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GEOLOGICAL SURVEY

A case for plants in exploration: Gold in douglas-fir at the Red Mountain stockwork, Yellow Pine district, Idaho

By

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ABSTRACT

Evidence from this study indicates the presence of exploration targets beyond the Red Mountain stockwork not only for concealed deposits of Au, but also for Mo and W. The targets are new and, to a considerable degree, unexpected from other surface evidence. The biogeochemical anomalies that help define the targets are extensive, and the deposits that might be sought are presumably of low grade.

Red Mountain, which lies on the western edge of the ring-fracture zone of the Eocene Quartz Creek cauldron, has been prospected for Au and Ag for at least 50 years. A biogeochemical study was conducted in 1980-81 in an attempt to better assess the mineral potential of the stockwork area. Bedrock contacts are concealed by colluvium, glacial deposits, and forest cover. Soil and plant samples were collected on 200 yd centers over an area of 3600 ft x 8400 ft. The wood of douglas-fir (*Pseudotsuga menziesii*) and the leaves of beargrass (*Xerophyllum tenax*) were used because they concentrate Au and Mo, respectively. Results of the soil sampling were insignificant, although they did indicate a W anomaly south of the stockwork. Analysis of ashed wood by instrumental neutron activation yielded Au values of 0.07-14.2 ppm and revealed two distinct Au populations. More importantly, the highly anomalous samples (>4 ppm) are concentrated in the southern quarter of the grid in an area that has no anomalous Au in the sampled soils, has not been prospected for Au, and lies within inclusion-bearing granodiorite, not stockwork. Beargrass samples, which typically contain 20 ppm Mo, contained <5 to >500 ppm. A belt of above-median values of Mo transects some part of every map unit except the quartz body at the summit of Red Mountain. The great extent and the continuity of this belt require some comparably extensive bedrock source of the Mo. The location, shape, and Mo content of the bedrock source remain conjectural, but the source must be large. Subsequent geomagnetic traverses confirmed the belt configuration.

INTRODUCTION

Background

The Red Mountain stockwork is 3.5 mi north-northeast of Yellow Pine, a small settlement near the northwest corner of the Challis quadrangle. Red Mountain, so called from the reddish-brown color of its soil, is the local name for the land mass between Quartz Ridge and the forks of Quartz and Vein Creeks (fig. 1). The stockwork has been prospected for Au and Ag for at least half a century with little success. Recently, however, the area has received renewed interest by several claim-holders, in large measure owing to our geochemical efforts.

The purpose of this report is to present the results of biogeochemical studies that were conducted in 1980-1981 in an attempt to better assess the mineral potential of the stockwork area. Parts of this paper have been taken from the open-file report by Leonard and Erdman (1983).

Regional setting

The Red Mountain stockwork is a geologic anomaly in the region. Its structural setting and local features are perhaps unique for the following reasons: (1) it is a fine-scale stockwork, instead of a system of subparallel quartz veins with sporadic apophyses; (2) it is cut by radial dikes that are

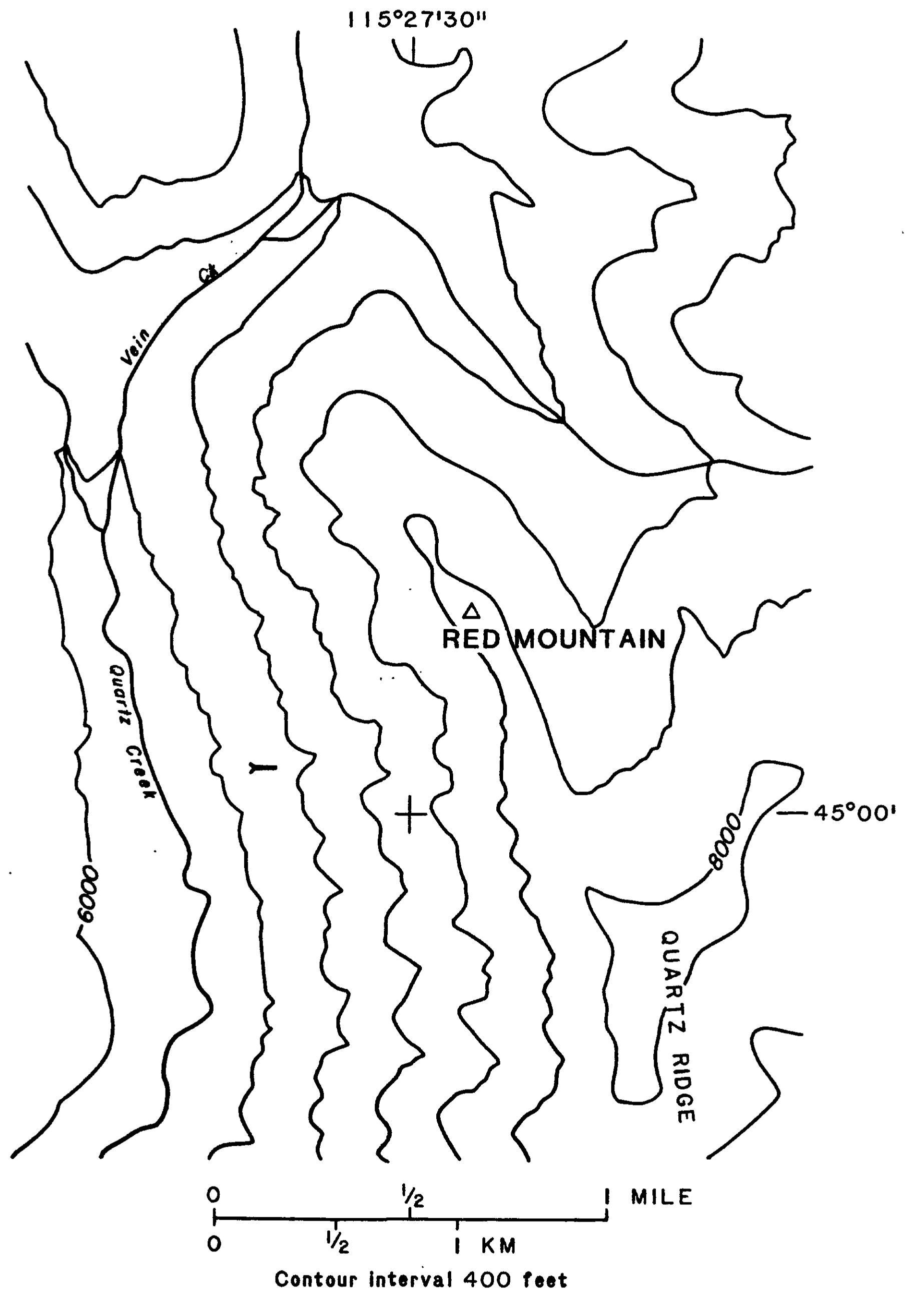

Figure 1.--Topographic map of Red Mountain and vicinity. (Adapted from U.S. Geological Survey 7.5-minute series topographic maps, Yellow Pine and Profile Gap quadrangles.)

small, instead of being accompanied by a few large dikes or by dike swarms; (3) it is locally dissected by radial faults; (4) it shows molybdenite, rarely seen in the Yellow Pine district, as well as scheelite and stibnite, which are common ore minerals in the district; (5) it contains sparsely disseminated pyrrhotite in addition to the ubiquitous pyrite and arsenopyrite; and (6) its envelope of clay-mineral alteration is quite the largest known in the region. Because the stockwork is geologically anomalous, it is the kind of feature that exploration geologists are always looking for--and hoping to find ore bearing.

The stockwork is close to the western margin of the Quartz Creek cauldron (fig. 2), the Eocene superstructure or very large subsidence feature that contains the Cougar Basin and Thunder Mountain calderas of Challis Volcanics (Leonard and Marvin, 1982). At the latitude of Red Mountain, north-striking ring fractures and attendant silicified zones of the cauldron appear to be offset along an ill-defined, east-trending zone that is partly occupied by the Red Mountain stockwork. The Johnson Creek-Quartz Creek silicified zone cannot be traced farther northward up Quartz Creek, and the Profile-Smith Creek silicified zone, passing through Profile Summit (Profile Gap), cannot be traced farther southward down Quartz Ridge. It is reasonable to suppose that, during subsidence of the Quartz Creek cauldron, the mechanical energy ordinarily released along radial or other faults linking discontinuous ring fractures was accumulated at the site now occupied by the stockwork. The Red Mountain block, severely strained, yielded partly by internal deformation and partly by intense crackling. Later, the silica-bearing solutions that produced the quartz veins and lodes of the great, ring-fracture-controlled silicified zones penetrated the crackled ground of the Red Mountain block and formed the stockwork.

Vegetation and soils

The study area is characterized by fairly rugged terrain that ranges from 6,000 ft at Quartz Creek on the west edge to about 8,000 ft at Quartz Ridge on the east (fig. 1).

The forest zone is mainly upper montane, and is dominated by douglas-fir (Pseudotsuga menziesii [Mirbel] Franco), although lodgepole pine (Pinus contorta Dougl.) and limber pine (P. flexilis James) are locally common. At higher elevations and on the slopes with northern exposures, elements of the subalpine forest, engelmann spruce (Picea engelmannii Parry) and subalpine fir (Abies lasiocarpa [Hook.] Nutt.), either partly or totally replace the douglas-fir. Douglas-fir is also absent along many of the stream bottoms; these are ideal habitats for blue spruce (Picea pungens Engelm.). The proximity of the sampling grid to the riparian and subalpine zones, therefore, leaves several "holes" in the plant-sampling design.

The forest understory consists of many species of small trees or shrubs, such as aspen (Populus tremuloides Michx.), alder (Alnus sp.), chokecherry (Prunus virginiana L.), and serviceberry (Amelanchier alnifolia Nutt.). Common ground-cover species are beargrass (Xerophyllum tenax [Pursh] Nutt.), grouseberry (Vaccinium scoparium Leiberg), and elk sedge (Carex geyeri Boott), plus a fairly rich assemblage of other herbaceous plants.

The soils of the Red Mountain area are mainly residual, or very nearly so. Even on 35° slopes one can usually find some soil that has not crept far. Most of the clay minerals in soil developed in bedrock reflect the hypogene alteration of the parent bedrock. The clay minerals in soil (Leonard and Erdman, 1983) are distinctively zoned. The sericite and kaolinite zones

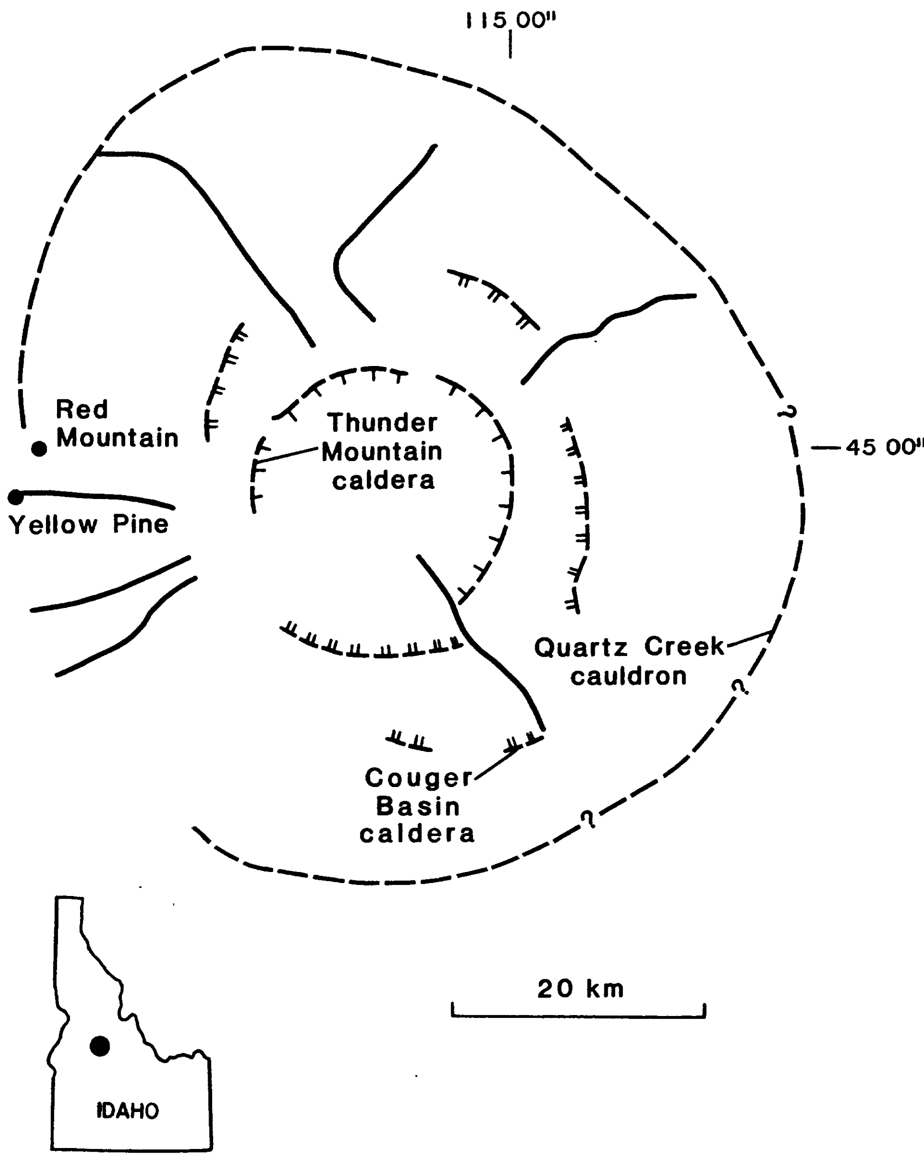

Figure 2.--Generalized map of the Thunder Mountain caldera complex. (After Leonard and Martin, 1982.)

are crudely central to the stockwork, and the montmorillonite and chlorite zones are peripheral. The zones, locally overlapping, are longitudinally asymmetric and southwardly displaced with respect to the Summit quartz body noted below.

Geology

Because contacts of the rock units are concealed at the surface by colluvium or, locally, by Quaternary debris, Leonard mapped the contacts by float. Details of the geology and ore minerals observed at Red Mountain are given in Leonard and Erdman (1983). For the purpose of this report the geology (fig. 3) has been simplified from 17 units (1:1,200-scale unpublished map of Leonard) to seven units, as follows:

(1) Undifferentiated Quaternary deposits.

(2) A virtually barren quartz body on the summit of Red Mountain--the Summit quartz body.

(3) A quartz stockwork surrounding the quartz body and underlying the upper slopes of the mountain. This stockwork contains quartz veins and veinlets, commonly intersecting, and replacement aggregates of quartz. It locally contains relics of granite.

(4) A small, isolated piece of a silicified zone, within granite, exposed low on the northwest flank of the mountain. The north end of the Quartz Creek silicified zone, here consisting of minor quartz veins, veinlets, and replacement patches in granite or in the mixed-rock unit, is poorly exposed southwest of Red Mountain.

(5) A Cretaceous granite surrounding most of the stockwork and underlying the lower slopes. This unit is variably deformed, locally argillized, and sporadically replaced by muscovite and quartz.

(6) A biotite-muscovite granodiorite of the Idaho batholith suite exposed at the north edge of the area. The unit approximates the regional type; it is porphyritic to subporphyritic and is generally little altered.

(7) A mixed-rock unit at the southeast corner. It is a mass of granodiorite and alaskite of the Idaho batholith suite, here containing sparse inclusions of quartzite, biotite schist, and amphibolite of the Precambrian Yellowjacket Formation.

Taken as a whole, the presence of radial dikes and faults, the existence and gross shape of map units (2), (3), and (5), the drainage pattern, the zonal distribution of clay minerals in soil, and the still to be described subelliptical shape of the Mo anomaly in beargrass and crudely oval pattern of magnetic anomalies suggest that a Tertiary intrusive is concealed beneath Red Mountain.

The Au anomaly that we will describe is in the area underlain, for the most part, by the inclusion-bearing granodiorite, not the stockwork.

METHODS

Field

In 1980 a sample grid with 200-yd centers was laid out mostly over the stockwork. Based on the initial analytical results, the grid was extended in 1981 to the south and east. Even the extensions failed to enclose the area of economic interest.

A soil sample, weighing 0.5-1 kg, was taken from each grid intercept at a depth of 4-8 in. after the site was scraped free of forest litter or plant

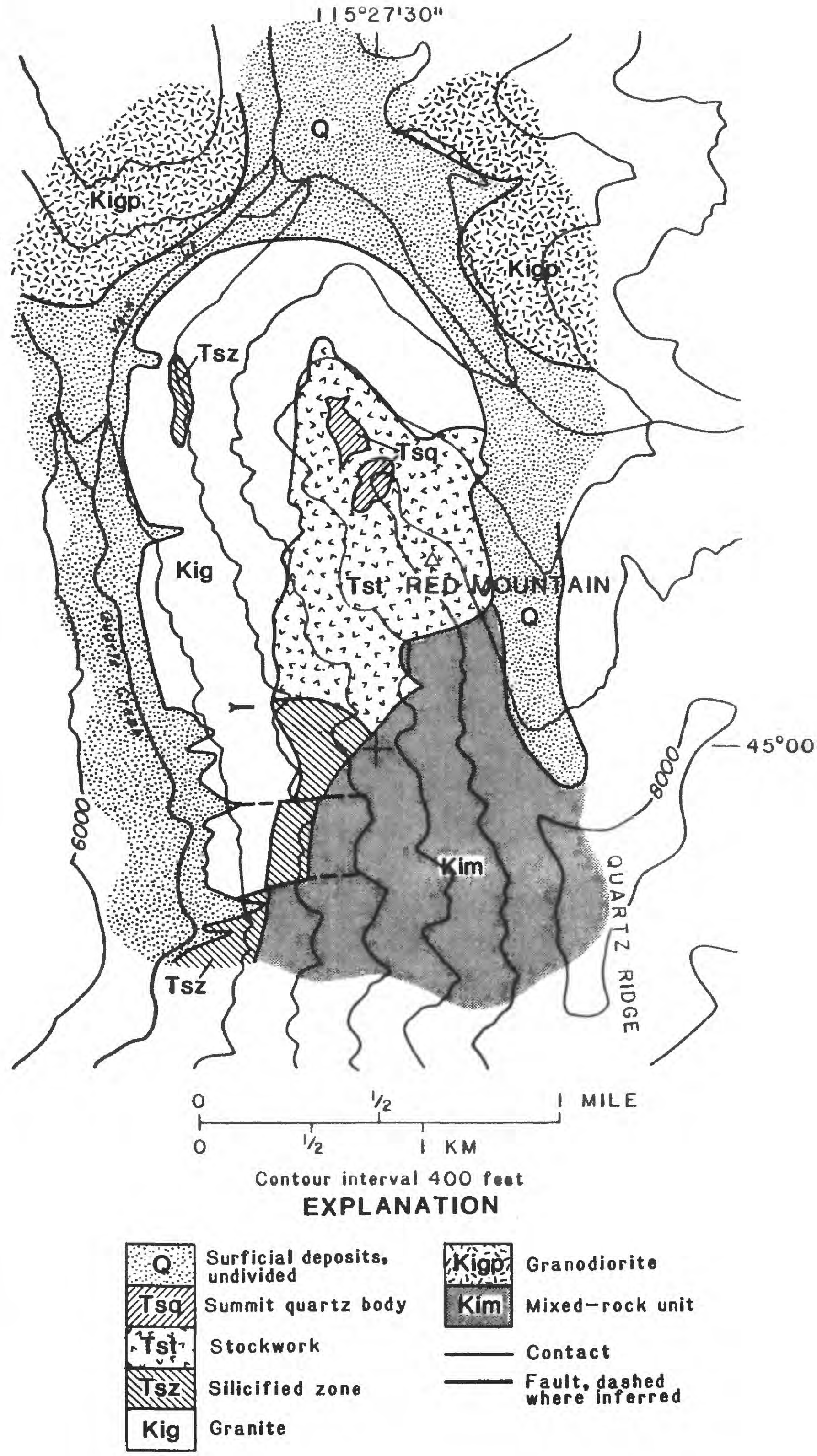

Figure 3.--Generalized geologic map of the Red Mountain stockwork and vicinity.

growth. The sample was screened to minus 10 mesh, mixed, and split into two parts, one for chemical analysis and the other for clay studies. Organic debris that passed the stainless-steel screen was later floated off with water in the laboratory.

Douglas-fir was selected as the main sampling medium for the biogeochemical survey for two reasons. First, although it does not grow everywhere in the study area, it is more common than the several other species of conifer that occur there. And second, ". . . wherever douglas-fir occurs it affords an excellent biogeochemical tool" (Warren, 1980, p. 361). Warren and Delavault (1950) were the first to report an Au content in douglas-fir--0.65 ppm in the ash of "fresh new growth" from a mineralized area in British Columbia.

Results from an earlier biogeochemical survey of a number of mineral prospects in the Challis quadrangle (Erdman, unpublished data) pointed to douglas-fir as a likely concentrator of Au, specifically its wood tissue. In a study of the Empire Au district in Colorado, Curtin and others (1968) concluded that Au is most concentrated in tree roots. In our judgment, wood from the tree trunk is more easily sampled than is that from the roots. These results run counter to those of Khotamov and others (1966), who found Au most concentrated in the leaves.

We selected a medium-sized douglas-fir tree (40-50 cm trunk diameter) that was closest to each sample point at the grid intercept. In some cases the tree was some distance from the intercept and soil pit, but all of the tree-sampling points were within 30 m of the grid point. Occasionally, the only tree available for sampling was not of moderate size and was either somewhat smaller or, more commonly, considerably larger.

Approximately 50 g of wood was extracted from the trunk by means of a brace and bit. This amount filled a small cloth sample bag and provided sufficient ash for analyses by emission spectroscopy and neutron activation. The ash yield of wood is 0.1-0.3 percent, so most samples yielded, at minimum, 50 mg of ash.

Two types of wood can be clearly recognized when coring--a usually thin zone of almost white sapwood and an interior zone of reddish heartwood. We sampled the sapwood, each sample requiring about six borings, on the average.

Analytical precision was estimated from analyses of duplicate samples taken from each of nine trees scattered throughout the grid area. Separate bags were filled from alternate sapwood borings. We found the reproducibility of analytical results to be satisfactory for the purposes of this study.

In addition to sampling douglas-fir mainly for its Au content, we also sampled two kinds of herbaceous plants, beargrass and elk sedge, because of their demonstrated ability to concentrate Mo. Molybdenum is often a pathfinder element in Au occurrences and is of special interest at Red Mountain because molybdenite occurs there. Beargrass, a member of the lily family, is a large clump-forming herb common to the area; samples of the leaves were collected from 96 of the grid sites. The samples were taken from three to five mature, healthy plants within 30 m of the soil pit and grid intercept, and the samples of leaves from the individual plants were combined to give one sample weighing several hundred grams. Eighteen samples of elk sedge, each sample a composite of leaves of three or more plants near the soil pit, were collected along the three southernmost traverse lines where beargrass was absent (14 sites) or where beargrass and elk sedge were collectible as paired samples (4 sites). Based on the small number of paired samples from a restricted area, elk sedge is the better concentrator of Mo, but beargrass is more quickly recognized, identified, and collected.

Analytical

The minus-10-mesh fraction of the soil samples was pulverized, then analyzed for 40 elements by semiquantitative emission spectroscopy and for Au, Hg, W, As, and Sb by special methods: atomic absorption for Au and Hg, inductively coupled plasma for W, and hydride generation-atomic absorption for As and Sb.

The plant samples were first oven-dried at 40°C, then pulverized to pass a 1.3-mm sieve in a Wiley mill, and finally ashed in a muffle furnace with temperature controls that permitted a slow increase in temperature to a maximum of 500°C. The heating and cooling cycle was 24 hours.

Small aliquots of ash (~10 mg) were submitted for analysis of 29 elements by semiquantitative emission spectroscopy.

Gold determinations were made on ~30-40 mg samples by neutron activation analysis, a technique considered to be ideal for samples of small mass and containing low element concentrations (Warren, 1980; Brooks and others, 1981; Hoffman and Brooker, 1982). Instrumental neutron activation analysis (INAA) provides a relatively convenient, precise measurement of low-level Au in ashed plant samples. In the analysis of the sapwood of douglas-fir the method yields a detection limit of ~0.008 ppm Au in the ash, which corresponds to 0.05 ppb in the dried raw wood. Based on replicate measurement of a single sample, the precision was within ±10% at the 0.1 ppm level. The technique is briefly described, as follows:

Aliquots of 30-40 mg of wood ash were weighed into pre-cleaned 2/5-dram polyvial irradiation containers. Elemental standards were prepared by weighing similar volume aliquots of USGS Au-quartz standard GOS-1 (Millard and others, 1969) and by evaporating aliquots of a multi-element standard solution, containing Au, As, and Sb, onto specpure SiO_2. Samples and standards were simultaneously irradiated in the USGS Triga reactor for 8 hr at 5×10^{12} n/cm^2/sec. Irradiated sample vials were cleaned externally with water and loaded into appropriate automatic sample changer vials (2-dram polyvials) for counting. Data were acquired automatically from a system consisting of multiple Ge(Li) detectors with sample changers coupled to a Nuclear Data ND-6620 computer-based multichannel analyzer. Samples and standards were successively counted for 20 minutes each after a decay period of 4-6 days, and a direct comparison of sample and standard peak area was made after appropriate normalization for differences in decay time, dead time, etc.

Tungsten was determined colorimetrically (Quin and Brooks, 1972) on samples of ashed beargrass leaves. The Mo content determined by semiquantitative emission spectroscopy was confirmed colorimetrically on a representative suite of these samples.

RESULTS

Metal anomalies in soils sampled from the gridded area are mostly weak and small, although the samples did indicate a W anomaly south of the stockwork. The only Au anomaly--1.1 ppm--occurred at a site on the stockwork. Gold concentrations in most soil samples were less than 0.05 ppm. Specifics of the soil results are given in Leonard and Erdman (1983, p. 21-29).

In contrast to the metals in soil, the metals in plant ash showed anomalies so strong and associated areas of above-median values so large that Red Mountain would be an attractive area for exploration even if the local geology were unknown. Few of the metal anomalies in plants are in the stockwork. Rather, they occur on geologically puzzling terrain: the valley fill of Quartz Creek and the inclusion-bearing granodiorite. The anomalies are consistent with the inference of a concealed elliptical substructure that may be hoodlike and may contain more than one mineralized zone.

Gold distribution

Gold concentrations in the ash of douglas-fir sapwood range from 0.07 to 14.2 ppm, more than two orders of magnitude. More important, the highly anomalous samples (>4 ppm) are concentrated in the southern part of the sampling grid (fig. 4) where no anomalous Au was found in the soils. This area has not been prospected for gold, and lies within inclusion-bearing granodiorite, not stockwork.

The mean of the raw Au values is 0.85 ppm and the standard deviation is 1.72. Because the frequency distribution is strongly skewed (skewness, 5.2), we plotted the frequency distribution on a log scale and transformed the data to logarithms to compute the geometric means (fig. 5). The histogram showed a bimodal distribution, which suggested the presence of two populations. This possibility was tested by using a statistic recently proposed by Miesch (1981). The statistic is a standardized gap which, if statistically significant, can be taken as the separation between two geochemical populations. The results indicate a significant gap (fig. 5) whose probability of occurrence if no anomaly were present is 0.086 (confidence level, 91.4%). The Au values for 53 of the 114 samples lie above the gap, whose center is at 0.35 ppm. Therefore, two populations of approximately equal size are indicated, the upper one being anomalous.

Another measure of the remarkably high concentrations of Au in the anomalous population at Red Mountain is provided by the Au found in a suite of 20 samples of douglas-fir wood from the Basin Creek watershed, which is also in the Challis quadrangle but in an area of no known Au mineralization. There the Au concentrations ranged from 0.04 to 0.31 ppm, which corresponds with the statement by Shacklette and others (1970, p. 2) that the amounts of Au in plant ash are usually much smaller than 1 ppm.

The only reasonable conclusion we can reach is that Au levels are unusually high in the southern quarter of the sampled area. Lakin and others (1974) stated, "The relative insolubility of gold drastically limits the portion of the total gold under the plant that is available to the plant roots." Therefore we would expect to find such unusual concentrations of Au in plants only in an area where Au is relatively abundant. The high concentrations observed in the ash of douglas-fir wood, but not in soil from the same sample sites and those nearby, suggest that the root system of the tree has taken up Au from a source deeper than that which commonly contributes Au to the soil.

Molybdenum distribution

Biogeochemical sampling of possible polymetallic occurrences may require the use of more than one type of plant. This we found to be true at Red Mountain. We sampled douglas-fir mainly for its Au content; but we sampled beargrass--and, to a limited extent, elk sedge--because of their ability to concentrate Mo.

The Mo content of 96 samples of ashed beargrass leaves ranged from <5 to >500 ppm; that of 18 samples of sedge leaves ranged from 5 to 100 ppm. The 50th and 95th percentiles were the same for both plants--20 and 100 ppm,

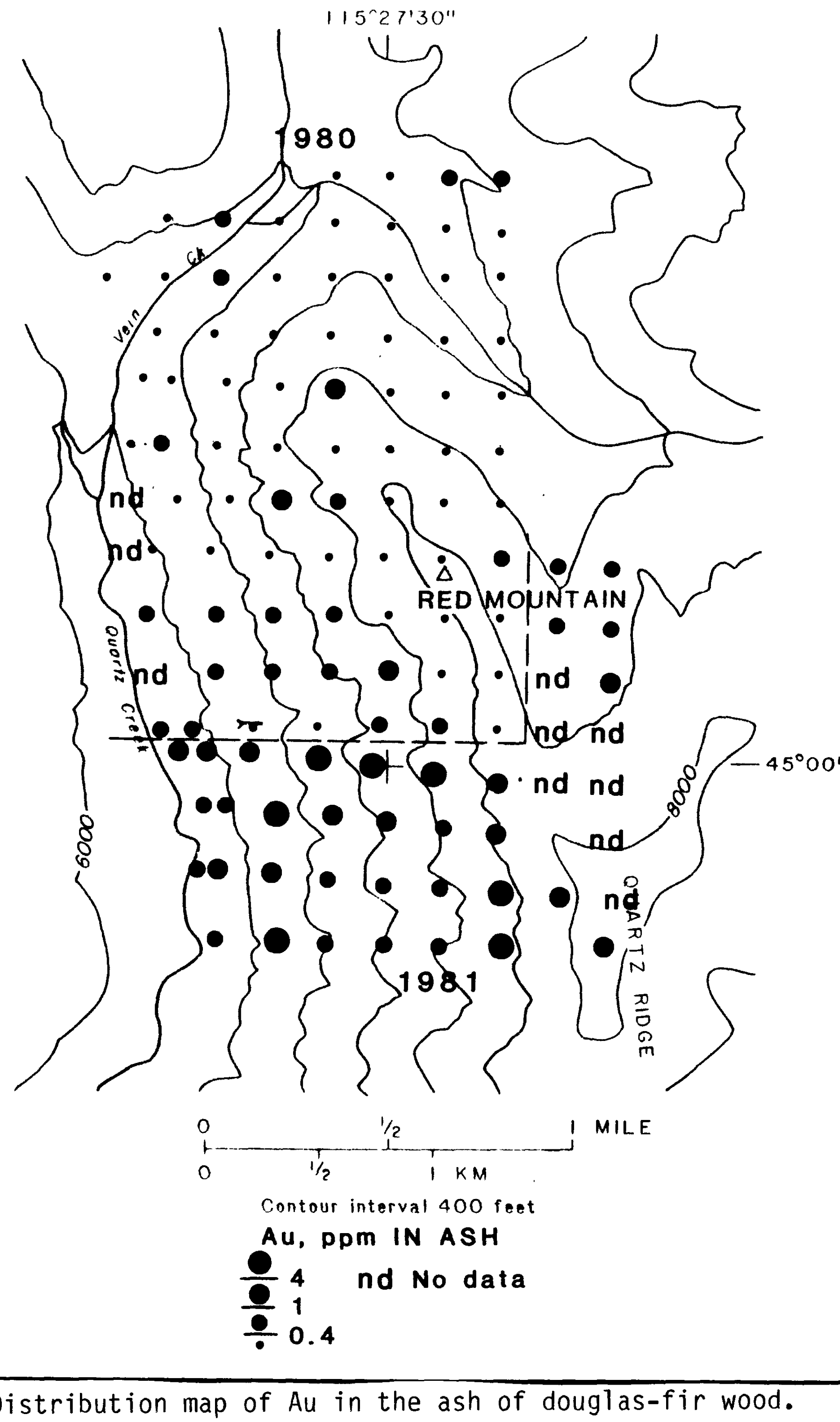

Figure 4.--Distribution map of Au in the ash of douglas-fir wood.

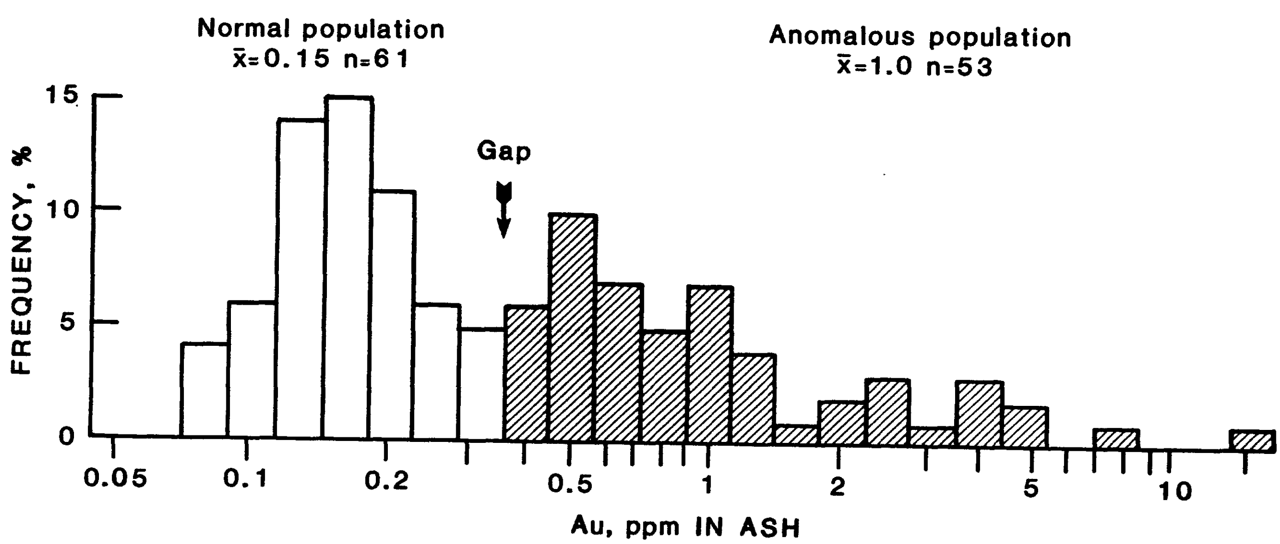

Figure 5.--Histogram of Au in the ash of douglas-fir wood, showing two populations.

respectively. When these extreme concentrations are compared with norms for the same kinds of plants collected elsewhere in the region, we see clear evidence for concealed Mo mineralization at Red Mountain.

Molybdenum concentrations in beargrass sampled from the Challis quadrangle in 1979 were <5-20 ppm; these occurred in areas that were considered background for Mo. On the other hand, concentrations of 200 ppm were found in samples collected at the ore body at the Sunnyside Au mine in the Thunder Mountain district. The host rock is a rhyolite ash-flow tuff where Mo is strongly associated with the Au.

Normal concentrations of Mo in elk sedge appear to be 20 ppm, based on 27 samples collected from nine prospects or mines that represented various kinds of mineral deposits in the region. Anomalous concentrations of 100 to 200 ppm were observed in samples from the Sunnyside Au mine mentioned above, the new Thompson Creek mine (a world-class Mo deposit), and several W occurrences. Molybdenum concentrations in the 18 samples of sedge collected at Red Mountain ranged from 5 to 100 ppm, with the anomalous samples corresponding to the zone established by the high levels of Mo in beargrass.

With few exceptions, all above-median values occur in a curved belt that extends around the western side of the grid and is peripheral to the exposed stockwork (fig. 6).

This, then, is evidence that a Mo occurrence is associated with the Au anomaly at Red Mountain, an anomaly that we were unable to close off with the present sampling design.

The belt of above-median values of Mo in beargrass and elk sedge transects some part of every geologic map unit in the area except the Summit quartz body. Much of the belt is on Quaternary deposits, either alluvial or glacial or colluvial, and is therefore most difficult to interpret.

We can draw one inference with assurance: the great extent and the continuity of the belt of above-median Mo values in beargrass and sedge require some comparably extensive bedrock source of Mo. The location, shape, and Mo content of the bedrock source remain conjectural, but the source must be large.

Tungsten distribution

In his book on biogeochemical exploration for mineral deposits, Kovalevskii (1979, p. 87) states, "The most important indicators of molybdenum and tungsten deposits are the elements themselves." Yet, very little is known of the absorption of W by plants (Kovalevskiy, 1966). Brooks (1972) does say (p. 885) that biological response to W occurrences is reasonably good. Quin and Brooks (1974) reported that even though soil sampling was generally satisfactory, tree-trunk sampling was effective in locating extensions of known scheelite-bearing reefs in New Zealand.

Previous studies by Leonard (in press) on the response of beargrass to W occurrences encouraged us to submit our samples for analysis by colorimetry. At Red Mountain, the tungsten anomaly in beargrass is clearly subtle; its ashed leaves contain <1 to 2 ppm W. Nevertheless, at this low level the areal distribution of the 1 and 2 ppm values shows a pattern generally resembling that of the major belt of above-median values of Mo in beargrass (fig. 7).

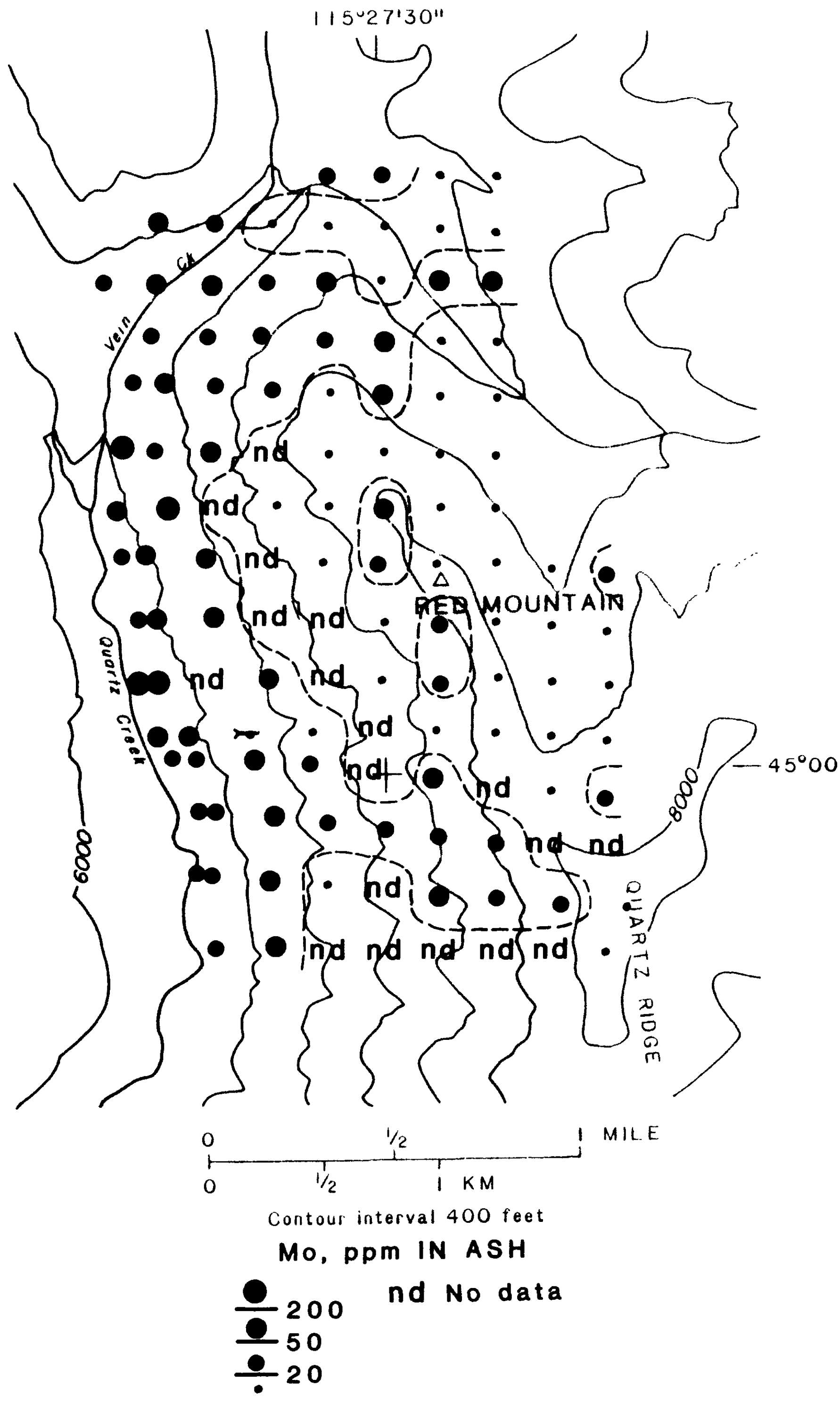

Figure 6.--Distribution map of Mo in the ash of beargrass and elk sedge. Isopleths enclose anomalous areas.

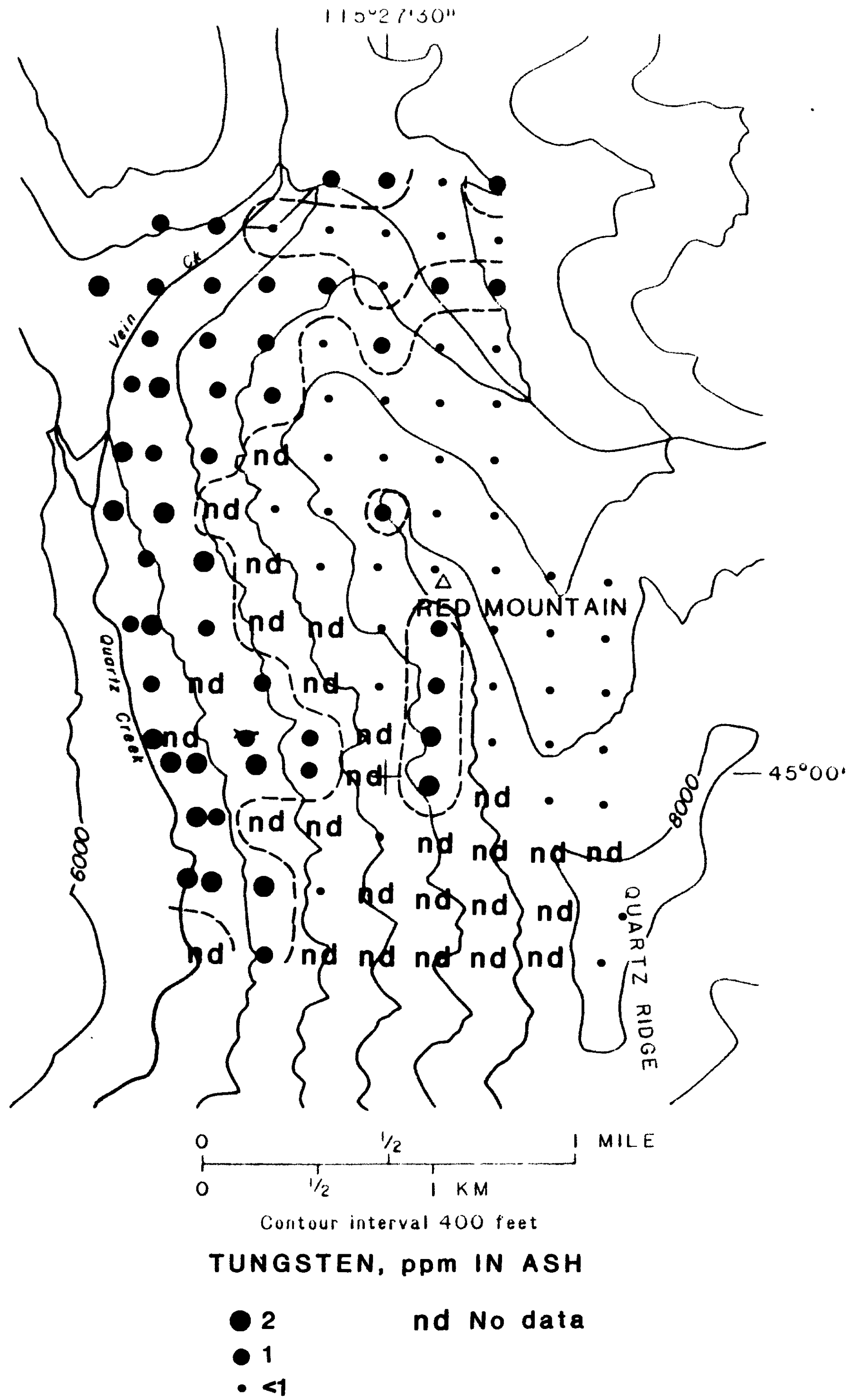

Figure 7.--Distribution map of W in the ash of beargrass. Isopleths enclose anomalous areas.

Geomagnetic anomalies

The biogeochemical data provide evidence of an apparent subsurface structure that was not obvious from detailed surface mapping. It is discordant with the bedrock structure. A subsequent packborne geomagnetic survey tended to confirm this.

Map GP-841 (U.S. Geological Survey, 1972), contour interval 20 gammas, shows a distinct crowding of contours in the Red Mountain area, but no isolated magnetic high or low. Therefore, in making a ground survey by precession magnetometer we did not expect to learn much about the gross structure of the area. We did hope that a ground survey would show the distribution of disseminated ferromagnetic pyrrhotite within stockwork or granite, and that the pattern of distribution would be useful in interpreting local structures. We found, instead, that Red Mountain itself is an area of uninterpretable magnetic noise, that magnetic anomalies having some continuity are present north, west, and south of the mountain, and that the northern and southern anomalies are discordant to the rock structure as mapped. Detailed work beyond what we have done would be required to choose between near-surface alteration and deep-seated structure as the probable cause of these magnetic anomalies.

Details of the packborne magnetometer survey and of the specific anomalies are described in Leonard and Erdman (1983). Collectively the magnetic anomalies of the Red Mountain area show the categorical features of an oval (fig. 8). Its major axis is nearly north-south, its top (north) flattened, its bottom (south) tapered, its west side rectilinear, and its east side barely sketched. The mappable part of the oval resembles the shape of the curved belt of above-median values of Mo in beargrass, and the two features are superposed along the west and south sides of the grid.

Our best guess is that the sources of the magnetic anomalies are somehow related to wallrock alteration attendant on mineralization. The anomalies discordantly overprint the east-trending belt of above-median values of Mo in beargrass and the swatch of high values of Au in douglas-fir, but they are confined to these biogeochemical domains.

CONCLUSION

Evidence presented in this report indicates possible exploration targets for concealed deposits of gold, molybdenum, and tungsten at Red Mountain. The targets are new, the biogeochemical anomalies that help define the targets are extensive, and the deposits that might be sought are presumably of low grade but perhaps large.

The distribution of metals in plants, of clay minerals in soil, and of low-intensity magnetic anomalies at the limits of the sampling grid strongly suggest that the subsurface structure is different from the structure that can be mapped. The subsurface structure may be hoodlike--relatively flat or gently undulating beneath the exposed quartz stockwork, but draped downward and covered by Quaternary deposits along Vein Creek and Quartz Creek.

Several of the targets would be unsuspected if plants did not concentrate metals. The advantage of sampling plants in lieu of or as a complement to sampling soils is especially clear in searching for gold. Two of these advantages are the circumvention of the particle sparsity effect (Harris, 1982) and the ability of plants to "sample" a large volume of soil and underlying weathered bedrock.

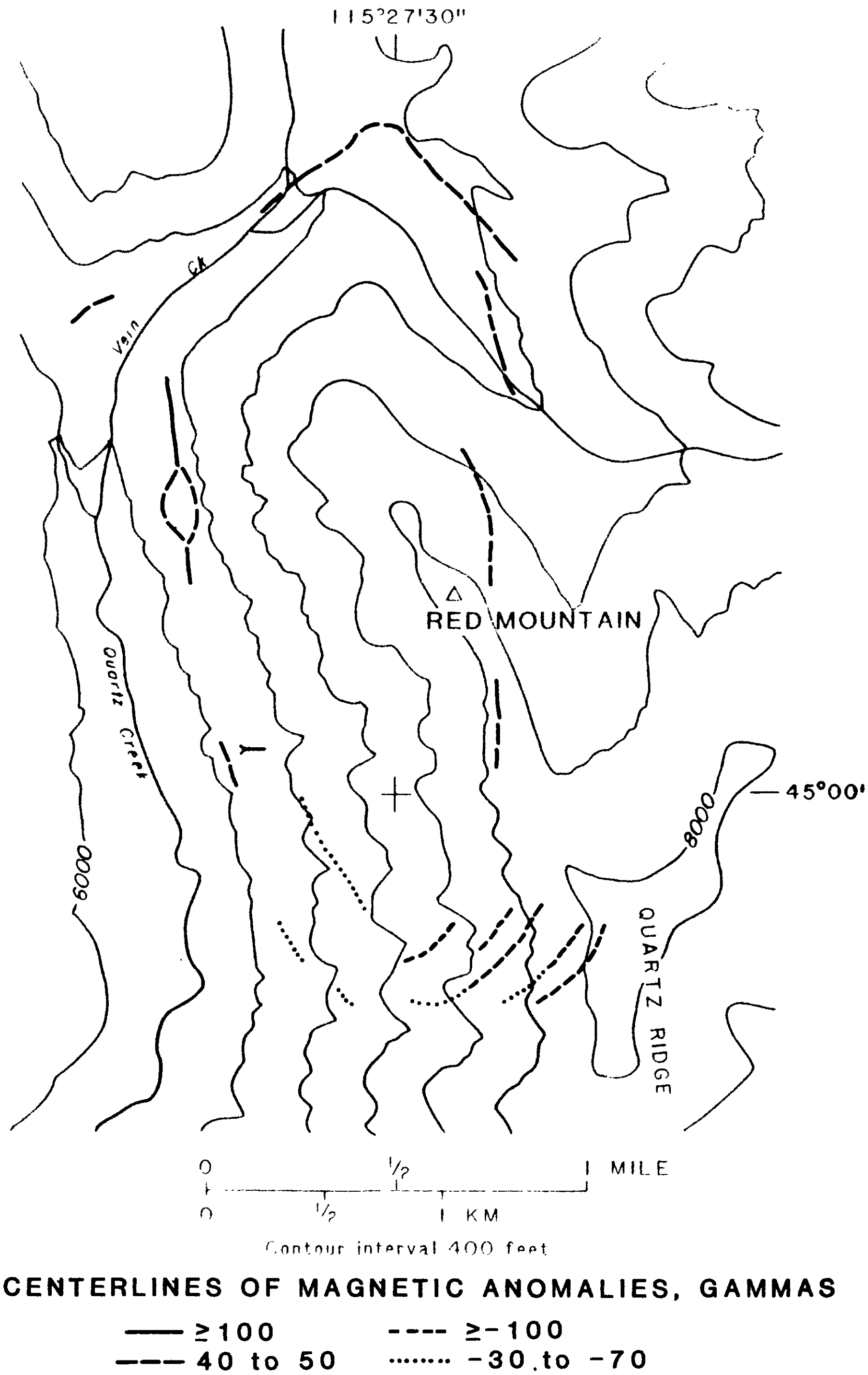

Figure 8.--Map of geomagnetic anomalies at the Red Mountain stockwork.

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James G. Brophy, William Lynch, and David K. Swanson served as field assistants in 1979-1981. Spectrographers Leon A. Bradley, E. F. Cooley, and Mollie Jane Malcolm, chemist James G. Crock and his associates, and plant analysts Thelma Harms and Clara Papp provided the analytical data essential to this report. Mary Lou Tompkins processed the analytical data for computer treatment. Alfred T. Miesch introduced us to the Gapmap program used for part of the statistical analysis. All the workers listed above are or were members of the Geological Survey. Volunteers Chris Erdman and Eleanor Leonard helped with surveying and sample collecting.

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