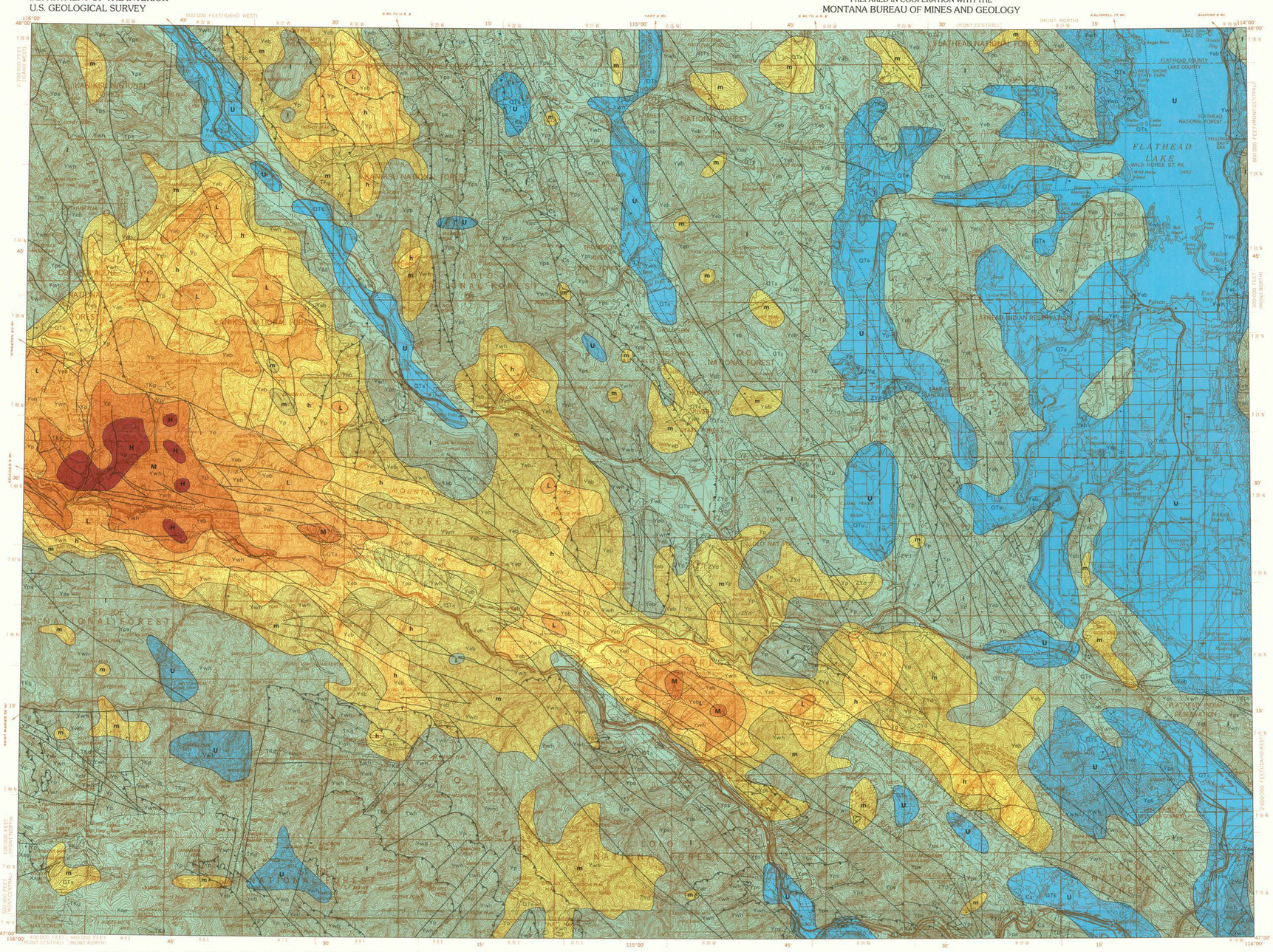
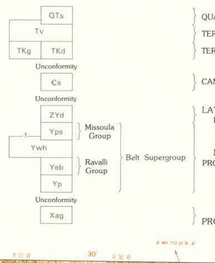


C. RESOURCE APPRAISAL MAP FOR MESOTHERMAL VEINS BASED ON LITHOLOGY, STRUCTURE, KNOWN MINERAL OCCURRENCES, GEOCHEMICAL DATA, AND GEOPHYSICAL DATA

Note: The generalized and simplified geologic map was prepared as an underlay for various geophysical and geochemical data collected in the Wallace 1° x 2° quadrangle. A fuller treatment of geologic units and structure can be found on map I–1509–A in the Wallace CUSMAP folio.

CORRELATION OF MAP UNITS



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)

Cs SEDIMENTARY ROCKS (CAMBRIAN)—Includes Red Lion Formation, Hasmark Dolomite, Silver Hill Formation, Flathead Quartzite, and equivalent rocks

ZYd DIORITIC TO GABBROIC SILLS AND DIKES (LATE AND MIDDLE PROTEROZOIC)

Yps MISSOULA GROUP (MIDDLE PROTEROZOIC)—Includes Pilcher, Libby, Garnet Range, and McNamara Formations, Bonner Quartzite, and Striped Peak, Mount Shields, Shepard, and Snowslip Formations

Ywh WALLACE AND HELENA FORMATIONS (MIDDLE PROTEROZOIC)

Yeb RAVALLI GROUP (MIDDLE PROTEROZOIC)—Includes Empire, St. Regis, Spokane, Revett, and Burke Formations

Yp PRICHARD FORMATION (MIDDLE PROTEROZOIC)

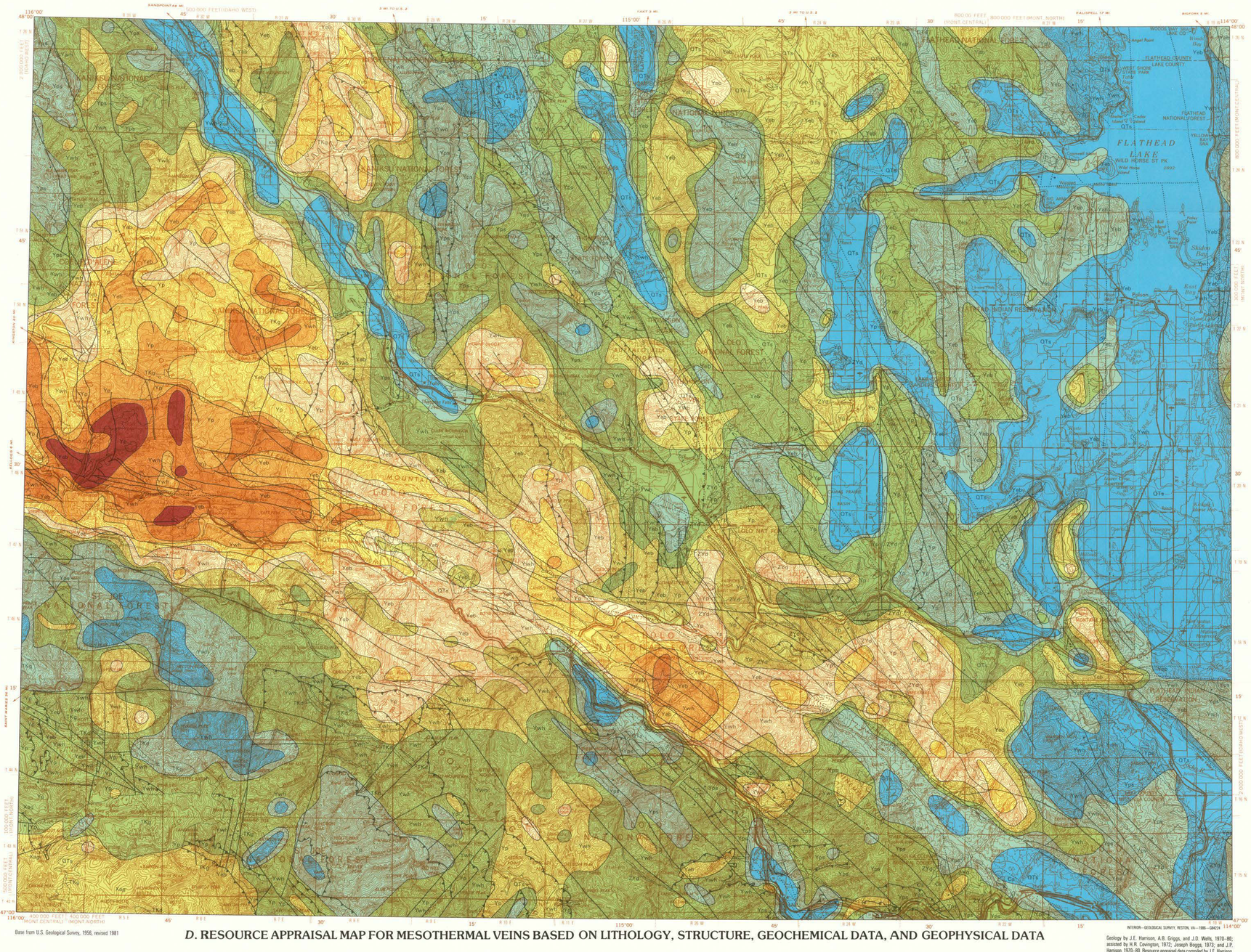
Xag ANORTHOSITE, SCHIST, AND GNEISS (EARLY PROTEROZOIC)

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

This map is part of a folio of maps of the Wallace 1° x 2° quadrangle, Montana-Idaho, prepared under the Conterminous United States Mineral Assessment Program (CUSMAP). Background information about this folio is published in U.S. Geological Survey Circular 920.



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

D. RESOURCE APPRAISAL MAP FOR MESOTHERMAL VEINS BASED ON LITHOLOGY, STRUCTURE, GEOCHEMICAL DATA, AND GEOPHYSICAL DATA

SCALE 1:250 000

5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

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

QUADRANGLE LOCATION

INTERIOR—GEOLOGICAL SURVEY, RESTON, VA.—1986—G84224

Geology by J.E. Harrison, A.B. Griggs, and J.D. Wells, 1970–80; assisted by R.R. Cavington, 1972; Joseph Boggs, 1973; and J.P. Harrison, 1970–80. Resource appraisal data compiled by J.E. Harrison, D.L. Leach, and M.D. Kleinkopf

OCCURRENCE MODEL FOR MEDIUM-TEMPERATURE (MESOTHERMAL) BASE- AND PRECIOUS-METAL VEIN DEPOSITS

REGIONAL SETTING

General setting

The highly faulted and fractured ground that is characteristic of the Wallace quadrangle is also punctured by mafic to felsic intrusive plutons, dikes, and sills. Both the faults and the intrusive rocks are more abundant than can be shown at the scale of the geologic map, where only the larger or better known or more persistent have been shown. Regionally, this area of highly fractured and intruded ground extends for tens to hundreds of kilometers beyond the boundaries of the Wallace quadrangle.

Faults within the quadrangle range in age from Proterozoic to post-early Tertiary, and many have probably had repeated movements along them. Most of the high-angle dip-slip faults represent an opening or extension of the ground, and many contain dikes or quartz-carbonate fissure fillings. By contrast, high-angle strike-slip faults tend to have wide zones of clay gouge and ground-up rock associated with them. Soles of more steeply dipping thrust faults also tend to show gouge, whereas the flatter thrusts may show silicified or feldspathized zones at their base.

Exposed intrusive rocks show a wide range of composition, relative temperature of intrusion, and amount of associated fluid activity. Some of the Precambrian mafic sills have contact metamorphic zones a few hundred feet wide above them and narrower zones below. Tertiary mafic dikes and plugs commonly show thin contact zones around them. Felsic plutons of Cretaceous and Tertiary age can have abundant pegmatite, quartz veins, sheared zones, and wide contact metamorphic zones. Most of the larger plutons contain sufficient magnetite to show distinct aeromagnetic highs.

In a regional sense, the Tertiary and Cretaceous intrusive rocks 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, an area about 45 km northwest of the quadrangle. Outlying plutons and dikes and the various intrusions that form the batholithic complexes range in age from about 200 million years (m.y.) to about 40 m.y. Many of the plutons are along or near major high-angle faults or fault zones, and most appear to intrude through or at least into thrusts plates, if such plates occur in the area of the intrusion.

Coeur d'Alene district

The category of mesothermal veins includes the veins of the famed Coeur d'Alene district, which deserves a more complete description.

The Coeur d'Alene district is near the western end of the fault zone that defines the Lewis and Clark zone. By local usage, the district includes an area about 42 km long and 14 km wide that is more or less centered on the town of Osburn, Idaho. The district is bisected by the Osburn fault, along which the mineralized area has been offset about 23 km right laterally. The Wallace quadrangle contains the eastern part of the district.

A larger area referred to by Fryklund (1964) 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.

Host rocks for veins are dominantly formations of the Belt Supergroup—mostly the Burke, Revett, and St. Regis Formations, although some veins occur in the stratigraphically lower Prichard Formation and in the higher Wallace Formation. The Burke and Revett, in particular, contain abundant quartzite and siltite, which are relatively brittle units in the local stratigraphic succession.

Quartz monzonite stocks (the Gem stocks) and dikes that are about 110 m.y. old form a small part of the Coeur d'Alene district, as do diabase and lamprophyre dikes that are about 50 m.y. old. Whether these stocks are significant to the origin of the district or whether they caused minor redistribution of metals in a preexisting district has been debated for generations.

The Lewis and Clark line is a wide crustal flaw that has existed probably since the Middle Proterozoic. Some have suggested that the Coeur d'Alene district occurred at the intersection between that flaw and a postulated deep fracture zone reflected by the northeast-trending line of stocks.

DEPOSIT CHARACTERISTICS

Major lead-zinc-silver ore bodies found in the Coeur d'Alene district occur as replacement veins in mineral belts that transect the Lewis and Clark line at a low angle. Some belts are zoned from dominantly copper sulfides on one end through lead-silver sulfides and sulfosalts to zinc sulfide on the other end. Principal ore minerals are galena, sphalerite, tetrahedrite, and chalcopyrite. Small amounts of gold, stibnite, and, more rarely, uraninite are found in some veins. 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-filling veins may be dominated by gold, antimony, or lead, and the linear mineral belts that characterize the district are apparently lacking.

Several periods of mineralization within the district are indicated by crosscutting relations among veins and between veins and intrusive rocks or folded strata. Galena from most major mines contains lead isotopes of Precambrian age, although some galena from veins near the Gem stocks contains isotopes of Mesozoic-Cenozoic age. In general, the same lead isotope relations hold true throughout the Greater Coeur d'Alene mineral belt: Precambrian lead isotopes in most galena in veins, except near Cretaceous-Tertiary intrusions or positive magnetic anomalies reflecting a buried intrusion, where lead isotopes change to a Mesozoic-Cenozoic age.

Gangue minerals associated with mineralization in the district range locally from silicates, specular hematite, and magnetite near the Gem stocks to ubiquitous quartz and various iron-carbonate minerals throughout the district. Massive siderite in veins is confined largely to a few of the mineral belts within the district.

Outside of the Coeur d'Alene district and the Greater Coeur d'Alene mineral belt, veins of this type of deposit are mostly fissure fillings, but they include some replacement veins. They commonly occur near exposed felsic plutons or in areas of positive magnetic anomalies. Lead isotopes in galena almost always give a Mesozoic-Cenozoic age. Primary ore minerals are galena, sphalerite, bornite, and chalcopyrite accompanied by varying amounts of gold or silver. Gangue is predominantly quartz or quartz-carbonate.

Some veins occur along the principal faults in the quadrangle, but most are in fractures that extend at an angle from those faults or that cross between them.

GEOCHEMICAL ANOMALIES

Veins in the mesothermal category range in composition from simple lead-zinc or copper ores through those that also contain gold and silver to the highly complex veins that characterize part of the Coeur d'Alene district, where antimony, arsenic, nickel, cadmium, cobalt, and barium are also commonly significant components.

The geochemical signature of these mesothermal veins is less complex in samples of stream sediment. We have used only lead, zinc, silver, copper, and antimony as key elements. As described in the text accompanying map *B*, we ranked the summed concentrations of lead plus zinc plus copper plus silver, as well as just lead plus zinc, for all stream-sediment samples collected in the Wallace quadrangle; we then identified areas containing the highest total values to show favorable ground. Added to these data are groups of sites for nonmagnetic heavy-mineral concentrates that contained anomalous concentrations of the signature elements plus arsenic. Cadmium, which is also commonly present in stream-sediment samples, 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 chemical factor. Antimony, on the other hand, was given special consideration, because antimony in stream sediments is unique, among all the occurrence models established in the quadrangle, to mesothermal veins.

GEOPHYSICAL CHARACTERISTICS

The model for mesothermal veins assumes that the veins are related to hydrothermal processes. The heat needed for pumping hydrothermal ore-bearing fluids into fractures is assumed to be related to known or inferred felsic intrusions.

Within the Wallace quadrangle, positive aeromagnetic anomalies are the most diagnostic feature of an exposed or buried pluton. Negative gravity anomalies help define the less dense (more felsic) plutons. The audio-magnetotelluric survey helped delimit plutons in the part of the quadrangle surveyed.

REMOTE SENSING CHARACTERISTICS

Lineament analysis of remotely sensed data shows zones and areas where specific trends of lineaments or abundant lineaments are well defined. The lineaments probably represent fracture patterns in bedrock, but, with the exception of the Lewis and Clark line, the lineament zones do not correspond well with the abundant mapped faults, fault zones, and mineralized fractures in the quadrangle.

We cannot specifically state that fractures represented by the lineaments are or are not mineralized, although the purpose of the lineament analysis was to obtain such an evaluation. As a consequence, we have not used the lineament data as a component of our resource appraisal for mesothermal veins. Interpretations of possible applications of the lineament data are described in the text accompanying the lineament maps in another part of the Wallace CUSMAP folio (Rowan and Purdy, 1983).

RESOURCE POTENTIAL

The Coeur d'Alene district is one of the world's larger producers of lead, zinc, and silver. Production of 1 to 2 million short tons of ore per year has been common since the turn of the century. In addition to lead, zinc, and silver, significant amounts of copper, gold, antimony, and sulfur have been recovered, as well as smaller amounts of cadmium and cobalt. Ore grades vary from mine to mine, but a districtwide average for the principal commodities is on the order of 7 ounces of silver, 0.02 percent copper, 4 percent lead, and 3 percent zinc per short ton (Fryklund, 1964).

Outside of the district, tonnage and grade range widely for this type of deposit. The most productive mines have yielded ore that generally contains a few percent lead, somewhat less zinc, even less copper, an ounce or more of silver, and, perhaps, part of an ounce of gold per short ton. Production from a given vein or vein system ranges from tens of thousands to a few tons.

RATING SCALE

The rating scale for each factor used to assess potential for mesothermal veins is explained in maps *A* and *B*. The following factors and their range of point scores were used together in deriving map *C*.

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

SCALE VALUES

Map *C* was prepared by combining maps *A* and *B* to determine total scale values for favorable ground as identified in figure 2 and portrayed in map *C*. Maps *A* and *B* were each digitized by recording favorability scores at the corners and center of a 2-mi grid. The numbers on the two grids were then combined arithmetically, and the resulting composite grid was contoured to outline areas that include point values corresponding to the lettered intervals of the confidence-favorability diagram (fig. 2). A 2-mi (3.2-km) grid was used because (1) the aeromagnetic data are based on flight-line spacings of 1 mi and 2 mi (1.6 km and 3.2 km), (2) the geochemical data represent samples from stream basins in almost all 2-mi² areas of the grid (except on the Flathead Indian Reservation), and (3) numbers on a grid of that size define various areas of maps *A* and *B* with an accuracy well within the limits of precision for boundaries of those areas.

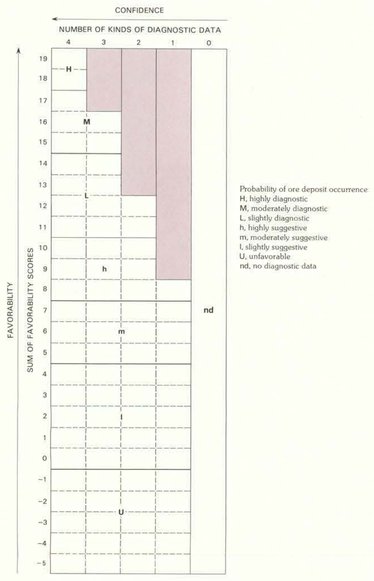


Figure 2.—Confidence-favorability diagram for mesothermal veins.

DISCUSSION

Mesothermal veins are abundant in the Wallace quadrangle. Almost half of this large area (about 17,000 km²) shows evidence that is at least moderately suggestive of the presence of such veins. The more favorable ground (labeled "H, M, and L") clearly shows the trend of the Greater Coeur d'Alene mineral belt extending southeast across the quadrangle from Wallace, Idaho. Our data suggest, however, that this belt has noticeably different mineral potential along its length. The lower potential, though not to be ignored, shows as a gap between the highly diagnostic area of the Coeur d'Alene district and the other diagnostic areas near Superior, Mont.

North of the Coeur d'Alene district is a broad area of favorable ground that extends north to northeast across the Clark Fork River. The area has a few mines and several prospects in it, but there seems to be a gap in mineral occurrence a few kilometers west of White Pine. An exposed pluton in the area is a syenite complex, which has been explored recently for rare-earth minerals but is not a particularly favorable type of intrusion for mesothermal base- and precious-metal veins. On the other hand, our geochemical and geophysical data suggest that the exposed syenitic complex may not be the sole intrusion beneath this ground and that further prospecting for mesothermal veins might be prudent.

Several small circular or oblong areas are designated on the map as moderately suggestive ("m") for mineralized ground. These are isolated areas that have relatively high values for one or two rating scales. Such small areas were checked individually to make sure they did not result from the contouring process. The areas that have realistic support from geologic, geochemical, or geophysical data were left on the map.

EXPLANATION FOR RESOURCE APPRAISAL

OUTLINE OF GROUND FAVORABLE OR UNFAVORABLE FOR MINERAL RESOURCES

PROBABILITY FOR OCCURRENCE OF MINERAL RESOURCES

- H — Highly diagnostic
- M — Moderately diagnostic
- L — Slightly diagnostic
- h — Highly suggestive
- m — Moderately suggestive
- l — Slightly suggestive
- U — Unfavorable

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DISCUSSION

A logical question that can be raised concerning our resource appraisal of mesothermal veins is: Would our geologic, geochemical, and geophysical analyses point to favorable ground if no mineral occurrences were known in the quadrangle? Map *D* attempts to answer that question, as well as to provide further insights into mineral potential of the area.

To compile map *D*, we have used the same rating scale and followed the same procedure described for deriving map *C*, except that we have omitted data on known mineral occurrences. At the point in the procedure where we assigned probability letters to areas in map *C* through use of the confidence-favorability diagram, we merely contoured total point scores for map *D* in increments of two and assigned all negative scores to a zero category, as shown below.

Total favorability scores	Favorable ground scores
14 or 15	8
12 or 13	7
10 or 11	6
8 or 9	5
6 or 7	4
4 or 5	3
2 or 3	2
0 or 1	1
−1 to −5	0

The resulting contoured map shows favorable ground graded on a scale of eight to zero. Our decision to use a graded scale rather than our standard confidence-favorability diagram is a deliberate attempt to avoid confusion between maps *C* and *D*. The two slightly different procedures do not significantly affect comparison of the two maps.

Map *D* appears to show greater detail than map *C*, but this is largely because map *D* has a contour inverval of two favorability points, whereas map *C* is contoured generally on broader contour invervals of three, four, or five points. Regardless of the apparent difference in detail, the two maps are remarkably similar. The Greater Coeur d'Alene mineral belt is still visible, as is its less favorable gap. A favorable zone extending north to northeast from the Coeur d'Alene district is apparent, as is a favorable area that contains few prospects and lies west of White Pine.

Comparison of map *D* with map *A* shows that 80 percent of the known producing mines are in areas that are five or higher on the scale for favorable ground used on map *D*. All major producing mines are in those areas. We conclude that our model for mesothermal veins is reasonably sound and that map *D* could be used as a guide to prospecting in favorable ground where few or no mines or prospects currently exist.

EXPLANATION FOR RESOURCE APPRAISAL

OUTLINE OF GROUND FAVORABLE OR UNFAVORABLE FOR MINERAL RESOURCES

PROBABILITY FOR OCCURRENCE OF MINERAL RESOURCES— Numbers are favorable ground scores derived from total favorability scores (see text for detailed explanation)

- 8
- 7
- 6
- 5
- 4
- 3
- 2
- 1
- 0

RESOURCE APPRAISAL MAPS FOR MESOTHERMAL BASE- AND PRECIOUS-METAL VEINS IN THE WALLACE 1° x 2° QUADRANGLE, MONTANA AND IDAHO

By
Jack E. Harrison, David L. Leach and M. Dean Kleinkopf

1986

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