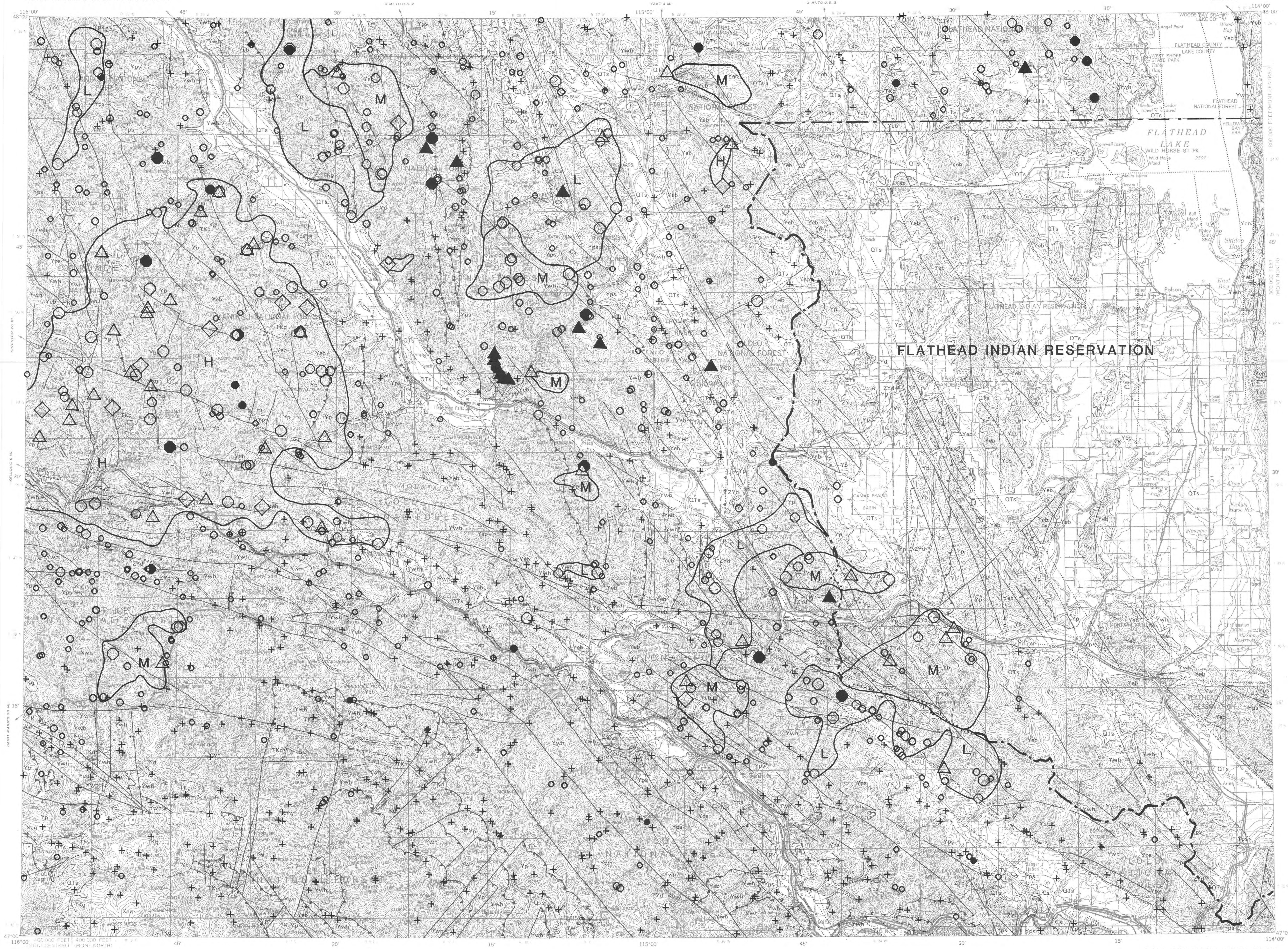
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

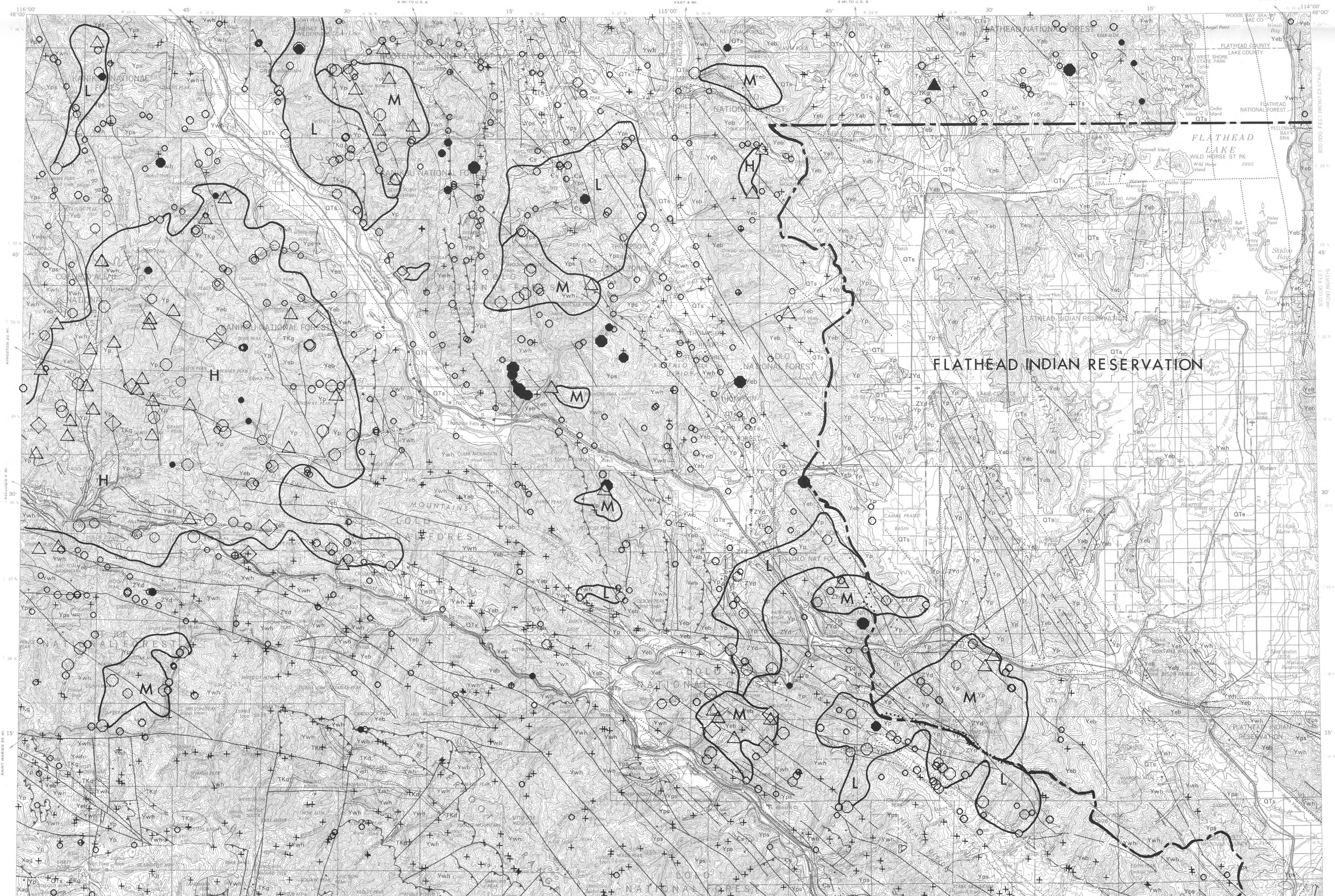
MISCELLANEOUS FIELD STUDIES
MAP MF-1354-D



Base from U.S. Geological Survey, 1956, revised 1981

Geology by J.E. Harrison, A.B. Griggs, and J.D. Wells, 1976–1980; assisted by H.R. Covington, 1972, Joseph Boggs, 1973, and J.P. Harrison, 1978–80

MAP A. SUM OF THE RANKS FOR CONCENTRATIONS OF LEAD+ZINC+COPPER+SILVER



Base from U.S. Geological Survey, 1956, revised 1981

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CONTOUR INTERVAL 200 FEET
WITH SUPPLEMENTARY CONTOURS AT 100 FOOT INTERVALS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

MAP B. SUM OF THE RANKS FOR CONCENTRATIONS OF LEAD+ZINC

MAPS SHOWING THE DISTRIBUTION OF SUM OF THE RANKS FOR CONCENTRATIONS OF LEAD+ZINC+COPPER+SILVER AND LEAD+ZINC IN SAMPLES OF STREAM SEDIMENT FROM THE WALLACE 1°X2° QUADRANGLE, MONTANA AND IDAHO

By

D.L. Leach and R.J. Goldfarb

1989

CORRELATION OF MAP UNITS

QTs — QUATERNARY AND TERTIARY
Tv — TERTIARY
TKg, TKd — TERTIARY AND CRETACEOUS
Unconformity
Ꞓs — CAMBRIAN
Unconformity
ZYd — PROTEROZOIC Z AND Y
Yps — Missoula Group — Belt Supergroup — PROTEROZOIC Y
?
Ywh — Belt Supergroup — PROTEROZOIC Y
Yeb, Yp — Ravalli Group — Belt Supergroup — PROTEROZOIC Y
Unconformity
Xag — PROTEROZOIC X

DESCRIPTION OF GEOLOGIC MAP UNITS

QTs	VALLEY FILL DEPOSITS (QUATERNARY AND TERTIARY)—Alluvium, glacial deposits, and semiconsolidated to consolidated conglomerate interlayered in places with shale, coal, and volcanic ash; shown only in major valleys and basins or along main stream courses.
Tv	VOLCANIC ROCKS (TERTIARY)—Largely andesitic to dacitic welded tuff
TKg	GRANITIC INTRUSIVE ROCKS (TERTIARY AND CRETACEOUS)
TKd	DIORITIC INTRUSIVE ROCKS (TERTIARY AND CRETACEOUS)
Ꞓs	SEDIMENTARY ROCKS (CAMBRIAN)—Includes Red Lion Formation, Hasmark Dolomite, Silver Hill Formation, Flathead Quartzite, and equivalent rocks
ZYd	DIORITIC TO GABBROIC SILLS AND DIKES (PROTEROZOIC Z AND Y)
Yps	MISSOULA GROUP (PROTEROZOIC Y)—Includes Pilcher, Libby, Garnet Range, and McNamara Formations, Bonner Quartzite, and Striped Peak, Mount Shields, Shepard, and Snowslip Formations
Ywh	WALLACE AND HELENA FORMATIONS (PROTEROZOIC Y)
Yeb	RAVALLI GROUP (PROTEROZOIC Y)—Includes Empire, St. Regis, Spokane, Revett, and Burke Formations
Yp	PRICHARD FORMATION (PROTEROZOIC Y)
Xag	ANORTHOSITE, SCHIST, AND GNEISS (PROTEROZOIC X)

CONTACT

FAULT—Dotted where concealed. Bar and ball on downthrown side; arrows show relative direction of apparent horizontal movement

THRUST FAULT—Dotted where concealed. Sawteeth on upper plate

EXPLANATION

Symbol	Percentile Class of samples
◇	100-99
△	<99-95
○	<95-90
○	<90-85
○	<85-75
○	<75-50
+	<50

Solid symbols are samples excluded from assignment of favorability (see text)

FAVORABILITY		SCORE
H	High	4
M	Medium	3
L	Low	2

INTRODUCTION

This set of maps is part of a folio of maps of the Wallace 1° x 2° quadrangle, Montana and Idaho, prepared under the Conterminous United States Mineral Assessment Program (CUSMAP). The publications in this series are given in the bibliography of the Wallace quadrangle folio (Harrison and others, 1986f). The maps presented here show the distribution of the sum of the ranks for concentrations of lead + zinc + copper + silver and lead + zinc in samples of minus-80-mesh stream sediments from the Wallace quadrangle. These rank sums give an indication of the favorability for occurrences of mesothermal base- and precious-metal veins in the Wallace quadrangle. In addition, on the basis of our interpretation of the rank sums, we show broad areas of the quadrangle that we believe have potential for the occurrence of mesothermal veins.

The areas of favorability shown on these maps represent the first step of a three-step procedure to assign geochemical favorability for mesothermal base- and precious-metal veins to areas of the quadrangle. The second step (Leach and Domenico, 1986) 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 (Leach and others, 1983) identified favorable areas of the quadrangle based upon 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, 1989). A mineral appraisal for the mesothermal base- and precious-metal veins (Harrison and others, 1986c) was made using the geochemical favorability map together with maps showing favorability indicated by lithology, structure, known mineral occurrences, and geophysics.

Samples of stream sediment were collected from 1,229 locations in the Wallace 1° x 2° quadrangle. Our sample coverage is incomplete on the Flathead Indian Reservation where we were asked to not sample. Each sample was analyzed by atomic-absorption spectrometry for total and partially extractable concentrations of six metals and by semiquantitative emission spectroscopy for 31 elements. For these maps, we used the total concentrations of lead, zinc, copper, and silver in the stream sediments as determined by atomic-absorption spectrometry. A complete tabulation of the data, detailed discussion of the sampling and analytical methods, and statistical summaries of the data are presented by Leach and others (1982). The data are also available in computer tape from the National Technical Information Service (McDanal and others, 1982).

OCCURRENCE MODEL

The Wallace folio includes a series of mineral resource appraisal maps based upon mineral occurrence (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 in the Wallace quadrangle or, if there are no known occurrences in the quadrangle, from characteristics of deposits as nearby as possible. For each of these occurrence models, we have identified a suite of elements that best characterizes the most common geochemical signature (table 1). The mesothermal vein category includes vein occurrences of the famed Coeur d'Alene district as well as numerous vein occurrences located over a wide area in the quadrangle. We have combined all of 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 throughout the quadrangle.

By local usage, the Coeur d'Alene district includes an area about 26 mi long and 9 mi 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, and silver ore deposits in the Coeur d'Alene district are found 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, and 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 Au or Ag.

Host rocks for mesothermal veins are formations of the Belt Supergroup--mostly the Prichard, Burke, Revett, 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 is from veins located in quartzite and siltite units in the Revett and St. Regis Formations.

The mesothermal-type deposits 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 concentrations of silver, bismuth, cadmium, copper, lead, antimony, and zinc are observed in samples of stream sediments near known occurrences of mesothermal veins (see Leach and Hopkins, 1988). For our identification of favorable ground for mesothermal veins using samples of stream sediment, we considered the total metal concentrations of lead, zinc, copper, and silver. Antimony was also considered but treated separately (see Leach and others, 1983). Cadmium, which is commonly present in anomalous concentrations in stream sediments near mesothermal veins, was not used as a signature element. Cadmium is so closely related to zinc, commonly in sphalerite, that use of both elements would in effect give double weight to a single variable. Bismuth, also common to some mesothermal veins, was not used because its high local variability in the Wallace quadrangle limits its usefulness to define regional trends. Some potentially useful elements (Sb, Mo, and Au) in stream sediments were not included in the geochemical signature for mesothermal veins because only a few samples contained detectable concentrations with the analytical technique used.

SUM OF RANKS

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 in the stream sediments 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 Pb ± 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 stream-sediment samples from areas of known mesothermal veins tend to contain all four or relatively high amounts of at least three. Because mesothermal veins generally contain lead and zinc and tend to yield a more complex suite of elements than do the other resource types, a measure of the total content of lead, zinc, copper, and silver would be favorably weighted to the mesothermal-type occurrences.

To quantify this suite of elements for each sample of stream sediment, we chose to use a simple nonparametric statistical treatment of the data to rank each sample based upon the relative concentration of all four elements. This allowed us to compare the relative elemental content of the samples of stream sediment while avoiding absolute or threshold concentrations to identify anomalous samples. In the statistical procedure, all 1,229 samples of stream sediment were assigned a rank number for their lead, zinc, copper, and silver concentrations. For example, the sample with the greatest lead concentrations was assigned 1,229, the sample with the second greatest concentrations 1,228, and so forth. If a number of samples had the same concentration, they were all ranked equally. This procedure was completed for all four elements, and then the sum of all four rank numbers was determined for each sample. The net effect of this procedure was to transform four separate elemental distributions (fig. 1) into a single unitless distribution that represents a total-metal signature for the four summed elements. The rank sums were divided into seven percentile classes that are 100-99, <99-95, <95-90, <90-85, <85-75, <75-50, and <50. In order to describe broad regional geochemical trends, the locations of samples with rank sums falling within these percentiles were plotted at a scale of 1:250,000 (map A).

In addition to the rank sums for lead + zinc + copper + silver we computed the rank sums for lead + zinc only and prepared a plot (map B) using the same criteria as before. This plot was necessary to identify areas possibly containing lead-zinc mesothermal veins that may have low concentrations of silver and copper.

The rank sums shown on the maps indicate for each sample the relative total-metal content of lead + zinc + copper + silver and for lead + zinc. Although we believe that samples with high rank sums for these two suites of elements are most suggestive of mesothermal vein occurrence, some samples from other occurrence types were not completely excluded. Using our reconnaissance-scale geological and geochemical data, it is not possible to unequivocally classify each and every anomalous sample into an occurrence model. Some of the uncertainties and distinctions for each occurrence model as they relate to the rank sums are discussed below.

Stratabound copper-silver--The presence of anomalous concentrations of copper and(or) silver, with lead as a permissable addition was used to identify geochemically favorable ground for stratabound copper-silver occurrences (Harrison and others, 1986b). Samples that contained anomalous concentrations of other elements not characteristic of stratabound copper-silver occurrence were excluded from consideration in our appraisal for this occurrence type. Some samples that met our criteria for stratabound copper may have high (but yet below threshold) concentrations of zinc, antimony, cadmium, and so forth, and may be more related to mesothermal veins than stratabound copper-silver occurrences. This points out one of the difficulties in applying a fixed threshold value to reconnaissance-scale geochemical data on samples derived from a variety of rock types, topography, and mineral resource types. Another complication arises from the possible spatial coincidence of the mesothermal veins with stratabound copper-silver. Stratabound copper-silver deposits occur within the Coeur d'Alene district, and there may be stratabound ore zones within some of the mesothermal vein deposits. In addition, some stratabound copper-silver deposits in the Precambrian Belt rocks are cut by mesothermal veins. Samples collected from drainage basins containing both mineral resource types could have geochemical characteristics of either type. Most samples that were assigned to the stratabound copper-silver category do have low rank sums; however, 13 of the 58 samples assigned to stratabound copper-silver type do have high rank sums for the elements that comprise the mesothermal vein category. It is not possible to determine if these samples reflect atypical stratabound occurrences, spatial coincidence of more than one resource type, or mineralogically simple mesothermal veins. Because the samples have been assigned to the stratabound copper-silver category, we have excluded them from consideration for mesothermal veins.

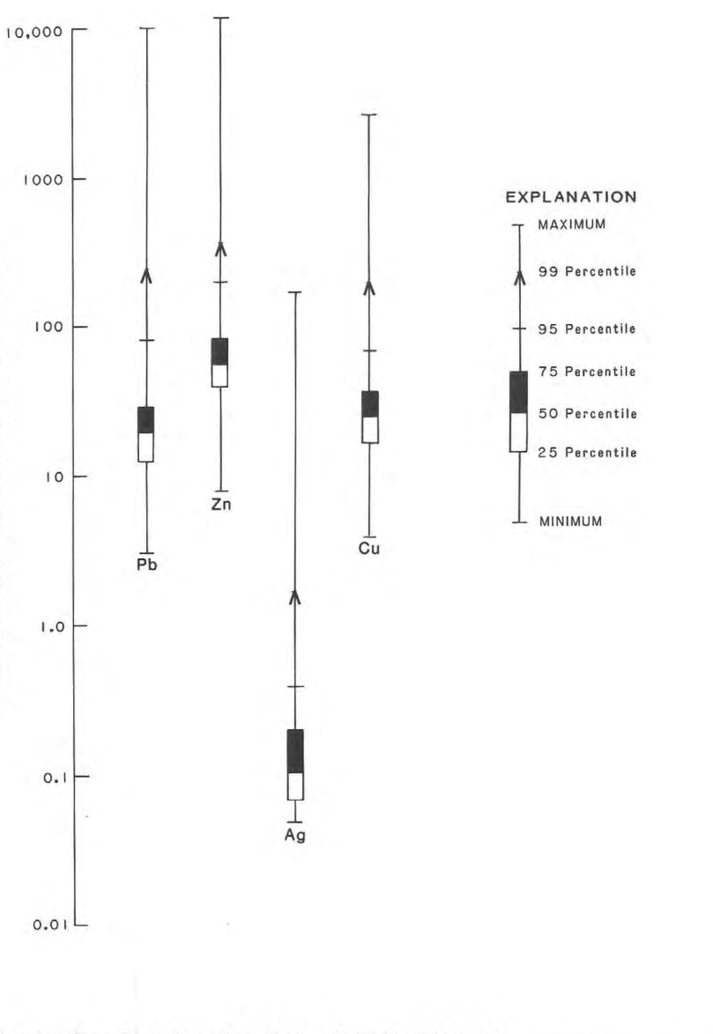

Figure 1.--Boxplot showing distribution of concentrations of lead, zinc, silver, and copper in samples of stream sediment from the Wallace 1° x 2° quadrangle, Montana and Idaho.

Stockwork porphyry molybdenum-tungsten--The single known occurrence of a stockwork porphyry molybdenum-tungsten deposit in the Wallace quadrangle is 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. The geochemical signature used to identify favorable areas in the Wallace quadrangle for stockwork porphyry molybdenum and tungsten occurrences is anomalous concentrations of bismuth, tin, tungsten, and molybdenum in samples of nonmagnetic heavy minerals (Harrison and others, 1986e). Samples of stream sediment near the known occurrence contain anomalous concentrations of lead, copper, zinc, and cadmium, which accounts for the high rank sums on maps A and B. However, other samples in the quadrangle showing some level of favorability for porphyry molybdenum and tungsten deposits have low rank sums for the elements that make up the mesothermal vein category. The samples with high rank sums near the known porphyry molybdenum and tungsten deposit were not considered in our evaluation of favorability for mesothermal veins.

Sullivan-type stratabound lead-zinc--Sullivan-type stratabound lead-zinc deposits have not been identified to date in the Wallace quadrangle. However, some of the geologic characteristics of the Sullivan deposit occur in the Prichard Formation--which is stratigraphically equivalent to the host formation, the Middle Proterozoic Aldridge Formation, of the Canadian Sullivan mine. For the Wallace quadrangle, samples of stream sediment that contain anomalous concentrations of zinc and(or) lead and that are underlain by the Prichard Formation, may have some potential for Sullivan-type mineral occurrences (Harrison and others, 1986a). Elements other than lead and zinc that occur in anomalous concentrations in the stream sediments include antimony, silver, copper, and cadmium. This suite of elements may also be produced from mesothermal veins. For example, the veins that occur in the Prichard Formation in the Coeur d'Alene district are dominantly lead-zinc veins. Because of these similarities, we cannot distinguish between the two using our reconnaissance data, and we realize that samples with high concentrations of lead and zinc (± Ag, Cu, Sb, and Cd) suggest potential for both occurrence types. Therefore, we have included all samples suggestive of Sullivan-type occurrence in our identification of favorable ground for mesothermal veins.

Epithermal silver--Epithermal high-grade silver deposits are associated with a small Tertiary volcanic center in the northeastern part of the Wallace quadrangle. Samples of stream sediment from this area are characterized by anomalous concentrations of silver and zinc (Harrison and others, 1986e). Because the geologic setting of this deposit type is unique in the quadrangle, the other zinc and silver anomalies outside this area probably reflect other deposit types. One of the six samples related to the epithermal silver deposit type has a high rank sum for lead + zinc and will not be considered in our evaluation for mesothermal veins.

DISCUSSION

Identification of favorable areas for mesothermal veins

The rank sums for lead + zinc + silver + copper and for lead + zinc give a quantitative indication of favorability for mesothermal veins within individual stream drainage basins; however, because only a small percentage of the drainage basins was sampled in our reconnaissance program, the data are best applied to defining broad geochemical trends. This is consistent with our assumption that the many mesothermal veins present in the Wallace quadrangle relate to some large-scale geologic or geochemical processes. Therefore, we have identified broad and highly generalized areas that contain groups of samples that score relatively high on the rank sums for lead + zinc + silver + copper and for lead + zinc. A relatively high score for the rank sum was arbitrarily chosen as the top 15 percent of the rank sums. In general, the boundaries for the areas have been drawn approximately along drainage divides. Because some mesothermal veins have rather limited exposure and subsequently limited geochemical expression in samples of stream sediment, we have included within some favorable areas a few samples with lower rank sums.

Some samples with high rank sums were excluded from assignment of favorability for mesothermal veins because they probably were derived from epithermal silver, porphyry molybdenum-tungsten, or stratabound copper-silver occurrences. These samples are indicated on maps A and B by solid symbols. Samples identified as possibly related to Sullivan-type stratabound lead-zinc (Harrison and others, 1986a) were included in our evaluation of mesothermal veins because our geochemical data cannot distinguish between the two. We considered isolated single samples in our evaluation only if their rank sums were within the top 5 percent of the rank sums.

The boundaries for geochemically favorable ground are clearly subjective within reasonable limits that are largely dependent on the density of samples. Typically, the reconnaissance geochemical samples are 2 mi apart, but some are as much as 5 mi apart. The uncertainty of a boundary between two samples, therefore, typically will be 1 mi but in some cases as much as 2.5 mi. The precision of the geochemical boundaries is within the limits of the boundaries established by some of the geologic and geophysical data used in the mineral resource evaluation. For most areas, the boundary between geochemically favorable and unfavorable ground can be clearly defined, whereas in some areas considerable judgment was used to locate the boundary.

Geochemical favorability scores

For the mineral resource appraisal for mesothermal veins (Harrison and others, 1986c), a confidence-favorability matrix diagram was used to establish a measure of probability for the occurrence of an ore body. For a given subarea of the quadrangle, confidence in the appraisal increases directly with the number of kinds of diagnostic data that were applied, whereas the favorability of that subarea is a function of the sum of the favorability scores for each kind of diagnostic data. A favorability score was assigned to criteria that form subdivisions within each kind of diagnostic data. The favorability scores for each kind of diagnostic data were deliberately kept low so that a few broad subdivisions could be used for classifying the reconnaissance data. The types of diagnostic data and their range of point scores used in the mineral resource appraisals for mesothermal veins are shown in table 2.

Table 2.--Favorability characteristics and the range of favorability scores used in the mineral resource assessment for mesothermal veins (Harrison and others, 1986c)

Favorability characteristics	Range of favorability scores
Geologic	
Lithology	-3 to +4
Structure	-1 to +4
Known mineral occurrences	0 to +4
Geochemical	0 to +4
Geophysical	-1 to +3
Total range	-5 to +19

Point scores for geochemical favorability that range from 2 to 4 were assigned from the data for rank sums for lead + zinc + silver + copper and for lead + zinc (this report) or from data for nonmagnetic heavy-mineral concentrates (Leach and Domenico, 1986). Areas of antimony enrichment (Leach and others, 1983) in the quadrangle were assigned a favorability score of 1. The criteria used to assign favorability for the rank sums are given in table 3. Point scores were assigned to the favorable areas with full recognition that many subareas of favorability could be assigned to each. However, making the favorable areas broad and the favorable scores low is consistent with the generalized favorability established from other kinds of data used to establish the mineral resource assessment, as well as keeping the assessment process simple. We recognize that a slight modification of some boundaries shown on maps A and B could change the favorability by a point, particularly for some of the smaller areas. However, the mineral resource appraisal for mesothermal veins is relatively insensitive to small changes in any of the diagnostic data.

Areas of Geochemical Favorability

A broad area of highly favorable ground, as indicated on maps A and B, surrounds the Coeur d'Alene district. This zone extends north and northeast to the Clark Fork River. Although there are numerous mines and prospects in and near the Coeur d'Alene district, the northern and northeastern half of this favorable zone contains only a few known occurrences of mesothermal veins. This suggests that there is high potential for discovery of mesothermal veins in this area. South of the Coeur d'Alene district is an area of medium favorability where only one occurrence of mesothermal veins is known (maps A and B).

Table 3.--Criteria used to assign geochemical favorability score from rank sums for lead + zinc + silver + copper and for lead + zinc

Favorability point scores	Criteria
4 (high)	Groups of samples of stream sediment that have rank sums predominantly in the 90-95th percentile; at least 1/3 are in the 95+ percentile. Single sample of stream sediment with rank sums in the 90-100 percentile.
3 (medium)	Groups of samples of stream sediment that have rank sums predominantly in the 85-95 percentile; at least 1/3 are in the 90+ percentile. Single sample of stream sediment with rank sums in the 95+ percentile.
2 (low)	Groups of samples of stream sediment that have rank sums in the 85-90th percentile; at least 1/2 are in the 85+ percentile.

Northeast from the town of Trout Creek and across the Clark Fork River are areas with high, medium, or low favorability (maps A and B). These areas are separated from the highly favorable zone that surrounds the Coeur d'Alene district by the flood plain of the Clark Fork River. The areas contain several known occurrences of mesothermal veins.

In the southeast part of the quadrangle near Superior, Mont., several areas show geochemical favorability for mesothermal veins (maps A and B). Parts of these areas lie within the greater Coeur d'Alene mineral belt and contain many mines and prospects. The geochemically favorable ground extends well away from the known vein occurrences, which suggest that favorable ground in the greater Coeur d'Alene mineral belt extends to the southeast of Superior, Mont. Our data also suggest a noticeable gap in mineral potential that extends from Superior, Mont., to east of the Couer d'Alene district.

The two small areas of medium favorability in the central part of the quadrangle on both maps A and B result from single samples that rank in the 95+ percentile for the rank sums. Both of these areas contain known occurrences of mesothermal veins. Favorable zones in the north-central part of the quadrangle are indicated by the rank sums for lead + zinc + copper + silver (map A). Only a few occurrences of mesothermal veins are known in these areas. Further prospecting in these areas seems warranted.

Table 1.--Elements that may be present in anomalous concentrations for the mineral resource occurrence models of the Wallace 1°x 2° quadrangle
[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
Stratabound 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, Cu, Zn	Bi, Mo, Sn, W
Epithermal high-grade silver	Ag, Zn, minor Cd	Zn	
Placer gold	None detected	None detected	Au, minor Ag

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INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1989

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