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# Preliminary Report on Geology, Geochemical Exploration, and Biogeochemical Exploration of the Red Mountain Stockwork, Yellow Pine District, Valley County, Idaho

By

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Contents

Tables

Abstract

New exploration targets for gold, molybdenum, tungsten, and tin are indicated by the systematic distribution of metals in soil and plants of the Red Mountain stockwork and its environs. The stockwork is built of countless quartz veins and veinlets, extensively argillized and containing sparsely disseminated gold, pyrite, arsenopyrite, pyrrhotite, fluorite, and other minerals. The stockwork developed along the outer ring-fracture zone of the Eocene Quartz Creek cauldron where subsidence strain, unrelieved by radial faulting, produced internal deformation and intense small-scale fracturing in rocks of the Idaho batholith. The stockwork, cropping out as a fault-bounded polygon 2,700 ft long and 2,000 ft wide, contains (underlies?) a large, virtually barren quartz body 1,350 ft long and 350 ft wide. Deformed, shattered granite flanks and presumably underlies the stockwork, which may plunge southward beneath inclusion-bearing granodiorite and alaskite of the Idaho batholith suite. Narrow dikes of rhyolite and latite radiate from two centers within the quartz body. Many dikes and small bosses of rhyolite and latite intrude stockwork and granite. The radial habit of some dikes and the high frequency of small intrusives concentrated within the sericite and kaolinite alteration zones suggest that a Tertiary porphyry is concealed beneath the mountain. Clay-mineral alteration zones mapped in residual soil extend far outward from the stockwork. Valleys filled with Quaternary deposits bound the stockwork-granite complex on the east, north, and west, effectively concealing elements of a crudely elliptical substructure that differs from the fault-dissected, mappable part of the complex.

Metal anomalies in soil of the 3,600-ft x 8,400-ft gridded area are mostly weak and small. In contrast, metal anomalies in plants are strong, large, and consistent with the inference of a concealed elliptical substructure that may be hoodlike and may contain more than one mineralized zone. Gold in ashed sapwood of douglas-fir (*Pseudotsuga menziesii*) indicates a major gold anomaly, peak value 14.2 ppm Au, on inclusion-bearing granodiorite in an unprospected area south of the exposed stockwork. Locally, the gold anomaly is accompanied by a sizable tin anomaly, peak value 100 ppm Sn, in douglas-fir. Molybdenum in ashed leaves of beargrass (*Xerophyllum tenax*), peak value >500 ppm Mo, indicates extensive anomalies within a 2-mile-long semi-elliptical belt of Mo values exceeding the 20 ppm median. Most of the belt is on valley fill, but the southern segment of it, near the major gold anomaly, is mainly on inclusion-bearing granodiorite. Here, where beargrass is sparse, the peak value of Mo in beargrass drops to 70 ppm. Where beargrass is absent, ashed leaves of sedge (*Carex geyeri*) have anomalous values of 100 ppm Mo. An additional target for molybdenum is indicated by molybdenite from the inaccessible part of the main adit. The molybdenite, seen only in dump specimens, is in weakly silicified granite that may underlie part of the stockwork. The source body of the molybdenite is blind, and no clue to it is given by samples of soil or plants. Just north of the major gold anomaly, 2 ppm values of W in beargrass coincide approximately with a tungsten anomaly in soil (peak value 22 ppm W) in an area of float containing disseminated scheelite in weakly silicified inclusion-bearing granodiorite. Other areas of 2 ppm W values in beargrass are nearly coextensive with the Mo-in-beargrass anomalies on Quaternary deposits of Quartz Creek valley. Some of the target areas for gold, molybdenum, tungsten, and tin have not been circumscribed by our sampling.

## Introduction

The Red Mountain stockwork (U.S. Geological Survey, 1981) is in the SE1/4 of sec. 3, T. 19 N., R. 8 E., Boise meridian, 3.5 miles north-northeast of Yellow Pine settlement. 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, Profile Gap 7 1/2-min quadrangle. Claims on Red Mountain are held by Rudolph C. Schulz and Robert Schulz, Oroville, California, and by Stephen G. Zahony, Denver, Colorado. Nearby claims are held by System Fuels, Inc., New Orleans, Louisiana.

This preliminary report is intended to provide some of the information urgently requested by claim holders and exploration companies. The report is issued without maps because the delay in preparing them would defeat the intention of releasing information promptly. Company interest focuses on the results of our geochemical and biogeochemical work, which can be summarized as tables of analytical data and coordinates of critical sample sites and survey stations. Sample sites listed in table 1 can be recovered in the field by walking out the essential lines of the sample grid, finding the orange-painted stakes that mark the grid points, and looking near each stake for a soil pit marked with an aluminum tag and for a mature douglas-fir showing auger holes at breast height. Sampled clumps of beargrass near the stake may still show cut leaves among the new growth. Information on sampling methods is given in a subsequent section of the report.

The coordinate system and layout of the essential part of the sample grid can, from table 1, be reconstructed by the user of the report and then superposed on a suitable enlargement of parts of the Profile Gap and Yellow Pine 7 1/2-min quadrangles. The enlarged topographic base will be deficient in many respects, serving only as a rough guide for fieldwork.

The coordinate system has a meridian approximating true north and an origin at (20 000N, 20 000E), close to spot elevation 7717 shown on the Profile Gap quadrangle (compare data of table 1). Primary survey points within the coordinate system were established by electronic distance measurement, secondary points were established by stadia, and both methods were used to make a topographic base for selective geologic mapping (scale 1:1,200) and to rectify the sample grid.

The original sample grid, based ideally on 200-yard (~200-m) centers, was laid out from a taped 6,000-ft baseline running north from OWO (table 1). Grid lines 0 through 10 were run west from the baseline at 200-yard intervals, and grid points for sample sites were measured off, by string and clinometer, at 200-yard intervals. The numbering scheme for points of the original grid is illustrated by the following: 1W3 is a point on Line 1 North at a distance of 1 sample interval (200 yards) north of OWO and 3 sample intervals (600 yards) west of the baseline ("north one, west three"). The grid was later extended south of Line 0, as lines 2<u>1</u>, 2<u>2</u>, 2<u>3</u>, and 2<u>4</u>. Thus 23W4 is a point on Line 23 at a distance of 3 sample intervals south of OWO and 4 sample intervals west of the extended baseline ("south three, west four"). A third grid, established east of the baseline, has points such as 21E1 and 2E2, whose numbering should be obvious from the foregoing examples. Steep slopes, forest and snow cover, local magnetic declination, and not-so-skillful sighting and chaining contributed some distortion to the grid. A nearly correct position for the grid points then had to be determined by stadia ties to points near the ends of the grid lines and by interpolation or extrapolation to neighboring points. The rectified sample grid is the one that exists on the mountainside, not the one ideally conceived.

The original sample grid accommodated what seemed in 1979 to be the economically significant part of the local geology. A year later, preliminary analyses of soil samples collected in 1980 showed that the grid had to be extended southward and eastward. Even these extensions have failed to box the area of economic interest. But since each year's marking of survey stations and sample sites has been closely observed and followed up by claim stakers, we are confident that private interest in the area will continue.

## Geology

### Regional setting

The Red Mountain stockwork is a geologic anomaly in the region. Its structural setting is perhaps unique; it is a fine-scale stockwork, instead of a system of subparallel quartz veins with sporadic apophyses; it is cut by radial dikes that are small, instead of being accompanied by a few large dikes or by dike swarms; it is locally dissected by radial faults; it shows molybdenite, rarely seen in the Yellow Pine district, as well as scheelite and stibnite, which are common ore minerals in the district; it contains sparsely disseminated pyrrhotite in addition to the ubiquitous pyrite and arsenopyrite; and 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, the Eocene superstructure or very large subsidence feature that contains the Cougar Basin and Thunder Mountain calderas of Challis Volcanics (Leonard and Marvin, in press). At the latitude of Red Mountain, meridional 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 here accumulated. 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.

The Red Mountain block, like some other parts of the intra-cauldron terrane, may bear the marks of Eocene, post-subsidence regional extension that gave rise to the northeast-striking Little Pistol dike swarm discussed by Leonard and Marvin (in press). Northeast-striking faults within the Red Mountain block are difficult to explain as an accident of cauldron subsidence, yet they are an expectable accompaniment of the Little Pistol structural event. Some of these northeast-striking faults at Red Mountain are cut by faults that displace glacial deposits. The youngest faults are thus Quaternary--perhaps mainly or wholly recent (Holocene)--as are the faults that cut alpine moraines and modern talus aprons in the Big Creek-Yellow Pine country.

## Rock units and contacts

The main elements of the geology of Red Mountain are simple. It is only the structural relation of the rock units that is difficult to visualize without access to the geologic map. However, the fundamental structural relation for the larger rock units cannot be determined by surface mapping alone. Drilling and trenching, as well as mapping of the now-inaccessible part of the main adit, will be needed to make the structural relation clear. Since all contacts of the rock units are concealed at the surface by colluvium or Quaternary debris, the contacts must be mapped by float. No matter how carefully this is done, many uncertainties remain.

The bedrock units are: quartz body on the summit of Red Mountain--the Summit quartz body; quartz stockwork surrounding the quartz body and underlying the upper slopes of the mountain; granite surrounding most of the stockwork and underlying the lower slopes; a small, isolated piece of a silicified zone, mainly within granite, exposed low on the northwest flank of the mountain; 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; and myriad Tertiary dikes and perhaps small stocks. A little biotite-muscovite granodiorite of the Idaho batholith suite is exposed at the north edge of the area. The rock is not described in this report.

Summit quartz body.--The Summit quartz body is about 99 percent quartz--milky, commonly fine grained, compact, outwardly homogeneous but actually built of intersecting quartz veinlets ranging in thickness from less than a millimeter to some centimeters. The veinlets very likely formed initially as fracture fillings, but quartz has almost completely replaced the preexisting rock, leaving only an occasional feldspar grain and perhaps some relict muscovite. Flakes of new muscovite are very sparingly present, clay minerals are seldom visible, and specks of sulfides--mostly limonitized pyrite--are rare. The Summit quartz body is bounded by faults, two of which divide the body into a larger northern segment and a smaller southern one, exposing a narrow strip of stockwork between the segments. The Summit quartz body is the only easily mapped unit in the area, but because it is fault bounded its original attitude is indeterminate. One likes to view it as a sort of cap to the stockwork, but the inference that it is a cap may be seriously biased by what one reads about well known orebodies such as Climax and Henderson, Colorado.

Stockwork.--The stockwork consists of networks of quartz veinlets, veins of quartz, and masses of replacement quartz in a matrix of granite. Petrographically the stockwork is transitional between the outwardly homogeneous mass of the Summit quartz body and the least altered material of the granite next to be described. Within the stockwork, the proportion of the end-members quartz and granite varies widely, but introduced quartz commonly makes up 60 to 80 or 90 percent of the mappable unit. All the quartz is milky, much of it is fine grained, and some of it is chalcedonic. The veinlets are variously oriented, clearly of several generations, of variable thickness, and sporadically vuggy. Some of the veinlets are fracture fillings, but many were formed by replacement. Fragments of granite interstitial to the quartz veinlets usually have outlines somewhat blurred by replacement. A few flakes of muscovite and chlorite are present in some granite fragments, the feldspars are chalky from argillic alteration, and a little new muscovite grows at random in the granite-quartz aggregates. Veins of quartz in altered granite are sparse, as much as 2 ft thick, and variable in attitude. Masses of replacement quartz resembling the Summit quartz body are present locally. Some of these masses are tens of feet in dimensions. They may be faulted bits of the Summit quartz body, but they seem to be intrinsic to the stockwork. Specks of pyrite, arsenopyrite, tetrahedrite(?), and their alteration products are visible here and there in the stockwork, argillic alteration is pervasive and locally intense, and the whole mass is variably stained reddish or brownish from goethite, yellowish from jarosite, and rarely greenish from scorodite and other arsenates.

The stockwork is mostly fault bounded. The inner contact has already been described. Most of the west contact is interpreted as a concealed, north-striking, nearly vertical fault, locally with jagged reentrants, between stockwork and granite. One reentrant of the contact seems not to be a pair of short, normal faults, but a segment of the pre-fault, or relatively little faulted, contact between stockwork and granite. This exceptional part of the west contact is described on page 6.

The northwest contact is obscured by dike float. Part of the north contact is similarly obscured; part of it is concealed by colluvium and dense vegetation. The northeast contact, against granite, is along or near a fault marked by abundant gouge. The northwest, north, and part of the northeast contacts bend around the north end of Red Mountain at elevations between 7,300 and 7,100 ft, higher on the west, lower on the east. Five hundred feet of the east-side mine road follows the gouge zone southeastward from the large, sloughed cut near the east-side switchback. The northeast contact then turns abruptly, extends eastward for about 700 ft, and is lost in glacial debris of the south fork of the south fork of Vein Creek.

The east contact of the stockwork is against glacial debris. The contact extends generally southward from grid latitude 21 450N to 19 400N, thus paralleling the south fork of the south fork of the creek and lying at or near the toe of its west wall. Part of the contact is surely a fault; all of it may be. Recent faults have produced a series of rock benches, thinly mantled with colluvium but free of glacial debris, near (20 800N, 20 600E). Another, larger bench is near (19 900N, 20 700E). Conventionally, the benches would be attributed to plucking by valley glacier ice, but such an interpretation does not fit the local evidence, which need not be given in this preliminary report. Recent faulting, not ice work, has produced the benches. Recent faulting has very likely determined the stockwork contact downslope from the benches.

The east contact of the stockwork ends near (19 400N, 20 900E), where a small dike of rhyolite is interposed between stockwork and inclusion-bearing granodiorite. Thence a fault contact between the latter two units extends roughly west-southwestward 1,000 ft, nearly to the upper west-side mine road;

the contact crosses Goat Ridge at elevation 7690. (Goat Ridge is our name for the narrow ridge that connects Quartz Ridge and Red Mountain.) This segment of the south boundary of the stockwork is studded with small bodies of rhyolite and latite. At the west end of the segment, the contact turns abruptly southeastward, runs 500 ft, turns again, and runs southwestward 600 ft to (18 000N, 19 600E), a point about 150 ft east of the south end of the upper west-side mine road.

At this point, the geologist wishes he did not have to map contacts, for the rest of the south boundary of the stockwork is at present indeterminate. But before geologist and reader proceed into indeterminacy, two place names are needed. Geer Gulch is the accepted local name for the gulch just south of the main adit, and Elk Spur is the geologist's name for the main spur just south of Geer Gulch. (The names Elk Spur, Geer Gulch, and Goat Ridge have no standing with the U.S. Board on Geographic Names.) Now let us stumble down Elk Spur, the general course of the south boundary of the stockwork.

The stockwork truly loses its continuity at this latitude. The rock of Elk Spur is inclusion-bearing granodiorite, and locally this rock contains small replacement veinlets of quartz, as well as small patches of stockwork material. However, it is not a stockwork. Exposures and float on the south slope of the spur give the impression that strands of weakly silicified rock pinch out--or, better, fray out--along the north edge of the broad, west-trending gully south of the spur, though one 500-ft-wide strand continues southward, low on the mountainside, in a very crude way linking the south part of the Red Mountain stockwork with the north part of the Quartz Creek silicified zone.

Two of many possibilities deserve mention as an "explanation" for the disappearance of the stockwork in the Geer Gulch-Elk Spur area. The first is that the stockwork passes gradually south-southeastward beneath the structurally higher block of inclusion-bearing granodiorite, and that this transition, though gradual, is accomplished in a horizontal distance of a few hundred feet, between one of the lower, minor spurs of Elk Spur and the crest of the main spur. The second is that the stockwork is cut off by a fault whose trace is lost to view in the dense underbrush of the spur's north slope and in the alder-and-snowslide tangles of the upper reaches of Geer Gulch. Surface mapping alone will not solve the riddle.

Surface mapping will not solve another problem, that of the pre-fault shape of the stockwork. Nevertheless, one reentrant in the west contact of the stockwork does present some tantalizing bits of information. The reentrant is at Geer Gulch, at elevation 6,450 ft, adjacent to a rhyolite dike. The V of the reentrant points up-gulch. Except for some conflicting evidence, the reentrant would be interpreted as one of many zig-zags in the fault contact. However, if the position of the float contact is approximately correct and the short, north segment of the reentrant is the trace of a steep fault, the fault contact of the stockwork should be exposed in the main adit at a distance of 500±100 ft from the portal. The adit, not mapped in detail, was examined with enough care to indicate that the ribs were in granite as far as the caved, impassable ground at 796 ft. Therefore, at the adit the contact between stockwork and granite must dip gently west, at some angle less than the 20-degree topographic slope, or it must dip east at some angle less than 55 degrees. The relations between the reentrant and the spurs just north and south of Geer Gulch indicate that if the contact is not vertical, it must be nearly horizontal. A horizontal contact is consistent with evidence from the adit dump (no fragments of obvious stockwork in the upper 0.5 ft of the dump) and from horizontal holes drilled years ago from the faces of the Y at the end of the adit (no stockwork in the core fragments, which are jumbled). A reasonable inference is that the adit passed beneath the stockwork, perhaps as much as 300-350 ft below the stockwork base.

The outline of the exposed stockwork is not crudely circular and nearly a mile in diameter, as reported earlier (U.S. Geological Survey, 1981), but polygonal and slightly elongate. The north-south dimension of the polygon is about 2,700 ft; the east-west dimension is about 2,000 ft. The original estimate of shape and size was based on mapping at 1:48,000, in which two bodies that seemed to be part of the Red Mountain stockwork were included under that name.

The first of these bodies, here called the Sharp body, crops out on the spur east of the south fork of the south fork of Vein Creek, SW1/4SW1/4 sec. 2 (see Profile Gap 7 1/2-min quadrangle), 0.5 mi east of Red Mountain. The body is a stockwork, it looks like the less stained parts of the Red Mountain stockwork, and it may be part of the latter, severed from it by a fault concealed beneath glacial and alluvial deposits of the valley. We did not map the Sharp body in detail, and we collected few soil and plant samples from it.

The second body is exposed near the northwest base of Red Mountain, 300 ft east-northeast of a pullout on the valley stretch of the mine road. The Pullout body is a fault-bounded, sparsely pyritic silicified zone of north-striking quartz veins and veinlets in granite. The few veins and replacement pods are as much as 1 ft thick. The veinlets are less than 0.1 ft thick. Many of them dip 30-45 degrees east. A few dip 45 degrees west or are vertical. The body strikes north, is 900 ft long and 50 to 200 ft wide, and is flanked on the east, south, and west by granite. The north end of the body comes against a block of glacial deposits dropped down along a fault that radiates from the center of the Summit quartz body. The Pullout body may be a fault sliver of a strand of the Quartz Creek silicified zone, or a sliver of some element peripheral to the Red Mountain stockwork but not exposed elsewhere.

Granite.--Granite flanks the Red Mountain stockwork on the west, north, and northeast. The granite is a deformed and altered variant of porphyritic biotite-muscovite granodiorite of the Idaho batholith suite, the rock in which the stockwork was emplaced. Little-altered porphyritic granodiorite is exposed west of Quartz Creek and on the divide between Quartz and Vein Creeks. It is also exposed at random within the granite of the Red Mountain block.

Typically the granite of the Red Mountain block is greenish gray. Less deformed parts of the granite are porphyritic or subporphyritic; more deformed parts are porphyroclastic, variably granulated, and locally weakly silicified. Weathered fragments of the more deformed granite are rough and knobby, the porphyroclasts and less granulated parts of the matrix standing in relief against intertwined or smeared-out granulated material. Even in hand specimen one can see that former biotite has been completely altered to chlorite, that some muscovite flakes of the same size as the chlorite flakes look primary, and that coarser muscovite flakes and books seem to replace the rock. These features of fabric and mineralogy are readily confirmed in thin sections, which show in addition that (1) much of the quartz is leafy, strained, and shot through with trains of minute secondary fluid inclusions; (2) some chlorite, primary muscovite, and the twin lamellae of plagioclase are bent; (3) microcline, some of it coarse and perhaps newly grown, is commonly present with the expected orthoclase; (4) clay minerals are sparingly present as pervasive dust or as intergranular films and nets. Rarely one finds in thin section a "phenocryst" identical in shape and size to the plagioclase phenocrysts of ordinary granodiorite and even showing the dust specks that outline growth zones in such phenocrysts, but this "phenocryst" has been entirely replaced by quartz.

As the granite becomes progressively shattered, replaced by quartz and chalcedony, and veined by quartz, calcite, chlorite, epidote, and other secondary minerals, it grades into and becomes part of the stockwork.

Greisen.--Greisen is rare at Red Mountain. Fist- to head-size chunks of it are present in scree of granite. The greisen is an aggregate of randomly oriented muscovite flakes, roughly a centimeter in diameter, interspersed with stubby prisms and "barrels" of apatite and minute granules of pink garnet. The greisen may represent an advanced stage of the development of muscovite flakes and books in granite, but since the greisen has been found only as float, its source and origin are unknown.

Inclusion-bearing granodiorite.--Granodiorite and alaskite containing angular, diversely oriented inclusions of gray quartzite, biotite schist, and amphibolite of the Precambrian Yellowjacket Formation come against the south border of the stockwork and extend southward and eastward for some miles. The map unit is not altogether an igneous breccia, for in many places the relict fold systems of the Precambrian rocks, though disrupted, are still recognizable in some of the larger inclusions. In general, inclusions range in size from tens or a few hundreds of feet to less than 1 ft. The proportions of granodiorite, alaskite, and inclusions vary within the map unit. The north part of the unit has more granodiorite and fewer and smaller inclusions. The south part has more alaskite and larger inclusions. The middle part has one or two stocklike bodies of uncontaminated alaskite that could be mapped separately but were not. This local geographic subdivision of the heterogeneous unit is arbitrary, useful for indicating a gross variation, but unfaithful in setting boundaries for it. The mixed-rock tract as a whole is somewhat unusual for the region because of the scarcity of alaskite, a roof facies of the Idaho batholith suite commonly developed as dikes and sheets within the invaded Yellowjacket Formation and lowermost part of the overlying Precambrian Hoodoo Quartzite.

For Red Mountain geology, only the more important regional and local features of the inclusion-bearing granodiorite are given. The unit is "stratigraphically" higher than the homogeneous granodiorite that has been converted to the local greenish-gray granite. Thus the inclusion-bearing granodiorite along the south border of the stockwork is in places down-faulted relative to the stockwork. Where a contact between the two units is at present indefinable, in the Elk Spur area, the inclusion-bearing granodiorite at least sits low relative to the stockwork. This relation implies that some stockwork may be concealed beneath the inclusion-bearing granodiorite, though an inference--equally valid at present--drawn from the weak silicification of the inclusion-bearing granodiorite is that the inclusion-bearing granodiorite was not a suitable host for a stockwork. The principal finds of scheelite, as well as several metal anomalies in soil and plants, are in the area underlain by inclusion-bearing granodiorite. Evidently the presence of a stockwork as a host or cap for metals is not the sole and sufficient condition for the occurrence of metals at Red Mountain. For this reason, one must not substitute facts to be sought for hypotheses already formed, and one must entertain a good many working hypotheses while searching out the facts.

Dikes and stocks(?).--Small dikes and little stocks(?) or bosses are abundant in the Red Mountain area. The dikes are mostly 5 or 10 ft wide and tens of feet or a few hundred feet long. Small bodies compositionally like the dikes, but commonly subequant and polygonal in outline and having dimensions of 50 to 250 ft, are also present. Many of these bodies are fault bounded, so it is not at all clear whether they are fault segments or apices of larger dikes, or small stocks, or bosses, if the last term can be applied without genetic connotation. Let us call them bosses here.

Compositionally, three kinds of rock are present: rhyolite, latite, and "felsite." The first is dominant. The last is not common. It is a gray, aphanitic dike rock, at least in part a quartz-bearing bostonite. Most of the rhyolite and latite look like the rhyolite and latite of the large dike swarms of the region: rhyolite buff, showing phenocrysts of rounded bipyramidal quartz and tablets of sanidine and plagioclase; latite greenish, showing phenocrysts of white feldspar and some altered mafic mineral, usually biotite, locally accompanied by a few phenocrysts of quartz. In addition to "garden-variety rhyolite," another kind of rhyolite, not common regionally, is present at Red Mountain. This variety shows minute (~1 mm), almost spherical, very sparse phenocrysts of quartz; feldspar phenocrysts are present but in hand specimen inconspicuous. In mapping, the two varieties of rhyolite have not been distinguished.

Some bosses are of rhyolite only, but several are miniature igneous complexes of rhyolite and latite. In these composite bosses, as in the dikes of Red Mountain and the whole region, the age relations of rhyolite and latite are indeterminate. One float block near dikes of rhyolite, latite, and felsite shows a network of rhyolite veinlets apparently intruding latite and forming a small-scale igneous breccia. However, the block is small (less than 2 ft across; third dimension concealed), both component rock types are chilled, and the relation that one geologist interprets as intrusive might be taken by others as evidence for the mixing of magmas or for the existence of a breccia pipe. So ambiguous a relation does not deserve extrapolation to the composite bosses.

Rhyolite and latite at Red Mountain may be fresh or nearly so, or highly argillized. Whether this points to a difference in age (the argillized dikes provisionally being taken as older) or merely to variation in intensity of alteration, one cannot say. Both altered and unaltered dikes cut the Summit quartz body, the stockwork, the granite, and the inclusion-bearing granodiorite. One piece of rhyolite dike float is cut by a hair-thin, slightly contorted, threadlike veinlet of chalcedony. Does this imply that some hypogene silica is younger than some of the dikes, or does it imply that a little silica moved about, during alteration or during weathering, and by chance penetrated a dike? The implications seem to be as wispy as the veinlet.

The dikes and bosses at Red Mountain have not been dated radiometrically, and their age relation to other Tertiary intrusives of the region is indeterminate. Leonard and Marvin (in press) found that intrusives within the Quartz Creek cauldron block range widely in age, and that material suitable for dating is difficult to obtain. One must, therefore, be sanguine to believe that dating the hypabyssal rocks of Red Mountain could be achieved with ease and assurance.

Dikes of Red Mountain have three distinctive modes of occurrence: (1) radial, (2) parallel, and (3) fault related. Other dikes seem to have no systematic distribution. Several dike-infested areas are still to be mapped.

Dikes of rhyolite and latite radiate from two centers on the summit of the mountain. One dike center is at the north end of the Summit quartz body, at (21 750N, 18 970E). Outward from the dikes of this center, and concentric with them, is an arcuate area of dike float, mainly rhyolite, reminiscent of the plan view of a ring dike or cone sheet. The other dike center is at the mid-point of the southern segment of the quartz body, at (20 840N, 19 460E). No central intrusive to which either assemblage of radial dikes might be referred is exposed. It is reasonable to believe that the radial dikes come from one or more intrusives concealed beneath the Summit quartz body. Furthermore, it is reasonable to suppose that the concealed intrusive is sizable, for discontinuous faults mappable hundreds of feet from the mountaintop radiate from the center of the Summit quartz body, not from the centers of the radial dikes. The concealed intrusive is a likely target to explore in the hope of finding, within or about the intrusive, a large, low-grade ore deposit of porphyry type.

Parallel dikes of rhyolite and "felsite" are poorly exposed as a miniswarm at (22 300N, 18 800E). The miniswarm, mappable for a width of 350 ft, contains seven narrow dikes of rhyolite and felsite. The dikes are exposed in a sloughed road cut near the undefined north contact between stockwork and granite. The miniswarm is not more than 200 ft outward from the arcuate area of dike float previously described and is discordant to the arc. The discordance may be tenuous evidence for multiple intrusion at Red Mountain.

Dikes along or near the fault contacts between stockwork and granite or stockwork and inclusion-bearing granodiorite are common. Some dikes are at the fault contacts and parallel to them. Some are subparallel to fault contacts, usually on the stockwork side, and 10 to 30 ft from the contact. Other dikes, some with short branches, are perpendicular to fault contacts. Dikes seem to favor the short zig-zags in fault contacts, rather than the long, uninterrupted stretches of contact. Rhyolite and latite occur with nearly equal frequency as fault-related dikes.

Rhyolite bosses and composite bosses are sparingly studded throughout the stockwork, some near its contacts, others not. A group of rhyolite bosses trends north-northeast athwart the fault contact between stockwork and inclusion-bearing granodiorite near the southwest corner of the mapped area.

Pebble dike(?).--A feature thought by Ming Ho Du (oral commun., 1981) to be a pebble dike is present 550 ft N. 85$^{\circ}$ W. of DDH 2. Leonard has not seen the feature. Its site plots within the stockwork, about 100 ft east of the fault contact between stockwork and granite. In the hand specimen kindly made available by Mr. Ming, the rock resembles a pebbly argillaceous sandstone. Thin sections cut from this specimen show quartz fragments several millimeters in diameter embedded in an extremely fine grained, locally slightly schistose, variably argillized, slightly feldspathic, quartz-rich matrix. The fragments are subequant, most of them angular, a few subrounded and indented, showing every variant of highly siliceous stockwork material. Fragments of recognizable granite, granodiorite, or porphyry are lacking. A trace of granular pyrite is present in the matrix, but a replicate whole-rock sample contains no Mo (Ming Ho Du, oral commun., 1981). Leonard interprets the pebble dike(?) as part of a local zone of intense deformation within the stockwork itself. If the deformation feature is truly a pebble dike, its inclusions and matrix have come from no great depth; they do not provide a sample of the terrane, either mineralized or barren, that underlies the stockwork.

Quaternary deposits.--These include glacial debris, alluvium, colluvium, talus, and snowslide debris. It is not necessary to describe them in this report, but it is necessary to refer to those having structural and economic implications.

Water-worked debris from small alpine glaciers and alluvium from ice melt and modern streams are present along Quartz Creek, Vein Creek, and the tributaries of Vein Creek. The margins of the deposits are locally draped with colluvium. We found some major metal anomalies and belts of above-median metal values in the soils from these Quaternary deposits and in the plants growing on them. Quaternary deposits of the south fork of the south fork of Vein Creek may conceal an eastward extension of the Red Mountain stockwork.

Two fault blocks, centered at (22 350N, 17 300E) and (22 950N, 19 150E), are capped by glacial debris that may have come from a distant source. The debris includes angular and subrounded boulders a yard and more in diameter, ice-faceted stones, and water-worn cobbles and pebbles--a mixed assemblage of moraine and outwash origin, locally mingled with colluvium from nearby slopes. The glacial component is not much weathered, and it has no rocks that require a source more than 10 mi distant. It might be a legacy of the small glaciers of Vein Creek and its tributaries, but this seems unlikely, mainly because it would require too deep a valley filling from too-shallow areas of ice catchment. Instead, the glacial component is more likely the analog, though not necessarily the time equivalent, of "old," deeply weathered till, derived from a once-extensive ice sheet, which is found as remnants on spur flats hundreds of feet above the fault valley of Johnson Creek, near Yellow Pine.

The age and source of the moraine debris at Red Mountain will not matter much to a structural geologist; if the debris is fault bounded, the area has indeed been faulted during the Quaternary. However, the exploration geologist who finds a metal anomaly in the soil of the glacial capping might be wary of attributing the anomaly to rock fragments borne there by ice from local cirques. More likely the source of the anomaly is bedrock thinly mantled by glacial debris that did not come from nearby cirques.

The eastern block capped by glacial debris is 100 to 200 ft wide. It extends northward down the gently sloping north spur of Red Mountain from elevation 7,000 ft to the mine road, below which the toe of the block is concealed beneath road debris and valley fill. The lateral faults or fault lines (the glacial capping may have weathered back from the fault traces) radiate from the Summit quartz body. Probably the capping is underlain by granite, not by stockwork.

The western block capped by glacial debris is 400 to 500 ft wide. It extends northwestward from elevation 6,600 ft to the mine road, beyond which it cannot be mapped. The block is bounded laterally by northwest faults that radiate from the Summit quartz body. The southwest edge of the block marks the north contact of the Pullout body, a part of which may be concealed beneath the moraine-capped fault block.

Talus sheets, if they are not obviously forming at the base of cliffs, are an encouragement to the geologist to look nearby for evidence of faulting. Often that evidence can be found as breccia fragments and as offset contacts of bedrock units.

## Ore minerals and their occurrence

The observable ore minerals are sparse, and some of them have not been seen in place. In the following account, the minerals are grouped so: pyrite and arsenopyrite, the commonest ore minerals; the minerals thought to be economically significant--gold and silver minerals, scheelite, molybdenite, cassiterite(?); miscellaneous ore minerals, associates, and alteration products.

One sample will be mentioned often. Called "the adit dump sample," it was collected in 1971 by Leonard, assisted by Neil Dale. The sample poorly represents the upper 0.5 ft of material on the top and slope of the dump of the main adit. The sample was taken on 10-ft centers, and it poorly represents the surface layer because by accident no sample site was on material containing an appreciable amount of molybdenite. Molybdenite was present in selected samples collected at the same time. The discrepancy illustrates the pitfalls that may attend systematic sampling on a carefully taped grid. The bulk sample that we collected systematically was nevertheless important. The few grams of ore minerals recovered from heavy-liquid separation of a 10-kg split of the bulk sample contained 500 ppm Sn and, after further splitting and examination, yielded useful information on ore minerals not seen elsewhere at Red Mountain. Most of the ore-mineral particles recovered from this sample are much less than 1 mm in diameter. Many are perfect crystals, undamaged by crushing of the sample. In size and habit, the crystals of sulfides are comparable to those seen in outcrop.

Pyrite and arsenopyrite.--Specks of these minerals are sparse in the stockwork and rare in granite. Some of the pyrite and arsenopyrite tarnishes quickly and looks like chalcopyrite. Pyrite seems to be more abundant than arsenopyrite. Taken together, these commonest ore minerals of Red Mountain have an estimated abundance of hundredths or thousandths of 1 percent in outcrops and float. Their low abundance is not accounted for by oxidation and leaching; their oxidation products are similarly sparse but conspicuous enough to attract attention. In cores from DDH 2, at intervals 236-276 ft and 340-358 ft, several percent of pyrite and arsenopyrite is present as wisps, streaky veinlets, and replacement patches in stockwork. Within the interval 185-197 ft, brecciated stockwork cemented by veinlets of pyrite and minor arsenopyrite is cut by a thin veinlet of milky quartz. The combined evidence from outcrops and cores suggests that the abundance of pyrite and arsenopyrite increases somewhat with depth.

Pyrite is present in some dikes, as well as in stockwork and granite. Pyrite cubes in the dikes are as much as 5 mm in diameter. The host dikes may be either altered or fresh.

Pyrite and arsenopyrite are abundant in heavy-mineral concentrates of the adit dump sample.

Gold and silver minerals.--Red Mountain has been prospected for gold and silver for at least 50 years. Most of the information on these metals is privileged, but Rudolph C. Schulz has generously released some of it for incorporation here without reference to the source.

Assays of six samples taken during a recent, systematic investigation show Au equal to 0.03 to 0.245 troy oz/ton. The Ag content of these samples ranges from 0.04 to 3.42 troy oz/ton. The samples are from a 4-acre triangular area whose center is close to the 90-ft adit. The area is within the stockwork. One 10-in. sample from a trench assayed 79 troy oz Au/ton and 215 troy oz Ag/ton, according to a 1937 map by "H. T. A." [Henry T. Abstein, 1878-1964, mining engineer and homesteader of Yellow Pine, and sometime co-holder of claims on Red Mountain]. A comparison of Mr. Abstein's map and the Geological Survey's indicates that this trench is very likely the one 80 ft east of the 90-ft adit. No value later reported from that area is so high. The intensity of sampling of the principal gold-bearing area has made it futile for us to repeat the work of previous investigators, of which there have been at least five.

The gold that Leonard has seen is native gold unaccompanied by other ore minerals. To remove ambiguity in the following description of it, Leonard will write in the "I, me" form. Robert Chandler, then a claim holder at work on Red Mountain, showed me a gold specimen of his in 1953. I remember it as having one or more gold particles, clearly visible with a hand lens, in a small piece of iron-stained quartz. Rudolph C. Schulz showed me a gold specimen of his in 1980. In it I saw a gold particle, perhaps a millimeter in diameter, in vuggy quartz dusted with limonite. I do not believe that the Chandler and Schulz specimens were the same, but I have no reason to doubt that both specimens came from Red Mountain, though the sample sites were not precisely described.

The composition of gold from Red Mountain has not been determined. A study of two sets of assay data suggests that some of the gold contains little Ag in solid solution, whereas some contains so much that it is better called electrum.

Ming Ho Du (oral commun., 1981) states that the silver minerals acanthite and stetefeldtite have been identified in Red Mountain samples. The remarkable constancy of Ag-Au ratios in 23 of 39 10-ft core samples from DDH 1 suggests to Leonard that native silver containing 4.0±0.7 percent Au may be one of the minerals present in the mineralized rock cut in that hole. The Ag:Au ratio in the other 16 samples ranges widely, from 35:1 to >100:1.

Polished sections of heavy-mineral concentrates from the adit dump sample showed no gold or silver mineral. Gold was not detected in samples taken at 50-ft intervals in the adit; the highest value reported for silver was only 0.7 ppm, present in a single sample.

Geochemically, the precious-metal signature of Red Mountain is that of a silver "deposit" in which the Ag:Au ratio of paired samples of mineralized rock and material of ore grade commonly ranges from 1.2:1 to 35:1. Locally the ratio exceeds 100:1.

Scheelite.--The principal showing of scheelite is at the scheelite pit. The pit or small cut is on the south slope of Elk Spur, and its coordinates are given in table 1. According to Rudolph C. Schulz, the showing was found some years ago by prospectors tracing scheelite float, some of it lodged in trees. Scheelite at the pit occurs as a 0.3-ft-wide veinlet paralleled on one side by a stringer of stibnite that is partly altered to stibiconite. Much of the scheelite visible in September 1980 has since been carried off by collectors. A year later, one could only guess that the veinlet had a strike of about N. 15$^{\circ}$ E. and a dip of 70$^{\circ}$ E. The showing is in the unit mapped as inclusion-bearing granodiorite, here weakly and intermittently silicified.

In 1981, Theresa M. Cookro, of the Geological Survey, and volunteer Eleanor Leonard lamped the area about the scheelite pit and found scheelite-bearing float at 10 sites. Most of the float is scattered over an elliptical area, 600 ft long and 300 ft wide, that lies northwest of the scheelite pit and extends from the north slope of Elk Spur, over the spur crest, and down the south slope. Scheelite in the float occurs as 1-5 mm particles in rock matrix; the scheelite particles have not weathered free of their host. Clearly the float did not all come from vein scheelite at the pit. One bit of scheelite float was found on the spur south of Elk Spur, 500 ft southwest of the pit.

Scheelite is present as specks in fragments on the dump of the main adit and in bulldozed blocks of stockwork along the mine road, about 400 ft east-southeast of DDH 2 and also at the south end of the road. The last occurrence is 200 ft northeast of the scheelite pit.

The quantity of scheelite so far observed at Red Mountain is small. However, the occurrence of disseminated scheelite in several areas and in several rock types, taken together with tungsten anomalies in soil and douglas-fir, suggests that one or more low-grade tungsten bodies may be present. Earlier prospectors sought vein scheelite, and there is no record of a systematic search for disseminated scheelite or disseminated huebnerite. The latter is an ore mineral in lode deposits of tungsten in the neighboring Big Creek district. The possibility that disseminated huebnerite occurs at Red Mountain should not be overlooked.

Molybdenite.--This mineral has been seen only in specimens from the main adit dump, where it occurs as hair-thin veinlets, millimeter-thick fracture coatings, and minute flakes in slightly to moderately silicified granite. Viewed under the microscope, molybdenite in veinlets usually shows no intergrowths with other ore minerals, but a trace of intergrown arsenopyrite is present in one sample and a trace of pyrrhotite in another. Gangue minerals in the molybdenite veinlets include quartz and the assemblages described below under Fluorite. Wallrock near the veinlets contains disseminated specks of arsenopyrite, pyrrhotite, sphalerite, and rutile or some other Ti oxide mineral. Molybdenite occurring as isolated flakes in wallrock is usually near or attached to microscopic particles of arsenopyrite, pyrrhotite, or sphalerite, and one molybdenite flake is partly overgrown by pyrrhotite. Pyrite is sparingly present in many specimens collected nearby, but it has not been found in polished sections that contain molybdenite. All the individual flakes of molybdenite in veinlets, fracture coatings, and wallrock are small, about 10 to 100 micrometers in diameter.

The occurrence of molybdenite, first reported in a note (U.S. Geological Survey, 1981), was not known to the claim holders until Leonard called their attention to it in 1979. Most of the molybdenite visible on the dump is in fragments from a narrow streak that extends down the west slope of the dump. This distribution suggests that the molybdenite came from one of the last carloads of muck tipped over the berm. The inference is consistent with the results of Leonard and assistant Lynch's reconnaissance sampling of the adit. Samples taken at 50-ft intervals along the north rib, from 50 ft (end of timbering) to 750 ft (last 50-ft station before caved and impassable ground), showed no Mo at the 3-ppm limit of 6-step semiquantitative spectrographic analysis. However, the adit must have cut some Mo-bearing rock, for a reputable commercial assayer's analysis, kindly shown Leonard by Rudolph C. Schulz, reports 0.011 percent Mo in a sample of "adit rock" (not a dike) collected from an unspecified site during or shortly after the driving of the adit in 1958. According to Mr. Schulz (oral commun., 1983), the sample may have been collected at the face of the north fork of the Y, the farthest point of advance of the adit. The existence of the analysis is a pretty firm indication that molybdenite on the dump came from the adit and is not a "plant," unsuspected by the present claim holders and of no promotional advantage to a prankster.

Leonard and Lynch have looked in vain for molybdenite in many specimens from outcrops of the granite, stockwork, and Summit quartz body. The minute bright particles sparingly present in some of these specimens have proved to be arsenopyrite, hematite, or rutile. Core from DDH 2, logged to a depth of 358 ft, also fails to show molybdenite. However, the mode of occurrence of molybdenite on the dump, the rather wide distribution of molybdenum anomalies in soils and plants of the area, and the extent of zoned clay-mineral alteration of the sort that accompanies major molybdenum deposits all suggest that Red Mountain may conceal a low-grade molybdenum deposit.

Cassiterite(?).--One polished section of the heavy-mineral concentrates of the adit dump sample contains a particle whose crystal habit, reflectance, and microindentation hardness are appropriate for cassiterite. Positive identification of the particle still awaits confirmation by X-ray.

Rutile is present in the concentrates. The possibility that it is a tin-bearing variety remains to be checked by microprobe analysis.

Attempts to demonstrate the presence of a tin-bearing mineral in the adit dump sample thus lead to frustration. However, tin anomalies are present in plants of the area, and the samples that contain appreciable tin are from areas where mining equipment has never been driven or repaired. Tin is present naturally at Red Mountain; that is all we know. The element is, of course, a common one in some deposits of molybdenum and tungsten, and in them it occurs mostly as cassiterite.

Pyrrhotite.--Next to pyrite and arsenopyrite, ferromagnetic monoclinic pyrrhotite is the most abundant ore mineral in heavy-mineral concentrates from the adit dump sample. Pyrrhotite is rarely seen in outcrop, but specks of it are visible in the core from DDH 2 and in the wallrock of molybdenite-bearing samples from the adit dump. Small patches of pyrrhotite are present in fragments of core from underground DDH 1. Microscopic inclusions of pyrrhotite are present but rare in pyrite sparsely disseminated in a rhyolite dike cut by that drill hole. Ferromagnetic pyrrhotite, sparse but widespread, might cause the weak, local magnetic declination observed at many stations occupied during stadia surveying with a compass-plate theodolite. Local declination seldom exceeds 30 min of arc, and pyrrhotite may not be the cause of it. For example, if clay-size maghemite were present in the soil, or if a magnetite alteration zone accompanying clay-mineral alteration were concealed at depth, those features might cause local disturbances of the earth's magnetic field. The economic implications of the last possibility are an incentive for further mineralogical and geophysical research.

Minor sulfides and their associates.--Sphalerite is sparingly present in heavy-mineral concentrates from the adit dump sample. The sphalerite contains microscopic inclusions of chalcopyrite. Sphalerite is also present as microscopic grains and clusters in dump samples of wallrock. Some of this sphalerite is inclusion free; some contains almost irresolvable inclusions of pyrrhotite(?). A single, microscopic bleb of cubanite(?) is included in one isolated crystal of pyrrhotite. Sphalerite is sparingly present in pyrite disseminated in a rhyolite dike cut by underground DDH 1. Malachite and azurite derived from inclusions of copper minerals, or perhaps from discrete chalcopyrite grains not yet seen, are sparingly present on the adit dump. Specks of an unidentified gray mineral (tetrahedrite?) are present in the stockwork near one or two dikes and bosses.

Manganese oxides coat the surfaces of joints and fractures in some argillized dikes of the area. Other alteration products of ore minerals have been mentioned in the description of the stockwork.

Fluorite is not an ore mineral, but for convenience it is discussed in this section of the report. Disseminated purple fluorite is present in bulldozed stockwork debris along the mine road 300 ft east-southeast of DDH 2 and along the stub road 200 ft southwest of the first site. White fluorite, resembling pegmatitic feldspar, was found as a narrow replacement veinlet in granite in an outcrop 250 ft southeast of DDH 2. Purple fluorite occurs as thin veinlets and fracture fillings in dump material at the main adit. This fluorite is usually accompanied by chalcedony, calcite, chlorite, clay minerals, or epidote or by some combination of these minerals. Adularia is present in one molybdenite-bearing fluorite veinlet. Microscopic grains of fluorite, distributed like an accessory mineral in the rock, are present in granite samples collected at 50-ft intervals in the main adit and at outcrops scattered over the whole body of granite. Fluorite is not an accessory mineral in granodiorite of the region, so its presence in the granite of Red Mountain strongly suggests that the microscopic grains, like fluorite of the other occurrences noted above, have been introduced locally.

Barite, another nonopaque mineral, accompanies a secondary red lead mineral in a specimen collected from the stockwork. Primary lead minerals have not been found at Red Mountain, and barite seems to be rare.

Fluid inclusions, mentioned in the description of granite, are abundant in the quartz from granite, stockwork, molybdenite-bearing veinlets, and Summit quartz body. A few fluid inclusions are present in quartz from weakly altered granodiorite at the north limit of the grid and from inclusion-bearing granodiorite south of the stockwork. All the fluid inclusions are secondary. Charles G. Cunningham, U.S. Geological Survey, has kindly confirmed our identification of the inclusions. In examining a single thin section of granite, he remarked (oral commun., 1982) that many of the inclusions contain two fluid phases, are not highly saline, and are not rich in $CO_2$. The genetic information inferrable from fluid inclusions, even secondary ones, is worth obtaining but has not been systematically sought.

## Clay-mineral alteration zones in rock and soil

Some readily visible aspects of wallrock and stockwork alteration have already been mentioned. These include growth of muscovite in the Summit quartz body, stockwork, and granite; local development of greisen, presumably in granite; complete conversion of primary biotite to chlorite, locally with a little sericite, in granite; and preservation of primary muscovite in granite. In the adjacent inclusion-bearing granodiorite, biotite is also chloritized and primary muscovite preserved, just as they are in the wallrocks of the silicified zones of the region. Minor alteration features at Red Mountain include veinlets of chlorite, calcite, chalcedony, and epidote. These minerals, occurring singly or in combination, have been seen mainly in specimens from the main adit and its dump. The presence of microscopic crystals of adularia in one dump specimen may be a clue to concealed K-feldspar alteration at depth.

Clay minerals are conspicuous but usually sparse in all the rocks from Red Mountain. Preliminary sampling of altered bedrock showed that some key alteration assemblages varied in a systematic way, outward from the Summit quartz body, much as they do in the phyllic, argillic, and propylitic alteration zones that accompany porphyry copper and molybdenum deposits. This variation suggested that the alteration assemblages at Red Mountain might be similarly zoned (U.S. Geological Survey, 1981). The task of collecting an adequate number of very large bedrock samples and recovering the few percent of clay by ultrasonic cavitation of uncrushed samples was too formidable to attempt, no matter how much the hypothesis of zonal alteration needed testing. Instead, the geologist made the assumption that clay minerals in the immature and largely residual soils might be similar in species to those in the bedrock, but vastly more abundant and far easier to study. The assumption has proved to be valid. X-ray diffraction analysis of the clay suspension of ultrasonically cleaned splits of the soil samples collected during geochemical exploration shows that all the common clay-mineral species found in bedrock are present in the soils. Some new clay minerals, mainly vermiculite and several mixed-layer clay minerals, have developed during the soil-forming process, the proportion of noncrystalline clay has increased, and clay-size chalcedony (rare in ultrasonically cleaned bedrock samples) has formed by chemical rearrangement of the soil constituents.

Quantitative data would be needed to show how the pattern of clay-mineral distribution differs between soil formed on the essentially residual colluvium of the ridges and slopes and soil formed on the transported Quaternary deposits of the stream valleys. However, valley deposits underlie less than

10 percent of the area sampled and therefore cannot much distort the gross pattern of clay-mineral distribution in soil. If soil creep on slopes has distorted the pattern, we cannot detect the effect.

The mapped distribution of all the clay minerals in soil shows the zoning sought, but in a report without maps we must focus on sericite and view its associates rather broadly. All the soil clays are mixtures of several clay minerals, here discussed singly or in closely related groups. The name sericite is, in this section on alteration, restricted to clay-size muscovite.

The sericite zone lies mostly west, south, and south-southeast of the Summit quartz body. The zone laps over the south half of the quartz body, excludes an area of Quaternary deposits at the west end of sample lines 21 through 24, necks down abruptly over the narrow silicified zone at 24W4, but overprints most of the map units south of 22 400N and west of 20 000E. Sericite is also present in soil at the isolated sites 8W0-8W1 and 8W7, near the north edge of the map area. Most of the metal anomalies in soil and plants are in the sericite zone; the rest of the anomalies are within about 1,000 ft of the perimeter of the zone.

The kaolinite zone is, in general, coextensive with the sericite zone but substantially larger. If the kaolinite zone has a southern limit, that limit must be south of our southernmost sample line, Line 24. The northern and eastern limits of the kaolinite zone are not far beyond the boundaries of the sericite zone. The isolated patches of sericite near the north edge of the map area are accompanied by kaolinite.

Illite is more extensively distributed than sericite and kaolinite, but it is not present everywhere. If the two 10-angstrom clay minerals illite and sericite are mapped together, one sees that the 10-angstrom clay minerals occur only as a trace in, or are entirely absent from, the north-central and eastern parts of the area, and from the southeast corner and a small area midway along the west edge. That is, the map of the 10-angstrom clay minerals looks as if someone had taken little bites out of it.

Montmorillonite forms a broad zone that sweeps across the area south of Line 0 and extends about 1,000 ft northeast of 0W0. The zone is embayed--that is, montmorillonite is absent--along a 500-ft-wide strip that extends north-northeast from 23W5 to 21W4. The broad zone covers most of the southern third of the sericite zone, and, like the kaolinite zone, apparently continues south of Line 24. Montmorillonite also forms patches within the northern two-thirds of the sericite zone.

Chlorite, in contrast to montmorillonite, forms a broad zone that covers the northern quarter of the sericite zone and nearly all the area north of the sericite zone. A narrow projection of the chlorite zone fingers into the southwest corner of the map area.

Data for vermiculite are incomplete, those available do not make sense spatially, the mineral has not been found in the bedrock, and the combined information strongly suggests that vermiculite developed during the soil-forming process. The mineral, overlooked by Leonard, was identified and carefully distinguished from chlorite and montmorillonite by our colleague Paul D. Blackmon, a specialist on clay minerals.

Mixed-layer clay minerals in soil are distributed somewhat like chlorite. Mixed-layer clay minerals are difficult to identify, absent or too sparse to recover from bedrock samples, and very likely related to soil formation.

Noncrystalline clay, where sufficiently abundant to be recognized, has a distribution that approximately fills the "bites" of the map of 10-angstrom clay minerals; that is, noncrystalline clay is most abundant as a sort of fringe to the area of those crystalline clay minerals.

Now let us try to see the picture whole. The distribution of clay minerals in soil is systematic and zonal. While it may not perfectly represent the distribution of clay minerals in bedrock, it cannot be accidental, and as a first approximation it is taken as nearly true. The sericite zone is large. The kaolinite zone extends beyond it and is enlarged toward the south. The illite zone seems still larger. It and the chlorite zone are best developed north of the sericite zone. The zone of 10-angstrom clay minerals seems to peter out near the west, north, and east margins of the map area but continue to the south. Noncrystalline clay comes in where 10-angstrom minerals die out. The montmorillonite zone is within the southern third of the sericite zone and south of it. The pattern is not so simple as expected, but it is a zonal one, and the zones are at least crudely comparable to the phyllic, argillic, and propylitic zones that accompany metal-bearing porphyries.

The marked north-south asymmetry of the alteration zones, together with the apparent centering of the sericite zone near (18 300N, 18 500E) instead of near the center of the Summit quartz body at (21 200N, 19 300E), suggests that the mappable plan view of the zones is an oblique section, not a right section, of the zones. To state the matter another way: the axis of the alteration envelope is not vertical, it plunges. Whether one guesses it plunges north or south will depend on how one chooses to arrange the chlorite and montmorillonite zones, a point on which there is disagreement in the literature. Our guess is that the axis plunges south.

If the axis of the alteration envelope plunges south, some other features of local geology and geochemistry seem to fall into place while some become more difficult to understand. The following section is intended to stimulate thought, not to support a hypothesis, plainly labeled a guess, that at best is wild and at worst wrong.

Features that seem to fit are: (1) the southward elongation of the exposed stockwork relative to the position of the Summit quartz body; (2) the indefinable southern boundary of the stockwork; (3) the relative position of molybdenite in the adit and scheelite at the scheelite pit; and (4) the clustering of metal anomalies in the southern part of the area.

Opinions regarding the above are: (1) the southward elongation of the stockwork corresponds to the slighter width of the kaolinite zone north of the sericite zone and the much greater extent of the kaolinite zone south of the sericite zone; (2) the stockwork loses coherence southward as it plunges beneath the indefinable boundary; (3) by analogy with the Climax deposit, where tungsten orebodies overlie molybdenum orebodies, scheelite at the scheelite pit is zonally higher than molybdenite at the adit; (4) the up-plunge source of metals has largely been eroded, the down-plunge source has not. Note that the above are opinions; they are not facts.

Features that become more difficult to understand are: (1) faults, evidently vertical, that though discontinuous nevertheless radiate from the center of the Summit quartz body; and (2) dikes, vertical or nearly so, that radiate from centers near the north and south ends of the quartz body. One can hold opinions and even manufacture explanations, but the puzzles remain.

## Geochemical and biogeochemical exploration

### Metal anomalies--an overview

Metal anomalies are present in soil, but most of the anomalies are weak relative to those found at West End Creek (Leonard, 1973) and at the Golden Gate tungsten deposit (Leonard, in press). Metal anomalies in the ash of plants are strong, judged by the range of metal values found by Erdman in his 1979 regional biogeochemical reconnaissance of mineralized and unmineralized areas in central Idaho. Some data from that reconnaissance are given below. The high intensity of the metal anomalies in Red Mountain plant ash, and the large size of the areas of above-median metal values associated with the anomalies, would make Red Mountain an attractive area for exploration even if the local geology were unknown.

The area is well suited for geochemical and biogeochemical study because there is no contamination from ore treatment and, at the sample sites, no contamination from mining or bulldozing. Moreover, ash from the May 1980 eruption of Mount St. Helens volcano did not fall in the country near Yellow Pine (Emma Cox, local weather observer; written commun., 1980).

The following account deals separately with metals in soil and metals in plants, but some parts of each section are intentionally interwoven. Tables of data for soil and plants are combined.

The values and sites of metal anomalies in soil, ash of douglas-fir sapwood, and ash of beargrass leaves are given in table 2. Background values for the metals are given in table 3. Anomaly, as the word is used in table 2, refers to the three highest values for a given metal. If a "high three" value is present at more than one site, all the pertinent sites are listed (*e.g.*, 50 ppm Sn in ashed douglas-fir sapwood). Values judged to be not significantly different analytically are treated as if they were identical numerically (*e.g.*, 4.15 and 4.41 ppm Au in ashed douglas-fir sapwood). At the level $\bar{x}+2s$, several metals have anomalous values somewhat below the "high three," but the latter serve as an adequate guide to the principal areas of geochemical interest. One of the gold anomalies in ashed douglas-fir sapwood is open at the south edge of the area sampled. The molybdenum and tungsten anomalies in ashed beargrass leaves sampled along the east side of Quartz Creek are also open. Areas west of Quartz Creek and east of grid departure 3E were excluded from the sampling grid.

Clustering of the metal anomalies in soil and plants is evident from table 2. The clusters consist of "pile-ups" of anomalies at a single site (*e.g.*, 1W6, table 2), and of individual anomalies at adjacent sites (*e.g.*, 1.5W5.5, table 2). Anomalies in the "pile-ups" may be principally of one element in several media (*e.g.*, Mo in soil, douglas-fir, and beargrass at 1W6), or of different elements in different media (*e.g.*, As and Sb in soil but W in douglas-fir, 21W2, table 2).

Most of the clustered anomalies are in a belt that sweeps southward from 5W5-5W6-5W6A to the neighborhood of 21W5. Here the belt turns eastward and extends to 21W1 and 22W2. A prong of the belt projects northeast from 2W5 to 5W2. The south-trending segment of the belt is mainly on Quaternary deposits of Quartz Creek valley, though a narrow, eastern strip of the segment is on granite and on talus and colluvium derived from granite. The east-trending segment of the belt passes from Quaternary deposits of Quartz Creek valley onto a narrow strip of the silicified zone and then onto inclusion-bearing granodiorite. The northeast-trending prong crosses granite and stockwork and ends in the north part of the Summit quartz body.

A second cluster of anomalies forms an arc or arcuate belt across the stockwork. The chord of the arc trends east, the midpoint of the chord is 250 ft east of DDH 2, and the arc is convex southward. The arcuate belt includes, from west to east, the anomalies at 2W3, 1W3, 1W2, 2W1, and 1.5W0.5 (table 2). The belt so defined is about 2,200 ft long. Sampling at close intervals would be required to determine the width of the belt.

A third cluster, on inclusion-bearing granodiorite at 24W0 and 23W0, contains two of the Au anomalies in douglas-fir and one of the Mo anomalies in that plant. The Au anomaly at 24W0 has not been closed off on the south.

A fourth cluster of anomalies, on stockwork at 2E2 and 3E1, contains Sn and Mo anomalies in douglas-fir.

Isolated anomalies at 21E1 (on inclusion-bearing granodiorite), 6W0 (on granite), and 7W2 (on heavily vegetated soil, perhaps derived from a gouge zone between stockwork and granite) are indicated in table 2.

Rather few of the anomalies sketched above are on stockwork. Only one, an As anomaly, is on the Summit quartz body. A few anomalies are on granite. Most of the anomalies are on geologically puzzling terrane--on Quartz Creek valley fill and the join between it and granite, and on the inclusion-bearing granodiorite south of Geer Gulch.

So much for the overview, presented without interpretation. Now let us look at the systematics of the geochemical and biogeochemical study, and at the detailed results of the study.

## Soil

The soils of the Red Mountain area are residual, or very nearly so. Even on 35-degree slopes one can usually find some soil that has not been transported more than one-fifth or one-fourth of the sample interval. We sought out these little pockets of residual soil, instead of collecting right at the grid points. Most of the soils are immature. Consequently, our samples represent the C horizon, slightly reworked and variably enriched in clay. Except for soil developed on the alluvium and glacial debris of the main valleys, most soil of the area has been formed on bedrock. Soil on fault blocks thinly capped by glacial debris is of mixed parentage, partly glacial and partly colluvial. The colluvial component results partly from creep and partly from turbation. There are no major metal anomalies on the debris-capped fault blocks, so the presence of a soil of mixed parentage has no great effect on our study. For additional comments on soil, see the section on clay-mineral alteration zones.

Sampling and analytical methods.--Soil samples were collected where possible on 200-yd (~200-m) centers. Additional samples were collected on 100-yd centers about three sites at which soil samples yielded above-median Mo values. The sample grid is described in the introductory section of this report.

A soil sample weighing 0.5-1 kg was taken at a depth of 10-20 cm after the site was scraped free of forest litter or plant 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 in the laboratory. The minus-10-mesh fraction was 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, induced coupled plasma for W, and hydride generation-atomic absorption for As and Sb.

Some indication of the reliability of the analyses is given by the results for six pairs of samples submitted in duplicate under different field numbers. The results for Au, Ag, Hg, Mo, W, and Sb agree within one or two reporting intervals of the low ranges involved. The results for As are slightly less reliable than one would expect from the assigned reporting intervals. By inspection, it appears that a value of ±15 percent, relatively, should be assigned to As. The agreement in results for the seven elements in the paired samples is entirely satisfactory for reconnaissance purposes. Therefore gross analytical errors in the whole set of 146 samples are unlikely to exist.

The amount of irremovable organic matter in the soil samples affects the analytical results to an unknown but perhaps substantial extent. "Irremovable" here means not floated off in water during routine preparation of samples for analysis. Such material includes both the charcoal dust left from forest fires and the organic compounds or colloids formed by the decay of vegetation. The problem is illustrated by the results obtained for two samples taken close together at one station, OW1 (values in ppm, first for the organic-rich sample, second for the organic-poor sample): Ag--<0.5, <0.5; Au--<0.05, <0.05; Hg--0.09, 0.07; As--57, 60; Sb--2, 6; Mo--<3, <3; W--5, 11. Antimony and W show major differences. So do several elements that are of subordinate interest in the present study: B--50, 200; Be--1.5, 5; Cr--50, 10; Cu--10, 3; V--70, 20; Na--2, 0.7. Clearly, the organic matter has not acted uniformly, either as an inert diluent or as a concentrator of metals, in these samples collected to study the problem. Elsewhere, we sampled organic-poor soil if it was available; if it was not, we took what we could get, recognizing the impossibility of adjusting for variable amounts of organic matter.

Gold anomaly.--The site of the single anomalous value (anomalous at $\bar{x}$+2s), 1.10 ppm Au at 2W3, is about 100 ft northeast of the small rock cut from which, according to Rudolph C. Schulz (oral commun., 1980), all the gold-rich samples from Red Mountain have been taken. Soil samples collected north, east, and south of the cut have Au slightly above the median value of 0.15 ppm Au. All the foregoing samples are from soil on stockwork. A smaller area showing above-median Au values in soil on Quaternary deposits is centered near 1W5. The area is discussed below. Isolated "blips" of 0.34 and 0.38 ppm Au are present at 4W1 and 5W3, respectively, in soil on stockwork.

The spotty distribution and low concentration of Au in soil on stockwork suggests that there is no large, low-grade, near-surface gold deposit within or close to the stockwork area sampled by reconnaissance. Moreover, the area that yielded above-median Au values in soil near 2W3 extends only a little beyond the area that has already been prospected for high-grade gold ore. (See description of gold and silver minerals.) The distribution of Au in douglas-fir does not at present seem to be a reliable guide to high-grade pockets of gold in the stockwork, for the Au content of douglas-fir wood ash at site 2W3 is 0.55 ppm--not highly anomalous--, whereas the soil at that site contains 1.10 ppm.

The foregoing statements on Au in soil are based on a conservative approach to the statistics of Au distribution and on an acquaintance with several gold deposits and districts in the region. Seventy-nine percent of the 140 soil samples from the Red Mountain area contain <0.05 ppm Au. (Six blind samples submitted as duplicates are excluded. The Au content of the paired samples is identical.) The median, as well as the mode, of all 140 samples is thus <0.05 ppm Au. The median value in the 30 samples containing Au $\geqq$0.05 ppm is 0.15 ppm, the mode is 0.08 ppm, $\bar{x}$+2s is 0.60 ppm, and only one soil sample contains Au $\geqq$0.60 ppm. The value of $\bar{x}$+2s in soil samples from well explored or productive low-grade gold deposits of the region may not be much greater, but the proportion of samples in which Au exceeds that value is considerably higher, and the peak value approaches or exceeds 10 times the value of $\bar{x}$+2s.

The area showing above-median Au values in soil on Quaternary deposits is of geologic interest because it is in a "pile-up" of high-three metal values. Here, Au values ranging from 0.20 to 0.28 ppm are present in an area, 600 ft in diameter, centered at 1W5.5, the site of one of the high-three Au values listed in table 2. The "pile-up" receives special attention in a concluding section of the report.

Silver anomalies.--The distribution of Ag in soil resembles that of Au, though the highest values for the two elements do not coincide precisely (compare table 2). Only 17 percent of the 140 samples contain Ag $\geqq$ 0.5 ppm. This part of the population has a normal distribution: median, mode, and mean 1 ppm, $\bar{x}$+2s = 2 ppm. Three samples have anomalous values; these values are the high three listed in table 2. Sample 1W3 comes from the previously described arcuate belt of clustered metal values in soil on stockwork. Two samples come from the "pile-up" on Quaternary deposits. The largest area of Ag values $\geqq$ the median contains the isolated gold "blip" at 4W1. Though Ag is low in all Red Mountain soil samples, the median value of 1 ppm is five times higher than that reported by Leonard (in press, table 3) for soils from apparently unmineralized areas in the Yellow Pine district.

Mercury in soil.--The Hg content of Red Mountain soil is very low. The Hg values in 92 percent of the soil samples fall in the narrow range from 0.01 to 0.08 ppm. The rest of the samples contain <0.01 ppm Hg. The whole population has essentially a normal distribution: mode, median, and mean 0.03 ppm, $\bar{x}$+2s = 0.06 ppm. The seven anomalous values are from sites in the south half of the study area. Two sites, 21W1 and 0.5W0.5, are at "pile-ups" of metal anomalies. The rest are scattered. Mercury is a pathfinder element in some mineralized areas, but at Red Mountain it takes us on a random walk.

Molybdenum anomalies.--The high-three anomalies (table 2) of Mo in soil are not impressive. Only 13 percent of the samples contain Mo $\geqq$ 3 ppm. Molybdenum in this part of the sample population shows a nearly normal distribution: mode and median 5 ppm, mean 6 ppm. At the level $\bar{x}+2s = 13$, only one value is anomalous. It is 15 ppm, at site 1W6, and all the 10 ppm values shown in table 2 accompany it as part of a conspicuous cluster of high-three metal anomalies in soil and plants on Quaternary deposits. One of the 7 ppm Mo values, at site 3W4, is on granite in the northeast-trending prong of the western belt of high-three metal anomalies. The other, at 1.5W0.5, is on stockwork near the southwest edge of the mappable stockwork and about 100 ft northeast of a composite rhyolite-latite boss. All the high-three Mo anomalies in soil are north of Elk Spur, and all are accompanied by areas, variable in size, in which the soil contains 3 to 5 ppm Mo; the high-three Mo anomalies are not isolated "hot spots." Moreover, an east-trending belt of low Mo values connects the principal anomaly at 1W6 with the 7 ppm Mo high at 1.5W0.5. Low values, here, means those below the 3 ppm limit of determination but nevertheless detectable by the spectrographer. The east-trending belt of low Mo values coincides in part with the arcuate belt of high-three metal anomalies described in the introduction to this chapter.

The low concentration of Mo reported for Red Mountain soil samples may result from analyzing the whole minus-10-mesh fraction, rather than finer splits of that fraction. Having found that the bulk samples yielded information sufficient for a reconnaissance, we have not sought to refine the original data for soil. Instead, we have relied on plants to concentrate Mo. Beargrass does that in a spectacular way. (See subsequent section on molybdenum in beargrass.)

Tungsten anomalies.--For tungsten in soil, the high-three values given in table 2 clearly indicate the only areas in which the concentration of W exceeds the 10 ppm limit of determination. Eight percent of all soil samples contain W $\geqq$ 11 ppm; no sample was reported to contain 10 ppm. This part of the sample population has a slightly skewed distribution: mode 11 or 13, median 13, mean 14; $\bar{x}+2s = 22$ ppm. At the level $\bar{x}+2s$, only one sample is anomalous, another is nearly so (compare table 2), and both samples come from the area of scheelite-bearing float near the scheelite pit. Other soil samples from this area contain 11 to 15 ppm W. The low values of W in soil samples from this area may result from analyzing bulk samples taken with too fine a sieve. Grains of scheelite in fragments of float are slightly larger than 10-mesh size, and the float fragments themselves are >1 cm in diameter. The oversize, not the undersize, may contain the higher tungsten values. The area of interest is on sporadically silicified inclusion-bearing granodiorite on Elk Spur and south of it.

A second area of interest, at site 22W5+64, is on Quaternary deposits in the cluster of high-three metal anomalies in Quartz Creek valley. The 16 ppm W value (table 2) is accompanied by values of 11 to 14 ppm W.

Arsenic anomalies.--The As content of Red Mountain soil ranges from 8 to 290 ppm. Histograms of the As values, as well as the mapped distribution of

As in soil, indicate that the values belong to two populations that overlap in the range 50 to 89 ppm. Population I, range 8 to 69 ppm, is log-normally distributed. Population II, range 74 to 290 ppm, has a nearly normal distribution: mode 130, median 120, mean 131; $\bar{x}$+2s = 247 ppm. Population II includes 18 percent of all samples and is restricted to two sizable areas. The first, a broad band extending southwestward from 3W0 to 22W4, contains the high-three As values listed in table 2. The band passes diagonally across stockwork, granite, inclusion-bearing granodiorite, and the tail of silicified zone in inclusion-bearing granodiorite. The second area coincides with the cluster of high-three metal anomalies on Quaternary deposits of Quartz Creek valley. Here the As values do not exceed the median of population II.

The geologic significance of the high-three As values is obvious for one and uncertain for two. The site of the highest value, 290 ppm at 2W1, is close to DDH2. Cores from this hole show more arsenopyrite than we have seen anywhere else in the study area. The arsenopyrite-enriched zone penetrated by the drill hole is expressed in the soil as an As anomaly and as above-median As values grouped about the anomaly. The area of above-median As values does not overlap the Au anomaly in soil at site 2W3, near the gold prospects, but the Au anomaly and the As anomaly in soil are only 1,200 ft apart. To that extent--proximity without site specificity--As in soil can be construed as a pathfinder to Au at Red Mountain. The early prospectors took the direct approach; they found gold by looking for gold.

The As anomaly in soil at 21W2, the As high in soil at 21W4, and the As anomaly in douglas-fir sapwood at 21W3 have no visible source as a concentration of arsenopyrite or any other As mineral. The As anomaly in douglas-fir sapwood at 21W3 coincides with an Au anomaly in the same medium, and the high values of As in soil and douglas-fir in this area are close to the principal Au anomaly in douglas-fir at site 22W4. For additional information, see subsequent sections on Au and As in douglas-fir.

Antimony anomalies.--The Sb content of Red Mountain soil is about one-tenth the As content. Antimony values range from <1 ppm to 22 ppm. The values belong to two populations, each of which shows a normal distribution with some overlap at 3 ppm. Population I comprises 71 percent of the samples. It is the background population, with mode, median, and mean of ~2 ppm Sb. Population II comprises 29 percent of the samples. The frequency distribution within this population is irregular, but for convenience it is treated as normal. The mode and median are ~5 ppm, the mean is $5._6$ ppm, and $\bar{x}$+2s is $8._6$ ppm. (Because the reproducibility for Sb at low concentrations is about 40 percent, relatively, the values have been rounded for statistical treatment.)

Population II is restricted to two areas that, in a gross way, resemble the two areas just described for As. The first area of Sb population II forms a broad band that extends southwestward from 3W0 to the southwest corner of the sample grid. The high-three Sb values (table 2) are in this band, and they are on Elk Spur and south of it. The northeast half of the Sb band coincides with the northeast half of the As band, but in detail the southwest halves differ one from the other. Though the Sb band as a whole extends across the same rock units as the As band, Sb highs within the southwest half of the band are confined to the tail of the silicified zone within inclusion-bearing granodiorite. The Sb anomaly of 22 ppm, at site 24W2, has not been closed off by our sampling.

The second area of Sb population II is in the cluster of high-three metal values in the southwest corner of the study area, but the highest Sb value within this area is only 6.5 ppm, barely above the median of ~5 ppm.

In spite of the gross similarity in the distribution of Sb and As, the statistical correlation of sample pairs is poor. However, one of the few good correlations of sample pairs at Red Mountain is that for Sb and W in the area of the 22 ppm W anomaly. In this area, the coefficient of determination of 8 sample pairs is 0.77 for the curve $y = 2.37x^{0.92}$, where x = Sb in ppm, y = W in ppm. Outside this limited area, there is no correlation between Sb and W. Note that the stibnite-scheelite veinlet at the scheelite pit is within the area of well correlatable values of Sb and W in soil.

Some other elements in soil.--A few elements deserve mention to indicate the general character of the soil, or to show that they are not abundant though one might expect them to be so, or to call attention to a geochemical or mineralogical distribution of some interest. All elements cited are characterized by low abundance and statistically normal distribution. If an element has one or a few anomalous values, these are usually widely scattered and seemingly unrelated to the distribution of Au, Ag, Mo, W, As, and Sb.

Iron. Red Mountain is named for its red-brown soil, but the Fe content of the soil is low (values in percent): general value 1.5 to 2, range 0.7 to 7, anomalous at 5 and 7.

Manganese. Manganese oxide coatings are locally conspicuous, but the Mn content of the soil is low (values in ppm): general value 1,000-1,500, range 150-2,000, anomalous only at the low concentration of 150.

Titanium. In percent, general value 0.15-0.2, range 0.07 to 0.5, anomalous at 0.5.

Niobium. Values for this and subsequent elements are in ppm. For Nb, general value 10, range <10 to 20, doubtfully anomalous at 20.

The elements Ta, Th, and U might be expected to occur in low concentrations in soil on an Mo-bearing stockwork. Unfortunately, the limit of determination is high for all three elements when they are sought by routine methods. None of the elements was detected by semiquantitative spectrographic analysis of the Red Mountain soil samples.

Vanadium. General value 20 to 30 (50 to 70 not rare), range 15 to 150, anomalous at 100(?) and 150. A slightly higher general value of 70 is common in soil on inclusion-bearing granodiorite, probably owing to the local occurrence of amphibolite inclusions. Chromium and Ni values show no comparable increase in general value.

Chromium. General value 15 to 30, range 5 to 300, anomalous at 300. The element is present in one or two unidentified arsenates that occur in trace amounts in specimens of stockwork and granite.

Nickel. General value <5 to 10, range <5 to 70, anomalous at 70.

Copper. General value 10 to 15, range 2 to 70, anomalous at 50 and 70.

Lead. General value 20 to 30, range <10 to 150, anomalous at 150. The anomalous value is in soil on the Summit quartz body. Of all the metals in Red Mountain soil, Pb is the only one to give an anomaly on the quartz body.

Zinc. General value <300, range <300 to 500, doubtfully anomalous at 500.

The prevalence of quite low values for Cu, Pb, and Zn in soil seems unusual to us.

Barium. General value 700 to 1,000, range 300 to 1,000; no anomalous values.

Boron. General value 20 to 50, range <20 to 200, anomalous at 150(?) and 200. Some difference in the distribution of B is evident. Values of 50 to 70 ppm are common in soil on stockwork and granite; values $\leqq$ 20 ppm are prevalent in granodiorite north of Vein Creek.

## Plants

Historical note.--As early as the 1930s, Goldschmidt, pioneer in the field of geochemistry, suggested that analysis of plants might be effective in prospecting. Yet the use of plant-tissue analysis in mineral exploration has received a great deal of skepticism and is viewed askance even today. This is the result of failures caused, in great measure, by a lack of understanding of the vagaries of the technique. Biogeochemical prospecting began in Fennoscandia and the U.S.S.R., areas where conventional methods of collecting soils and rocks are difficult owing to a mantle of glacial drift or muskeg. Under these conditions, especially, biogeochemistry ". . . provides a new and powerful aid for all those who prospect for buried mineral deposits" (Warren, 1980, p. 353). It has not received much use where residual soils occur since the same geochemical patterns are usually obtained through the use of simpler, more straightforward soil-survey methods. But there are exceptions, as the results of the present study well illustrate.

The best indication of Au mineralization is the presence of Au itself, but the sampling and analytical requirements for detecting Au in soils, for example, are quite demanding due to the "particle sparsity effect" (Harris, 1982). In commenting on this problem, Hoffman (1981, p. 5) said, "The difficulty associated with the search for gold stems from its property to form discrete grains (flakes or nuggets). These are typically so few and far between that sampling can become a hit or miss operation. The same bulk sample can yield both highly anomalous and background values, depending whether or not the gold grain(s) find their way into the subsample."

This effect can be avoided by analyzing plants to locate Au mineralization, a technique that was first suggested by Lungwitz (1900). The advantage of plants, especially trees, is their ability to "sample" large volumes of soil. A comprehensive review of the literature and occurrence of Au in plants is given by Shacklette and others (1970). Hoffman and Brooker (1982) cite several recent papers which show that biogeochemical prospecting for Au can be very useful if properly conducted. An earlier report (Jones, 1970) includes a table of the Au content in plants based on a literature survey. The use of plants in prospecting for Au is certainly encouraged by Warren (1980). He says (p. 376), "To sum up, it would seem not only on the basis of evidence produced by numerous Russian workers and reported by several members of the United States Geological Survey, . . . but also investigations carried out in British Columbia, that biogeochemistry may prove to be a most useful tool in prospecting for gold."

Vegetation.--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.

The forest zone is mainly upper montane, and it 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 forbs.

Role of cyanogenic plants.--Cyanogenic plants in the Red Mountain area are widespread and in places abundant. The suspicion that cyanogenic plants made Au available for uptake by douglas-fir led us to examine the role that some of the cyanogenic plants might play.

In a fascinating and definitive study on the absorption of Au by plants, Shacklette and others (1970) reported that glycosides, which yield hydrocyanic acid upon hydrolysis by enzymatic action, are found in about 1,000 plant species. In a related study Lakin and others (1974, p. 4) concluded, "Results of our studies show that gold cyanide and thiocyanate may be the most common stable gold complexes in soils, plants, and natural waters. Cyanide and thiocyanate ions are products of hydrolysis of plant glycosides by enzymatic action . . . . These ions have the ability to complex gold in moderately oxidizing environments . . . . The gold cyanide and thiocyanate ions remain in solution when in contact with common rocks and minerals, and they are readily taken up by plants. The other ions studied--chloride, bromide, iodide, and thiosulfate--may form complexes with gold which remain stable only long enough to permit some restricted movement of gold under special conditions."

Because serviceberry and especially chokecherry, both common to the study area, are strongly cyanogenic plants (Shacklette, 1974), their possible role in the occurrence of Au in douglas-fir seemed critical. Shacklette and others (1970, p. 22) earlier stated, "If gold is present in the soil and if cyanogenic plants are rooted in this soil, a mechanism is present for the entrance of gold into the biogeochemical cycling process." We found that there was no consistency between the pattern of high levels of Au in douglas-fir and abundance of the strongly cyanogenic plants. As an example, the site with the highest Au concentration in douglas-fir (14.2 ppm) supported neither chokecherry nor serviceberry. On the other hand, a site at which the douglas-fir contained only a normal level of Au (0.32 ppm) supported a dense cover of these cyanogenic plants.

It is possible but not likely that douglas-fir itself is cyanogenic, since other species of conifers tested by Shacklette (1974) were non-cyanogenic. The possibility needs no further consideration here. Douglas-fir is the only conifer for which we report data.

Selection of medium, sampling and analytical methods.--Douglas-fir was selected as the main sampling medium for the biogeochemical survey for two reasons. First, although as we learned during the sampling it was not ubiquitous in the study area, still it was 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. Of late, however, Warren's optimism toward the biogeochemical usefulness of douglas-fir has been directed to the role of its As as a pathfinder element (Warren, Delevault, and Barakso, 1964, 1968; Warren, 1980).

From the standpoint of ease in sampling, stems or needles, or both, would be most suitable (Warren, 1980). Moreover, As is most concentrated in the young stems. Yet As is simply a pathfinder to the target metal--Au. Results from an earlier extensive biogeochemical survey of a number of mineral prospects in the region 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 the ash of wood from 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 50-100 g of wood was extracted from the trunk by means of a brace and bit. This amount filled a small cloth sample bag and proved just sufficient for analyses by emission spectroscopy and neutron activation. The ash yield of wood is 0.2-0.3 percent, so most samples yielded barely 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 at all sites where douglas-fir could be found. Obtaining one sample required 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, in 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, the few withered leaves were discarded, and the samples of green 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 and stems 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). Judged from 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.

The samples were first oven-dried at 40$^{o}$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$^{o}$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, As, and Sb determinations were made on ~30-40 mg samples of douglas-fir ash 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).

Tungsten was determined colorimetrically on small samples of ashed beargrass leaves. The Mo content determined by semiquantitative emission spectroscopy was confirmed colorimetrically on a representative suite of these samples.

Gold anomalies in douglas-fir.--Gold concentrations in the ash of douglas-fir sapwood range from 0.07 to 14.2 ppm, more than two orders of magnitude. More importantly, the highly anomalous samples (>4 ppm) are concentrated in the south quarter of the sampling grid in an area that has no anomalous Au in the soils that were sampled, 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 obviously skewed (skewness, 5.2), we transformed the data to logarithms and plotted the frequency distribution. 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 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 rather strongly indicated, and we are confident that there is indeed an anomaly. For convenience, the value 0.35 is rounded to 0.4 in subsequent descriptions of individual Au anomalies in douglas-fir.

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 central Idaho 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.

Gold concentrations of 2 ppm or greater in 12 douglas-fir samples are extreme but are clearly real, as borne out by emission spectroscopic analyses (limit of detection, 2 ppm).

The only reasonable conclusion we can reach is that Au is abnormally abundant in the south quarter of the sampled area, south of Geer Gulch. 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. The "high three" gold anomalies listed in table 2 are especially attractive targets for exploration.

The "high three" gold anomalies are in a block of ground that can be discussed as a unit. The block occupies the southern quarter of the grid, from Line 21 (Elk Spur) southward, between Quartz Creek and the Goat Ridge-Quartz Ridge divide. Areas west, south, and east of the block have not been sampled. The block contains 35 sample sites. Douglas-fir is present at all but four sites, one on Goat Ridge and three east of it. Within the block, the Au content of ashed douglas-fir sapwood ranges from 0.27 to 14.2 ppm, median 1.15, mean 2.31, standard deviation 2.84. Only three values less than the arbitrary cutoff of 0.4 ppm Au are present, and they are not clustered; there is no "hole" within the block. Excluding the small triangle of sample sites at which douglas-fir is absent, the area of the block is about 200 acres, all of it constituting a target area for gold.

Continuous with and north of the block just described is a lobe or crude triangle outlined by the 0.4 ppm Au-in-douglas-fir cutoff. The vertices of the triangle are approximately at OW1, OW5A, and 2W5. Within the triangle, the Au content of ashed douglas-fir sapwood ranges from 0.07 to 1.00 ppm. Though the mode, median, and mean values are 0.5 ppm, a cluster of low values (0.07, 0.20, 0.20 ppm) produces a central "hole" in the triangle. Accordingly, we do not classify the triangle (lobe) as a target area, though in the past it has been prospected.

A triangular area separate from and northeast of the one just described contains Au values exceeding the 0.4 ppm cutoff. The vertices of the triangle are at 3W0, 3E2, and 1E2, east of Goat Ridge. Gold values at the six sample sites within the triangle range from 0.42 to 1.45 ppm, median 0.49 and 0.81, mean 0.76, $\bar{x}+2s = 1.54$. Site 3W0 (0.49 ppm Au) is on colluvium of the stockwork. Site 3E2 (0.49 ppm Au) is on talus of the Sharp body. The remaining sites are on Quaternary deposits along the south fork of the south fork of Vein Creek. The absence of douglas-fir at several sample sites south of the triangle and the lack of sampling north and east of the triangle make its economic significance indeterminate.

Isolated Au values of 1.03 ppm at 4W4, 0.73 ppm at 5W6, and 1.19 ppm at 6W3 are also of indeterminate significance. They are "blips" within the large tract of background values.

Arsenic in douglas-fir.--The potential use of As as a pathfinder element is really a moot point in this study. Because of the excellent results from the Au analyses, As as an indirect measure of Au mineralization is unnecessary. Moreover, the relationship of As to Au concentrations in douglas-fir is not convincing. The frequency distribution of As in the ash of douglas-fir sapwood (concentration range 14 to 463 ppm) is not bimodal, and the correlation coefficient for the 114 samples is only 0.22. This is significant at the 99 percent confidence level, but still accounts for only a few percent of the total variation between As and Au.

The statistical correlation between As in soil and Au in douglas-fir is also poor, but maps show that the As anomalies in soil are only slightly displaced laterally from the Au anomalies in douglas-fir (compare data in table 2). One who sees the maps is impressed by the gross similarity between them, rather than by the poorness of the site-specific statistical correlation between the elements. The same comments apply to a comparison of As in douglas-fir and Au in soil.

Molybdenum in douglas-fir, beargrass, and sedge.--Molybdenum values in ashed douglas-fir sapwood range from <5 to 50 ppm. Their frequency distribution is perfectly log-normal, and no anomalous value can be detected. All values of 30 and 50 ppm (5 percent of the total) are from the south-trending segment of the belt of above-median values of Mo in beargrass, subsequently described. Because beargrass and sedge yield more useful information on Mo in Red Mountain plants, Mo in douglas-fir needs no further consideration here.

The range (<5->500 ppm) of Mo concentrations in the ash of beargrass is in our judgment clear evidence for concealed Mo mineralization in the area, particularly so because the anomalous zone along the base of Quartz Ridge coincides fairly well with the pattern for Mo in douglas-fir wood. Molybdenum concentrations in beargrass sampled from the central Idaho region 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 on 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 douglas-fir and beargrass. This, then, is fairly convincing evidence that an 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 source of the Mo may not necessarily be where the biogeochemical anomaly occurs, however, as Levinson (1980) cautions. He says (p. 13), "Ideally, a soil [or plant] survey should yield the highest values for the element(s) being sought directly over a deposit, with lower values fanning out from it. In actual fact, such simple situations are not generally encountered because of many factors such as soil movement and hydrologic effects, and therefore, careful interpretation is usually necessary to locate the source of the anomaly." At Red Mountain the Mo may have been leached from the soil by water at the upper reaches of the area and redeposited where the water comes to the surface. Levinson calls such an accumulation of metals a seepage or "break-in-slope" anomaly, and drilling directly over such displaced anomalies might miss the mineralized body.

Molybdenum anomalies in beargrass.--The Mo content of 96 samples of ashed beargrass leaves ranges from <5 to >500 ppm. The range exceeds two orders of magnitude, and the maximum value is at least an order of magnitude greater than the maximum Mo content of Red Mountain soil and ashed douglas-fir sapwood. Even without an external base for comparison, one intuitively judges the Mo content of the ashed beargrass leaves to be high. Fortunately we have two external and concordant bases, one provided by Erdman's regional reconnaissance noted in the preceding section, the other provided by Leonard's reconnaissance of the district. The Mo content of ashed beargrass leaves from three widely separated, unmineralized control areas in the Yellow Pine district is 3 to 15 ppm, median 7 ppm (Leonard, in press). Fifty-seven percent of the Red Mountain beargrass samples have Mo >15 ppm, and the median value (20 ppm) in all 96 samples is three times the median value of the control samples.

The frequency distribution of Mo values in Red Mountain beargrass is so irregular that agreement on an appropriate statistical treatment of the data is not to be had. By inspection of histograms and the map, one easily divides the values into three sets, actually overlapping but arbitrarily taken as follows: low (<5 to 7 ppm), representing background; intermediate (10 to 50 ppm), with mode and median of 20 ppm, mean 25, $\bar{x}+2s = 53$ and thus representing a set that contains no anomalous value; and high (70 to >500 ppm; 15 percent of the total population)--distinctly anomalous relative to all other values but perhaps undesirably split off from some of the 50 ppm values. By calculation, using singly censored data for the method of Miesch (1981), one finds that the center of the largest significant gap is at 40 ppm, confidence level >99.9 percent. Singly censored data include values <5 ppm. The gap statistic and its confidence level deserve to be viewed with some caution because the 40 ppm value falls between the 30 and 50 ppm values reportable in six-step spectrographic analysis. Any gap due to natural causes will be enhanced artificially by the prescribed reporting interval, but the degree of enhancement cannot be specified. The 50 ppm values may be significant geologically as well as statistically, and they are discussed subsequently.

To attain geographic and geologic coherence in a report without maps, the description of Mo in beargrass is referred to the 20-ppm median value of the whole population. The shape and length of the main area of interest remain unchanged if we use the gap statistic value of 40 ppm as a cutoff; the width of the area is slightly less, and a few "holes" appear at the sites of 30 ppm values. With two exceptions, all above-median Mo values are in a belt that begins at 8W0 of the sample grid (the point is on the south slope of the divide between the forks of Vein Creek), extends westward across the north spur of Red Mountain and the south slope of Vein Creek-Quartz Creek divide, turns southward and follows Vein Creek to its confluence with Quartz Creek, continues southward along the east side of Quartz Creek, bends eastward near the mouth of Geer Gulch, and passes over the toe and south slope of Elk Spur. The high-three values for Mo in beargrass (table 2) are in the long south-trending segment of the belt. Values of 70 and 100 ppm Mo are scattered along the entire belt. The northeast end and west side of the belt are outside the study area. Values of 20 to 100 ppm Mo in sedge define an eastern extension of the east-trending belt of above-median Mo-in-beargrass values south of Elk Spur. Within this extension, beargrass is absent from all but one of the sample sites.

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

Two small areas of median or above-median values are isolated from the belt. One area (values 20, 30, and 50 ppm) centers 1,000 ft northwest of TBM 7717. This area overlaps the south end of the Summit quartz body and adjacent stockwork. The other area (median values only) centers 800 ft south of TBM 7717. This narrow area lies between two composite bosses within the south part of the stockwork.

Except for the obvious fact that the leaves of beargrass and the sapwood of douglas-fir concentrate Mo, the relation of Mo in plant and soil and of Mo in beargrass and douglas-fir is obscure. In some places, Mo highs in beargrass are close to Mo highs in douglas-fir, and at site 1W6 they coincide, not only with each other but with the Mo high in soil. But in a few places, Mo highs in beargrass are some distance from Mo highs in douglas-fir. Several Mo highs in beargrass are downslope from Mo highs in douglas-fir, but beargrass is lacking from some sites where one would wish to test the relation before accepting it as a general one. In spite of these annoying gaps in understanding the distribution of Mo in plants and soil, we can draw one inference with assurance: the great extent and the continuity of the belt of above-median Mo values in beargrass 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.

<u>Tungsten in plants</u>.--In his recently translated 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, apparently almost nothing is known of the absorption of W by plants (Kovalevskiy, 1966). Although average concentrations of W in plant ash are apparently not known, Brooks (1972) does say (p. 885) that biological response is reasonably good. He and a coworker (Quin and Brooks, 1974) reported that even though soil sampling was generally satisfactory, tree-trunk sampling had certain advantages in locating extensions of known scheelite-bearing reefs in New Zealand.

Tungsten in beargrass.--Previous studies by Leonard (in press) on the response of beargrass to W occurrences encouraged us to submit our samples for analysis by colorimetry, which has a detection limit of 1 ppm. At Red Mountain, tungsten is not concentrated in beargrass. 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 resembling that of the major belt of above-median values of Mo in beargrass if one were to punch holes in the Mo belt. Areas having 2 ppm W in beargrass are at the northwest corner of the Mo belt (one site only for 2 ppm W), midway along the south stretch of the belt (narrow, sinuous strip enclosing five sites), in the high-three metal cluster near 21W5 (three sites), and in the area of scheelite-bearing float about the scheelite pit (two sites). The last two areas are those having determinable W in soil.

Two of the sites that show 2 ppm W in beargrass coincide with, or are close to, sites that show 100 ppm W in douglas-fir. Elsewhere, tungsten at the 50 ppm level of determination was not detected spectrographically in douglas-fir. The sensitive colorimetric method used to determine W in beargrass was not applied to samples of douglas-fir.

Tin anomalies in douglas-fir.--The sapwood of douglas-fir is a highly effective concentrator of Sn. Ashed sapwood contains <5 to 100 ppm Sn. Tin was not detected in any soil sample, and it was detected in only one beargrass sample (10 ppm Sn).

Values of Sn in douglas-fir belong to two populations. Population I (77 percent of all values) has a normal distribution: range <5 to 15 ppm, mode and median 10 ppm; this population represents background. Population II (23 percent of all values) has essentially a log-normal distribution: range 20 to 100 ppm, mode and median 20, mean for the logarithmic distribution 29. In population II, values $\geqq$ 32 are anomalous at the $\bar{x}$+2s level.

Three-quarters of the samples represented by population II are from two areas. The larger area, south of Geer Gulch, has all but one of the high-three Sn values listed for douglas-fir (table 2). The area includes the scheelite pit and part of the cluster of high-three metal anomalies near 21W5. Most of the Sn values in the area are $\geqq$ 30 ppm. The area is underlain by slightly silicified inclusion-bearing granodiorite, the tail of the silicified zone flanked by the granodiorite, and Quaternary deposits of Quartz Creek valley. The smaller area, on stockwork, has a 70 ppm Sn value, but the three associated values are only 20 ppm. Other values--all 20's--assigned to population II are widely scattered. Some or all of these values may belong to a distributional tail of population I.

The Sn content of ashed douglas-fir sapwood from Cordilleran ore deposits of molybdenum or molybdenum and tungsten is barely known to us. Two examples from Erdman's regional reconnaissance are nevertheless instructive. Two samples of douglas-fir wood from the orebody of the Thompson Creek molybdenum mine contain 15 and 20 ppm Sn, respectively, and four samples from the environs of the Tungsten Jim mine near Thompson Creek contain Sn $\leqq$ 10 ppm. By comparison as well as by subjective judgment, the 100 ppm Sn values found in douglas-fir near the scheelite pit at Red Mountain are high. The 500 ppm Sn content of heavy-mineral separates from the adit dump sample has been attributed tentatively to cassiterite. (See section on ore mineralogy.) Cassiterite, the commonest Sn mineral in the Mo-W-Sn association throughout the world, is a highly insoluble mineral. If the Sn anomalies in douglas-fir at Red Mountain are attributable to cassiterite, the area of above-median Sn values south of Geer Gulch is of considerable economic interest for Sn as well as other metals.

Silver in douglas-fir.--Silver is roughly 100 times as abundant in ashed douglas-fir sapwood as it is in soil, but the increase in abundance does not tell us proportionally more about the local occurrence of the metal. Silver values in douglas-fir range from 2 to 300 ppm, the distribution is normal, and the mode, median, and mean are 50, 50, and 56 ppm, respectively; $\bar{x}+2s =$ 136 ppm, and at this level there are two anomalies (compare table 2). The 150 ppm anomaly at 4W3 is in the principal area of above-median values, which is on the Summit quartz body and on stockwork west and south of the body. The anomaly itself is on stockwork. A small area of above-median Ag values is in stockwork and granite northwest of the gold prospects. The 300 ppm Ag anomaly (table 2) is an isolated hot spot within a swatch of above-median values that laps over granite and Quaternary deposits and spreads laterally beyond the Mo-in-beargrass belt. Half a dozen small areas of above-median Ag values, unaccompanied by Ag anomalies, are scattered about the study area. This scattering of above-median values, together with the normal distribution of Ag within the sample population, suggests that Ag in douglas-fir is a biogeochemical signature of the Red Mountain area, even as the high Ag:Au ratio in samples from the gold prospects is a geochemical signature of those occurrences.

Antimony anomalies in douglas-fir.--Antimony in ashed douglas-fir sapwood is concentrated only twofold relative to Sb in soil. The Sb content of douglas-fir ranges from 1 to 42 ppm; the Sb content of soil ranges from <1 to 22 ppm. (All values have been rounded.) The maps of Sb values in the two media are broadly similar, but the correlation of paired values is poor.

Antimony values in douglas-fir, like those in soil, belong to two populations. Population I (62 percent of all samples) represents background. The distribution of values is normal: range 1 to 3 ppm, mode, median, and mean 2 ppm. Population II (38 percent of all samples) has approximately a log-normal distribution: range 4 to 42 ppm, mode 4, median 5, mean for the logarithmic distribution 6, anomalous at 10 ppm. The principal Sb anomalies (compare table 2) are at sites 21W0, 21W1, and 21W2; and at 21W5 and 21W5+100. Values of 10 ppm Sb are from sites 23W5 and 1W6. The broad similarity in the map patterns of Sb in douglas-fir and soil makes it unnecessary to describe a map of above-median Sb values in the plant.

Bismuth in douglas-fir, beargrass, and sedge.--Bismuth is quantitatively negligible in the ash of plants from Red Mountain, but the element is of interest because of its spatial association with Mo. Bismuth is detectable in 24 percent of the douglas-fir samples in concentrations of <1 to 5 ppm. Most of these samples are scattered throughout the belt of above-median values of Mo in beargrass. The rest of the samples are from the central part of the map area; their Bi content has no obvious association with geochemical or geologic features. Bismuth at <1 to 2 ppm is present in beargrass and sedge from the east-trending belt of above-median values of Mo in beargrass south of Elk Spur. Elsewhere at Red Mountain, Bi was not detected in beargrass or sedge. In spite of the good spatial association between above-median Mo in beargrass and detectable or measurable Bi in all three plant species, Bi does not correlate well with Mo or other elements in individual plant samples. At the 10-ppm limit of determination, Bi was not detected in soil, so we have no basis for comparing low concentrations of Bi in soil and plants.

## Geomagnetic effects

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 our doing would be required to choose between near-surface alteration and deep-seated structure as the probable cause of these magnetic anomalies.

The ground survey was made with the magnetometer in backpack mode. Nominally, the accuracy of measurements so made and suitably corrected for diurnal variation is 5 gammas. Lacking a recording magnetometer at a base station, we could not determine the local diurnal variation. Correction of all local readings for diurnal variation recorded at the Geological Survey's observatory at Newport, Washington, does not altogether eliminate an effect ascribed to long-range drift in base-station readings, but it scarcely changes the gross shape of the magnetic profiles along traverse lines. Consequently, our judgment of "anomaly" is based on inspection of the individual magnetic profiles in relation to twice-daily readings at one or more base stations in the Red Mountain area. In July and August 1982, the total intensity of the earth's magnetic field was 56,200 ± 35 gammas at base stations on valley fill. Departures of 100 gammas from the normal curve of each profile are taken as significantly anomalous; lesser departures are disregarded unless they occur in well-defined trends or as weak links in stronger anomalies.

East-west lines of the geochemical sample grid were traversed first. North-south traverses 300 ft apart were then run to define the anomalies detected on east-west traverses. The station interval, estimated by eye and corrected by ties to geochemical grid points, was 100 ft on all traverses. About 1,500 sets of observations were made.

Anomalies having some continuity are of rather low intensity, and their width seldom exceeds a few hundred feet. Positive anomalies are rarely accompanied by conspicuous negative anomalies; negative anomalies are seldom accompanied by conspicuous positive anomalies. Instead, the anomalies appear as spikes or clefts on the individual magnetic profiles. If topography has an effect on the profiles (one would expect the effect to be considerable in this area of strong relief), we cannot interpret the effect by inspecting the profiles.

Anomalies having some continuity are described below, area by area, in the order north, west, south, and east. The area of magnetic noise on Red Mountain is ignored, as are scattered magnetic "hot spots" that are similarly beyond interpretation at present.

A well-defined anomaly of +40 to +100 gammas lies mostly north and northwest of our geochemical sample grid. The outline of the anomaly approximates the curve made by extending one's thumb and forefinger widely, pointing them southward, and placing the midpoint of the bend near fictitious grid point 11W2.5. The positive anomaly is accompanied at the bend by a weak negative anomaly north of the positive. Where the east limb of the positive anomaly crosses the baseline between 8W0 and 9W0, the profile of the anomaly has a dip slope facing southwest. The rest of the anomaly, excepting a short segment at the bend, is bilaterally symmetrical. The sharpness of the profile suggests that the magnetic source is shallow, concealed beneath moraine debris. The +40 to +100 gamma anomaly is discordant to the bedrock structure of the area. Median values of 20 ppm Mo in beargrass at sites 10W2 and 10W3 provide the only suggestion of biogeochemical perturbation near the magnetic anomaly. All other metal values in soil and plants represent background.

In the western area, a discontinuous, segmented anomaly of +50 to +100 gammas extends southward along the valleys of Vein Creek and Quartz Creek from 6W6 to a point 200 ft west of 3W5. In profile, the north segment of the +100 gamma anomaly broadens southward and has a steep dip slope facing east. The south segment is bilaterally symmetrical. The middle segment consists of two rather broad +50-gamma strands. Application of the half-width, half-height rule for interpreting magnetic anomalies suggests that the pole depth of the magnetic source is greater than 100 ft. The segmented anomaly is parallel to the ring-fracture zone of the Quartz Creek cauldron and entirely within the belt of above-median values of Mo in beargrass.

Negative anomalies predominate south of Line 21. Stronger anomalies range in intensity from -50 to -200 gammas. They form parallel lines several hundred feet apart and as much as 2,000 ft long. The longest line is a parabola lacking a west limb. The other lines appear as the limbs of nested parabolas, best mapped in the southeast corner of the grid. The principal axis of the parabolas is directed north. The vertex of the best defined parabola is 200 ft west of fictitious grid point 24.5W1, at the southern limit of the supplementary traverses run for magnetic data; the focus of this parabola is on Line 24. The vertex and focus of the southeasternmost parabola of the nest lie far to the south of 24.5W1. In profile, the anomalies are sharp, as if the magnetic source were shallow, but since the distribution of soil of the area has an obvious relation to the closely spaced west-sloping spurs and gullies, we cannot suppose that the magnetic source is in the soil. The anomalies are on inclusion-bearing granodiorite. The attitude of relict structures in the inclusions can be reliably measured at half a dozen widely scattered sites near the southeast corner of the grid, where the inclusions are large and the magnetic anomalies trend northeast. Here, relict bedding strikes north-northwest and dips 5-15 degrees east. The axis of one set of minor folds trends east-northeast; the axis of another set trends southeast. The northeast trend of the anomalies is thus discordant to the strike of relict bedding and the trend of minor fold axes in the inclusions. Magnetic and structural trends in the southwest corner of the grid cannot be compared because the inclusions are small, sparse, and dioriented. Obliged to rely on evidence of discordance from the southeast corner, we are disinclined to relate the anomalies to a disseminated, primary accessory oxide mineral having reverse remanent magnetism, for we suppose that the distribution of the mineral would have some systematic and determinable relation to fold axes or relict bedding in inclusions within the granodiorite and alaskite. Our best guess is that the magnetic source is 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.

Positive magnetic anomalies $\geqq$ 100 gammas are present near the east border of the exposed stockwork. The bits of anomaly trend southward, but lack of continuity makes it hazardous to infer that they constitute a single string of magnetic beads.

Collectively, the magnetic anomalies of the Red Mountain area show the categorical features of an oval. 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.

## Conclusion

Evidence presented in this report indicates the presence of exploration targets for concealed deposits of gold, molybdenum, tungsten, and tin 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. No new, independent target for silver has been recognized.

The high-three values for Au in ashed douglas-fir sapwood (table 2) immediately call attention to a target area south of Geer Gulch, on inclusion-bearing granodiorite and the tail of silicified zone. All samples having anomalously high Au in douglas-fir are from the block between Lines 21 and 24. Line 24 is the south limit of sampling; the Au anomalies have not been closed off east, south, or west of that line. Above-median values of Au in douglas-fir are present north of Line 21, but the lobe containing these above-median values has a central and sizable Au "low" in which Au ranges from 0.07 to 0.20 ppm. Most of the lobe is on stockwork and has been prospected.

Within the 2-mile-long, semi-elliptical belt of above-median values of Mo in ashed beargrass leaves, the high-three values (table 2) mark the ends of a 2,600-ft segment containing values of 70 to >500 ppm Mo. This segment best defines a target within a belt that is open at the northeast end, all along the west side, and at the southwest corner, as sampled. The segment of the belt of above-median Mo values between the toe of Elk Spur and the crest of

Quartz Ridge coincides with the target area for gold and is not likely to be overlooked. Molybdenite from the inaccessible rear of the main adit presents a now-obvious additional target, one that is suitable for exploration underground. The source body of molybdenite from the adit has no outcrop, no geochemical or biogeochemical expression, and no clues in the form of accessory molybdenite in outcrops. The source body is completely blind.

Three target areas for tungsten are indicated. All are within or overlapping the long belt of above-median values of Mo in beargrass. The first target area, roughly centering on the scheelite pit south of Elk Spur, is outlined by the distribution of scheelite-bearing float and values of W exceeding 10 ppm in soil. Two of the high-three values of W in soil (table 2) are in this area. The bedrock of the area is mostly inclusion-bearing granodiorite. The second target area, west of the first, but in Quartz Creek valley, is indicated by values of 2 ppm W in beargrass and >10 ppm W in soil. The center of the area is at 22W5+65, the site of the third high W-in-soil value listed in table 2. The third target area, north of the second, is indicated by a sinuous strip of 2 ppm W-in-beargrass values extending from 6W6 to 2W6. The high value of 100 ppm W in douglas-fir (table 2, site 4W6, near the midpoint of the sinuous strip) supports the designation of the strip as a target area for tungsten. The strip is crudely coincident with the north half of the 2,600-ft segment of high Mo in beargrass. Tungsten target areas two and three are not closed along the west edge of the grid. Both target areas are on Quaternary deposits in the valley.

With some reluctance we call the environs of Sn anomalies in douglas-fir (table 2 and description in text) target areas for tin. No tin mineral has been positively identified at Red Mountain, and tin is not likely to be the primary commodity sought there by an explorationist. However, values of 50, 70, and 100 ppm Sn in plant ash are high, and the areas of above-median values have not been closed off by our sampling.

Molybdenum anomalies in the valleys of Vein Creek and Quartz Creek might be interpreted as break-in-slope anomalies, but the associated "pile-ups" of high values of W, Au, Ag, Sb, and As speak against that interpretation. Because the elements differ greatly in geochemical mobility, it is not reasonable to find them all together at the break in slope if all have migrated down the hydrologic gradient. Moreover, the metal anomalies along and south of Line 21 are on the mountain slope, not in the valleys. The south part of the 2-mile-long semi-elliptical belt of above-median values of Mo in beargrass is continuous from Quartz Creek valley onto the mountain slope. The shape and continuity of the belt are, we think, controlled by a subsurface structure.

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. Dispersed metals on and south of Elk Spur may be zoned downward in the sequence Au (and Sn?)-W-Mo. Molybdenite from the adit may belong to a lower zone within the hood. The south end of the hood may plunge southward, the north end and west side may be steep, the east side may be poorly developed or faulted off. The hood may overlie a sizable Tertiary intrusive, but the existence of a concealed intrusive is a convenience, not an essential, for the hypothesis of a hoodlike substructure.

The hypothesis--emphatically a hypothesis--relates observational detail and reasonable inference from Red Mountain to the Climax type of molybdenum deposit. The recent paper by White and others (1982) gives an excellent account of the type. Readers of that paper will recognize that the assemblage of features of Red Mountain geology and mineralization is not duplicated by any single example of the type. To accommodate Red Mountain, one must select, reject, and enlarge the existing model. Even a reference to the Climax type has its pitfalls. No one has yet found a Climax at Red Mountain, no one can be fully confident that a major ore deposit is concealed there, and no one can predict that molybdenum will be the chief metal of economic value. Red Mountain offers exploration targets for gold, tungsten, and tin, as well as for molybdenum.

Several of the targets would be unsuspected if plants did not concentrate metals and biogeochemists did not judiciously apply their knowledge of that peculiarity. 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 and the ability of plants to "sample" a large volume of soil and underlying weathered bedrock.

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Table 1.--Location of reference points and sample sites of metal anomalies, Red Mountain

| | Grid coordinates, ft N | E | Elevation, ft |
|---|---|---|---|
| Reference point | | | |
| Main adit[1/] | 18,552 | 17,825 | 6,134 |
| 90-ft adit | 19,280 | 18,572 | 6,783 |
| DDH 2[2/] | 19,651 | 19,121 | 7,285 |
| Quarter-section corner 3-10 | 20,080 | 18,020 | 6,553 |
| Section corner 2-3-10-11 | 20,060 | 20,667 | 7,341 |
| Scheelite pit | 17,901 | 19,264 | 6,932 |
| 0W0[3/] | 18,330.95 | 20,541.97 | 7,751.48 |
| 24W0[4/] | 15,951 | 20,543 | 7,476 |
| 10W0[5/] | 24,351 | 20,535 | -- |
| 7717[6/] | 20,020.31 | 20,007.17 | 7,716.04 |
| Sample site | | | |
| 24W0 | 15,951 | 20,543 | 7,476 |
| 24W2 | 15,971 | 19,319 | -- |
| 24W4 | 15,991 | 18,095 | -- |
| 23W0 | 16,545 | 20,542 | -- |
| 23W4 | 16,721 | 18,088 | -- |
| 22W2 | 17,273 | 19,341 | -- |
| 22W3 | 17,340 | 18,741 | -- |
| 22W4 | 17,406 | 18,141 | -- |
| 22W5+64 | 17,473 | 17,349 | -- |

Table 1.--Location of reference points and sample sites of metal anomalies, Red Mountain--Continued

| | Grid coordinates, ft N | E | Elevation, ft |
|---|---|---|---|
| Sample site | | | |
| 21E1 | 17,691 | 21,149 | -- |
| 21W1 | 17,820 | 19,850 | -- |
| 21W2 | 17,907 | 19,160 | 6,872 |
| 21W3 | 17,990 | 18,543 | -- |
| 21W4 | 18,004 | 17,944 | -- |
| 21W5 | 18,053 | 17,336 | 5,921 |
| 21W5+100 | 18,051 | 17,038 | 5,849 |
| 0W5 | 18,288 | 17,170 | 5,921 |
| 0W5.5 | 18,288 | 16,870 | -- |
| 1W2 | 18,920 | 19,309 | -- |
| 1W3 | 18,914 | 18,688 | -- |
| 1W5 | 18,899 | 17,440 | 6,045 |
| 1W5.5 | 18,899 | 17,140 | -- |
| 1W6 | 18,895 | 16,823 | 5,875 |
| 1W6A | 18,893 | 16,688 | -- |
| 1.5W0.5 | 19,232 | 20,242 | -- |
| 1.5W5.5 | 19,199 | 17,140 | -- |
| 1.5W6.5 | 19,199 | 16,540 | -- |
| 2E2 | 19,442 | 21,751 | -- |
| 2W1 | 19,530 | 19,930 | -- |
| 2W3 | 19,545 | 18,713 | -- |

Table 1.--Location of reference points and sample sites of metal anomalies, Red Mountain--Continued

| | Grid coordinates, ft N | E | Elevation, ft |
|---|---|---|---|
| Sample site | | | |
| 2W5 | 19,555 | 17,462 | -- |
| 2W6 | 19,560 | 16,836 | 5,947 |
| 3E1 | 20,118 | 21,153 | -- |
| 3W4 | 20,208 | 18,017 | -- |
| 3W6 | 20,242 | 16,730 | 5,947 |
| 4W3 | 20,801 | 18,737 | 7,253 |
| 4W6 | 20,793 | 16,977 | 6,101 |
| 5W2 | 21,372 | 19,325 | -- |
| 5W3 | 21,371 | 18,720 | 7,382 |
| 5W5 | 21,397 | 17,434 | -- |
| 5W6 | 21,410 | 16,790 | 6,086 |
| 5W6A | 21,416 | 16,490 | -- |
| 6W0 | 21,974 | 20,539 | -- |
| 7W2 | 22,603 | 19,291 | 6,978 |

1/ Adit shown on Profile Gap 7 1/2-min quadrangle.

2/ Abandoned DDH 1 is nearby.

3/ Origin of baseline.

4/ South end of baseline.

5/ North end of baseline.

6/ Spot elevation shown on Profile Gap 7 1/2-min quadrangle.

Table 2.--Metal anomalies in soil, ash of douglas-fir sapwood, and ash of beargrass leaves, Red Mountain

| Sample site | Material sampled, with metal concentration in ppm | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Soil | | | | | | Douglas-fir sapwood, ashed | | | | | | | Beargrass leaves, ashed | | |
| | Au | Ag | Mo | W | As | Sb | Au | Ag | Mo | W | Sn | As | Sb | Ag | Mo | Sn |
| 24W0 | | | | | | | 4.41 | | | | | | | | | |
| 24W2 | | | | | | 22 | | | | | | | | | | |
| 24W4 | | | | | | | 8.19 | | | | | | | | | |
| 23W0 | | | | | | | 5.07 | | 20 | | | | | | | |
| 23W4 | | | | | | | | | | | 50 | | | | | |
| 22W2 | | | | | | | | | | | 100 | | | | | |
| 22W3 | | | | 20 | | 9.5 | | | | | | | | | | |
| 22W4 | | | | | | | 14.2 | | | | | | | | | |
| 22W5+64 | | | | 16 | | | | | | | | | | | | |
| 21E1 | | | | | | | | | | | | | | 2[a/] | | |
| 21W1 | | | | 22 | | | | | | | 50 | | 32 | | | |
| 21W2 | | | | | 250 | 8.0 | | | | 100 | | | | | | |
| 21W3 | | | | | | 9.3 | 4.15 | | | | | 463 | | | | |
| 21W4 | | | | | 230 | | | | | | | | | | | |
| 21W5 | | | | | | | | | | | 50 | | 29 | | | |
| 21W5+100 | | | | | | | | | | | | | 42 | | | |
| 0W5 | | | | | | | | | 20, 10 | | | 151, 259 | | | | |
| 0.5W5.5 | | | 10 | | | | | | | | | | | | | |
| 1W2 | | | | | | | | | | | | 217 | | | | |
| 1W3 | | 2 | | | | | | | 20 | | | | | | | |
| 1W5.5 | 0.40 | | 10 | | | | | | | | | | | | | |
| 1W6 | | 2 | 15 | | | | | | 30 | | | | | | 500 | |
| 1W6A | | | | | | | | | | | | | | | >500 | |
| 1.5W0.5 | | | 7 | | | | | | | | | | | | | |
| 1.5W5.5 | | 2 | 10 | | | | | | | | | | | | | |

Table 2.--Metal anomalies in soil, ash of douglas-fir sapwood, and ash of beargrass leaves, Red Mountain--Continued

| Sample site | Material sampled, with metal concentration in ppm | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Soil | | | | | | Douglas-fir sapwood, ashed | | | | | | | Beargrass leaves, ashed | | |
| | Au | Ag | Mo | W | As | Sb | Au | Ag | Mo | W | Sn | As | Sb | Ag | Mo | Sn |
| 1.5W6.5 | | | 10 | | | | | | | | | | | | | |
| 2E2 | | | | | | | | | | | 70 | | | | | |
| 2W1 | | | | | 290 | | | | | | | | | | | |
| 2W3 | 1.10 | | | | | | | | | | | | | | | |
| 2W5 | | | | | | | | | 30 | | | | | | | |
| 2W6 | | | | | | | | | 50, 30 | | | | | | | |
| 3E1 | | | | | | | | | 30 | | | | | | | |
| 3W4 | | | 7 | | | | | | 20 | | | | | | | |
| 3W6 | | | | | | | | | 20 | | | | | | | |
| 4W3 | | | | | | | | 150[b] | | | | | | | | |
| 4W6 | | | | | | | | | 30 | 100 | | | | | 200 | |
| 5W2 | | | | | | | | | | | | 208 | | | | |
| 5W3 | 0.38 | | | | | | | | | | | | | | | |
| 5W5 | | | | | | | | 300 | | | | | | | | |
| 5W6 | | | | | | | | | 30 | | | | | | | |
| 5W6A | | | | | | | | | | | | | | | 200 | |
| 6W0 | | | | | | | | | 20 | | | | | | | |
| 7W2 | | | | | | | | | | | | | | | | 10[c] |

[a] Doubtfully anomalous. Values of 1 and 1.5 ppm are common, and the limit of determination is 1 ppm.

[b] 100 ppm, the lowest of the "high three," is too widespread to be anomalous.

[c] Sn not detected in other beargrass samples.

Table 3.--Background values of metals in soil, ash of douglas-fir sapwood, and ash of beargrass leaves, Red Mountain

| | Material sampled, with metal concentration in ppm | | |
|---|---|---|---|
| | Soil | Douglas-fir sapwood, ashed | Beargrass leaves, ashed |
| Au | <0.05 | 0.07-0.24[a] or 0.35[b] | [c], [d] |
| Ag | <0.5 | 2-15 | <0.2 |
| Mo | ≦3 | ≦5 | <5-7 |
| W | <10 | <50[c] | ≦1 |
| Sn | <5 | <5-15 | <5 |
| As | 8-15 or > | 14-28 | [c], [d] |
| Sb | 1-3 | 1-3 | [c] |

[a]By inspection.

[b]By statistical test.

[c]Insensitive analytical method used for element.

[d]Element not concentrated in beargrass sampled in Erdman's 1979 regional reconnaissance.