D. L., Hopkins, D. M., and Domenico, J. A., 1983a, Distributions of total cadmium in samples of nonmagnetic heavy-mineral concentrate and of total and partially-extractable cadmium in samples of stream sediment from the Wallace 1° x 2° quadrangle, Montana and Idaho: U.S. Geological Survey Open-File Report 83-305.

Leach, D. L., Hopkins, D. M., Domenico, J. A., and Dawson, H. E., 1983b, Distributions of total copper in samples of nonmagnetic heavy-mineral concentrate and of total and partially-extractable copper in samples of stream sediment from the Wallace 1° x 2° quadrangle, Montana and Idaho: U.S. Geological Survey Open-File Report 83-307.

________1983c, Distributions of total antimony in samples of nonmagnetic heavy-mineral concentrate and of total and partially-extractable antimony in samples of stream sediment from the Wallace 1° x 2° quadrangle, Montana and Idaho: U.S. Geological Survey Open-File Report 83-306.

________1983d, Distributions of total lead in samples of nonmagnetic heavy-mineral concentrate and of total and partially-extractable lead in samples of stream sediment from the Wallace 1° x 2° quadrangle, Montana and Idaho: U.S. Geological Survey Open-File Report 83-304.

Leach, D. L., Hopkins, D. M., Domenico, J. A., and Goldfarb, R. J., 1983e, Distributions of total silver in samples of nonmagnetic heavy-mineral concentrate and of total and partially-extractable silver in samples of stream sediment from the Wallace 1° x 2° quadrangle, Montana and Idaho: U.S. Geological Survey Open-File Report 83-308.

________1983f, Distributions of total zinc in samples of nonmagnetic heavy-mineral concentrate and of total and partially-extractable zinc in samples of stream sediment from the Wallace 1° x 2° quadrangle, Montana and Idaho: U.S. Geological Survey Open-File Report 83-309.

McDanal, S. K., Hopkins, D. M., and Domenico, J. A., 1982, Spectrographic and chemical analysis of stream sediments and concentrate samples from the Wallace 1° x 2° quadrangle, Idaho and Montana: U.S. Geological Survey Report GS-82-013; available only from U.S. Department of Commerce National Technical Information Service, Springfield, VA 22151.

Viets, J. G., Clark, J. R., and Campbell, W. L., 1979, A rapid, partial leach and organic separation for the determination of Ag, Bi, Cd, Cu, Pb, Sb, and Zn by atomic absorption spectrometry: Association of Exploration Geochemists, Basin and Range Symposium, Tucson, Arizona, abstracts with program, 12 p.