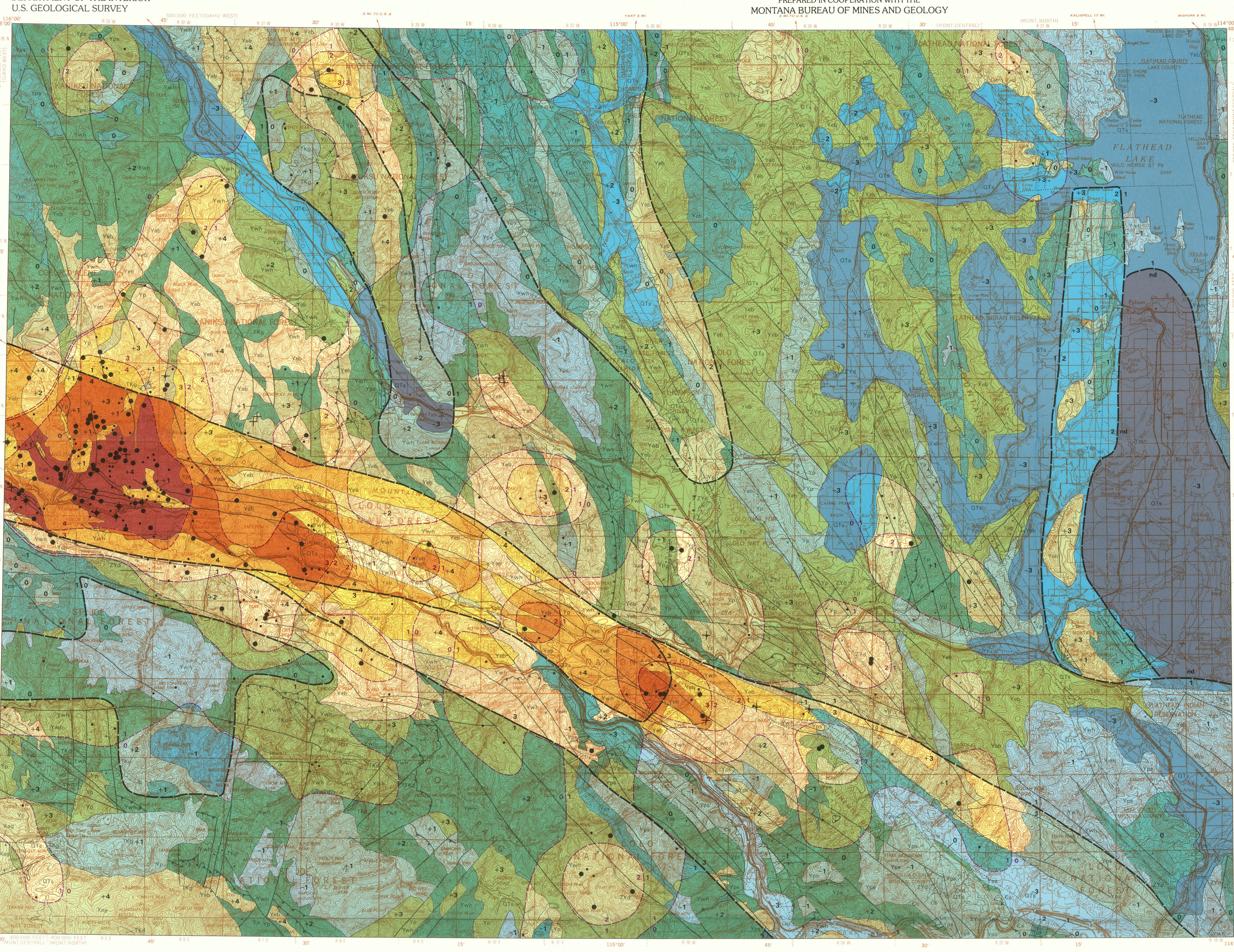
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
MONTANA BUREAU OF MINES AND GEOLOGY

MISCELLANEOUS INVESTIGATIONS SERIES
MAP I–1509–I (SHEET 1 OF 2)



A. RESOURCE APPRAISAL MAP FOR MESOTHERMAL VEINS BASED ON LITHOLOGY, STRUCTURE, AND KNOWN MINERAL OCCURRENCES

INTRODUCTION

Appraisal for mesothermal veins in the Wallace 1° x 2° quadrangle involves a complex procedure. Four maps and texts are used to show the data and the assessments; a single map, as used for other types of deposits in the quadrangle, would be extremely complex and essentially unreadable.

The group of four maps includes a map (*A*) showing analysis of three factors (lithology, structure, and known mineral occurrences) where sum total favorability scores are shown from high to low by sixteen colors that range from hot (red) to cold (blue), a map (*B*) showing analysis of two additional factors (geochemistry and geophysics) where a similar hot to cold system of nine colors is used, and a third map (*C*) that combines maps *A* and *B* to show resource assessment based on all five factors where the seven standard colors used for all resource probabilities ("H" to "U") are shown. A fourth map (*D*) was prepared to test the credibility of the occurrence model and the complex appraisal procedure, as well as to show, insofar as possible, what the resource appraisal would have been if few or no mines or prospects were known in the quadrangle (map *C* minus the factor for known mineral occurrences, but assuming that some observations on the occurrence of veins in rocks would have been made by field geologists who mapped the area). The point scores for map *D* also use a hot to cold system of nine colors.

DERIVATION OF FAVORABILITY SCORES FROM LITHOLOGY, STRUCTURE, AND KNOWN MINERAL OCCURRENCES

LITHOLOGIC CHARACTERISTICS

Our mesothermal vein occurrence model (see map *C*) requires fractures to act as conduits for ore-bearing fluids. In order for a given lithologic unit to retain through-going fractures, the unit may be characterized by brittleness based on metamorphic grade or by an abundance of quartzite. In addition, favorability for fractures may be based on our general observations regarding the rocks that commonly host veins in the quadrangle.

Boundaries of lithologic units on the map are more precise than lines bounding any other characteristic used to evaluate favorable ground for mesothermal veins. Within those lithologic boundaries, however, judgment has been used to classify areas. The favorability scores that result from these judgments range from +4 to −3 and are shown in figure 1.

STRUCTURAL CHARACTERISTICS

The structural factor for the occurrence of mesothermal veins involves recognition of both the type and amount of fracturing in various areas of the quadrangle. High-angle dip-slip faults and related fractures that tend to open the ground are more favorable than high-angle reverse or strike-slip faults, which tend to be less permeable because of the gouge formed along them. Exceptions to this tendency are common, however, because cross fractures in high-angle reverse or strike-slip fault zones may have produced relatively open ground. Intensive fracture cleavage also tends to produce openings.

Estimates were made of the relative occurrence of fractures that tend to open the ground to mineralizing solutions in large areas of the quadrangle. The boundaries between areas are not precise, but they separate general subareas that exhibit different amounts of fracturing. The favorability score for the structure factor is given below.

+4 Intensely fractured ground in a major zone of faulting; accompanied by tight to overturned folds and intense cleavage
+3 Intensely fractured ground in a major zone of faulting; accompanied by upright open folds and minor cleavage
+2 Highly fractured ground; may include thrust faults as well as high-angle faults
+1 Moderately fractured ground that contains mostly high-angle faults
0 Slightly fractured ground that contains any type of faulting
−1 Unfractured ground
nd No data on fracturing because of uncertainty of projections of faults and fault zones into covered bedrock

KNOWN MINERAL OCCURRENCES

Extensive mining and prospecting of mesothermal veins that have been discovered in the quadrangle provide information about favorable ground at the point of the mine or prospect. These point-source data were translated into favorable areas by establishing a grid and then counting and contouring the known occurrences. A producer was given a score of three points, and a developed or undeveloped prospect was scored as one point. All occurrences within an area the size of a township (6 mi on a side or about one half of 1 percent of the total area of the quadrangle) were summed, and the total point score was plotted at the center of the area. This process was repeated at each intersection of a 3-mi² grid, which results in a series of overlapping averages that give point scores at nine places per township, such as:

3 mi	—	13	13	5	—	
	—	12	17	9		6 mi
		0	4	4	—	

The procedure is a simple graphical method for statistical smoothing of geographic data. The point scores derived were then contoured to show generalized areas of higher to lower point scores, which in this example represent areas where greater or smaller numbers of mesothermal veins have been found.

The actual point scores derived from applying this statistical procedure to the several hundred mesothermal vein occurrences in the Wallace quadrangle range from 0 to a single extreme high of 101. These data were reduced by adjustments shown in the following table to levels of favorability scores comparable to those for lithology and structure, which have a maximum favorability score in our model of +4.

Total points	Favorability score	Examples of occurrences required
≥21	+4	Seven or more producers; five producers and six or more prospects.
10–20	+3	Six producers; three producers and two or more prospects.
5–10	+2	Two producers; one producer and two or more prospects.
1–5	+1	One producer; one to five prospects.
0	0	None known.

EXPLANATION FOR RESOURCE APPRAISAL

● MINE FROM WHICH BASE AND (OR) PRECIOUS METALS HAVE BEEN PRODUCED

• PROSPECT FOR BASE AND (OR) PRECIOUS METALS

+ MINE FROM WHICH ANTIMONY HAS BEEN PRODUCED—Symbol is combined with above symbols where antimony is mixed with base and (or) precious metals

+3 OUTLINE OF LITHOLOGIC UNIT—Number is favorability score for unit (see Lithologic characteristics section in text for detailed explanation)

3/1 BOUNDARY OF STRUCTURAL PROVINCE—Numbers are favorability scores for provinces (see Structural characteristics section in text for detailed explanation)

4/3 CONTOUR ON ABUNDANCE OF KNOWN MINERAL OCCURRENCES—Numbers are favorability scores used to identify favorable ground (see Known mineral occurrences section in text for detailed explanation)

SUM OF FAVORABILITY SCORES FOR LITHOLOGIC CHARACTERISTICS, STRUCTURAL CHARACTERISTICS, AND KNOWN MINERAL CHARACTERISTICS (SUM TOTALS NOT GIVEN ON MAP)

12, 11, 10, 9, 8, 7 | 6, 5, 4, 3, 2, 1 | 0, −1, −2, −3

GENERAL REFERENCES

Chesson, Sharon, Griffith, Thomas, and Wallace, R. R., 1984, Maps showing mineral occurrence data for the Wallace 1° x 2° quadrangle, Montana and Idaho: U.S. Geological Survey Miscellaneous Field Studies Map MF–1354–F.

Harrison, J. E., Griggs, A. B., and Wells, J. D., 1981, Generalized geologic map of the Wallace 1° x 2° quadrangle, Montana and Idaho: U.S. Geological Survey Miscellaneous Field Studies Map MF–1354–A.

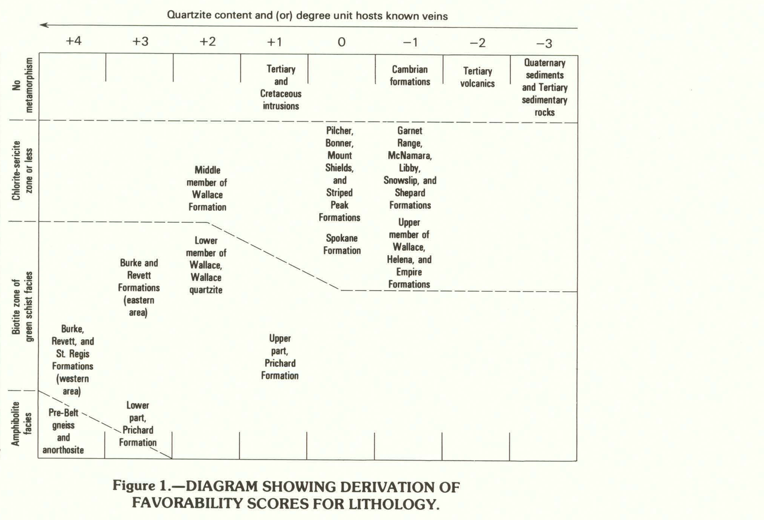
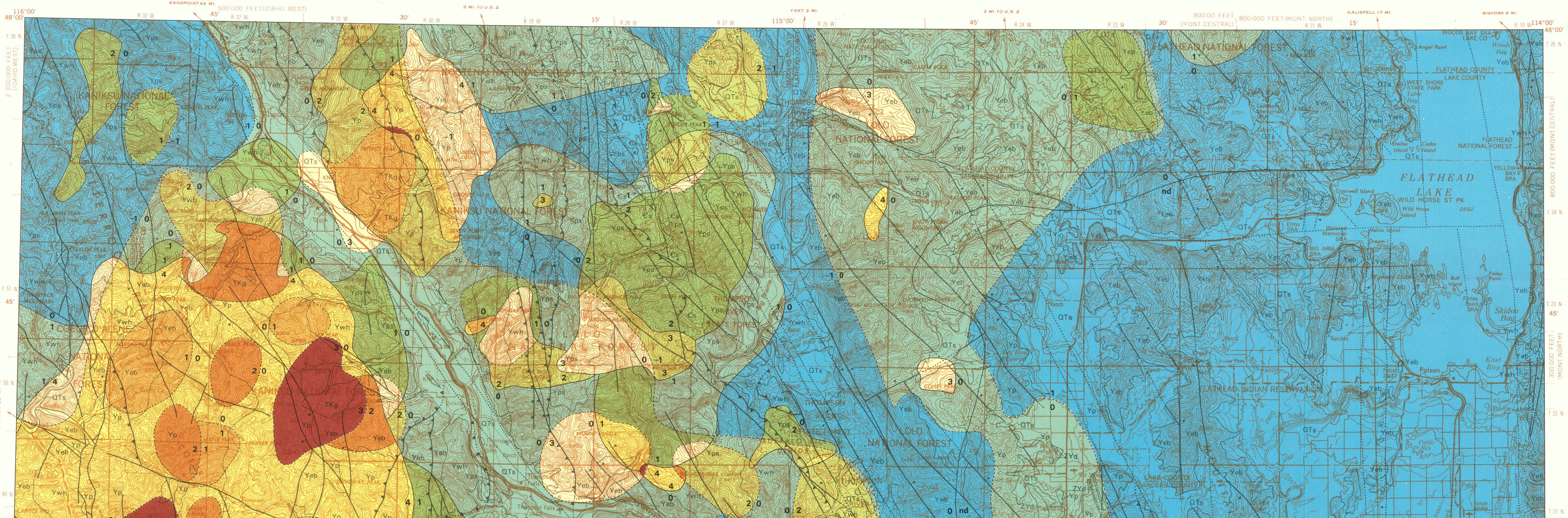


Figure 1.—DIAGRAM SHOWING DERIVATION OF FAVORABILITY SCORES FOR LITHOLOGY.

CORRELATION OF MAP UNITS

DESCRIPTION OF GEOLOGIC MAP UNITS



B. RESOURCE APPRAISAL MAP FOR MESOTHERMAL VEINS BASED ON GEOCHEMICAL AND GEOPHYSICAL DATA

DERIVATION OF FAVORABILITY SCORES FROM GEOCHEMICAL AND GEOPHYSICAL DATA

GEOCHEMICAL ANOMALIES

Mesothermal veins range in chemistry from simple to highly complex (see text accompanying map *C*). The veins of the Coeur d'Alene district yield a great range and variety of trace elements to stream-sediment samples from that district. But veins of the district, and mesothermal veins throughout the Wallace quadrangle, also can have a very simple chemistry, yielding stream sediments that show only anomalous amounts of lead, zinc, copper, or silver. This simple suite of anomalous elements may also be derived from other types of mineral occurrences, such as stratabound copper-silver occurrences (can have copper, silver, and lead) or stratabound Sullivan-type occurrences (can have lead, zinc, and silver). The probability is low, however, for any of the other occurrences to show all four elements consistently.

In identifying favorable ground for mesothermal veins, we considered the total concentrations of lead, zinc, copper, and silver in samples of stream sediments. Cadmium, which is commonly present in anomalous concentrations in steam sediments near mesothermal veins, was not used as a signature element. Cadmium is so clearly related to zinc, commonly in sphalerite, that use of both zinc and cadmium would, in effect, give double weight to a single factor. Bismuth, also common to some mesothermal veins, was not used as a signature element either, because it has a high local variability in the quadrangle. Such erratic behavior limits its usefulness in defining regional geochemical trends. Some other potentially useful elements for trace-element signatures in stream sediments, such as arsenic, molybdenum, and gold, also were not included in the generalized signature for mesothermal veins, because only a few samples contained amounts of those elements that were detectable by the analytical methods used.

Unique to mesothermal veins is the general persistence of antimony. Antimony-bearing veins form a crude outer zone around the Coeur d'Alene district and occur at other places in what Fryklund (1964) refers to as "the Greater Coeur d'Alene mineral belt"—essentially an extension of the Coeur d'Alene district along the Lewis and Clark line. In the quadrangle, partially extractable antimony is more closely related to mesothermal veins than is the total concentration of antimony in the same stream-sediment samples. The element is not part of the trace-element signature of any of the six other types of mineral occurrences identified in the Wallace quadrangle.

To help identify ground favorable for mesothermal veins, we also used a suite of elements that show anomalous concentrations in samples of nonmagnetic heavy-mineral concentrates. This suite consists of lead, zinc, silver, copper, antimony, and arsenic.

The identification of favorable ground by use of geochemical data includes three successive steps. In the first step, all 1,229 samples of stream sediments were ranked according to their individual contents of lead, zinc, copper, and silver. For example, the sample having the greatest concentration of lead, according to atomic-absorption analysis, was assigned a rank of 1,229, the sample having the second greatest concentration was assigned a rank of 1,228, etc. Where samples had the same concentration, they were given the same rank. This ranking procedure was completed for all four elements, and then each sample was assigned a number that represented the sum of the ranks for lead plus zinc plus copper plus silver, and another number was assigned for just lead plus zinc. Each sum gives an estimate of the relative enrichment of the four-element suite and of the two-element suite. The sum of the ranks was used to give equal weight to each element. For example, actual values for silver rarely exceed a few parts per million, whereas values for lead are commonly in the hundreds of parts per million. If we used total-metal content (sum of the actual vlaues), then lead would be weighted unintentionally by tens of times more than silver, whereas the sum of the ranks gives lead the same weight as silver for significance in the geochemical signature. The numbers representing the sum of the ranks were divided into seven percentile classes that had upper limits of 100, 99, 95, 90, 85, 80, 75, and 50. Geographic groups of sample sites that could be characterized as being in the 85th percentile or higher for lead plus zinc plus copper plus silver were identified and assigned a favorability of high, medium, or low, as outlined in the criteria described below. This same procedure was applied to the numbers for the sum of the ranks for just lead plus zinc, which identified additional groups of sites that possibly represent lead-zinc veins containing little or no silver or copper. With the exception of

percentile. Nonmagnetic heavy-mineral concentrates from groups of sites have anomalous amounts of a single signature element, or a single site has two or more signature elements
+1 Stream sediments enriched in partially extractable antimony
0 Stream-sediment samples predominantly below the 85th percentile for summed signature elements. No isolated single-site anomalies for one signature element. Partially extractable antimony in the weighted concentrations is below the geometric mean value of 1.2 parts per million

GEOPHYSICAL DATA

The occurrence model for mesothermal veins (see text accompanying map *C*) assumes that mesothermal veins are related to known or inferred intrusions. Map *B* shows our interpretation of favorable ground based on interpretation of the total intensity aeromagnetic and Bouguer gravity data and the audio-magnetotelluric (AMT) survey.

Aeromagnetic data provide the most diagnostic criteria for identifying shallowly buried plutons and for recognizing the subsurface extent of plutons that are exposed at the surface. The aeromagnetic map of the quadrangle was evaluated for positive anomalies that are possibly related to buried intrusions, as well as for positive anomalies related to exposed intrusions. Standard computer techniques were used for spectral filtering and upward continuation of the data to enhance anomaly definitions, so as to help select those anomalies that could be caused reasonably by a pluton at depth. Gravity data, and AMT data where available, were used to help confirm or deny the probable existence of such plutons. Boundaries of favorable ground were drawn, although the precision of such boundaries is probably at best 3.2 km. Ground within the various areas was assigned favorability points from +3 to −1 according to the criteria given below.

+3 High-amplitude positive magnetic anomaly, commonly correlating with a negative gravity anomaly
+2 Lower amplitude positive magnetic anomaly, commonly expressed as a nose extending from an anomaly of point score +3. May or may not correlate with a negative gravity anomaly
+1 Low-amplitude positive magnetic anomaly or negative gravity anomaly, or some combination. One-station gravity anomalies not included. Magnetic anomalies related to magnetite-rich rocks of the Ravalli Group also not included
0 Broad zones of higher magnetic intensity that surround areas having point scores of +3, +2, or +1
−1 Other areas where the regional magnetic and gravity data show no anomalies judged to be related to plutons

DISCUSSION

Geochemical and geophysical factors used to derive map *B* are independent of the lithology, structure, and mineral occurrence factors used to derive map *A*. The Coeur d'Alene district and an area to the north and northeast of it are clearly favorable ground on both maps. However, the Greater Coeur d'Alene mineral belt, which extends southeast from the Coeur d'Alene district, is highly discontinuous in map *B*.

Boundaries for both geochemical and geophysical data are generalized and should not be considered precise. Original data for both kinds of information are of a reconnaissance nature, and boundaries between areas of differing point values commonly have a precision of about 2 km. The geochemical and geophysical boundaries were generated independently and then combined without modification. As a consequence, small areas of overlap (perhaps those of 4 km^2 or less) that result in isolated spots of higher favorability scores may not be as significant as they might appear on the map.

EXPLANATION FOR RESOURCE APPRAISAL

4/1 BOUNDARY BETWEEN AREAS THAT ARE ASSIGNED DIFFERENT RESOURCE POTENTIAL BASED ON GEOCHEMICAL DATA—Numbers are favorability scores for areas (see Geochemical anomalies section in text for detailed explanation)

1/0 BOUNDARY BETWEEN AREAS THAT ARE ASSIGNED DIFFERENT RESOURCE POTENTIAL BASED ON GEOPHYSICAL DATA—Numbers are favorability scores

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

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1986

MONTANA BUREAU OF MINES AND GEOLOGY
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MA 4-I