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MISCELLANEOUS FIELD STUDIES
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PAMPHLET

MINERAL RESOURCE POTENTIAL OF THE WELCOME CREEK WILDERNESS, GRANITE COUNTY, MONTANA

By

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STUDIES RELATED TO WILDERNESS

Under the provisions of the Wilderness Act (Public Law 88-577, September 3, 1964) and related acts, the U.S. Geological Survey and the U.S. Bureau of Mines have been conducting mineral surveys of wilderness and primitive areas. Areas officially designated as "wilderness," "wild," or "canoe" when the act was passed were incorporated into the National Wilderness Preservation System, and some of them are presently being studied. The act provided that areas under consideration for wilderness designation should be studied for suitability for incorporation into the Wilderness System. The mineral surveys constitute one aspect of the suitability studies. The act directs that the results of such surveys are to be made available to the public and be submitted to the President and the Congress. This report discusses the results of a mineral survey of the Welcome Creek Wilderness, Lolo National Forest, Granite County, Montana. The area was established as a wilderness by Public Law 95-237, January 1979.

MINERAL RESOURCE POTENTIAL SUMMARY STATEMENT

On the basis of these mineral resource studies, three areas in and adjacent to the Welcome Creek Wilderness were assigned low-moderate-high potential for the occurrence of small deposits of metallic mineral resources.

An area of alluvium along Welcome Creek (A-1 in fig. 1) is assigned a high potential for the occurrence of a small placer gold resource. Sampling indicates that small and scattered gold placers are present. However, much of the Welcome Creek streambed has been placer mined, and the average gold content of the alluvium along Welcome Creek apparently is low. The potential for the occurrence of gold resources in alluvium of Rock Creek (A-1 in fig. 1), along the eastern boundary of the wilderness, is ranked as moderate between Cinnamon Bear Creek and Bear Gulch and as low north of Bear Gulch.

An area along the western boundary of the wilderness (A-2 in fig. 1) is assigned moderate to high potential for the occurrence of small silver and gold resources in veins. The veins typically are thin, discontinuous, and low grade. The BET claim group (no. 10 in fig. 1), located in the southern part of area A-2 and just outside the wilderness, is assigned a moderate potential for gold and tungsten resources of probable replacement origin.

An area (A-3 in fig. 1) in the northeastern part of the wilderness is assigned a low potential for the occurrence of copper resources. Here rock types favorable for stratabound copper-bearing zones are present, and copper was detected in anomalous concentrations in some stream-sediment samples. However, no copper-bearing rocks were found. No indications of the existence of oil, gas, coal, radioactive minerals, and geothermal energy resources were found in the wilderness.

INTRODUCTION

Location, size, and geographic setting

The Welcome Creek Wilderness (fig. 1) encompasses an area of about 71 sq mi in the Lolo National Forest southwest of Missoula, Mont. The two most prominent topographic features, the Bitterroot Divide and Rock Creek, define respectively, the western and eastern boundaries of the wilderness. Steep-sided valleys that confine east-flowing tributaries of Rock Creek dissect much of the wilderness. The wilderness is densely forested except for cliff-faces and has a total relief of about 3,000 ft; the maximum elevation is 7,723 ft along the Bitterroot Divide, and the minimum elevation is 3,680 ft along Rock Creek. The east side of the wilderness is accessible by an unpaved road that follows Rock Creek south from Interstate 90, about 18 mi southeast of Missoula. The north, south, and west sides are accessible by unpaved Forest Service roads from Highway 93, about 12 mi south of Missoula.

Previous and present studies

Lyden (1948) briefly described placers along Welcome Creek, and Sahinen (1957) discussed lode prospects near Cleveland Mountain. Jerome (1968) mapped and described the geology of an area northeast

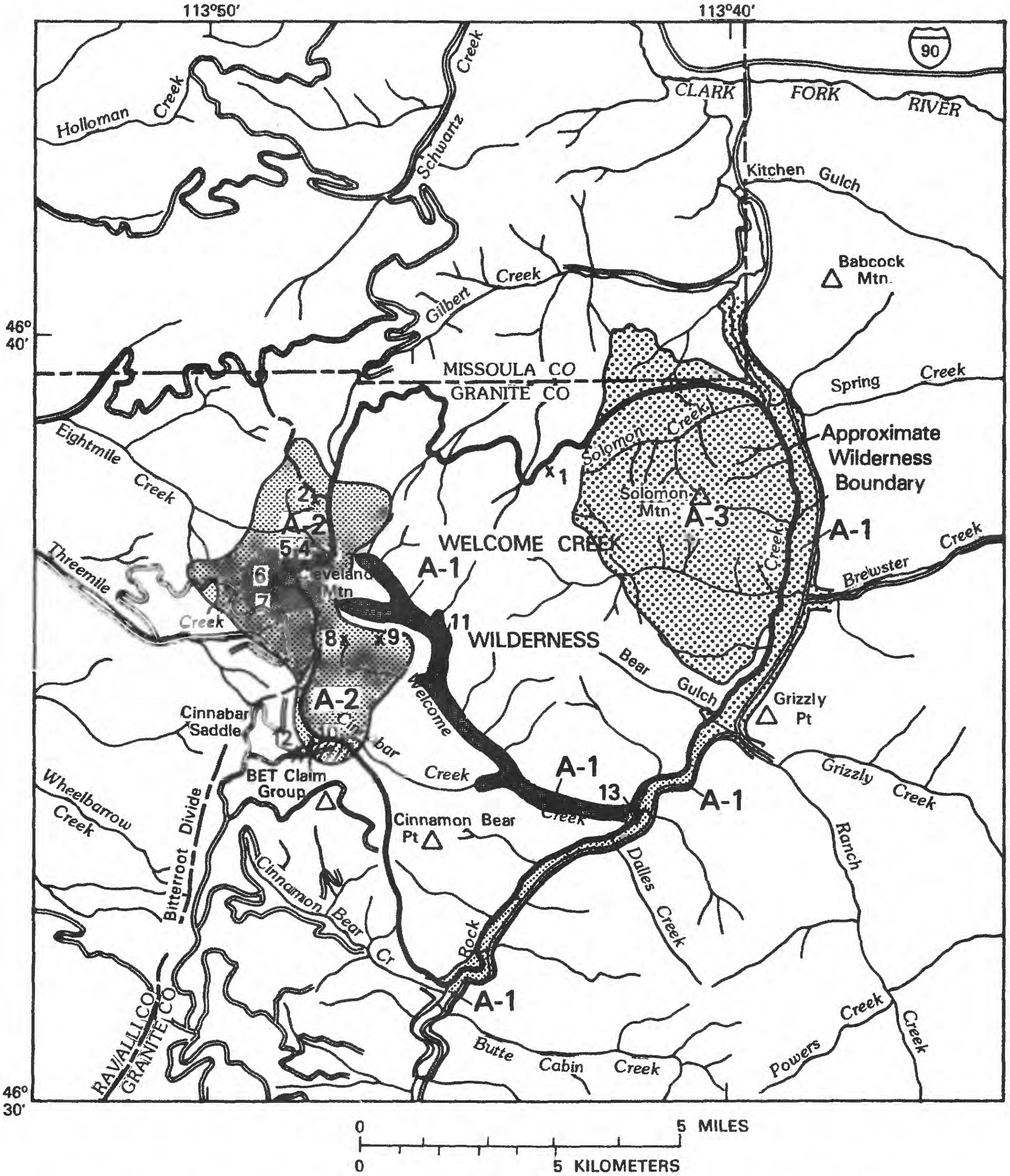


Figure 1.—Mineral resource potential map of the Welcome Creek Wilderness.

Figure 1.--Continued.

EXPLANATION

x MINE OR PROSPECT--Number is keyed to table 2

1	B and J claim
2	J. Jay No. 2 claim
3	Cleveland Summit prospect
4	Ellen M. claims
5	Cleveland Spring prospect
6	Cleveland mine
7	Lucky Star claim
8	Carron prospect
9	Lucky Hancock claim
10	BET claims
11	Hungry Horse and Big Dipper claims
12	Miss Fortune claims
13	Midnight Placer claims

PLACER-MINED STREAM

A-2 AREAS ASSIGNED RESOURCE POTENTIAL--See table 4

High

Moderate

Low

of the wilderness. Desormier (1973) conducted geologic investigations north of the wilderness, along the northern border of the Sapphire thrust plate. Wallace and Klepper (1976) published a preliminary geologic map that includes the wilderness.

This report presents the results of a cooperative study conducted by the U.S. Geological Survey and the U.S. Bureau of Mines. Geologic mapping was done during 1982 by D. J. Lidke, C. A. Wallace, and S. E. Zarske. Most of the geochemical sampling was done in 1979, with additional sampling in 1982 by J. C. Antweiler, W. L. Campbell, and G. K. Lee (Campbell and others, 1983). Geophysical investigations were done by J. H. Hassemer and W. F. Hanna (Hassemer, 1981). Investigations of mines and prospects were conducted during 1980 by T. J. Close, C. Cossaboom, and W. Zschockke (Close, 1981).

GEOLOGY

The Welcome Creek Wilderness is on the northwestern part of the Sapphire thrust plate (Ruppel and others, 1982, p. 139-159). The Lewis and Clark line, a complicated northwest-trending zone of recurrent high-angle faulting, is north of the wilderness; the Bitterroot Lobe of the Idaho batholith is southwest. The Welcome Creek Wilderness is underlain mainly by sedimentary rocks of the Belt Supergroup (Proterozoic Y age). These Belt Supergroup rocks were thrust faulted during Cretaceous time, and later displaced along high-angle faults that also displace the thrust faults. Some high-angle faults apparently displaced Belt Supergroup rocks prior to thrust faulting as well. Small granitic and gabbroic intrusive bodies are scattered through the area. Low-grade thermal metamorphism has affected most of the Belt Supergroup rocks exposed in the wilderness. Rocks of the Belt Supergroup are metamorphosed to hornblende-hornfels facies near contacts with larger intrusive bodies. Surficial deposits consist mostly of minor amounts of Quaternary till, outwash, and alluvium.

Rock units and surficial deposits

The middle and upper parts of the thick sequence of Belt Supergroup sedimentary rocks, which were deposited during Proterozoic Y time (900-1,600 m.y. ago), are exposed in the wilderness. The laterally equivalent Wallace and Helena Formations are the oldest sedimentary rocks of the Belt Supergroup exposed in the wilderness, and these rocks consist of carbonate-bearing, interbedded argillite, siltite, and quartzite. A sedimentary breccia is present in the middle member of the Wallace Formation. Green and red argillite, and interbedded argillite, siltite, and quartzite of the Snowslip Formation (Missoula Group) conformably overlie the Wallace and Helena Formations. Carbonate-bearing green argillite and siltite of the Shepard Formation (Missoula Group), which commonly overlies the Snowslip Formation, are exposed just north of the wilderness. The absence of the Shepard Formation in the northern part of the wilderness results from thrust faulting. Overlying the Shepard Formation is the Mount Shields Formation (Missoula Group), which is mainly a sequence of interbedded argillite and quartzite with a thick middle quartzite member. The Mount Shields Formation is the youngest unit of the Belt Supergroup exposed in the wilderness. Green argillite and siltite beds of the Mount Shields and Snowslip Formations are favorable hosts for stratabound copper deposits (Harrison, 1972).

Rocks of the Belt Supergroup are intruded by stocks of medium-grained monzogranite and granodiorite of probable Tertiary or Cretaceous age, and by dikes, sills, and pods of medium- and fine-grained gabbro and diabase that are no younger than Tertiary and some may be Proterozoic Y in age. Contacts of intrusive rocks with Belt Supergroup rocks are generally sharp and discordant. Near larger stocks, contact metamorphism produced hornblende hornfels and spotted hornfels in clastic rocks of the Missoula Group and calc-silicate hornfels in carbonate-bearing rocks of the Helena and Wallace Formations.

Surficial deposits in the wilderness and vicinity consist of Pleistocene till and outwash deposits and younger Holocene alluvium, colluvium, and talus. Poorly developed cirques and glacial valleys are present near the northern border of the wilderness and these contain till and outwash deposits. Most of the stream-cut valleys are steep sided and have narrow floors that generally are overlain by only minor amounts of alluvium. Colluvium and talus are distributed sporadically along most of the ridges.

Structure

Thrust faults, high-angle faults, and broad open folds occur throughout the wilderness and vicinity. Preliminary interpretations suggest that Proterozoic rocks were displaced by high-angle faults prior to Cretaceous time. During Cretaceous time, Proterozoic rocks were displaced along thrust faults. After thrust faulting in Late Cretaceous time or early in Tertiary time, intrusive rocks were emplaced. Following thrust faulting and emplacement of intrusive rocks, both Proterozoic and intrusive rocks were displaced by high-angle faults.

Thrust faults trend nearly east-west in the northern and southern parts of the wilderness, and change to a northerly trend in the east part. Some thrust faults are nearly parallel to bedding whereas other thrust faults truncate bedding at a steep angle. Thrust faults are intruded and truncated by granitic stocks and by some gabbroic bodies. Radiometric ages were not obtained on these intrusive bodies, but regional interpretation of radiometric ages (Wallace and others, 1982) suggests that a minimum age for cessation of thrust faulting in this area is about 73 m.y., and other radiometric ages (J. D. Obradovich, written commun., 1983) suggest that thrust faulting may have ceased prior to 81 m.y. ago.

Northwest- and northeast-trending high-angle faults are present in the wilderness and vicinity. Geologic mapping suggests that some northwest-trending high-angle faults have moved recurrently; earliest movement along these faults apparently preceded thrust faulting, and latest movements postdated thrust faulting and intrusion of granitic and gabbroic bodies. North of the Welcome Creek Wilderness, in the Garnet Range, northwest-trending high-angle faults also show apparent recurrent movement (Desormier, 1975; Wallace and Lidke, 1980). As much as 1,600 ft of stratigraphic separation is suggested for the largest northwest-trending high-angle fault, but separations of a few hundred feet are most common. Northeast-trending high-angle faults commonly have stratigraphic separations of a few hundred feet or less. These faults do not appear to have as much lateral continuity as northwest-trending faults, and no evidence was found indicating recurrent movement along northeast-trending faults.

In general, folding has had only a minor effect on rocks in the area. A poorly defined, broad anticlinal structure occurs in thrust faulted Proterozoic Y rocks near the northeast border of the wilderness. On a smaller scale, tight dragfolds are present along some high-angle faults.

GEOCHEMISTRY

Sampling methods and analyses

A total of 46 stream-sediment, 22 panned-concentrate, and 56 rock samples were collected and analyzed by the U.S. Geological Survey during these investigations. Stream-sediment samples were collected from most active first-order drainages, as well as from all second-order and larger drainages. At each stream-sediment sample site, a composite sample was collected of fine material from several places within the stream bed. Panned concentrates of heavy minerals in alluvial deposits were collected near most stream-sediment sample localities. Nonmineralized rock samples were collected throughout the wilderness to determine background geochemical data. At mineralized sites, the most altered or mineralized material was collected. Background samples of country rock consisted of composite chips from outcrops. Samples of both mineralized and nonmineralized rock were collected at mines and prospects.

All rock and stream-sediment samples and a split of each panned-concentrate sample were analyzed spectrographically for 31 elements. The remainder of each panned-concentrate sample and all rock samples were analyzed using an atomic absorption method to determine gold values. Atomic-absorption determinations of copper, lead, zinc, silver, antimony, bismuth, and cadmium were made on selected samples. Analytical data are available in Campbell and others (1983).

Selection of geochemical anomalies

Threshold values for geochemically anomalous concentrations of elements of potential resource interest were determined using the following criteria: (1) for some elements threshold values were suggested by sharp breaks in the slopes of distribution curves or by discontinuities in statistical distributions as shown by graphical analyses; (2) a multiple of 2-3 times the geometric mean was chosen as the threshold for some elements; and, (3) in some cases the lower limit of analytical detection was used as the threshold. In addition, crustal abundance figures for elements were considered. The threshold values that were chosen are listed for each selected element in table 1; concentrations of elements equal to or above threshold are anomalous values.

Anomalous samples

Most of the anomalous geochemical samples (table 1) can be attributed to known mineral occurrences or to rock types in areas assigned mineral resource potential (fig. 1). Six samples taken by the U.S. Geological Survey from alluvium along Welcome Creek contained gold in anomalous concentrations; silver, bismuth, lead, zinc, antimony, and yttrium also were detected in anomalous concentrations in some samples (table 1). These elements apparently are derived from veins near Cleveland Mountain, which is upstream from the sample sites. Cobalt and titanium were also detected in anomalous concentrations in some stream-sediment and panned-concentrate samples from alluvium of Welcome Creek (table 1). These concentrations of cobalt and titanium may result from erosion of gabbroic stocks and dikes upstream. Erosion of gabbroic bodies in this region commonly results in anomalous concentrations of cobalt and titanium in alluvium downstream (J. E. Harrison, U.S. Geological Survey, oral commun., 1982). Silver, gold, copper, bismuth, and yttrium were detected in anomalous concentrations in a few samples of vein and country rock from area A-2. Copper was detected in anomalous concentrations in three samples from area A-3. Copper and the other elements shown for area A-3 (table 1) may result from unidentified copper-bearing stratabound or vein occurrences.

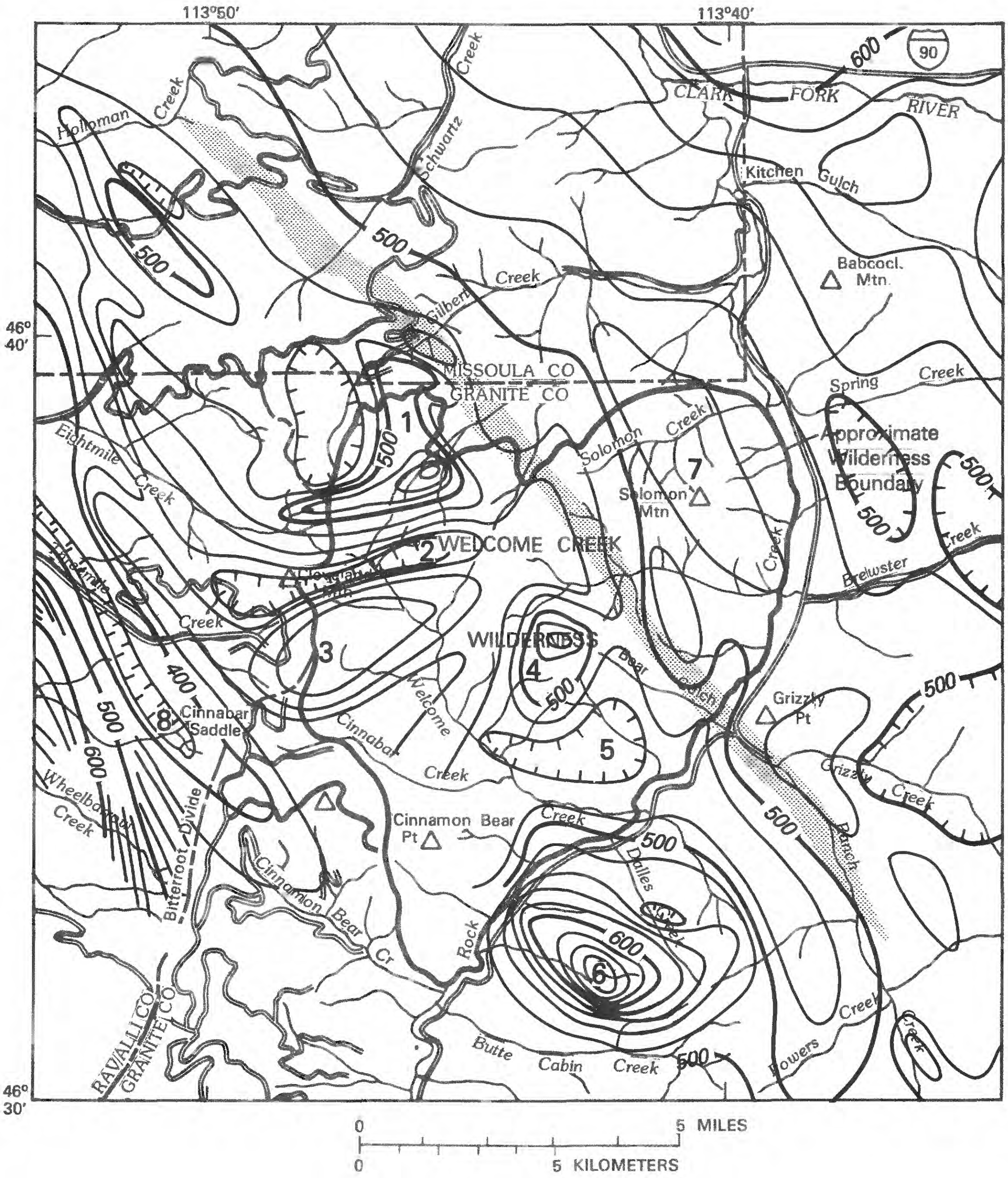
GEOPHYSICS

Contour maps of aeromagnetic and complete Bouguer gravity data reflect lateral variations of surface and subsurface rock density and magnetization in an area. The regional aeromagnetic anomaly map (fig. 2) was derived by Douglas (1972) from data acquired along north-south flight lines spaced 1-1.5 mi apart at a barometric elevation of 7,500 ft. These data agree to within a few tens of gammas with reconnaissance data acquired by the U.S. Department of Energy (Texas Instruments, Inc., 1979). Gravity readings were taken at 71 sites in and adjacent to the wilderness; figure 3 is a complete Bouguer gravity anomaly map for this data using a density of 2.67 g/cm^3 (Hassemer, 1981). The scale of the geophysical investigations is not adequate for detailed investigations of mineralization. However, the geophysical data may show possible hydrothermal alteration, and partly and entirely concealed plutons.

Aeromagnetic anomalies
(See figure 2)

Shaded zone.—Divides area into a magnetically quiet zone to the northeast and a zone of more numerous magnetic highs and lows of shorter wavelength to the southwest; this lineament in general coincides with a zone of northwest-trending high-angle faults.

Anomalies 1, 3, 4, and 6.—Magnetic highs associated with exposed or inferred occurrences of plutonic rocks; 3 and 6 correlate spatially with exposed plutonic rocks. Most of these highs coincide with



EXPLANATION

—500—┬┬┬ MAGNETIC CONTOUR--Contour interval 20 gammas; hachures indicate contour closure for negative magnetic anomaly

3 MAGNETIC ANOMALY--See text for discussion

MAGNETIC LINEAMENT--See text for discussion

Figure 2.--Aeromagnetic anomaly map of the Welcome Creek Wilderness, western Montana (from Douglas, 1972).

areas where sedimentary rocks show an increase in degree of thermal metamorphism.

Anomalies 2, 5, and 8.—Magnetic lows. Magnetic anomaly 2 is a northeast-trending low that in part coincides with the vein system near Cleveland Mountain and could reflect some hydrothermal alteration of sedimentary rocks in this area. Anomaly 5 may represent sedimentary rocks that are flanked to the north and south by plutons. Anomaly 8 is an elongate northwest-trending magnetic low that is a polarization effect; it is coupled with a high-amplitude magnetic high that is partly shown southwest of it. The trend and wavelength of these two anomalies are similar to those of the three northwest-trending highs immediately to the north; these northwest-trending anomalies may result from equally spaced northwest-trending narrow zones of subsurface intrusion.

Anomaly 7.—Low-amplitude magnetic high that may result from either a concealed pluton, or from a slight increase in the iron-oxide content of the Snowslip and Mount Shields Formations that are exposed in this region.

Gravity anomalies
(See figure 3)

Regional gravity contours trend east-west across the area with higher values in the north and decreasing values southward.

Anomaly 1.—Irregular gravity low centered west of Cleveland Mountain presumably associated with lateral density contrasts within the sedimentary rocks.

Anomaly 2.—Gravity high that may result from either higher rock densities of argillaceous rocks in this part of the Snowslip and Mount Shields Formations or possibly from a concealed gabbroic pluton.

Anomaly 3.—Gravity high, presumably associated with a lateral density contrast within sedimentary rocks; it perhaps correlates with a partly exposed thrust slice of the carbonate-bearing Wallace Formation here that contrasts with the rock density of quartzite and argillite to the north and with a large, partly exposed granitic pluton to the south.

MINING AND MINERALIZED AREAS

Mining history

The Welcome Creek Wilderness encompasses most of the Welcome Creek mining district and has been the site of placer mining along Welcome Creek and lode prospecting near Cleveland Mountain. To the west of the wilderness are the Threemile and Eightmile mining districts, and to the east is the Alps mining district.

Placer mining began along Welcome Creek in the late 1880's and has been the dominant mining activity in the wilderness and vicinity. Lyden (1948) reported that $30,000 in placer gold was produced from placer deposits along Welcome Creek from 1890 to 1911. U.S. Bureau of Mines records list $500 in gold production between 1912 and the present (Close, 1981).

There has been no lode mining activity in many years within the Welcome Creek Wilderness. The Cleveland mine, located about 0.25 mi west of the wilderness, on Cleveland Mountain, is the most developed lode mine near the wilderness (no. 6 in fig. 1). Sahinen (1957) briefly discussed the mine and reported that it yielded some ore during the late 1890's to early 1900's, but no official records of production were kept. The other lode prospects on Cleveland Mountain and in the wilderness and vicinity have remained undeveloped.

Mining claim records for Granite County show that 48 placer and 16 lode claims have been located in the wilderness. Many of these claims are too poorly described in the records to determine their geographic location. The most recent locations were two placer claims staked along the upper part of Welcome Creek in 1980 (no. 11, fig. 1). The only recent mining activity has been intermittent small-scale, placer mining along upper Welcome Creek.

Mineral occurrences

Known mineral occurrences in the Welcome Creek Wilderness are: (1) gold-bearing placers; and (2) silver- and gold-bearing veins. Geochemical data and favorable host rocks suggest that stratabound copper zones may occur in the northeastern part of the wilderness. Just outside the southwestern boundary of the wilderness, gold and tungsten were detected in samples from a probable replacement occurrence at the BET claim group. The locations of the mines and prospects examined by the U.S. Bureau of Mines are shown on figure 1 and summary descriptions of these are presented in table 2. Table 3 summarizes U.S. Bureau of Mines investigations of the gold placers along Welcome Creek and Rock Creek.

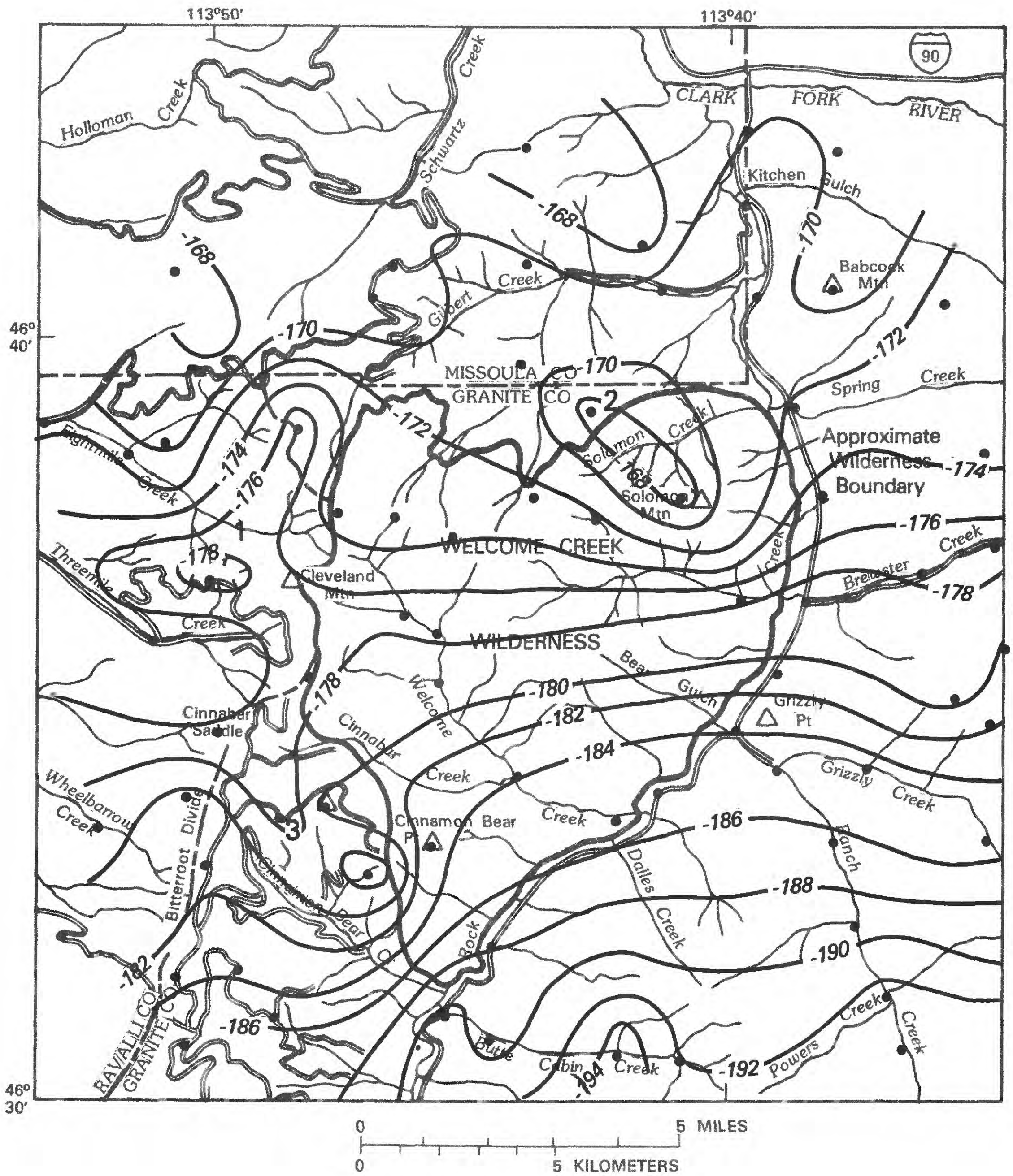
Placers

In the Welcome Creek Wilderness, small gold placers occur along Welcome and Cinnabar Creeks. Adjacent to the wilderness, gold placers are present along upper Cinnabar Creek and along Rock Creek.

Much of the alluvium in Welcome Creek was mined in the past. However, samples taken by the U.S. Bureau of Mines from 42 sites indicate that deposits with as much as 0.0038 oz of gold per cubic yard of gravel remain in the estimated 500,000 cubic yards of alluvium along Welcome Creek. Seven of the 42 samples contained more than 0.0002 oz of gold per cubic yard of gravel. These seven samples came from sites along the upper part of Welcome Creek, possibly indicating that placers in the upper part of Welcome Creek have higher gold concentrations than do those downstream. Currently, to be minable by suction dredge, an average gold content of more than about 0.003 oz per cubic yard would be required.

Little placer mining has been done in the Rock Creek drainage, along the eastern boundary of the wilderness. Seventy-six samples collected by the U.S. Bureau of Mines from the estimated 25 million cubic yards of alluvium in terraces and the stream channel along Rock Creek contained as much as 0.011 oz of gold per cubic yard of gravel. Samples that contained more than 0.0002 oz of gold per cubic yard were all collected between Cinnamon Bear Creek and Bear Gulch, apparently delineating the part of Rock Creek that is most likely to contain significant placers. However, because these gravel deposits are thick, no samples were obtainable of gravels in contact with bedrock.

Alluvium along Cinnabar Creek was placer mined for gold adjacent to the wilderness at prospect 12 (fig.



EXPLANATION

● GRAVITY STATION LOCATION

-176 GRAVITY CONTOUR--Contour interval 2 milligals; hachures indicate contour closure for negative gravity anomaly

3 GRAVITY ANOMALY--See text for discussion

Figure 3.--Complete Bouguer gravity anomaly map of the Welcome Creek Wilderness, western Montana (from Hassemer, 1981).

1), and in the wilderness at the junction of Welcome Creek and Cinnabar Creek. Except at the junction with Welcome Creek, very little alluvium is present along Cinnabar Creek.

Veins

Small quartz-sulfide veins are common along the western border of the wilderness, and a few are scattered throughout the wilderness. Most of the veins examined are fissure fillings along fault and fracture zones. The veins vary in width and continuity, but typically they are thin and discontinuous along strike over a distance of a few feet to a few hundred feet. The veins often contain quartz, specular hematite, siderite, magnetite, pyrite, and galena(?). Quartz is present as granular-to-massive pods, stringers, and small tabular bodies. Limonite is commonly present as a probable alteration of pyrite. Samples from these veins generally contained anomalous concentrations of some of the following elements: silver, bismuth, gold, lead, copper, and yttrium (tables 1 and 2); silver and bismuth were most commonly detected in anomalous concentrations. These veins may represent late-stage fluids from granitic intrusions, some of which are exposed near the veins.

The greatest concentration of veins is in the Cleveland Mountain area. The Cleveland mine, located about 0.25 mi west of the wilderness on Cleveland Mountain, apparently is the only lode mine in, or adjacent to, the wilderness that produced ore. Veins at the Cleveland mine are poorly exposed, and the mine is inaccessible. Near Cleveland Mountain, the veins occur in interbedded argillite and quartzite of the Mount Shields Formation, and generally trend northeast. Sulfide minerals are visible in many of the veins, and chemical analysis of vein samples detected silver in more samples and at higher concentrations than gold (tables 1 and 2). Veins were usually oxidized and leached, and most were covered by soil. The possibility of supergene secondary enrichment in the veins is unknown.

Copper occurrences

Copper occurrences, possibly the stratabound type, may be present in the northeastern part of the wilderness where favorable host rocks are present and where anomalous copper concentrations were detected in a few stream-sediment samples. Copper in these samples may have been derived from green argillaceous beds of the Missoula Group that are present in this part of the wilderness. Green-bed zones in Missoula Group rocks are known to be favorable hosts for stratabound copper deposits (Harrison, 1972). However, no stratabound deposits were found, and anomalous copper concentrations were not detected in rock samples from this area. Regionally, green-bed stratabound copper deposits in the Missoula Group are commonly small, lenticular, and discontinuous.

BET claim group

Tungsten and gold were detected in samples taken by the U.S. Bureau of Mines from gossan-capped calc-silicate rocks of the Wallace Formation at the BET claim group (table 2, fig. 1), about 0.5 mi west of the wilderness. There is no exposure of an intrusive body at these prospects, but small granitic and gabbroic bodies are present nearby. This mineral occurrence is apparently of replacement origin. The mineralized zone at the BET claims was investigated to determine if it extends into the wilderness. No extensions or other replacement deposits were found in the Welcome Creek Wilderness.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

Evaluation of the mineral resource potential of the Welcome Creek Wilderness is based on: (1) investigations of mines and prospects; (2) geochemical investigations; (3) geological investigations; and (4) geophysical investigations. Three levels of potential for the occurrence of mineral resources (high, moderate, and low) were defined on the basis of the criteria listed in the section below. Three areas were assigned potentials for the occurrence of small deposits of metallic mineral resources; these three areas are shown in figure 1 and summarized in table 4.

Ranking scheme for evaluation of mineral resource potential

High resource potential.--Geologic terrane ranked as having high potential for the occurrence of a mineral resource. The geologic terrane must satisfy at least criteria 1 and 2 (see below for criteria), but commonly satisfies all criteria for the type of mineral deposit.

Moderate resource potential.--Geologic terrane ranked as having moderate potential for the occurrence of a mineral resource. The geologic terrane must satisfy at least criteria 2, but commonly satisfies criteria 2, 3, and 4 for the type of mineral deposit.

Low resource potential.--Geologic terrane ranked as having low potential for the occurrence of a mineral resource. The geologic terrane must satisfy criteria 3 or 4, but commonly satisfies both criteria 3 and 4 for the type of mineral deposit.

Criteria for evaluation of mineral resource potential

Placers

1. Presence of placers from which gold has been produced.
2. Occurrences of gold at anomalous concentration in samples taken from alluvium.
3. Occurrences of gold in subanomalous concentration, but above detection limits in samples taken from alluvium.
4. Presence of gold in lode deposits upstream from the area.

Veins and replacement bodies

1. Presence of vein or replacement bodies from which metals have been produced.
2. Occurrences of metallic minerals in veins or replacement bodies at mines, prospects, or in undeveloped areas.

3a. Occurrences of faults, fractures, or shear zones that may contain metal-bearing veins along strike.
3b. Presence of a nearby contact zone between an intrusive body and sedimentary rocks that are favorable hosts for replacement bodies.
4. Occurrences of anomalous concentrations of most of the following elements: gold, silver, lead, bismuth, zinc, antimony, tungsten, and other pathfinder elements in rock samples and in samples from alluvium of streams that drain the area of possible mineralized rock.

Stratabound copper zones

1. Presence of stratabound zones from which copper has been produced.
2. Occurrences of copper in stratabound zones.
3. Presence of favorable host rocks.
4. Occurrences of anomalous concentrations of copper and, commonly, silver, mercury, molybdenum, bismuth, lead, barium, and other pathfinder elements in rock samples and in samples from alluvium of streams that drain the area of possible mineralized rock.

Areas assigned mineral resource potential

Area A-1—Gold

Area A-1 includes alluvium along Welcome and Rock Creeks. Alluvium along Welcome Creek is ranked as having high potential for the occurrence of a gold resource in small, scattered placers. A high potential is assigned because: (1) alluvium along much of the drainage has been placer mined and gold has been produced; (2) anomalous gold values were detected in some samples from mined and unmined alluvium along Welcome Creek; and (3) veins present upstream, near Cleveland Mountain, are probable sources for the gold in Welcome Creek.

The alluvium along Rock Creek between Bear Gulch and Cinnamon Bear Creek is ranked as having a moderate potential for the occurrence of a placer gold resource because: (1) most pan samples taken there contained anomalous gold values; and (2) erosion of veins in area A-2 and other scattered veins probably contributes gold to the alluvium along Rock Creek. Alluvium along Rock Creek to the north of Bear Gulch is assigned a low potential for the occurrence of gold resources because: (1) gold was detected in some pan samples, but generally the concentrations are low; and (2) again, erosion of nearby veins probably has contributed some gold to this part of Rock Creek.

Alluvium of Welcome Creek and of Rock Creek is of sufficient quantity to be considered a sand and gravel resource. However, sand and gravel probably have only local uses and other sources of sand and gravel are more readily accessible to large population centers.

Area A-2—silver, gold, and tungsten

Area A-2, which includes the lode prospects along the western border of the Welcome Creek Wilderness, is assigned high to moderate potential for the occurrence of small silver and gold resources in veins. The Cleveland Mountain part of area A-2 is ranked as having high potential because: (1) ore probably was produced from the Cleveland mine; (2) there are metal-bearing veins; (3) fault and fracture zones are present that may contain undiscovered veins; and; (4) geophysical anomalies coincide with this area. The remainder of area A-2 is ranked as having moderate potential because: (1) some veins are present; (2) fault and fracture zones are present that may contain veins and; (3) anomalous concentrations of gold, silver, and some base metals were detected in rock samples.

Just outside the wilderness, a small area on which the BET claim group is located, in the southern part of area A-2 (10, fig. 1), is ranked as having moderate potential for the occurrence of gold and tungsten resources in a probable replacement deposit because: (1) gold and tungsten were detected in samples from gossan-capped calc-silicate rocks at the BET claims; and (2) intrusive rocks are present nearby. The BET claim group was examined to determine if the mineralized zone extends into the wilderness; no extensions were found.

Area A-3--copper

Area A-3, in the northeastern part of the wilderness, is ranked as having a low potential for the occurrence of copper resources. This rating is based on the presence of (1) green beds of the Missoula Group, which are favorable host rocks for stratabound copper zones, and (2) copper in anomalous concentrations in a few stream-sediment samples collected from area A-3. Geologic mapping and geochemical sampling of rocks in area A-3 did not identify stratabound copper-bearing zones, or other types of copper-bearing rock.

Energy resource potential

There were no indications of oil, gas, radioactive minerals, coal, or geothermal resources in the Welcome Creek Wilderness. No source rocks with oil or gas potential are known, and the thermal history of the area suggests that pre-Cretaceous oil and gas, if any, might have been destroyed. No indications of coal or radioactive mineral resources were found, and these are not known to occur in rocks of Proterozoic Y age in southwestern Montana. Hot springs or volcanic rocks, which are commonly associated with known geothermal areas, are not present in the wilderness.

REFERENCES CITED

Campbell, W. L., Lee, G. K., Antweiler, J. C., and Hopkins, R. T., Jr., 1983, Analytical results for 56 rock samples, 46 stream-sediment and soil samples, and 22 panned-concentrate samples from the Welcome Creek Wilderness, Granite County, Montana: U.S. Geological Survey Open-File Report 83-829.

Close, T. J., 1981, Mineral resources of the Welcome Creek Wilderness, Granite County, Montana: U.S. Bureau of Mines unpublished open file mineral land assessment report 17-82, 14p; available from U.S. Bureau of Mines, E 360 3rd Ave., Spokane, WA 99202.

Desormier, W. L., 1975, A section of the northern boundary of the Sapphire Tectonic Block:

Missoula, University of Montana M.A. thesis, 65 p.

Douglas, J. K., 1972, Geophysical investigations of the Montana Lineament: Missoula, University of Montana M.S. thesis, 75 p.

Harrison, J. E., 1972, Precambrian Belt Basin of the northwestern United States—Its geometry, sedimentation, and copper occurrences: Geological Society of America Bulletin, v. 83, p. 1215-1240.

Hassemer, J. H., 1981, Principal facts and complete Bouguer gravity anomaly map for the west half of the Butte 1 X 2 quadrangle, Montana: U.S. Geological Survey Open-File Report No. 81-949, 39p.

Jerome, N. H., 1968, Geology between Miller and Eightmile Creek, northern Sapphire Range, western Montana: Missoula, University of Montana M.S. thesis, 49 p.

Lyden C. J., 1948, The gold placers of Montana: Montana Bureau of Mines and Geology Memoir 26, V. 15, 99p.

Ruppel, E. T., Wallace, C.A., Schmidt, R. G., and Lopez, D. A., 1982, Preliminary interpretation of the thrust belt in southwest and west-central Montana: Montana Geological Society Guidebook, Southwest Montana Field Conference, 1981, p. 139-159.

Texas Instruments Inc., 1979, National uranium resource evaluation aerial radiometric and magnetic survey, Butte Quadrangle, Montana—Final Report: U.S. Department of Energy Grand Junction Office (Report) GJBX 126-79, v. 2-G, n.p., scale 1:500,000.

Sahinen, U. M., 1957, Mines and mineral deposits, Missoula and Ravalli Counties, Montana: Montana Bureau of Mines and Geology Bulletin 8., p. 50-51.

Wallace, C. A., and Klepper, M. R., 1976, Preliminary reconnaissance geologic map of the Cleveland Mountain and north half of the Ravenna quadrangles, Western Montana: U.S. Geological Survey Open-File Report 76-527, P.

Wallace, C. A., and Lidke, D. J., 1980, Geologic map of the Rattlesnake Wilderness Study Area, Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF-1235-A.

Wallace, C. A., Lidke, D. J., and Obradovich, J. D., 1982, Geologic map of the Sapphire Wilderness Study Area, Granite and Ravalli Counties, Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF-1469-A.

Table 1.--Anomalous geochemical samples, Welcome Creek Wilderness (areas shown in fig. 1)

[Atomic absorption analyses by W. L. Campbell (USGS); emission spectrographic analyses by R. T. Hopkins, Jr. (USGS). Threshold values shown in the bottom part of table]

Element	Sample type	Number of samples	Range (ppm)
	Area A-1--Welcome Creek		
Au	Panned concentrate	6	0.4-10.4
Co	--do---------------	3	70-100
	Stream sediment---	1	30
Y	Panned concentrate	3	150-300
Ag	Stream sediment---	1	.14
Zn	--do---------------	1	14
Sb	--do---------------	1	3
Bi	Panned concentrate	2	20-50
Ti	--do---------------	5	>2[1]
Pb	--do---------------	1	3,000
	Area A-1--Rock Creek Not sampled by the U.S. Geological Survey		
	Area A-2--Cleveland Mountain part		
Ag	Rock---------------	3	1.5-7
Bi	--do---------------	3	4-12
	Area A-2--remainder of area		
Cu	Rock---------------	1	70
Au	--do---------------	1	.41
Y	--do---------------	1	200
	Area A-3		
Cu	Stream sediment---	3	100-200
Zn	--do---------------	2	20-40
Pb	--do---------------	1	150
Co	--do---------------	1	30
Ag	--do---------------	1	.7
Bi	--do---------------	1	5.5
Sb	--do---------------	1	1.5
Sr	--do---------------	1	300

[1]Percent.

THRESHOLDS[1] FOR SELECTED ELEMENTS IN GEOCHEMICAL SAMPLES

[Established by the U.S. Geological Survey. Concentrations in parts per million unless specified as percent (%)]

Stream-sediment samples	Panned-concentrate samples	Rock samples
Cobalt (Co)- [2]spec= 20	Titanium (Ti)-spec= 2%	Gold (Au)- AA= 0.05
Copper (Cu)- spec=100	Bismuth (Bi)- spec= 20	Silver (Ag)- spec= 1
Lead (Pb)- spec= 50	Cobalt (Co)- spec= 50	AA= 0.1
Zinc (Zn)- spec=200	Yttrium (Y)- spec=100	Copper (Cu)- spec= 70
[3]AA= 6	Gold (Au)- AA= 0.1	Yttrium (Y)- spec=150
Silver (Ag)- AA= 0.1		Lead (Pb)- AA= 3.5
Bismuth (Bi)- AA= 1		Bismuth (Bi)-AA= 1.5
Antimony (Sb)- AA= 1		
Strontium (Sr)-spec=150		

[1]Threshold, upper range of background concentrations. Concentrations of elements equal to or above threshold are anomalous.

[2]Spec, six-step emission spectrographic analysis.

[3]AA, atomic-absorption analysis.

Table 2.--Summary of investigations of mines and prospects in and adjacent to the Welcome Creek Wilderness

[Sampling and analyses by the U.S. Bureau of Mines (Close, 1981). Lode samples were fire assayed for gold and silver and at least one sample from each mineralized zone was analyzed spectrographically for 31 elements. Placer samples were panned or sluiced, and gold was amalgamated and weighed. N.M.S.E., no mineralized structure exposed; n.d., not detected in analysis; N/A, not applicable]

Prospect/ mine no.	Name	Workings	Description	Number of samples analyzed	Maximum metal content of samples analyzed (oz/ton) Au	Ag
			Lode prospects			
1	B and J claim.	One adit----------	Shear zone in quartzite----------	2	0.007	0.6
2	J. Jay No. 2 claim.	Seven pits and trenches, one caved shaft.	Silicifed zone, quartz and limonite in argillaceous quartzite.	6	.02	.2
3	Cleveland Summit prospect.	Forty pits and trenches.	N.M.S.E. Alinement of workings suggests northeast-trending vein in quartzite and argillite.	6	n.d.	.4
4	Ellen M. claims.	Fourteen pits and trenches.	N.M.S.E. Alinement of workings suggests northeast-trending silicified zone in quartzite and argillite.	5	n.d.	.4
5	Cleveland Spring prospect.	Two pits, one trench.	N.M.S.E. Alinement of workings suggests north-trending quartz vein in quartzite and argillite.	2	.491	.8
6	Cleveland mine.	One trench, three caved adits.	Northeast-trending fracture zone quartz veins or pods in quartzite and argillite.	8	.193	.6
7	Lucky Star claim.	Two caved adits---	N.M.S.E. Alinement of workings suggests a northeast-trending silicified zone in quartzite and argillite.	2	.018	.4
8	Carron prospect.	One trench--------	N.M.S.E. Dump material suggests quartz vein along north-trending contact between small granitic intrusive and quartzite.	1	n.d.	n.d.
9	Lucky Hancock claim.	Two pits----------	N.M.S.E. Alinement of workings indicate northwest-trending quartz vein in gabbroic intrusive.	2	n.d.	.4
10	BET claims	None--------------	Gossan-capped zone in calc-silicate rocks.	22	.4	.03[1]
			Placer prospects			
				Sample sites		
11	Hungry Horse and Big Dipper claims.	Two recent discovery pits, many older workings.	Stream alluvium------------------	4	.0004[2]	N/A
12	Miss Fortune claims.	Eight pits, steel sluice box and small dam.	Immature angular gravel-bearing sediments.	13	.0003[2]	N/A
13	Midnight placer claims.	Small hydraulic working, water ditch, caved shaft, and numerous small pits.	Terrace and stream alluvium-------	22	.011[2]	N/A

[1]Value shows percent Wo^3.
[2]Values given in oz/yd^3.

Table 3.--Estimates of gold in alluvium of Welcome Creek and Rock Creek

[By U.S. Bureau of Mines (Close, 1981]

Drainage	Workings	Volume of alluvium (yd^3)	Sample sites	Gold (oz/yd^3) Average	Gold (oz/yd^3) Maximum
Welcome Creek placers.	Placer workings scattered along most of stream.	500,000	42	0.0003	0.0038
Rock Creek placers:	Small workings at mouth of Welcome Creek.		76		
1. Stream alluvium.		13,000,000		.0006	.009
2. Terrace alluvium.		12,000,000		.0002	.011

Table 4.--Evaluation of mineral resource potential

[Criterion numbers refer to criteria for evaluation of mineral resource potential]

Area	Commodity	Deposit type	Criteria	Mineral resource potential
A-1, Welcome Creek.	Gold-------	Placer-----	Satisfies criteria 1, 2, 3, and 4.	High.
A-1, Rock Creek (between Bear Gulch and Cinnamon Bear Creek.	--do-------	--do-------	Satisfies criteria 2, 3 and 4.	Moderate.
A-1, Rock Creek (north of Bear Gulch).	--do-------	--do-------	Satisfies criteria 3 and 4.	Low.
A-2, Cleveland Mountain Area.	Gold, silver.	Vein-------	Satisfies criteria 1, 2, 3a, and 4.	High.
A-2, Remainder of area A-2.	--do-------	--do-------	Satisfies criteria 2, 3a, and 4.	Moderate.
A-2, BET claims	Gold, tungsten.	Replacement	Satisfies criteria 2, 3b, and 4.	Moderate.
A-3, area A-3---	Copper-----	Stratabound	Satisfies criteria 3 and part of 4.	Low.