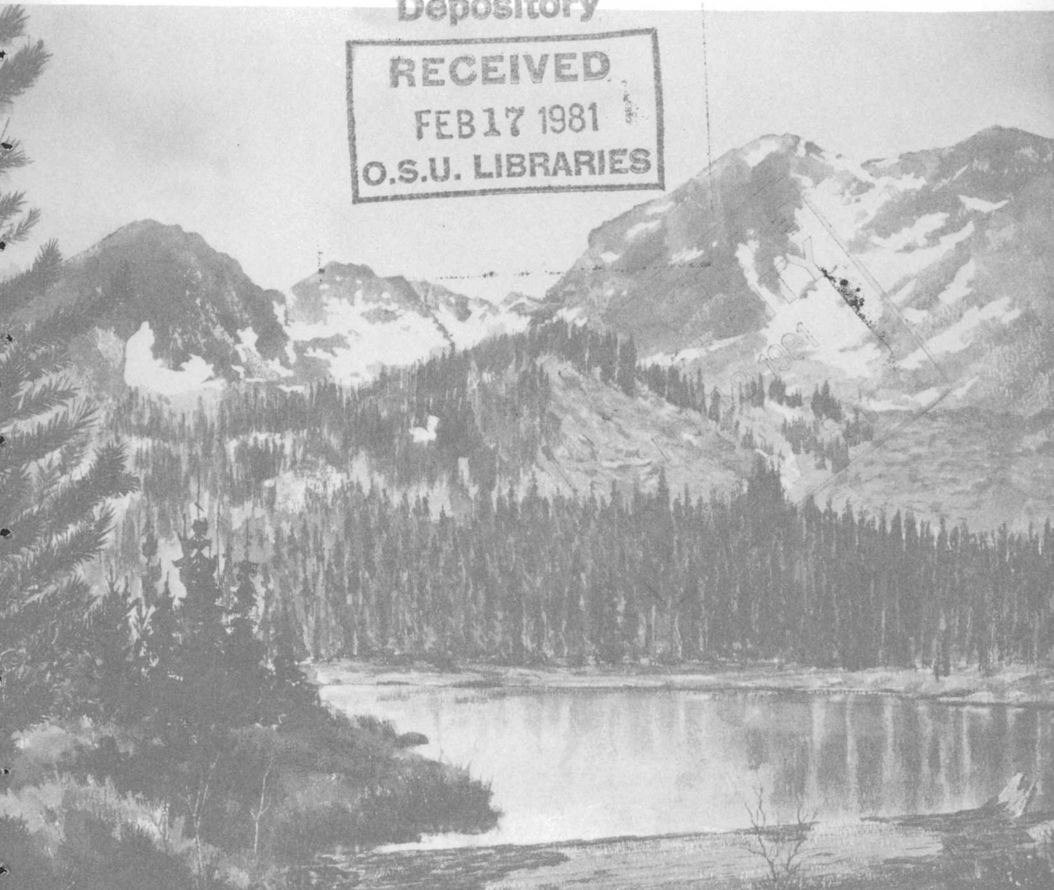
STUDIES RELATED TO WILDERNESS





# SCOTCHMAN PEAK STUDY AREA, MONTANA AND IDAHO



GEOLOGICAL SURVEY BULLETIN 1467

# Mineral Resources of the Scotchman Peak Wilderness Study Area, Lincoln and Sanders Counties, Montana, and Bonner County, Idaho

*By* U.S. GEOLOGICAL SURVEY *and* U.S. BUREAU OF MINES

A. Geology of the Scotchman Peak Wilderness Study Area, Lincoln and Sanders Counties, Montana, and Bonner County, Idaho

*By* ROBERT L. EARHART, U.S. Geological Survey

B. Aeromagnetic and Gravity Studies of the Scotchman Peak Wilderness Study Area, Lincoln and Sanders Counties, Montana, and Bonner County, Idaho

*By* M. DEAN KLEINKOPF *and* DOLORES M. WILSON, U.S. Geological Survey

C. A Geological and Geochemical Evaluation of the Mineral Resources of the Scotchman Peak Wilderness Study Area, Lincoln and Sanders Counties, Montana, and Bonner County, Idaho

*By* DAVID J. GRIMES *and* ROBERT L. EARHART, U.S. Geological Survey

D. Economic Appraisal of the Scotchman Peak Wilderness Study Area, Lincoln and Sanders Counties, Montana, and Bonner County, Idaho

*By* NICHOLAS T. ZILKA, U.S. Bureau of Mines

STUDIES RELATED TO WILDERNESS

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GEOLOGICAL SURVEY BULLETIN 1467

*An evaluation of the mineral potential of the area*

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STUDIES RELATED TO WILDERNESS

# WILDERNESS AREAS

In accordance with the provisions of the Wilderness Act (Public Law 88–577, September 3, 1964) and the Joint Conference Report on Senate Bill 4, 88th Congress, the U.S. Geological Survey and U.S. Bureau of Mines have been conducting mineral surveys of wilderness and primitive areas. Studies and reports of all primitive areas have been completed. 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 currently 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. This report discusses the results of a mineral survey of some national forest lands in the Scotchman Peak study area, Idaho, that are being considered for wilderness designation.

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[Letters designate chapters]



# PLATES

# MINERAL RESOURCES OF THE SCOTCHMAN PEAK WILDERNESS STUDY AREA, LINCOLN AND SANDERS COUNTIES, MONTANA, AND BONNER COUNTY, IDAHO

By U.S. Geological Survey and U.S. Bureau of Mines

## SUMMARY

A mineral survey of the Scotchman Peak Wilderness study area by the U.S. Geological Survey and the U.S. Bureau of Mines in 1974 and 1975 covers about 37,000 acres (15,000 ha) of the Kootenai and Kaniksu National Forests in northwestern Montana and northeastern Idaho. The mineral resource potential of the area was evaluated by geological, geochemical, and geophysical studies by the U.S. Geological Survey, and by the examination of rocks and mining claims by the U.S. Bureau of Mines. The investigations indicate that the eastern part of the study area could contain disseminated copper-silver deposits similar to an area 2 mi (3.2 km) northeast of the area at Mount Vernon. American Smelting and Refining Co. is planning to develop the deposit near Mount Vernon. One of the several base-metal-bearing quartz veins in the Ross Point area is estimated to contain 430,000 tons (390,000 t) of copper resources. The Blue Creek and Broken Hill mines outside the study area have produced zinc-lead-silver ore. Unexplored northern extensions of faults exposed in the mines extend into the study area and probably contain small vein deposits. The study area has little to no potential for oil and gas, coal, geothermal resources, or other energy-related commodities.

The area is mostly underlain by fine-grained metasedimentary rocks of the Belt Supergroup of Precambrian Y age that are locally intruded by granodiorite and diorite plutons, sills, and dikes. In the western half of the area, the rocks of probable Cretaceous and Tertiary age form a westerly dipping homocline; in the eastern half of the area, the rocks are highly faulted and folded. The Hope fault, a major strike-slip structure of regional importance, approximately parallels the southern boundary. Uplift in Cretaceous-Tertiary time followed by glacial and stream erosion from Pleistocene to Holocene time has resulted in the present extremely rugged topography.

Geophysical investigations consisted of aeromagnetic and gravity surveys. The results suggest the presence of several buried intrusives that may have associated mineral deposits. They also delineate major fault zones that may be related to base and precious metal vein deposits.

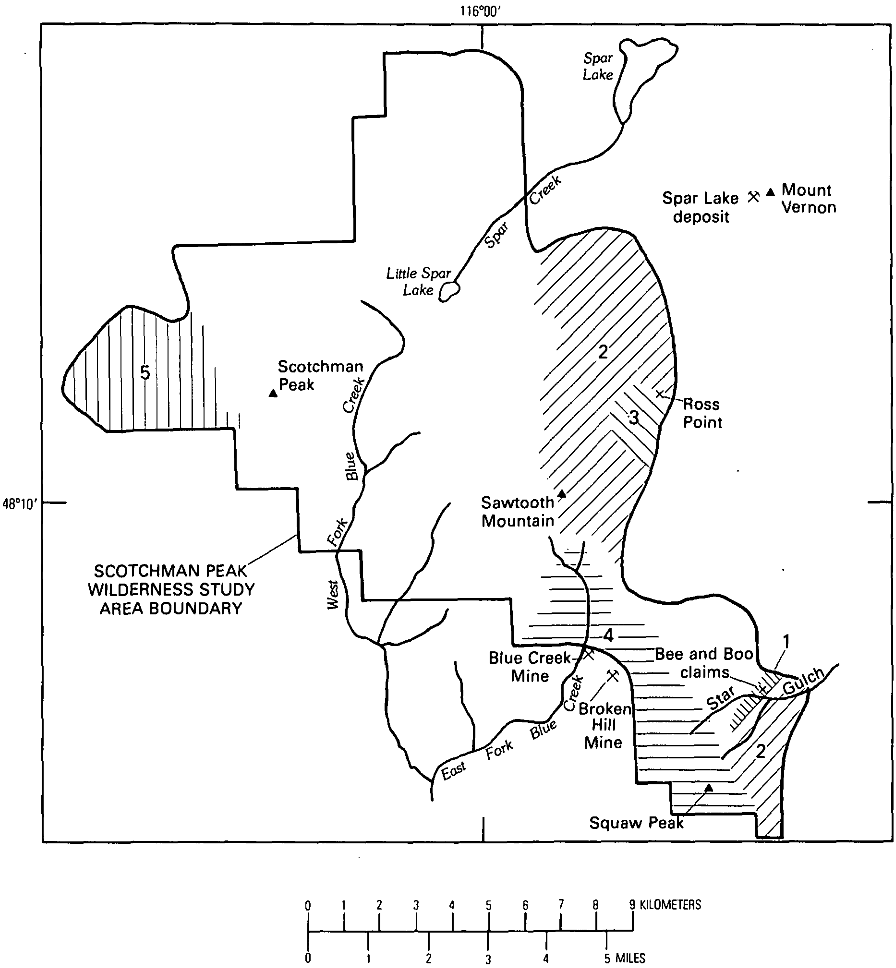
The Scotchman Peak study area has no recorded mineral production, but the area does have mineral potential. Mines near the southern border of the study area have produced 297,048 tons (269,477 t) of gold, silver, copper, lead, and zinc ores, and they may still contain significant mineral resources. Recently discovered mineral occurrences on the east boundary of the study area are being explored. During the period 1887–1973 about 439 claims, grouped in the areas of Mount Vernon-Squaw Peak, Blue Creek, and Hope fault, were located within the study area.

Areas containing potential metallic resources are shown on index map, p. 3. The area has a high potential for large tonnage stratabound deposits of copper and silver similar to the deposit near Mount Vernon. Zinc, lead, copper, and silver in vein deposits are of secondary importance because of their small tonnage potential. The stratabound copper deposit near Mount Vernon, the Spar Lake deposit, contains about 58 million tons (52 million t) of ore with an average grade of 0.79 percent copper and 1.67 oz/ton (47 g/t) silver. American Smelting and Refining Co. is developing this deposit.

The Star Gulch area (index map, loc. 1) contains highly anomalous amounts of copper and silver in a zone that is about 10,000 ft (3,000 m) long and 100 ft (30 m) wide. The anomaly straddles the southeastern boundary of the study area and reflects a zone of disseminated copper and silver minerals in quartzite of the lower part of the Revett Formation. The southwestern part of the anomaly is over a weakly mineralized zone that is exposed on the Bee and Boo claims where discontinuous outcrops of quartzite contain disseminations of bornite, chalcopyrite, brochantite, and limonite over a strike length of about 7,000 ft (2,000 m). Samples of the outcrops average 0.04 percent copper. The U.S. Bureau of Mines estimates that the zone in and near the study area contains 35 million tons (29 million t) of copper- and silver-bearing material. The U.S. Geological Survey's evaluation of the anomalous zone suggests that the consistently high copper and silver values in stream-sediment and soil samples reflect a buried deposit because the metal values in the outcropping rocks are too low to explain the anomaly. Furthermore, the highest consistent values of copper and silver in stream sediments are from the northeastern part of the anomalous zone where the surface rocks are unmineralized. The geochemical results from the Star Gulch area are similar to those near the Spar Lake deposit. This summary suggests that the anomaly at Star Gulch could reflect ore grade material at shallow depth.

A broad area in the eastern part of the Scotchman Peak area (index map, loc. 2) contains scattered occurrences of stratabound copper, small copper-silver anomalies, and a few copper-bearing quartz veins in the Revett Formation. The widespread occurrences suggest that the area has a moderate to high potential for larger deposits too deep to detect by surface sampling methods.

The Ross Point area (index map, loc. 3) contains several base metal-quartz veins in the Revett Formation that have been explored by means of small adits and pits. One vein with small amounts of bornite and chalcopyrite has a maximum thickness of 16 ft (5 m) and contains 430,000 tons (390,000 t) of indicated and inferred resources that average 0.07 oz silver per ton (2.49 g/t) and 0.13 percent copper. The area has been partially explored, by diamond drilling, for stratabound copper deposits. Additional subsurface exploration may reveal higher grade material in either the vein or stratabound occurrences.




Scotchman Peak Wilderness study area showing in order of relative importance areas of potential resources. 1, Stratabound copper deposits in the Revett Formation—very high potential. 2, Stratabound copper deposits in the Revett Formation and copper-bearing quartz veins—moderate to high potential. 3, Copper-bearing quartz veins in the Revett Formation—moderate potential. 4, Lead-zinc veins and copper-bearing quartz veins—moderate potential. 5, Lead-bearing veins associated with a granodiorite intrusive—low potential.

The Blue Creek and Broken Hill mines, just outside the Scotchman Peak study area (index map, loc. 4) have produced 675 tons (612 t) of zinc-lead-silver ore from north- to northwest-trending shear zones within the Blue Creek fault set. The mines contain about 13,000 tons (12,000 t) of measured and indicated paramarginal resources. The fault set trends into the study area for 7 mi (11 km) of its 10-mi (16 km) total length. The unexplored extension of the shear zones in the study area (fig. 1, loc. 4) may contain small additional resources.

Eight mineral properties, which are near granodiorite intrusives, the Hope fault, and sites of former mining activity in the Clark Fork district, are in the southwest part of the study area (index map, loc. 5). The known veins have a low potential because of their narrow width and highly localized base metal concentrations.

# Geology of the Scotchman Peak Wilderness Study Area, Lincoln and Sanders Counties, Montana, and Bonner County, Idaho

By Robert L. Earhart, U.S. Geological Survey

MINERAL RESOURCES OF THE SCOTCHMAN PEAK WILDERNESS STUDY AREA, LINCOLN AND SANDERS COUNTIES, MONTANA, AND BONNER COUNTY, IDAHO

GEOLOGICAL SURVEY BULLETIN 1467-A

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## TABLE

STUDIES RELATED TO WILDERNESS

# GEOLOGY OF THE SCOTCHMAN PEAK WILDERNESS STUDY AREA, LINCOLN AND SANDERS COUNTIES, MONTANA, AND BONNER COUNTY, IDAHO

By ROBERT L. EARHART, U.S. GEOLOGICAL SURVEY

## INTRODUCTION

A mineral survey of the Scotchman Peak area was conducted in 1974 and 1975 by the U.S. Geological Survey and the U.S. Bureau of Mines as a part of a study to determine the suitability of the area for inclusion in the National Wilderness Preservation system. The Scotchman Peak area covers about 37,000 acres (15,000 ha) of the Kootenai and Kaniksu National Forests between lat 48°05′ and 48°16′ N., and long 115°53′ and 116°10′ W. in Lincoln and Sanders Counties, Montana, and Bonner County, Idaho; about two-thirds of the area is in Montana (fig. 1).

The extremely rugged topography of the area (fig. 2) is characterized by steep-sided glacial valleys, precipitous peaks, knife-edge ridges, and other features, such as cirques and aretes, that are the products of alpine glaciation. The highest point in the area is Scotchman Peak at an elevation of 7,009 ft (2,136 m), and the lowest point is about 2,300 ft (700 m) in the valley of Lightning Creek near the west boundary. Except for Little Spar Lake in the north-central part, the area contains only a few small lakes and ponds found mostly in the high cirques. The treeline is at an elevation of about 6,500 ft (1,980 m). The area is accessible by horse trails from Spar Lake to Little Spar Lake, from the Bull Lake valley up Ross Creek, and up Star Gulch to Squaw Peak from the east, and from Cabinet Gorge Reservoir up Big Eddy Creek to Squaw Peak from the south. In addition, several unmaintained trails provide access into parts of the area from Lightning Creek and from the mouth of the east and west forks of Blue Creek (pl. 1). There is no trail system through the area.

The Sandpoint and Kalispell 2° topographic maps cover the Scotchman Peak Wilderness study area at a scale of 1:250,000. The western part of the area is covered by the Clark Fork 15-minute sheet at a scale of 1:62,500. The eastern part is included on the Spar Lake, Sawtooth, and Heron 7½-minute quadrangles at a scale of 1:24,000. The base map for plate 1 was compiled from the Clark Fork

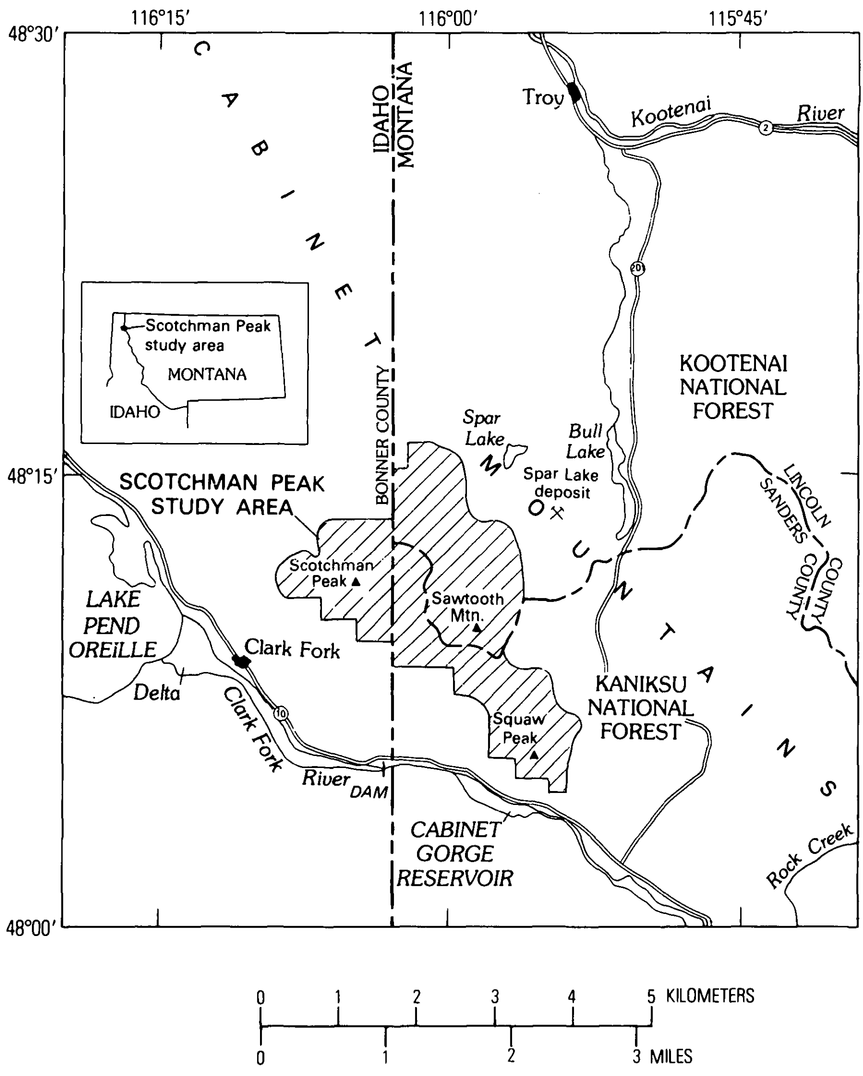


FIGURE 1.—Location of the Scotchman Peak Wilderness study area in northwestern Montana and northeastern Idaho, scale 1:500,000.

sheet and from the reduction of the $7\frac{1}{2}$-minute quadrangles to a scale of 1:62,500.

## PREVIOUS INVESTIGATIONS

The Scotchman Peak area was included in past surveys, and the area has been mapped at various scales. The area was investigated by Calkins and MacDonald in 1909 during a reconnaissance survey of parts of northeastern Idaho and northwestern Montana from the Canadian border south to the Coeur d'Alene district and southeastward nearly to Missoula, Mont. Anderson (1930) studied the geology and mineral deposits in the Clark Fork district of Idaho, which covered the Idaho part of the Scotchman Peak area. The geology of the Montana part of the area was mapped at a scale of 1:125,000 by Gibson (1948) who also studied the mineral deposits. The geology of the western half of the area was mapped by Harrison and Jobin (1963) at a scale of 1:62,500, and this mapping, with only minor modifications, was used in the present studies. Johns (1970) made a reconnaissance of the geology and mineral deposits in Lincoln County, Mont., which includes a part of the study area. An aeromagnetic map (U.S. Geological Survey, 1969) of the area compiled at a scale of 1:62,500 from a survey flown on approximately 1-mi line

FIGURE 2.—Scotchman Peak (center), viewed from a point northwest of the center of the Scotchman Peak Wilderness study area.

spacings at a barometric elevation of 7,000 ft (2,134 m) was used in the present studies. In addition, an aeromagnetic and geologic map of northwestern Montana and northern Idaho compiled at a scale of 1:250,000 includes the Scotchman Peak area (Kleinkopf and others, 1972). Zartman and Stacey (1971) have published data on the ages of mineralization based on lead isotope compositions from several deposits in northern Idaho and northwestern Montana. One sample was collected from a vein-type deposit near the southwestern boundary of the Scotchman Peak area; the lead-isotope composition suggested a Precambrian age.

Extensive exploration, much of it in the Scotchman Peak area, was conducted in recent years by mining and exploration companies; however, the results of these investigations are not published and are unavailable. In 1973, Norman Lutz of Bear Creek Mining Co. reported (unpub. data) on the geology, mineralization, and character of the Spar Lake copper-silver deposit at the Pacific Northwest Metals and Minerals Conference in Coeur d'Alene, Idaho. The deposit is in the Revett Formation a short distance to the northeast of the study area.

## PRESENT INVESTIGATIONS AND ACKNOWLEDGMENTS

The present investigations by the U.S. Geological Survey were conducted by R. L. Earhart and D. J. Grimes during the summers of 1974 and 1975. About 12 weeks were spent in the field collecting geological and geochemical data. Richardson Allen and Kerwin Stark assisted in the fieldwork in 1974. T. D. Bowden made detailed stratigraphic and sedimentological studies of the Revett Formation. The results of his work were used in the present studies. Gravity stations throughout the area were established by D. M. Wilson, who also assisted M. D. Kleinkopf in the interpretation of gravity and aeromagnetic data.

The geological work consisted of ridge and valley foot traverses to examine the rocks closely, to complete the geologic mapping at a scale of 1:62,500, and to collect rock and stream-sediment samples. A helicopter was used to shuttle the field party during the 1974 season. The analytical results of the samples collected during reconnaissance provided the basis for more detailed geochemical studies in which closely spaced samples of rocks, stream sediments, and soils were collected from areas that contained anomalous amounts of metals. All samples were analyzed spectrographically for 30 elements, and many samples were analyzed by other techniques described in this report, chapter C. The samples were analyzed by J. M. Motooka,

D. J. Grimes, R. N. Babcock, L. Sanchez, R. T. Hopkins, and R. W. Leinz.

The analytical computer data are available through the U.S. Department of Commerce, National Technical Information Service on magnetic tape (McDanal and others, 1976). L. O. Wilch, S. K. McDanal, and R. J. Smith obtained statistical retrievals of the sample data.

The area was also studied by the U.S. Bureau of Mines whose activities are reported in chapter D of this report.

We gratefully acknowledge the close cooperation and support from the supervisors and staff of the Kootenai and Kaniksu National Forests. We are especially indebted to geologists Lawrence Prinkki and William Straley for their fieldwork assistance and their knowledge of the regional geology.

## GEOLOGIC SETTING

The Scotchman Peak area is in the northwest part of the Belt Basin, an epicratonic re-entrant of a sea that extended along the western edge of the North American Precambrian craton during Belt time (Harrison, 1972). The rocks are mostly fine grained, sandy to argillitic clastic sedimentary rocks, and carbonate beds that were deposited in shallow water and metamorphosed to the biotite subfacies in Precambrian time. Broad regional uplift and the development of normal and strike-slip faults probably originated in Precambrian time and were rejuvenated in Late Cretaceous–early Tertiary time. Granodioritic to dioritic intrusive bodies, which are exposed over small parts of the area, were emplaced during a Cretaceous–Tertiary event. Glacial and stream erosion from Pleistocene to Holocene time has resulted in the present topographic configuration of the area.

## STRATIGRAPHY

The rocks exposed in the Scotchman Peak area are primarily metasedimentary rocks of the Belt Supergroup of Precambrian Y age. (Precambrian Y time, 1,600 to 800 m.y. ago, refers to an interim time scale for the Precambrian adopted for use by the U.S. Geological Survey (James, 1972).) The metasedimentary rocks are locally intruded by a diabase sill and by granodiorite and quartz diorite sills and stocks—all of probable Cretaceous-Tertiary age. Fractures and faults in the metasedimentary rocks locally contain quartz veins. Glacial deposits occupy the high cirques and major valleys, extensive talus deposits occur along the base of the many cliffs, and thin deposits of colluvium locally mantle the mountainsides. Small alluvial deposits occur locally in the valleys.

## METASEDIMENTARY ROCKS

A large part of the Scotchman Peak area is underlain by fine-grained quartzite, siltite, argillite, and impure limestone and dolomite that compose the lower and lower-middle parts of the Belt Supergroup. The Belt strata consist of five formations with a total thickness of about 18,000 ft (5,478 m), which are, from oldest to youngest, the Prichard, Burke, Revett, St. Regis, and Wallace Formations. The base of the Prichard is not exposed, and only the lower part of the Wallace occurs in the area. Geochronological data by Obradovich and Peterman (1968, 1973) suggest that the age of Belt rocks equivalent to those exposed in the Scotchman Peak area ranges from 1.1 to 1.7 b.y. (billion years; Precambrian Y).

The Belt strata have been regionally metamorphosed to the biotite subfacies. Metamorphic grade increases slightly in the older formations, which suggests a prograding metamorphism related to depth of burial.

The formation boundaries used in this report are the same as those described in more detail by Harrison and Jobin (1963) in the Clark Fork quadrangle. Except for the Revett Formation, the following descriptions are largely summarized from that report, but also include some additional observations made by the present investigators.

### PRICHARD FORMATION

The Prichard is the oldest formation exposed in the Scotchman Peak area, and it is divided into upper, middle, and lower members; the base of the lower member is not exposed. The minimum thickness of the formation is about 10,000 ft (3,048 m). The Prichard Formation contains argillite, argillitic siltite, siltite, and quartzite, and the upper contact is transitional with the overlying Burke Formation. Prichard Formation crops out in the western one-third of the area in Idaho, and near the southern boundary in Montana (pl. 1). The Prichard is easily distinguished from the other formations in the Belt Supergroup by the abundance of thinly laminated dark-gray to black argillitic strata and by the abundance of limonite, derived from the oxidation of pyrrhotite, which gives the rock a rusty appearance in outcrop.

The lowest member of the Prichard contains interlayered argillite, argillitic siltite, and quartzite, and it crops out only in the western one-third of the area. The argillite and argillitic siltite is dark to locally, particularly in the lower part of the section, have a purple tinge. They consist of very fine grained and fine-grained sand. Original grain size and rock textures are to a large degree obscured because the grains are sutured and interlocked, owing to recrystallization associated with regional metamorphism. All the quartzite beds are thin bedded or laminated, even those that appear massive in outcrops. Parallel, tabular beds are most common, but some beds are wedge-shaped, lenticular, or irregular. Many beds contain tabular cross-stratification and ripple-drift cross-laminations.

The tabular quartzite beds commonly grade from quartzite to argillitic siltite in the upper 5-10 cm. The top of a graded sequence is marked by a sharp contact, and it is overlain by another quartzite unit. Argillitic siltite at the contact commonly contains asymmetric ripple marks or mud cracks. The thickness of a graded sequence ranges from 60 to 100 cm.

The quartzites of the Revett commonly contain syndeformational features that include load casts, associated "flame structures," and pseudonodules. Locally, closely spaced, parallel to irregular, hematitic bands transect bedding planes. This feature, which is especially prominent in quartzite and siltite beds on the ridge to the northwest of Little Spar Lake, is interpreted to reflect oxidation fronts associated with the movement of meteoric or possibly connate water through the rocks prior to or during regional metamorphism. The banding may have formed early in the diagenesis of the sediments.

In general, the typical quartzite in the Revett is pure (as much as 90 percent quartz) relative to quartzites in other formations of the Belt (Harrison and Grimes, 1970). The remainder of the rock consists mostly of intermediate feldspar, micaceous minerals, and magnetite. Biotite with associated magnetite is locally concentrated along alternating thin-bedded laminae in the tabular-shaped quartzite beds. Magnetite also occurs as scattered octahedra in some quartzites. Some beds contain local concentrations of cubic pyrite that is commonly 2–4 $mm^2$ and rarely more than 1 $cm^2$. Quartzite beds in the Revett east of the Blue Creek fault (pl. 1), are more pyritic than those west of the fault. Locally, the quartzite contains copper minerals, principally bornite and malachite, that occupy the interstices between quartz grains in the coarser grained quartzites and in small fractures of the finer grained rocks. Copper minerals are extremely rare in the quartzites of the Revett, west of the Blue Creek fault (pl. 1), but are more common east of the fault. Copper occurrences are discussed in greater detail in the following chapters.

In addition to quartzite, the Revett Formation contains a gradation of lithologic types from quartzose siltite to argillite that are light

Peak and other nearby areas. Detailed stratigraphic and sedimentological studies of the Revett were made by T. D. Bowden, U.S. Geological Survey, whose work in the Scotchman Peak area was concurrent with the mineral investigations. Bowden studied a well-exposed section on a ridge to the south of Little Spar Lake (pl. 1). The following description of the Revett is summarized from Bowden's work supplemented by observations made elsewhere in the area.

The Revett near Little Spar Lake is 2,323 ft (708 m) thick and consists of about 55 percent quartzite, 35 percent siltite, and 10 percent argillite. The upper and lower contacts with the St. Regis and Burke Formations are transitional. They are placed within the transitional zones so as to include in the Revett all strata in which quartzite is the dominant lithology; siltite and argillite are the dominant rock types in the formations below and above the Revett. T. D. Bowden (written commun., 1975) divided the Revett into eight units on the basis of distinctive differences of the relative amounts of quartzite, siltite, and argillite in stratigraphic intervals of significant thickness (table 1). The character of the lithologic types in each of the units is similar. According to Bowden, these units are apparently correlative to similar lithostratigraphic units in a Revett Formation section about 30 mi (48 km) to the southeast of the Scotchman Peak area.

Quartzites in the Revett Formation are light gray to white and

TABLE 1.—*Lithostratigraphic units of the Revett Formation listed from youngest to oldest from a section on a ridge to the south of Little Spar Lake*

[Described by T. D. Bowden]

| St. Regis Formation<br>Revett Formation:<br>Unit No. | Lithology [1] | Thickness in meters |
|---|---|---|
| 1 | Quartzite with 30 percent argillite and siltite. | 58.5 |
| 2 | Argillite and siltite with 25 percent quartzite. | 54 |
| 3 | Siltite and argillite with 15 percent quartzite. | 88.5 |
| 4 | Quartzite with 30 percent siltite and argillite. | 262.5 |
| 5 | Siltite and argillite with 25 percent quartzite. | 49.5 |
| 6 | Quartzite with 5-10 percent siltite and argillite. | 52.5 |
| 7 | Siltite and argillite with 25 percent quartzite. | 67.5 |
| 8 | Quartzite with 10 percent siltite and argillite. | 75 |
| | Total | 708 |
| Burke Formation | | |

[1] Determination of lithologic types is based partly on thin section examination and partly on megascopic examination.

locally, particularly in the lower part of the section, have a purple tinge. They consist of very fine grained and fine-grained sand. Original grain size and rock textures are to a large degree obscured because the grains are sutured and interlocked, owing to recrystallization associated with regional metamorphism. All the quartzite beds are thin bedded or laminated, even those that appear massive in outcrops. Parallel, tabular beds are most common, but some beds are wedge-shaped, lenticular, or irregular. Many beds contain tabular cross-stratification and ripple-drift cross-laminations.

The tabular quartzite beds commonly grade from quartzite to argillitic siltite in the upper 5-10 cm. The top of a graded sequence is marked by a sharp contact, and it is overlain by another quartzite unit. Argillitic siltite at the contact commonly contains asymmetric ripple marks or mud cracks. The thickness of a graded sequence ranges from 60 to 100 cm.

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In addition to quartzite, the Revett Formation contains a gradation of lithologic types from quartzose siltite to argillite that are light gray, medium gray, green gray, and purplish gray. The siltites and argillites are either interlaminated or are parts of graded sequences. A typical siltite sequence contains interbedded slabby quartzose siltite (5–15 cm) and flaggy siltite and argillitic siltite (1–5 cm), and the lower contact contains cut-and-fill features that result in irregular- and lenticular-shaped beds. Bedding planes commonly contain asymmetric ripple marks (straight crested to lunate), mud cracks, and mud chips. Syndeformational structures are common where a sandy layer overlies a silty or argillaceous layer; they consist of load casts, with associated "flame structures," and pseudonodules. Siltite is more abundant than argillite throughout the section; the upper part contains increasing amounts of argillite.

## ST. REGIS FORMATION

The St. Regis Formation is about 500 ft (152 m) thick in the eastern part of the area, but thickens to about 1,100 ft (335 m) in the central part. It consists mostly of purple and green argillite and siltite. The color of the St. Regis changes rapidly over short lateral distances. For example, St. Regis that overlies the Revett on the ridge to the south of Little Spar Lake contains interlaminated purple and green argillite and siltite; however, just 1.5 mi (2.4 km) south of the ridge, where the entire formation is exposed in a cirque, it contains mostly green siltite and argillite, a few thin beds of sandy and calcareous siltite, and only minor purple argillite and siltite. The predominantly green lithologies in the St. Regis at this locality have some similarities to the Empire Formation, which underlies the Wallace Formation or the Wallace equivalent in the central and eastern parts of the Belt Basin. The St. Regis and Empire may have an intertonguing relationship in the Scotchman Peak area; however, detailed stratigraphic studies beyond the scope of the present investigations would be necessary to establish the presence of the Empire Formation. All the beds between the Wallace and Revett Formations were mapped as St. Regis (pl. 1). Where the St. Regis contains predominantly green beds, the upper contact is placed at the top of a green siltite bed that is overlain by a pitted carbonate bed. Above the contact, carbonate rocks are predominant, and below the contact the rocks consist of green siltite, silty argillite, and argillite with minor thin, pale-green to light-gray sandy siltite beds. The siltite and sandy siltite beds are locally calcareous. Minor purple siltite and argillite as much as 6 ft (2 m) thick, are interbedded with the green beds mostly in the middle and lower parts of the formation. Green siltite beds in the upper part of the formation are commonly pyritic and contain pyrite cubes as much as 2 cm square. The St. Regis is well exposed along a narrow north-south belt in the center of the area and near Ross Creek in the eastern part of the area.

### WALLACE FORMATION

The lower 1,500 ft (457 m) of the Wallace Formation, the youngest formation in the Belt Supergroup in the Scotchman Peak area, crops out in the central and eastern parts of the area (pl. 1); overlying beds have been removed by erosion. Harrison and Jobin (1963) divided the Wallace into five members; only part of the lowest, the lower calcareous member, crops out in the study area. The lower member of the Wallace is mostly light gray limestone and dolomite that appears buff to light tan on the weathered rind of outcrops. The carbonate rocks are interbedded with gray to green, commonly calcareous or dolomitic, argillite, siltite, and rarely quartzite. Carbonate strata locally contain well-developed colonies of stromatolites and "molar tooth" structures. Both the carbonate and siltite beds of the Wallace commonly contain nodular pyrite and cubes of pyrite as large as 3 $mm^2$. The lower contact with the St. Regis Formation is gradational.

## SURFICIAL DEPOSITS

Surficial deposits of Quaternery age in the Scotchman Peak area include glacial till and moraine, colluvium, and alluvium; only the largest glacial deposits are shown on plate 1.

Glacial deposits occupy the floors of the main valleys and the high cirques. Glacial till is mostly restricted to within a few hundred feet of the valley floors and small moraines occupy the cirques. Little Spar Lake and other smaller lakes in the area are dammed by moraines.

The most extensive colluvial deposits of the area are talus accumulations along the base of cliffs, especially those formed from the Revett and Burke Formations. A thin mantle of colluvium commonly covers the sides of valleys.

A few small alluvial deposits, including alluvial fans, occur along the largest streams and at their intersection with tributaries. The extremely rugged terrain, high annual precipitation, and the resulting high rate of stream erosion prevent the accumulation of large alluvial deposits.

## IGNEOUS ROCKS

The igneous rocks in the Scotchman Peak area are intrusions of granodiorite, granodiorite porphyry, quartz diorite, and diabase dikes, sills, and plugs—all of probable Cretaceous and Tertiary age (Harrison and Jobin, 1963). The granodiorite is mostly a gray, medium-grained rock that consists mainly of plagioclase, orthoclase, biotite, quartz, and hornblende; biotite is the most abundant mafic mineral in the rock. The mafic mineral content and grain size of the granodiorite varies widely; local variations include fine- and coarse-grained mafic phases. The eastern margin of an oval plug in the valley of Lightning Creek crops out near the western boundary (pl. 1). Harrison and Jobin (1963) have described pegmatitic phases of the granodiorite plug at its margin. The granodiorite intrudes the Prichard Formation, and the strata near the contacts are commonly hornfelsed.

A fine-grained, dark-greenish-gray diabase sill intrudes the Burke Formation near the top of Scotchman Peak (pl. 1). A dike of similar appearance intrudes the Burke, Revett, and St. Regis Formations in the upper part of the West Fork of Blue Creek. The sill and dike are less than 5 ft (1.5 m) thick, and chlorite, plagioclase, and augite are the principal rock-forming minerals. Harrison and Jobin (1963) noted from observations outside the area that diabase similar to that in the Scotchman Peak area is younger than the granodiorite.

## STRUCTURE

The Scotchman Peak study area has a long structural history that extends from Precambrian to Tertiary time. The present attitude of the strata reflects broad open folds of probable late Precambrian age as modified by Cretaceous-Tertiary tectonic events.

The oldest structure is the Revett dome (Harrison, 1972), which probably began forming about mid-Wallace time. The dome is a broad northerly striking regional structure, and the Scotchman Peak area lies a short distance west of the axis. At least some of the faults probably originated in late Precambrian time. A Precambrian age is suggested by lead isotopes from a galena-bearing quartz vein that occupies a normal fault near the East Fork of Blue Creek (Zartman and Stacey, 1971). Harrison and Jobin (1963) suggested that the Hope fault, a major normal and strike-slip fault that borders the area to the southwest, may be as old as Precambrian. Movement on the faults, accompanied by granodiorite and related intrusions, was rejuvenated in Late Cretaceous and early Tertiary times.

East of the Blue Creek fault (pl. 1) the rocks are highly faulted and folded. This part of the area contains high-angle normal faults that strike northeasterly to northwesterly and locally have apparent reverse movement. Several faults have a right-lateral component to their displacement. The Hope fault has the largest throw. Harrison and Jobin (1963) estimated an 18-mi (28.8-km) right-lateral displacement; this is accompanied by an apparent vertical displacement of 22,000 ft (6,710 m). The Blue Creek fault has a vertical displacement of about 5,000 ft (1,500 m). Most of the other faults have small to minor apparent displacements. Local folding is closely related to faulting and ranges from broad open folds to crenulations associated with shearing.

The area west of the Blue Creek fault and north of the Hope fault is a mostly unfaulted, northerly striking homocline that dips gently to moderately eastward.

The rocks throughout the area contain numerous joint sets of varied orientations. Joints locally contain quartz or calcite fillings in accord with the composition of the adjacent rocks.

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# Aeromagnetic and Gravity Studies of the Scotchman Peak Wilderness Study Area, Lincoln and Sanders Counties, Montana, and Bonner County, Idaho

*By* M. Dean Kleinkopf *and* Dolores M. Wilson, U.S. Geological Survey

MINERAL RESOURCES OF THE SCOTCHMAN PEAK WILDERNESS STUDY AREA, LINCOLN AND SANDERS COUNTIES, MONTANA, AND BONNER COUNTY, IDAHO

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# AEROMAGNETIC AND GRAVITY STUDIES OF THE SCOTCHMAN PEAK WILDERNESS STUDY AREA, LINCOLN AND SANDERS COUNTIES, MONTANA, AND BONNER COUNTY, IDAHO

By M. DEAN KLEINKOPF and DOLORES M. WILSON,
U.S. GEOLOGICAL SURVEY

## INTRODUCTION

Aeromagnetic and gravity surveys were made of the Scotchman Peak Wilderness study area as part of the geologic assessment of the mineral resource potential of the area. Previous studies of reconnaissance aeromagnetic and gravity surveys in the region provide background information for the current evaluations (Kleinkopf and others, 1972; Harrison and others, 1972).

## FIELD MEASUREMENTS

The aeromagnetic survey was made in 1974 by Aerial Surveys under contract to the U.S. Geological Survey. The survey was flown at a constant elevation of 2,135 m above sea level and at a flightline spacing of 1.6 km. A regional geomagnetic gradient dipping southwesterly about 7 gammas per kilometer was removed from the total intensity data to form the residual magnetic intensity map (pl. 1). The magnetic data were referenced to an absolute datum of 57,934 gammas near the southwestern corner of the mapped area.

The gravity survey was done in and around the study area mainly during the summer of 1974. Because of difficult terrain, the 64 stations within the study area were established by helicopter. In surrounding areas, stations were set on roads and trails by truck and by foot. The data were supplemented by stations from the Cabinet Mountain Wilderness survey and by stations obtained from the Defense Mapping Agency.

The gravity measurements were tied to the U.S. Geological Survey base at Trout Creek, Mont., which had been tied earlier to the Woollard airport base, station 100 (Woollard and Rose, 1963) located at Coeur d' Alene, Idaho. Elevations of stations were obtained from bench marks, spot elevations, and estimations on 7½- and 15-minute quadrangle topographic maps. The data were reduced to Bouguer anomaly values using an assumed average rock density of

2.67 g/cm$^3$. Terrain corrections were made through the H zone of Hammer (1939) with hand templates and out to 167 km by means of a digital computer program prepared by Plouff (1966) and modified by R. Wahl (unpub. data, 1973). The corrections ranged from 1 mGal in the Clark Fork Valley to 28 mGal for the station on Scotchman Peak. The resulting complete Bouguer gravity map is shown in plate 2.

## INTERPRETATION OF GEOPHYSICAL DATA

The rocks exposed in the area are predominantly low grade metasedimentary rocks of the Precambrian Belt Supergroup. One body of coarse-grained granodiorite of probable Cretaceous or Tertiary age outcrops at the mouth of Lightning Creek, and several sills of granodiorite to diorite composition, also of probable Cretaceous or Tertiary age ranging in thickness from 2 to 6 m (Harrison and Jobin, 1963) intrude the Prichard Formation in the western part of the area. Magnetic anomalies reflect mainly variations in magnetite content, whereas the gravity map reflects variations of rock density.

The predominant gravity feature shown on the map (pl. 2) is a broad high that trends north-northwesterly in the western half of the study area and corresponds to the broad uplift of the western Cabinet Mountains. Some expression of the Hope fault is evident where the gravity high is elongated along the fault and shows some parallelism of contours near the southeastern corner of the wilderness study area.

The gravity data show a west-northwesterly trend of unknown origin across the area in the vicinity of Scotchman No. 2 mountain. The trend is exhibited as a saddle across the major gravity high and by west-northwesterly gravity contours. There is no surface geologic evidence of faulting or structural break in the subsurface. The Lightning Creek stock lies along the gravity trend. To the east the gravity trend crosses the Blue Creek fault where the strike changes.

The prominent north-northwesterly trending gradient zone along the eastern side of the Wilderness is distorted by locally east-northeasterly trends in the vicinity of Sawtooth Mountain, which may reflect the structural complications shown on the geologic map.

The gravity control is not adequate to provide quantitative information about the igneous rocks. Density determinations in the laboratory indicate lower values for the granodiorite than for the Belt rocks. Nineteen samples representative of the Belt rocks had an average density of 2.72 g/cm$^3$ with a range of 2.68 to 2.75. Two samples of granodiorite were analyzed and were found to have densities of 2.61 g/cm$^3$ each. This low value may mean that the sample was not from fresh rock. Harrison and others (1972) obtained similarly low values, with an average of 2.67 g/cm for granodiorites and dacite porphyries from this region. These results indicate that granodiorites intruded into Belt rocks should produce negative gravity anomalies. The Lightning Creek granodiorite does in fact show as a low, though control is poor. This stock lies along the west-northwesterly gravity trend discussed above. The one station gravity low located about 5 km southeast of Scotchman Peak corresponds to an area where Harrison and Jobin (1963) postulated a buried granodiorite intrusive similar in composition to the Lightning Creek stock.

The gravity lows 2 km east and 5 km southeast of Sawtooth Mountain may be due to buried intrusives of a composition similar to the Lightning Creek stock. Quartz veins were mapped in this area by geologic field studies. Another buried intrusive may be near the southeastern corner of the study area where a negative gravity residual is defined by nosing of the gravity contouring along the north side of the Hope fault. The low gravity values plus several intersecting surface faults may indicate a large volume of shattered rocks in the subsurface, possibly related to a buried intrusive.

The major magnetic trend is northerly across much of the study area in conformity with trends of major faults and the strike of many of the Belt outcrops. The exception to this trend is the general parallelism of magnetic features and contours along the northwesterly trending Hope fault.

The most intense magnetic anomalies shown on the map are related to the relatively magnetic igneous intrusives and to magnetic-rich Belt sedimentary rocks that stand in topographic relief. None of the magnetic anomalies could be attributed to the Precambrian crystalline basement. Harrison, Griggs, and Wells (1974) estimated that there are at least 13 km of Belt sedimentary rocks overlying the basement in this area.

The correlation of positive magnetic anomalies with topographic highs in this region has been described by Kleinkopf, Harrison, and Zartman (1972). They found that the Burke Formation, where topographically high, produced positive magnetic anomalies typically 50–100 gammas in amplitude. Both the Burke and Revett Formations contain abundant euhedral magnetite grains that can be seen in hand specimen. Laboratory determinations showed magnetic susceptibilities for three samples of Burke ranging from 0.0010 to 0.0028 emu/cm$^3$, large enough to account for the anomalies in the Belt metasedimentary rocks. The Prichard, Wallace, and St. Regis Formations were found to have very low susceptibilities and were taken to be nonmagnetic for purposes of this study.

The prominent magnetic ridge that trends northerly through the central part of the study area correlates with high topography. In particular, the high gradient zone on the west side of the magnetic ridge and north of Blacktop Mountain follows topographic crests and steep slopes in outcrops of Burke Formation. Five principal magnetic highs form the magnetic ridge. Magnetic highs H–131 and H–122 center over steep topographic slopes of outcrops of Burke and Revett Formations. H–156, just southeast of Scotchman No. 2 mountain, corresponds to high topography of the Burke Formation. This high might also reflect a small underlying intrusive, for it lies along the postulated crosscutting structural feature suggested in this area by the gravity data. H–167 correlates with the steep south slope of Savage Mountain in Burke and Revett outcrops. H–150 is related to topographic highs of Burke and Revett Formations at the northern edge of the study area. Farther to the east, anomalies, magnetic high H–141 and magnetic low L–242, appear to reflect different forms of mineralization along fault zones. Some topographic influence is probable along the north part of L–242, particularly at L–230, its northeastern extension. In its central and southern parts, L–242 crosses the drainage divide; the low magnetic values in this portion may be indicative of destruction of magnetite caused by hydrothermal alteration.

Magnetic anomaly H–162 lies just east of a fault zone, and its coincidence with the gravity low just described above provides further evidence for a buried intrusive in this area. H–156 and the adjacent unnamed high at the southeastern corner of the study area correlate only with the lower slopes of Squaw Peak and are beyond the influence of the high topography. Their circular outlines suggest the presence of small stocks that may have been intruded into or near the Hope fault zone. Just north, H–87 occurs in an area of structure complexity and may reflect an underlying intrusive.

The only magnetic anomaly that can be correlated with outcrops of igneous rock is the 3- to 40-gamma high over the Lightning Creek stock. The low amplitude of the anomaly is not surprising in view of the low magnetization values $< 4 \times 10^{-4}$ emu/cm$^3$ found by Harrison, Kleinkopf, and Obradovich. The data suggest a greater lateral extent with depth of the stock. The outcrops of sills of similar composition show no detectable magnetic expression, apparently owing to their small volume.

## CONCLUSIONS

The geophysical evidence suggests several buried igneous intrusives and fault zones that could have associated mineral deposits within the study area. Magnetic high H–156, just southeast of Scotchman No. 2, may reflect a small igneous intrusive along a crosscutting structure suggested by the gravity data. H–141 may represent a buildup of magnetic minerals along the Blue Creek fault. The elongated magnetic low, L–242, is suggestive of an altered area along a fault detected by geologic studies. H–162 and the associated gravity low may point to a buried intrusive. Finally, in the southeastern corner of the study area, low gravity values and three magnetic highs, H–156, H–87, and the unlabeled high paired with H–87, are indicative of buried intrusives.

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# Geological and Geochemical Evaluation of the Mineral Resources of the Scotchman Peak Wilderness Study Area, Lincoln and Sanders Counties, Montana, and Bonner County, Idaho

*By* David J. Grimes *and* Robert L. Earhart, U.S. Geological Survey

MINERAL RESOURCES OF THE SCOTCHMAN PEAK WILDERNESS STUDY AREA, LINCOLN AND SANDERS COUNTIES, MONTANA, AND BONNER COUNTY, IDAHO

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By David J. Grimes and Robert L. Earhart,
U.S. Geological Survey

## TYPES OF MINERAL DEPOSITS

The principal types of mineral deposits in the Scotchman Peak study area are (1) base metal and silver veins and (2) stratabound copper deposits. Minor occurrences of base metals are in green, calcareous, clastic rocks of the St. Regis Formation.

### BASE METAL AND SILVER VEINS

Three types of base metal and silver veins in the Scotchman Peak study area are (1) lead with minor zinc, copper, and silver in quartz gangue, (2) lead-zinc with minor copper and silver in shear zones, and (3) copper with minor lead and silver in quartz gangue. All three types contain iron sulfide minerals (pyrrhotite and (or) pyrite).

The first type of vein is in the western part of the area (pl. 1) in the Prichard Formation near granodiorite and related intrusive rocks. The veins are a few inches to about 2 ft (0.6 m) wide and commonly either occur in parallel sets or are anastomosing. Quartz is the principal constituent followed by pyrrhotite, pyrite, galena, arsenopyrite, chalcopyrite, and sphalerite. Except for the iron sulfides, the sulfide minerals are highly localized. Silver is associated with galena and with arsenopyrite. The veins are laterally discontinuous and can be traced for a maximum of a few hundred feet. The rocks immediately adjacent to the veins commonly contain fracture fillings and disseminations of the metallic vein minerals.

The second type of vein occurs in the southern part of the area, mainly near the East Fork of Blue Creek (pl. 1). The sulfide minerals are similar to those in the first type except for sphalerite, which is about as abundant as galena. The sphalerite is marmatitic and cadmium-rich. Analytical results indicate that the veins locally contain minor amounts of antimony and gold. The veins occur as parallel thin seams in a line of steeply dipping shear planes in a highly faulted part of the Prichard Formation; the maximum shear zone width is about 8 ft (2.4 m). The seams contain quartz and minor calcite, and an erratic distribution of sulfide minerals.

The third type of vein occurs only in the Revett Formation and consists of quartz with local concentrations of iron sulfides, chalcopyrite, bornite, subordinate amounts of galena, and an unidentified silver mineral. The exclusive association of these veins with the Revett Formation and the predominance of copper over the other base metals suggest a spatial or genetic relationship of these veins to the stratabound copper occurrences discussed in the following paragraphs. The veins are exposed near Ross Point and the South Fork of Ross Creek, near Squaw Peak, and at the head of the East Fork of Blue Creek near Middle Mountain (pl. 1). The veins range in width from 2 to 5 ft (0.6–1.5 m). A notable exception is the vein exposed on the west bank of the South Fork of Ross Creek (sample No. 11235) that occupies a northwesterly trending fault and is as much as 16 ft (4.9 m) wide.

In addition to the three types of veins just described, quartz veins as much as 5 ft (1.5 m) wide that contain trace to minor amounts of specularite and limonite occur locally in all the formations.

## STRATABOUND COPPER DEPOSITS

Stratabound copper deposits with subordinate amounts of silver are in the Revett Formation in and near the Scotchman Peak study area. The term "stratabound" is used to describe the geometry of the mineralized zones and their generally concordant relationship to the enclosing strata; it does not have a genetic connotation. The general shape of the deposits is tabular; the length and width dimensions are many times greater than the thickness, and the long axes are approximately parallel to bedding in the adjacent rocks. In detail, the deposits have discordant features, such as crosscutting fractures and faults that contain concentrations of copper minerals. The economic potential of the stratabound deposits is far greater than that of the veins in the study area because they contain large tonnages that may be amenable to large-scale mining. Known stratabound copper deposits containing economic grades and tonnages occur about 2 mi (3.2 km) northeast of the Scotchman Peak study area near Spar Lake and about 13 mi (21 km) east near the head of Rock Creek (chap. A, fig. 1). The results from the present studies suggest a similar occurrence in the Scotchman Peak study area.

The stratabound copper deposit near Spar Lake is described here because it served as a model of comparison for evaluating the geological and geochemical data of the present studies. The setting and grade of this deposit is known from extensive core drilling and underground workings by private firms. The following descriptive information is mostly from an oral presentation by Norman Lutz (Bear Creek Mining) given in 1973 at the Pacific Northwest Metals and Minerals Conference in Coeur d'Alene, Idaho.

The deposit near Spar Lake is on the ridge between Ross and Stanley Creeks and is about 8,500 ft (2,590 m) long, 1,800 ft (548 m) wide, and on the average, about 50 ft (15 m) thick. It contains about 58 million tons (52.2 million t) of ore with an average grade of 0.79 percent copper and 1.67 oz/ton (47 g/t) silver. Copper is in bornite, chalcocite, and chalcopyrite in a 7-3-1 ratio, and the silver is predominantly native; silver may also be in stromeyerite ($AgCu_2S$) and possibly in argentite ($Ag_2S$). The deposit is in quartzite in the upper-middle part of the Revett Formation on the east limb of a broad, open syncline. Small exposures of the mineralized zone on the north and south fringes of the deposit contain submarginal copper values, but the orebody is completely buried by the upper part of the Revett, the St. Regis, and the lowermost part of the Wallace Formations. The highest grade ore is concentrated along a northwesterly trending fault that terminates the deposit to the east, but the bulk of the orebody consists of disseminations, blebs, and discrete laminae of copper minerals in the coarser fractions of the quartzite. Commonly, the grade of ore is a function of grain size of the host rock, and the upper and lower contacts of the ore deposit correspond to lithologic changes from quartzite to siltite or argillite. Although pyrite is not a principal constituent in the ore zone, the rocks surrounding the deposit contain abnormal amounts of pyrite. Pyrite is most abundant on the fringes of the deposit.

The Spar Lake deposit is in rocks equivalent to lithostratigraphic unit 4 (chap. A, table 1). Deposits near Star Gulch in the study area and at Rock Creek to the east of the study area are in units 6 and 8. However, coarse grain size of the host rock is probably a more important control than the stratigraphic position in the localization and concentration of copper minerals.

### OTHER STRATABOUND OCCURRENCES

A minor occurrence of lead in green beds of the St. Regis Formation is shown by anomalous analytical results (table 1) from rocks (pl. 2, samples 11071 and 11072) and stream sediments (pl. 2, samples 16052, 16053, and 16054) collected in a cirque in the central part of the area. The stream drains the St. Regis where the formation consists almost entirely of green beds. Some of the sandy siltite and siltite beds are pyritic and may locally contain anomalous amounts of lead. Alternatively, the source of the lead in the stream sediments could be derived from the lowermost Wallace Formation. Rock samples (11070 and 11071) from the St. Regis at this locality also contain slightly anomalous amounts of copper and silver in slightly calcareous sandy siltite included as thin lenticular-shaped interbeds in green siltite (table 1).

## GEOLOGIC CONTROLS OF MINERALIZATION

The association of mineral deposits with particular geologic features was used in estimating the potential for mineral resources in the Scotchman Peak study area. A genetic classification of the deposits or causal relationships based on geologic associations are neither intended nor inferred.

The vein deposits are controlled by faults and related shear zones that predate the mineralization and (or) by Cretaceous-Tertiary intrusive activity. The mineralogy of the veins, at least in part, is controlled by the composition or character of the host rocks; chalcopyrite or bornite is the dominant economic sulfide mineral in veins in the Revett, and galena or galena-sphalerite are dominant in veins in the Prichard Formation.

The geologic features that control the distribution of the stratabound deposits are not well understood; however, a few observations appear to be highly pertinent to the search for these deposits. Stratabound deposits of possible economic importance are restricted to the Revett Formation. Lithologic features, particularly grain size, appear to control the distribution of stratabound copper deposits in the Revett. The coarser grained quartzites are the most favorable host rocks, and copper minerals are most highly concentrated in these units near their contacts with siltite or argillite. Regional and local structural features also appear to be important geologic controls. The study area is near the axis of the Revett dome (Harrison, 1972). The regional distribution trend of copper prospects in the Revett approximately parallels the axial trend of the dome. On a local scale, faulting and perhaps folding influence the distribution of the deposits. The deposit near Spar Lake, which is near the axis of a syncline, is bounded to the east by a highly mineralized fault that terminates the ore body. A mineralized zone near Star Gulch in the eastern part of the study area is near a northeast-trending fault (pl. 1). Conversely, anomalous concentrations of copper are rare in the Revett west of the Blue Creek fault where the formation is unfaulted and gently to moderately dipping.

## GEOCHEMICAL INVESTIGATIONS

### INTRODUCTION

The geochemical investigations in the study area consisted of the collection and analyses of rock, soil, and stream-sediment samples and the evaluation of the resulting data. Most samples were analyzed in the field in mobile laboratories by emission spectrographic and atomic absorption techniques. In addition, many stream sediments were tested by colorimetric field methods for acid extractable copper and heavy metals at the sample site as a guide to sampling. Analytical results of samples collected during geologic mapping indicated that the elements essential to the mineral evaluation were—in order of economic importance—copper, silver, lead, zinc, and gold. Areas of greatest mineral potential were identified and evaluated by detailed sampling.

The most detailed sampling was done in the vicinity of Star Gulch in the southeastern part of the area, where geochemical results indicated significant copper and silver anomalies. The analytical and geological data were entered into a computer storage system (RASS II). Statistical procedures were used to determine background and threshold values for the important elements in each of the sample types. The distribution of anomalous amounts of these elements was plotted (figs. 1–6); selected elements are shown in table 1. All analytical data are available on tape (McDanal and others, 1976).

### SAMPLING AND ANALYTICAL METHODS

Rock samples were collected along most of the ridges and streams in the area (pl. 2). "Background" samples of fresh unaltered rocks were collected from the various rock types in all formations and from igneous intrusions to determine the normal concentration ranges of the elements critical to the mineral evaluation. Where indications of mineralization were observed, the most highly mineralized or altered rocks were collected.

The rock samples were crushed in a jaw crusher to approximately 0.25 in. (6 mm), split through a Jones splitter, and ground to minus

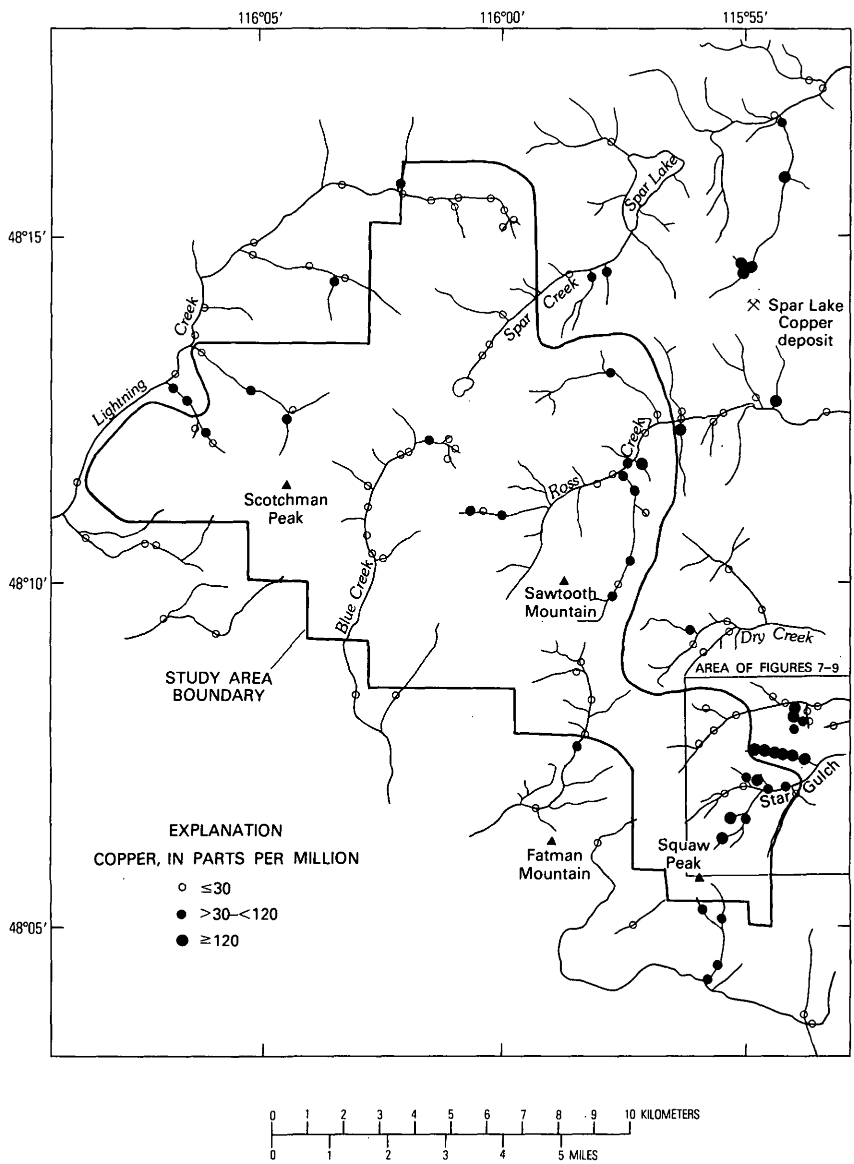


FIGURE 1.—Distribution of total copper in stream sediments, Scotchman Peak Wilderness study area, Montana and Idaho.

150 mesh (0.1 mm) on ceramic plates in a vertical pulverizer. A semiquantitative emission spectrographic technique (Grimes and Marranzino, 1968) was used to analyze all samples for presence of 30 elements. Atomic absorption methods (Ward and others, 1969) were used to detect copper, gold, lead, and zinc in all samples, and a

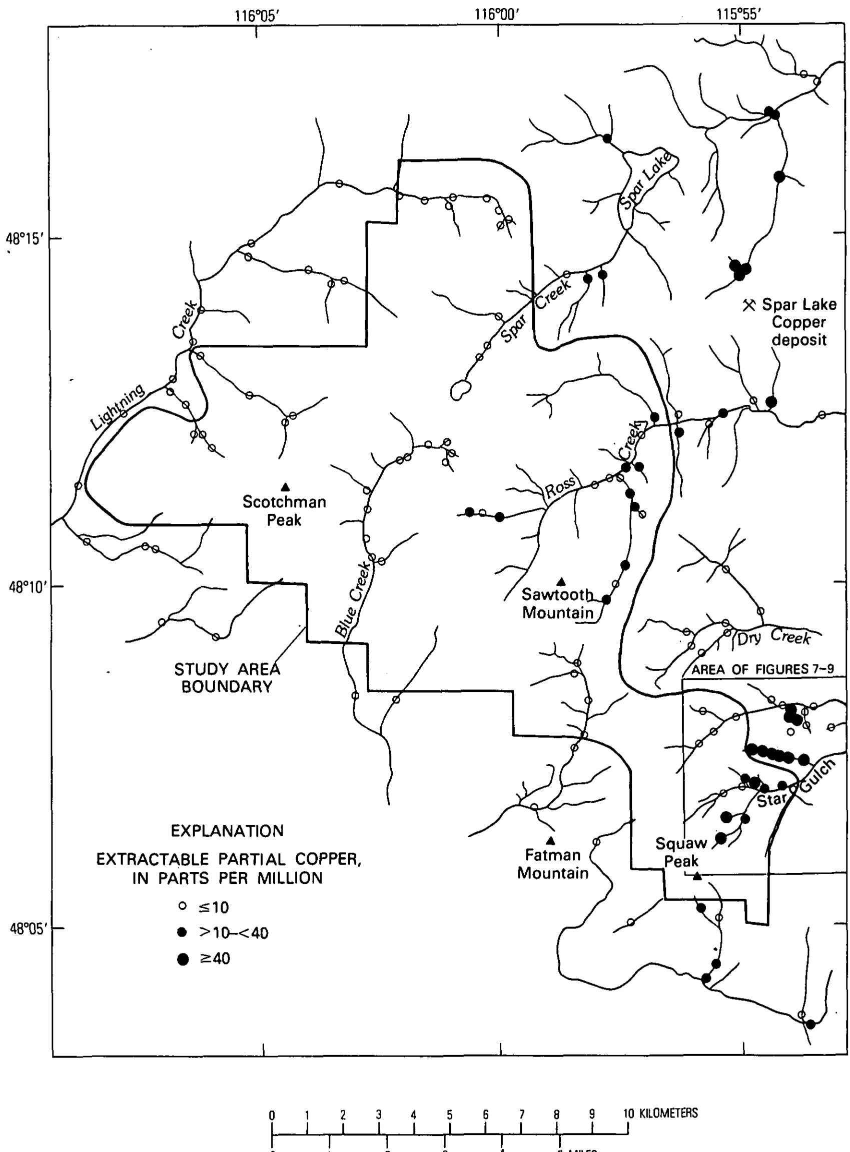


FIGURE 2.—Distribution of acid-extractable partial copper (0.8N $HNO_3$) in stream sediments.

vapor detector method (Vaughn and McCarthy, 1964), was used to determine the amounts of mercury in all samples.

Stream-sediment samples were collected at approximately 1-mi (1.6-km) intervals in the major drainages and above the mouth of most tributaries. Areas investigated in 1974 that contained anomalous metals in the stream sediments were resampled in greater detail

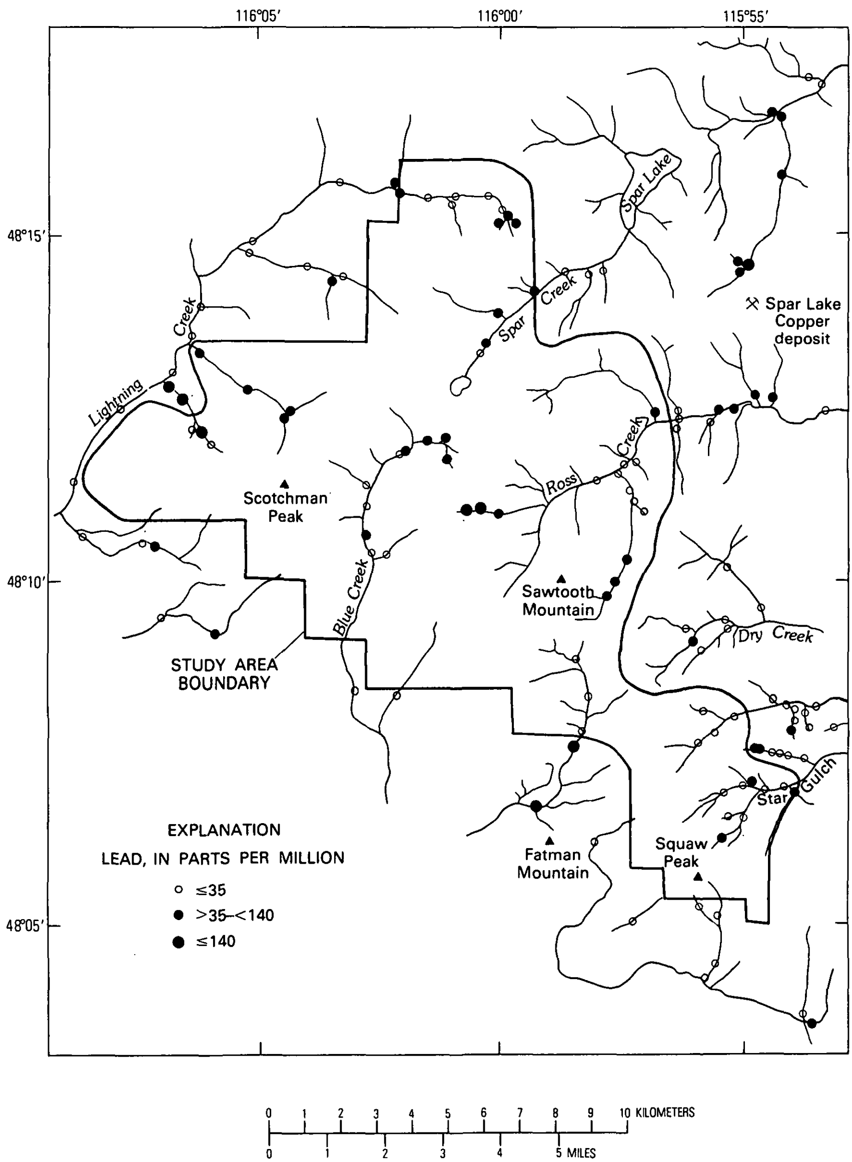


FIGURE 3.—Distribution of lead in stream sediments.

during the 1975 field season. Sediment samples of 300–400 g each were collected by hand and, where possible, in the most active part of the stream. The wet samples were placed in high-strength, metal-free paper envelopes; later they were air dried, and sieved to minus 80

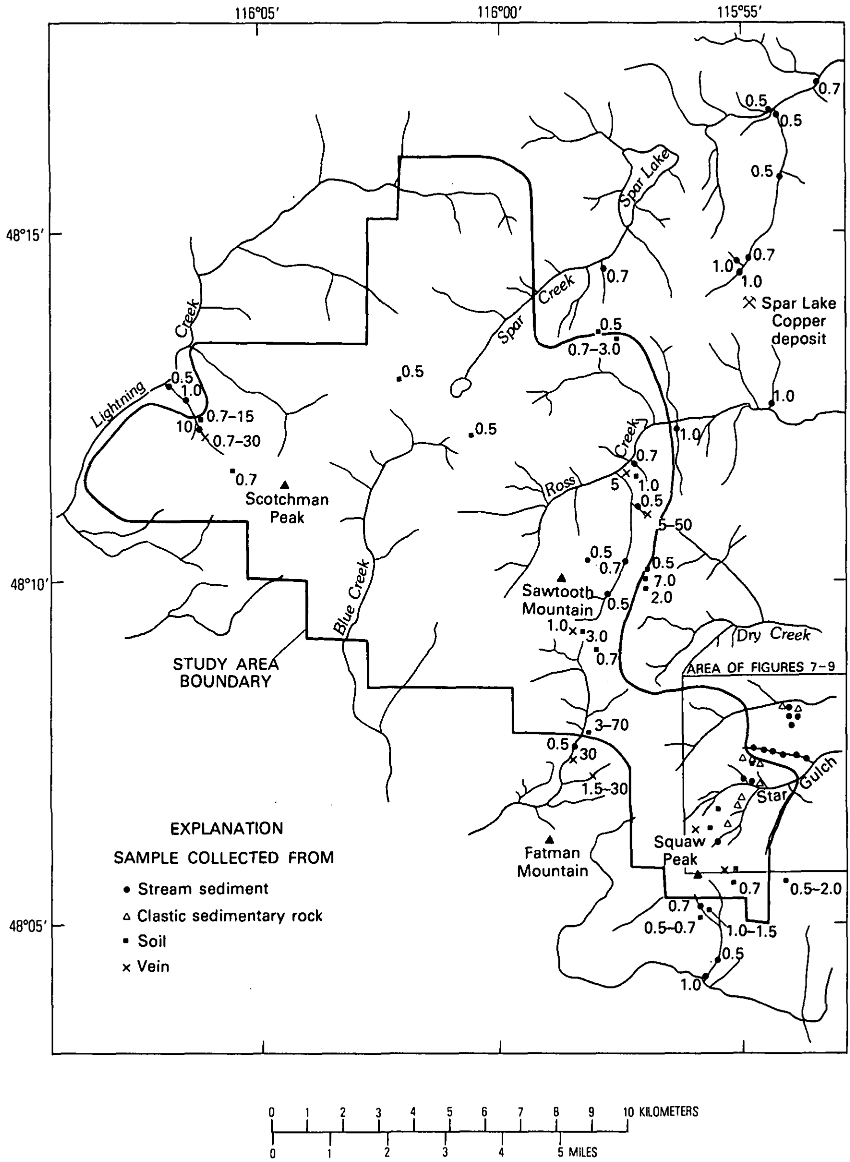


FIGURE 4.—Distribution of samples containing detectable amounts of silver, in parts per million. Minimum and maximum contents given where two or more samples were collected at one locality.

mesh (0.18 mm). The sediments were analyzed for 12 elements by emission spectroscopy, for total copper, lead, and zinc by atomic absorption, and for acid-extractable copper, lead, and zinc by a 0.8-nitric acid-leach atomic absorption method.

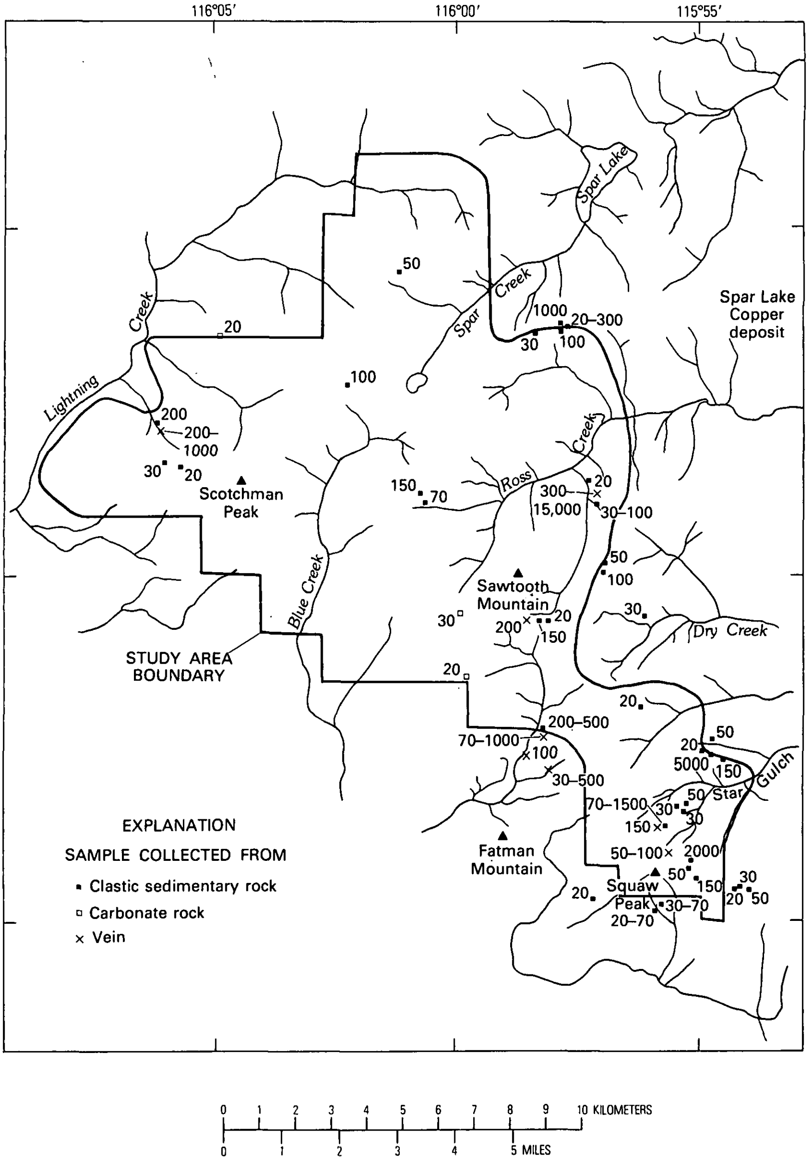


FIGURE 5.—Distribution of rock samples containing greater than 15 ppm copper. Minimum and maximum contents given where two or more samples were collected at one locality.

Cold extraction colorimetric methods, for citrate-soluble heavy metals (Bloom, 1955) and 6*N*-hydrochloric-acid-soluble copper (Canney and Hawkins, 1958), were adapted for field use and provided invaluable analytical data at the sample site.

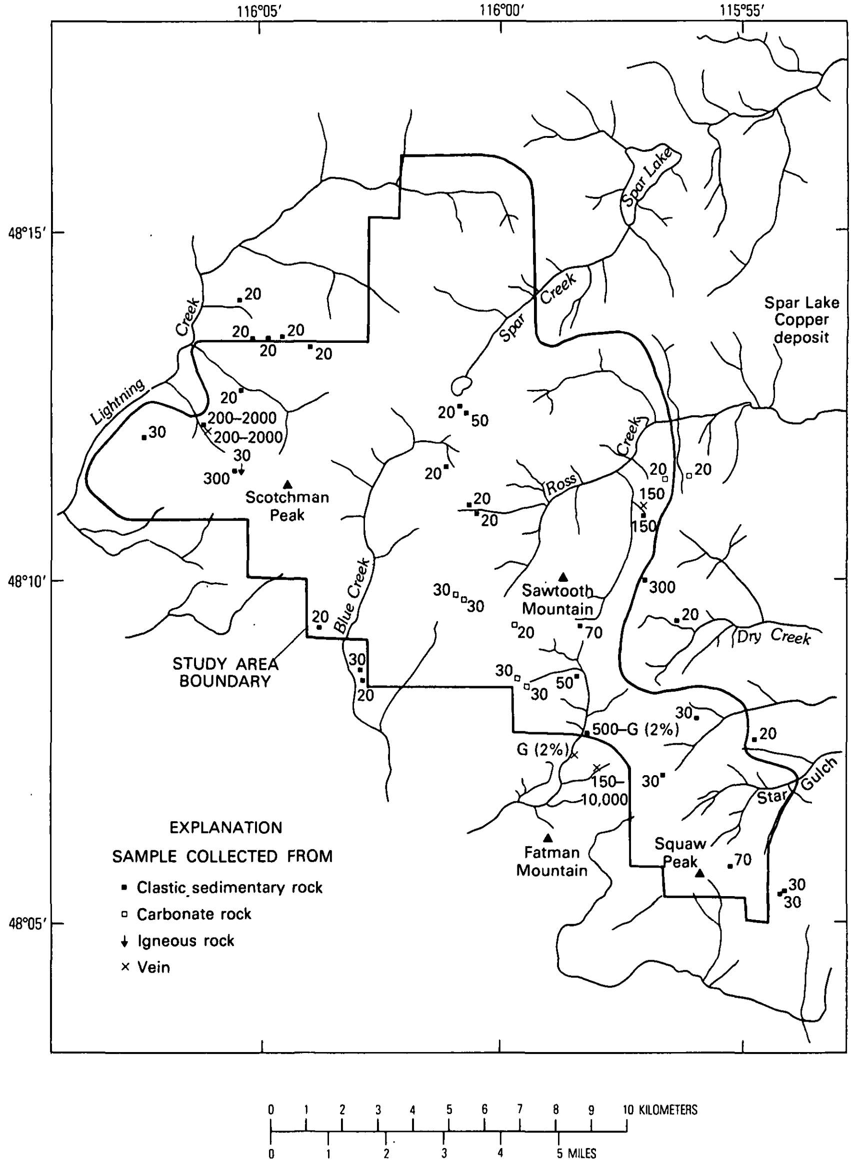


FIGURE 6.—Distribution of rock samples containing greater than 15 ppm lead. Minimum and maximum contents given where two or more samples were collected at one locality.

Soils were collected in the Star Gulch area to better delineate a large geochemical copper-silver anomaly found by stream-sediment sampling. Soil-sampling traverses were made (1) from the upper part of the Burke Formation through the middle part of the Revett Formation, (2) along strike in the lower part of the Revett Formation, and (3) across a spring that issues from a fault zone and flows into Hamilton Gulch (pl. 2). The soils were sampled at 500- to 700-ft (150- to 215-m) intervals in the B-horizon at a depth of 8-12 in. (20-30 cm); later the samples were air dried and sieved to minus 80 mesh (0.18 mm). The soils were analyzed for 12 elements by emission spectroscopy, and they were analyzed for copper, lead, and zinc by atomic absorption methods (Ward and others, 1969).

## METHODS OF EVALUATION

The geochemical evaluation was based on the distribution and variation of key elements in rocks, soils, and stream sediments. The threshold value, which is defined as the upper limit of background, was determined for most key elements in each of the three kinds of samples by plotting cumulative percent frequency on log probability paper as described by Sinclair (1974). Amounts greater than threshold are considered anomalously high. The copper and lead threshold values in rock samples from the five Precambrian formations in the area ranged only from 10 ppm (parts per million) in the Revett Formation to 18 ppm in the Prichard; therefore, an average threshold value of 15 ppm was selected for copper and lead in rocks. Other threshold values include 0.8*N*-nitric-acid-extractable copper in stream sediments, 10 ppm, and total copper in soils and stream sediments, 30 ppm. Most silver values were below the limits of determination of the analytical methods used; thus, samples with detectable amounts of silver were considered anomalous.

The analytical data are presented on element distribution maps (figs. 1–6) with emphasis only on those samples containing an element in amounts greater than its threshold. Partial analytical results for samples with an anomalous amount of one or more key elements are given in table 1. The distributions of total copper, 0.8*N*-nitric-acid-extractable copper, and lead in stream sediments are shown in figures 1–3. The distribution of anomalous amounts of silver in stream sediments, soils, and rocks is shown in figure 4, and the distributions of anomalous amounts of copper and lead in rock samples are shown in figures 5–6. A geochemical map for zinc is not shown because the spectrographic limit for determination of zinc is very high, and highly anomalous amounts of zinc generally correspond to those of lead. The distribution of gold in rocks is not shown because few samples, mostly near the southern boundary, contained detectable amounts. In the geochemically anomalous Star Gulch area, where more detailed investigations were conducted, the distributions of copper, 0.8*N*-nitric-acid-extractable copper, and silver in soils and stream sediments are shown on larger scale maps (figs. 7–9).

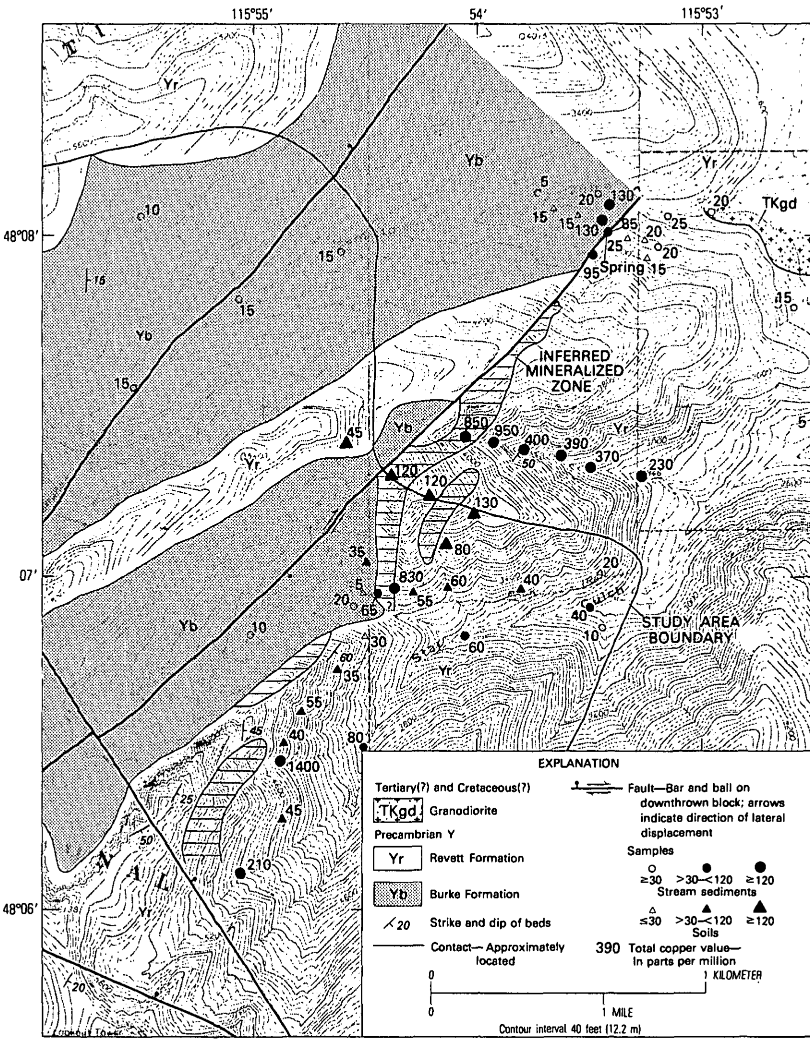


FIGURE 7.—Star Gulch area, showing distribution of copper in soil and stream-sediment samples. Base from U.S. Geological Survey, 1 : 24,000, Heron and Sawtooth, Montana (1966).

## GEOCHEMICAL ANOMALIES AND THEIR GEOLOGIC RELATIONS

The results of geochemical sampling indicate that parts of the Scotchman Peak wilderness study area contain anomalous amounts of copper, lead, zinc, and silver. Geologic investigations show that the anomalies are derived from veins and from stratabound deposits. The veins that are reflected by geochemical anomalies were all

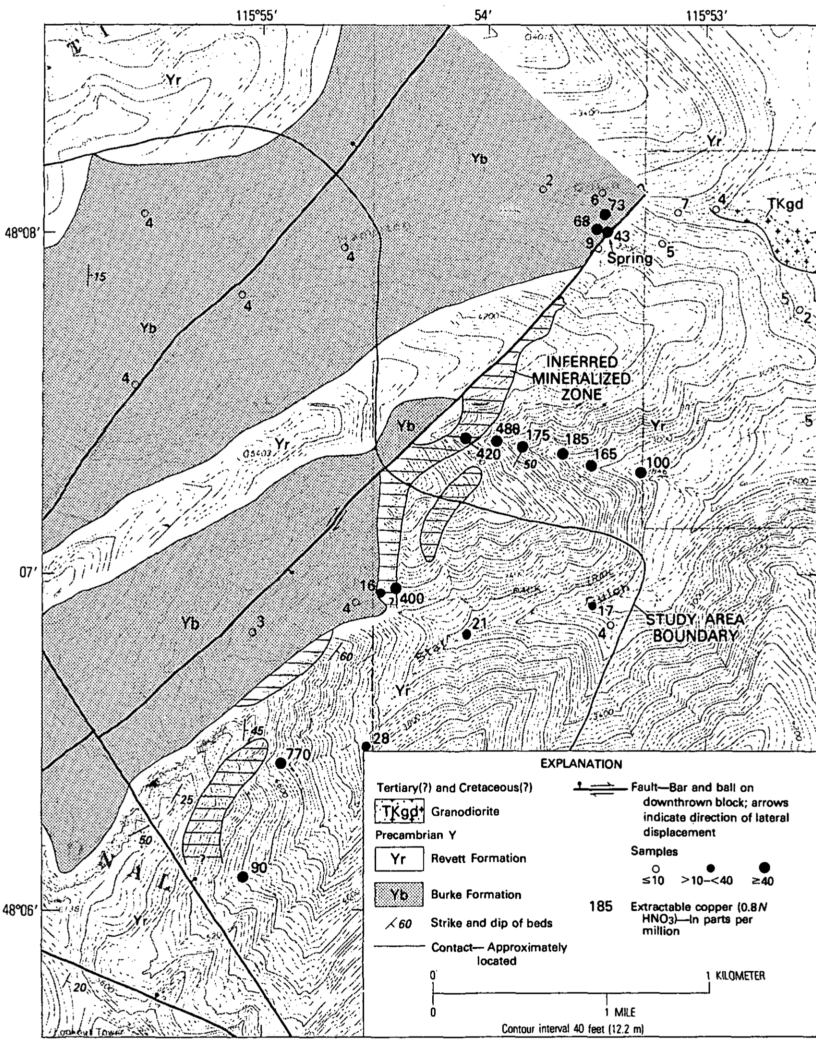


FIGURE 8.—Star Gulch area showing distribution of extractable copper (0.8*N* $HNO_3$) in stream sediments. Base from U.S. Geological Survey, 1:24,000, Heron and Sawtooth, Montana (1966).

previously known; the results do not indicate any significant undiscovered veins, nor do they suggest previously unknown extensions of base- or precious-metal vein systems. The results do indicate that the Revett Formation to the east of the Blue Creek fault (pl. 1) has a moderate to very high potential for deposits of stratabound copper with subordinate amounts of silver.

The largest and by far the most significant anomaly is derived from a stratabound copper deposit in the vicinity of Star Gulch

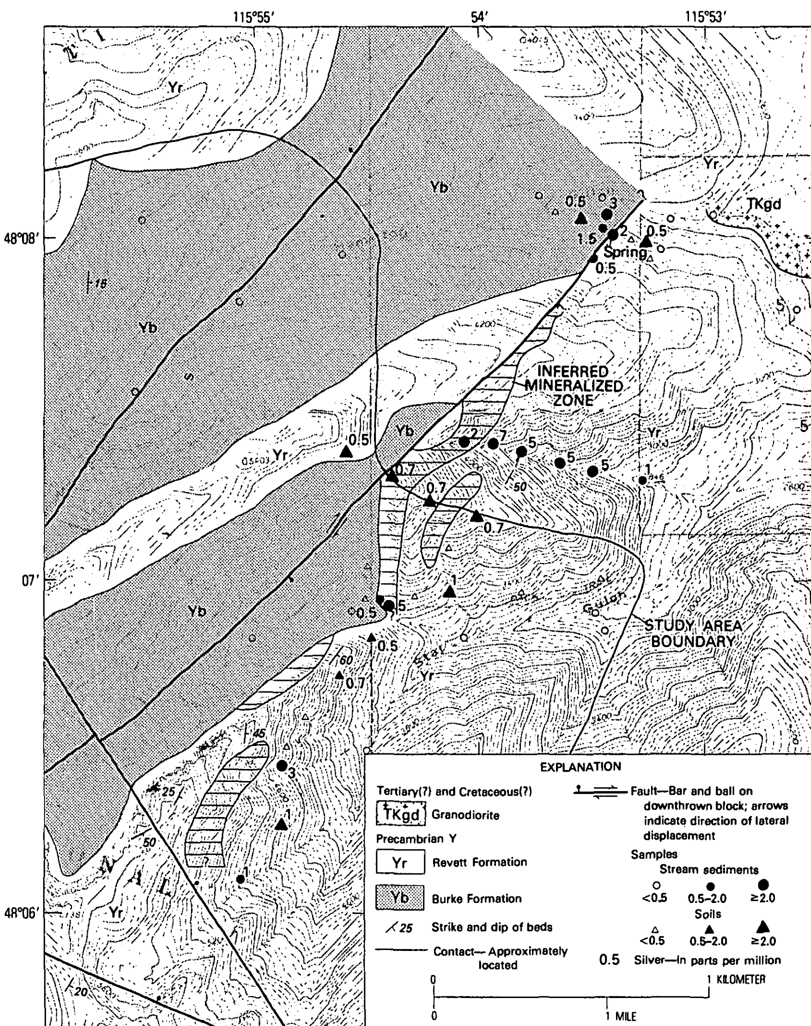


FIGURE 9.—Star Gulch area showing distribution of silver in soil and stream-sediment samples. Base from U.S. Geological Survey, 1: 24,000, Heron and Sawtooth, Montana (1966).

TABLE 1.—*Analytical results of selected elements from samples with anomalously high values*

[Samples containing an anomalous amount of one or more key elements, Scotchman Peak study area. All values in parts per million. Analytical methods: xCu by a 0.8*N*-nitric-acid-extraction-atomic absorption; AACu, AAPb, AAZn, and AAAu, by atomic absorption; SCu, SPb, SZn, and SAg by emission spectroscopy; and INST. Hg by mercury vapor detector. Lower limits of determination xCu—1 ppm, AACu, AAPb, AAZn—10 ppm, AAAu—0.05 ppm, SCu—5 ppm, SPb—10 ppm, SZn—200 ppm, SAg—0.5 ppm, and INST. Hg—0.05 ppm. N, not detected; L, present but less than limit of determination; G, greater than value shown; B, no data. Analysts: R. N. Babcock, D. J. Grimes, R. T. Hopkins, R. W. Leinz, and J. M. Motooka]

| SAMPLE | X-COORD. | Y-COORD. | AA-Cu | AA-Pb | AA-Zn | S-Ag |
|---|---|---|---|---|---|---|
| | | | SOILS | | | |
| S1 | 113650 | 35290 | 45 | 15 | 80 | .5 |
| S2 | 113500 | 35530 | 120 | 20 | 80 | .5 |
| S3 | 113410 | 35690 | 120 | 15 | 55 | .7 |
| S4 | 113330 | 35890 | 130 | 20 | 40 | .7 |
| S5 | 113140 | 35880 | 80 | 15 | 40 | N |
| S6 | 112990 | 35410 | 35 | 10 | 55 | N |
| S7 | 114750 | 36930 | 20 | 25 | 55 | .5 |
| S9 | 114710 | 36620 | 15 | 35 | 50 | .5 |
| S14 | 112660 | 35500 | 30 | 10 | 55 | .5 |
| S15 | 112250 | 35380 | 35 | 35 | 100 | .7 |
| S16 | 112110 | 35090 | 55 | 10 | 25 | N |
| S17 | 111980 | 34990 | 40 | 20 | 55 | N |
| S18 | 111680 | 35000 | 45 | 15 | 65 | 1.0 |
| S19 | 112780 | 35670 | 55 | 5 | 10 | N |
| S20 | 112800 | 35820 | 60 | 25 | 65 | 1.0 |
| S21 | 112840 | 36310 | 40 | 25 | 65 | N |
| S22 | 112920 | 36710 | 20 | 25 | 110 | L |

| SAMPLE | X-COORD. | Y-COORD. | xCu | AA-Cu | AA-Pb | AA-Zn | S-Ag |
|---|---|---|---|---|---|---|---|
| | | | STREAM SEDIMENTS | | | | |
| 16078 | 117000 | 33950 | 4 | 50 | 35 | 75 | N |
| 16079 | 116725 | 33975 | 9 | 30 | 50 | 65 | N |
| 16083 | 112850 | 35400 | 16 | 65 | 20 | 45 | 0.5 |
| 16023A | 113450 | 37070 | 67 | 230 | 30 | 85 | 0.7 |
| 16023B | 113450 | 37070 | 71 | 230 | 30 | 100 | 1.0 |
| 16023C | 113450 | 37070 | 69 | 220 | 30 | 85 | 0.7 |
| 16023D | 113450 | 37070 | 64 | 210 | 30 | 85 | 0.7 |
| 16023E | 113450 | 37070 | 83 | 240 | 30 | 90 | 1.0 |
| 16084 | 109375 | 34150 | 18 | 75 | 25 | 60 | 0.7 |
| 16085 | 107950 | 34500 | 36 | 95 | 30 | 60 | 0.5 |
| 16086 | 124000 | 31800 | 5 | 35 | 35 | 70 | L |
| 16089 | 120675 | 31225 | 11 | 60 | 30 | 90 | L |
| 16090 | 121300 | 31975 | 8 | 45 | 25 | 60 | N |
| 16092 | 124780 | 28140 | 2 | 15 | 60 | 55 | N |
| 16093 | 125560 | 28750 | 3 | 25 | 60 | 65 | N |
| 16094 | 126200 | 29470 | 5 | 25 | 45 | 80 | N |
| 16096 | 117850 | 31600 | 11 | 35 | 50 | 40 | 0.5 |
| 16097 | 118300 | 31780 | 8 | 30 | 60 | 50 | L |
| 16098 | 118830 | 32060 | 29 | 85 | 40 | 80 | 0.7 |
| 16000 | 130175 | 31725 | 14 | 60 | 30 | 80 | L |
| 16001 | 127000 | 35350 | 60 | 130 | 100 | 200 | 1.0 |
| 16002 | 126900 | 35425 | 67 | 150 | 95 | 60 | 1.0 |
| 16003 | 126900 | 35525 | 95 | 240 | 170 | 90 | 0.7 |
| 16004 | 129475 | 36425 | 48 | 120 | 120 | 85 | 0.5 |
| 16005 | 131075 | 36375 | 23 | 75 | 90 | 65 | 0.5 |
| 16006 | 131175 | 36300 | 11 | 30 | 40 | 45 | 0.5 |
| 16008 | 131825 | 37500 | 10 | 30 | 35 | 35 | 0.7 |
| 16010 | 122700 | 32950 | 14 | 30 | 50 | 70 | L |
| 16013 | 122875 | 34825 | 14 | 35 | 55 | 75 | L |
| 16014 | 123325 | 35625 | 7 | 20 | 40 | 55 | N |
| 16021 | 112675 | 36725 | 4 | 10 | 40 | 50 | N |
| 16022 | 112750 | 36600 | 17 | 40 | 15 | 50 | N |
| 16023 | 113450 | 37075 | 100 | 230 | 35 | 70 | 0.7 |
| 16024 | 106300 | 37150 | 11 | 30 | 45 | 80 | N |
| 16026 | 102625 | 34325 | 36 | 80 | 35 | 60 | 1.0 |
| 16029 | 126675 | 23950 | 9 | 35 | 60 | 110 | N |
| 16032 | 129075 | 25800 | 10 | 30 | 40 | 75 | N |
| 16033 | 129225 | 25725 | 12 | 35 | 45 | 75 | N |
| 16039 | 123750 | 19400 | 7 | 35 | 250 | 150 | 0.5 |
| 16042 | 119775 | 16875 | 7 | 25 | 30 | 110 | N |

TABLE 1.—*Analytical results of selected elements from samples with anomalously high values*—Continued

| SAMPLE | X-COORD. | Y-COORD. | xCu | AA-Cu | AA-Pb | AA-Zn | S-Ag |
|---|---|---|---|---|---|---|---|
| | | | STREAM SEDIMENTS--Continued | | | | |
| 16044 | 122850 | 22700 | 10 | 40 | 50 | 100 | N |
| 16045 | 123000 | 22725 | 7 | 30 | 50 | 140 | N |
| 16046 | 123650 | 21500 | 9 | 35 | 45 | 90 | N |
| 16047 | 124700 | 20225 | 8 | 30 | 40 | 85 | N |
| 16048 | 119525 | 18650 | 8 | 30 | 45 | 140 | N |
| 16050 | 117450 | 19275 | 4 | 20 | 35 | 85 | N |
| 16051 | 117025 | 20700 | 8 | 25 | 55 | 210 | N |
| 16052 | 120400 | 27800 | 16 | 35 | 210 | 95 | N |
| 16053 | 120325 | 28025 | 9 | 30 | 170 | 90 | N |
| 16054 | 120250 | 28550 | 18 | 40 | 130 | 100 | N |
| 16062 | 126900 | 26075 | 6 | 20 | 70 | 55 | N |
| 16056 | 124650 | 24850 | 10 | 30 | 60 | 65 | N |
| 16059 | 112200 | 29600 | 3 | 25 | 150 | 250 | N |
| 16060 | 113750 | 30700 | 5 | 35 | 290 | 280 | 0.5 |
| 16061 | 114275 | 30925 | 3 | 25 | 35 | 95 | N |
| 16065 | 128200 | 28650 | 5 | 20 | 40 | 85 | N |
| 16067 | 128325 | 28875 | 3 | 25 | 40 | 80 | N |
| 16068 | 128275 | 29000 | 3 | 20 | 50 | 100 | N |
| 16074 | 127650 | 28850 | 3 | 15 | 20 | 90 | N |
| 16075 | 116050 | 30700 | 2 | 15 | 35 | 110 | N |
| 16077 | 115125 | 31000 | B | 25 | B | 130 | N |
| 16100 | 120180 | 32720 | 6 | 25 | 35 | 150 | N |
| 16106 | 114850 | 36710 | 73 | 130 | 30 | 65 | 3.0 |
| 16110 | 113510 | 36650 | 165 | 370 | 35 | 110 | 5.0 |
| 16111 | 113590 | 36480 | 185 | 390 | 35 | 120 | 5.0 |
| 16112 | 113650 | 36250 | 175 | 400 | 15 | 80 | 5.0 |
| 16113 | 112600 | 35930 | 21 | 60 | 10 | 50 | N |
| 16114 | 112850 | 35500 | 400 | 830 | 45 | 60 | 5.0 |
| 16115 | 111900 | 35010 | 770 | 1400 | 60 | 50 | 3.0 |
| 16116 | 111350 | 34790 | 90 | 210 | 20 | 45 | 1.0 |
| 16117 | 111920 | 35380 | 28 | 80 | 10 | 50 | N |
| 16118 | 109020 | 34650 | 8 | 40 | 15 | 55 | N |
| 16120 | 122490 | 33570 | 27 | 170 | 30 | 140 | 1.0 |
| 16121 | 121650 | 32400 | 38 | 200 | 20 | 130 | 0.7 |
| 16122 | 122400 | 32200 | 11 | 55 | 5 | 55 | N |
| 16123 | 120470 | 32360 | 27 | 120 | 10 | 120 | 0.5 |
| 16124 | 123100 | 36200 | 140 | 310 | 120 | 60 | 1.0 |
| 16125 | 113700 | 36050 | 480 | 950 | 40 | 65 | 7.0 |
| 16126 | 113700 | 35860 | 420 | 850 | 50 | 65 | 2.0 |
| 16127 | 126780 | 31080 | 21 | 60 | 20 | 50 | N |
| 16128 | 126870 | 31490 | 19 | 90 | 20 | 120 | 0.7 |
| 16130 | 114780 | 36700 | 68 | 130 | 30 | 50 | 1.5 |
| 16131 | 114500 | 36610 | 9 | 95 | 50 | 55 | 0.5 |
| 16132 | 114620 | 36710 | 43 | 85 | 30 | 30 | 2.0 |
| 16133 | 122160 | 27000 | 6 | 50 | 60 | 95 | N |
| 16134 | 121950 | 27210 | 4 | 30 | 25 | 130 | N |
| 16135 | 121850 | 27140 | 1 | 20 | 45 | 85 | N |
| 16136 | 122180 | 27050 | 3 | 10 | 40 | 45 | N |
| 16138 | 122710 | 20080 | 2 | 30 | 20 | 85 | N |
| 16139 | 122620 | 20280 | 10 | 65 | 2000 | 280 | 10.0 |
| 16140 | 122480 | 20420 | 3 | 25 | 35 | 85 | N |
| 16141 | 123430 | 19800 | 6 | 35 | 260 | 130 | 1.0 |

| SAMPLE | X-COORD. | Y-COORD. | S-Cu | S-Pb | S-Zn | S-Ag | AA-Au | INST-Hg |
|---|---|---|---|---|---|---|---|---|
| | | | | ROCKS--WALLACE FORMATION | | | | |
| 11213 | 115510 | 29340 | 5 | 30 | N | N | N | .02 |
| 11214 | 115740 | 29150 | 20 | 30 | N | N | N | L |
| 11114 | 122750 | 28150 | N | 10 | N | N | N | .08 |
| 11116 | 124750 | 28925 | 7 | N | N | N | N | .18 |
| 11162 | 118500 | 27700 | 15 | 30 | N | N | N | .04 |
| 11163 | 118450 | 27825 | 5 | 30 | N | N | N | L |
| 11166 | 117800 | 27950 | 30 | N | N | N | N | .18 |
| 11170A | 117575 | 29125 | 7 | 15 | L | N | N | .10 |
| 11171 | 117475 | 29500 | N | 20 | N | N | N | .06 |
| 11228 | 120825 | 33870 | 5 | 20 | N | N | N | .02 |
| 11229 | 120700 | 33150 | L | 20 | N | N | N | .02 |
| | | | | ROCKS--ST. REGIS FORMATION | | | | |
| 11000 | 118700 | 26950 | N | N | N | N | N | .10 |
| 11070 | 120750 | 27800 | 150 | 10 | N | 0.5 | N | .02 |
| 11071 | 120725 | 27900 | 70 | 20 | N | L | N | .02 |
| 11072 | 120250 | 28125 | N | 20 | N | N | N | N |
| 11110 | 123000 | 27225 | 15 | 20 | L | N | N | .06 |
| 11112 | 123000 | 27575 | L | 50 | N | N | N | .04 |
| 11133 | 124600 | 30050 | N | N | N | N | N | .30 |
| 11225 | 110050 | 37260 | L | L | N | N | N | .06 |
| 11226A | 110130 | 37080 | 30 | 10 | N | N | N | .08 |
| 11227 | 110050 | 37250 | 50 | N | N | N | N | .08 |

TABLE 1.—*Analytical results of selected elements from samples with anomalously high values*—Continued

| SAMPLE | X-COORD. | Y-COORD. | S-Cu | S-Pb | S-Zn | S-Ag | AA-Au | INST-Hg |
|---|---|---|---|---|---|---|---|---|
| | | | | ROCKS--REVETT FORMATION | | | | |
| 11187A | 120020 | 32690 | 30 | 150 | 200 | 1.0 | N | .04 |
| 11196 | 112090 | 34700 | 30 | N | N | 2.0 | N | L |
| 11197 | 112410 | 35010 | 50 | N | N | 1.0 | N | .06 |
| 11193A | 111610 | 34220 | 70 | N | N | 3.0 | L | L |
| 11203 | 109125 | 34200 | 70 | N | N | 0.7 | N | .04 |
| 11203A | 109125 | 34200 | 20 | N | N | 0.5 | N | L |
| 11204 | 109325 | 34375 | 30 | N | N | 1.0 | L | .04 |
| 11204A | 109325 | 34375 | 70 | N | N | 1.5 | N | L |
| 11211 | 122825 | 30325 | N | N | N | N | N | .06 |
| 11215 | 116780 | 31500 | L | 30 | N | N | N | .02 |
| 11216 | 116950 | 31300 | 5 | 15 | N | 0.7 | N | L |
| 11218 | 117180 | 31000 | 20 | 10 | N | L | N | L |
| 11060A | 117175 | 30825 | 150 | 70 | N | 3.0 | N | .08 |
| 11061 | 117000 | 31100 | 15 | N | N | N | N | .45 |
| 11077 | 126625 | 26975 | 50 | 15 | N | N | N | L |
| 11099 | 110500 | 34850 | 2000 | 70 | N | 1.0 | N | .02 |
| 11100 | 110425 | 34600 | 50 | N | N | N | L | .04 |
| 11117 | 122450 | 29200 | 7 | L | N | N | N | .35 |
| 11118 | 122350 | 29275 | 5 | N | N | N | N | .16 |
| 11113A | 122825 | 27775 | L | L | N | N | N | .16 |
| 11119 | 127500 | 28000 | N | N | N | N | L | .06 |
| 11120 | 127975 | 27975 | L | L | N | N | L | .06 |
| 11121 | 128000 | 28475 | N | N | N | N | L | .06 |
| 11122 | 127975 | 28850 | L | L | N | N | L | .08 |
| 11123 | 128850 | 28875 | N | N | N | N | N | .06 |
| 11124 | 128775 | 28325 | N | N | N | N | N | .06 |
| 11125 | 128875 | 29850 | L | N | N | N | L | .08 |
| 11134 | 124875 | 30600 | 30 | N | N | N | N | .04 |
| 11134C | 124875 | 30600 | L | N | N | N | N | .06 |
| 11136 | 125025 | 31100 | 100 | N | N | 0.5 | N | L |
| 11138 | 125150 | 31425 | 20 | N | N | N | N | L |
| 11138A | 125750 | 31425 | 300 | N | N | 3.0 | N | L |
| 11137 | 125125 | 31275 | 1000 | N | N | N | N | .12 |
| 11139 | 125175 | 31750 | 10 | N | N | 0.7 | N | .04 |
| 11147 | 118700 | 30550 | L | N | N | 0.5 | N | L |
| 11157 | 118150 | 32450 | 15 | N | N | 2.0 | N | .04 |
| 11158 | 118400 | 32600 | 100 | 300 | N | 7.0 | N | L |
| 11159 | 118700 | 32700 | 50 | N | N | 0.5 | N | L |
| 11174 | 117325 | 30275 | N | N | N | N | .25 | .04 |
| 11219A | 110290 | 34810 | 150 | L | N | 0.7 | N | .04 |
| 11223 | 110330 | 36550 | 7 | 30 | N | N | N | .02 |
| 11224 | 110280 | 36790 | 20 | 30 | N | N | N | .04 |
| 11230E | 120470 | 32510 | 100 | 20 | N | N | .05 | .02 |
| 11232 | 120790 | 32250 | 20 | 10 | N | N | N | .02 |
| 11233 | 112160 | 35100 | 30 | 15 | N | N | N | .04 |
| 11234 | 111710 | 34680 | 150 | 10 | N | 0.5 | N | .06 |
| 11234A | 111710 | 34680 | 50 | L | N | N | N | .04 |
| 11234B | 111710 | 34680 | 1500 | L | N | 2.0 | N | .02 |
| 11236 | 114020 | 35800 | 50 | 20 | N | N | N | .02 |
| 11237 | 113600 | 35300 | 20 | L | N | N | N | .02 |
| 11238 | 113420 | 35600 | 5000 | L | N | 30.0 | N | .02 |
| 11239 | 113330 | 35890 | 150 | L | N | 7.0 | N | .04 |
| | | | | ROCKS--BURKE FORMATION | | | | |
| 11181 | 117100 | 33910 | 30 | 20 | N | N | N | L |
| 11010 | 116000 | 24925 | 15 | 30 | L | N | N | L |
| 11027 | 123875 | 25250 | 100 | N | N | 0.5 | N | L |
| 11034 | 124300 | 23325 | 10 | 20 | N | N | N | L |
| 11063 | 112900 | 32975 | N | 30 | N | N | N | .02 |
| 11105 | 125425 | 24875 | 7 | 20 | N | N | N | L |
| 11126 | 128775 | 27375 | N | N | N | N | L | .06 |
| 11128 | 128800 | 26475 | 15 | N | N | N | L | .06 |
| 11129 | 115950 | 30875 | L | 50 | N | N | N | .06 |
| 11130 | 116375 | 30725 | L | 10 | N | N | N | .06 |
| 111231 | 114560 | 34000 | 20 | 30 | N | N | N | .02 |

TABLE 1.—*Analytical results of selected elements from samples with anomalously high values*—Continued

| SAMPLE | X-COORD. | Y-COORD. | S-Cu | S-Pb | S-Zn | S-Ag | AA-Au | INST-Hg |
|---|---|---|---|---|---|---|---|---|
| | | | | ROCKS--PRICHARD FORMATION | | | | |
| 11011 | 115850 | 24825 | 7 | 20 | L | N | N | L |
| 11023 | 117100 | 23800 | 15 | 20 | N | N | N | N |
| 11037 | 124900 | 21700 | 15 | 20 | N | N | N | L |
| 11039 | 124875 | 22125 | 20 | 20 | N | N | N | .02 |
| 11040 | 124900 | 21700 | L | 20 | N | N | N | L |
| 11042 | 125875 | 21275 | L | 20 | N | N | N | .04 |
| 11044 | 123525 | 21475 | 15 | 20 | N | N | N | .02 |
| 11046A | 121450 | 21350 | 5 | 300 | 200 | 0.7 | N | L |
| 11047 | 121400 | 20825 | 20 | 10 | N | N | N | L |
| 11049 | 121700 | 20100 | 30 | 15 | N | N | N | .02 |
| 11052 | 122125 | 18500 | 10 | 30 | N | N | N | L |
| 11176 | 109625 | 32375 | 20 | N | N | N | N | .04 |
| 11177 | 110200 | 32300 | 10 | 10 | N | N | L | .06 |
| 11240A | 122710 | 20200 | N | 200 | N | 0.7 | N | .02 |
| 11240B | 122710 | 20200 | 200 | 2000 | N | 15.0 | N | .04 |
| | | | | ROCKS--IGNEOUS | | | | |
| 11046 | 121450 | 21350 | N | 30 | L | L | N | .02 |
| | | | | ROCKS--VEIN | | | | |
| 11193 | 111610 | 34220 | 150 | N | N | 0.5 | N | L |
| 11230 | 120470 | 32510 | 300 | N | N | N | N | .06 |
| 11230B | 120470 | 32510 | 1000 | 150 | N | 5.0 | N | .04 |
| 11230D | 120470 | 32510 | 15000 | 150 | N | 50.0 | .25 | .22 |
| 11240 | 122710 | 20200 | 1000 | 200 | N | 30.0 | .20 | .08 |
| 11240A | 122710 | 20200 | N | 200 | N | 0.7 | N | .02 |
| 11240B | 122710 | 20200 | 200 | 2000 | N | 15.0 | N | .04 |
| | | | | ROCKS--OTHER | | | | |
| 11199 | 110225 | 33800 | N | N | N | 1.0 | L | L |
| 11203 | 109125 | 34200 | 70 | N | N | 0.7 | N | .04 |
| 11098 | 110575 | 34700 | 50 | N | N | 0.5 | N | .04 |
| 11098A | 110575 | 34700 | 100 | N | N | 0.7 | N | .02 |
| 11235A | 120350 | 32210 | 5000 | 20 | N | 5.0 | N | .02 |
| 11107D | 114200 | 30875 | 500 | G(20000) | G(10000) | 70.0 | .50 | .40 |
| 11107E | 114200 | 30875 | 200 | 500 | 7000 | 3.0 | .25 | .16 |

(figs. 7–9). The mineralized zones inferred on figures 7–9 were interpreted from analytical results taking into consideration the movement of the elements owing to topography, soil creep, comparative concentrations of extractable copper in stream sediments, and from the location of rock samples (pl. 2; fig. 5) that contained anomalously high amounts of copper (table 1). About one-third of the anomaly lies outside the east boundary. The mineralized zone(s), which trends northeasterly and is nearly continuous over a strike length of about 10,000 ft (3,048 m), is entirely in the lower part of the Revett Formation. The average width may be on the order of 100 ft (30.5 m). The principal zone appears to pinch out to the southwest, to widen to as much as 500 ft (152 m) in the central part, and to abut a normal fault to the northeast.

In addition to the sample localities shown on figures 7–9, more than 100 stream-sediment samples were collected at 100- to 400-ft (30- to 125-m) intervals from small, steep gullies that transect the mineralized zones and drain into Star Gulch from the northwest. These samples were analyzed on site for 6*N*-hydrochloric-acid–soluble copper by the colorimetric method previously described. The limits of the anomalous zones were inferred from anomalous peaks that occur immediately downslope from mineralized strata. For example, six sediment samples from the easterly flowing stream just outside the northeast boundary of the study area (fig. 7) were analyzed in the laboratory; in addition, numerous other samples on this stream were analyzed on site. (On-site analyses are not shown on the geochemical distribution maps.) The laboratory analyses established the anomaly and the on-site analyses further defined the mineralized zone. The westernmost sample in this drainage contained 850 ppm total copper (fig. 7). The next sample collected farther east contained 950 ppm total copper. East of this locality, the copper values steadily decline. This suite of samples is interpreted to represent a single mineralized zone whose eastern boundary is between the samples containing 850 and 950 ppm total copper. The width of the mineralized zone is inferred from onsite analyses of samples collected in the vicinity of the westernmost sample in the drainage. The zone is further defined by acid-extractable copper (fig. 8) and total silver (fig. 9). In the central part of the anomalous area, two parallel mineralized zones are suggested by onsite analyses, laboratory analyses, and by the occurrence of visible copper minerals in outcrops that contain as much as 5,000 ppm copper (fig. 5).

The northern end of the anomalous area is interpreted to be near the top of the ridge between Hamilton Gulch and the small parallel stream to the south. The gullies draining into Hamilton Gulch from the south do not contain anomalous amounts of copper; however, the sediments below a spring that issues from a fault have anomalous amounts. Thus, the mineralized zone is inferred to occupy the fault and to terminate at, or a short distance north of, the ridge. The stream-sediment sample from the southernmost locality shown in figure 7 contained 210 ppm copper. The sediments in the stream to the south of this sample were tested in the field and did not contain anomalous amounts of copper. Thus the southern end of the anomaly is near and upstream from the stream sediment containing 210 ppm copper.

The anomalous area is confirmed by mineralized outcrops within the study area (fig. 5), and several factors combine to suggest that the mineralized zone continues in the subsurface outside and northeast of the study area (figs. 7–9). First, the favorable stratigraphic zone (lower part of the Revett) is present to the northeast. Second, although no copper minerals were found in outcrops in the northeastern part of the zone, the Revett at this locality is pyritic, perhaps forming a halo similar to the pyritic halo around the deposit near Spar Lake. And third, the stream sediments contain highly anomalous amounts of total copper, acid-extractable copper, and silver (figs. 7–9). These data suggest that the deposit plunges northeasterly, and only the upper fringe of the copper deposit is exposed in the southwesterly and central parts of the anomalous zone. Analytical results indicate that the northeastern half of the mineralized zone, the unexposed portion, is the most highly anomalous.

The overall trend of the anomalous zones is parallel to subparallel to the strike of the strata. The anomalous zones are discordant to the strata in the vicinity of the fault at the north end, and perhaps discordant at the south end.

The Revett section in the vicinity of Star Gulch is too poorly exposed to identify the lithostratigraphic units (Ch. A, table 1) by surface mapping. If the lithologies and thicknesses of the units in the Revett section at Star Gulch are about the same as those studied in the section near Little Spar Lake, then the anomalous zones shown on figures 7–9 lie entirely in units 6 and 8 (Ch. A, table 1). The highest copper and silver concentrations are apparently derived from unit 8; the easternmost or upper anomalous zone, which contains lower but significant values, corresponds to the position of unit 6 (Ch. A, table 1).

The analytical results from stream sediments in the Star Gulch area were compared with results from areas without known mineral deposits and from the area of the copper deposit near Spar Lake. A sampling of these comparisons (table 2) shows that the streams

TABLE 2.—*Analyses of selected stream-sediment samples from in and near Scotchman Peak study area*

[All values in parts per million. Analytical methods: Extractable copper (xCu) by —0.8*N* nitric acid leach-atomic absorption; copper (Cu) by atomic absorption; silver (Ag) by emission spectroscopy. Determination limit for silver—0.5 ppm; N, not detected. Analysts: D. J. Grimes and J. M. Motooka]

| Sample locality | Sample No. | xCu | Cu | Ag |
|---|---|---|---|---|
| Drainages, in parts of the study area, without known mineral occurrences | 16016 | 4 | 10 | N |
| | 16065 | 5 | 20 | N |
| | 16075 | 2 | 15 | N |
| | 16093 | 3 | 25 | N |
| | 16134 | 4 | 30 | N |
| Near Spar Lake copper deposit | 16001 | 60 | 130 | 1.0 |
| | 16002 | 67 | 150 | 1.0 |
| | 16003 | 95 | 240 | .7 |
| | 16004 | 48 | 120 | .5 |
| | 16124 | 140 | 310 | 1.0 |
| Star Gulch area | 16023 | 100 | 230 | 0.7 |
| | 16082 | 4 | 20 | N |
| | 16083 | 16 | 65 | .5 |
| | 16112 | 175 | 400 | 5.0 |
| | 16114 | 400 | 830 | 5.0 |
| | 16115 | 770 | 1,400 | 3.0 |
| | 16116 | 90 | 210 | 1.0 |
| | 16125 | 480 | 950 | 7.0 |
| | 16130 | 68 | 130 | 1.5 |

draining the Spar Lake and Star Gulch occurrences are highly anomalous in total and extractable copper and silver (table 2). Although the magnitude of an anomaly is not necessarily related to the size of an orebody beneath it, the table shows that the Star Gulch area is more highly anomalous than the Spar Lake area. Because the Spar Lake area contains a known orebody, it is possible that the Star Gulch anomalous zone may be underlain by ore-grade material. The presence and (or) limits of ore zones in the Star Gulch area would have to be proved by drilling, but the size of the anomaly suggests that the deposit has large tonnage potential.

East of the Blue Creek fault (pl. 1), the distribution of small copper and silver anomalies derived from stratabound occurrences in the Revett Formation are shown on the distribution maps (fig. 1, 2, 4, and 5). Aside from the Star Gulch anomaly, the other most conspicuous anomalies straddle the study area boundary south of Spar Lake and the east boundary near Ross Creek. These anomalies suggest the possibility of widespread stratabound copper in the Revett under a large part of the area east of the Blue Creek fault. In view of the large known deposit near Spar Lake and the mineralized zone indicated by the Star Gulch anomaly, there is a moderate potential for other occurrences buried beyond the limits of geochemical detectibility to the east of the Blue Creek fault.

Weak copper and lead anomalies are associated with quartzite and sandy siltite beds in the upper part of the St. Regis Formation and (or) lower part of the Wallace Formation in the central part of the study area (figs. 5 and 6). The occurrences are small, discontinuous, and low grade; and they have a very low economic potential.

## CONCLUSIONS

### GENERAL

The Scotchman Peak Wilderness study area has a very high potential for copper and silver, and a moderate potential for lead, zinc, and gold. The area has a very low potential for other metallic and nonmetallic minerals. The area has little to no potential for oil and gas, coal, geothermal resources, or other energy-related commodities. The area does not contain exploitable deposits of sand, gravel, or limestone. Some of the slabby quartzites in the area may be suitable for building stone or flagstone, but a large supply of this commodity is available in more accessible areas.

### COPPER

The study area has a very high potential for stratabound copper deposits. The deposit with greatest economic potential is in the vicinity of Star Gulch in the southeastern part of the area. Copper is also present in the quartz-copper veins in the vicinity of Ross Creek and in the lead-zinc veins in the southern part of the study area.

### SILVER

Important amounts of silver may be recoverable as a byproduct of copper and lead-zinc mining in the study area. Silver is closely associated with copper in the stratabound occurrences in the Revett Formation, and with lead and copper in the vein deposits. The greatest potential for silver is in large stratabound deposits.

## LEAD AND ZINC

The Scotchman Peak Wilderness study area has a moderate potential for lead and zinc. Small vein deposits near the southern boundary have been mined in the past and could possibly support future small mining operations. Lead and minor amounts of zinc and copper in veins near the granodiorite intrusive in the western part of the area have a low potential owing to the small size of the veins and the erratic distribution of base metals.

## GOLD

Gold was detected in 18 rock samples; 6 contain measurable amounts. The values range from 0.05 to 0.5 ppm; the highest values are from the northerly striking lead-zinc veins near the southern boundary.

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# Economic Appraisal of the Scotchman Peak Wilderness Study Area, Lincoln and Sanders Counties, Montana, and Bonner County, Idaho

*By* Nicholas T. Zilka, U.S. Bureau of Mines

MINERAL RESOURCES OF THE SCOTCHMAN PEAK WILDERNESS STUDY AREA, LINCOLN AND SANDERS COUNTIES, MONTANA, AND BONNER COUNTY, IDAHO

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By Nicholas T. Zilka, U.S. Bureau of Mines

## SETTING

Several mining districts near, or partly in, the Scotchman Peak Wilderness study area have recorded production of ore; the most significant is the Clark Fork district. Most of this district lies south of the study area and north of the Clark Fork River. The northern part extends into the study area and includes part of Goat Mountain.

Lead-silver ore was first discovered here on Antelope Mountain. Significant development and production was begun in 1913 by the Lawrence Mining and Milling Co., Ltd. Between 1913 and 1923, several mines and prospects were developed, including the Clarinda, Copper Giant, and Carpie. In 1923, ore deposits were discovered on Middle Mountain, and shipments began from the Hope mine. The most significant deposit was found on Howe Mountain in 1926 (Whitedelf mine). Production has come from several properties but mostly from the Lawrence, Hope, and Whitedelf mines. Recorded production from 1913 to 1964 was 296,373 tons (269,865 t) containing 50.28 oz (1,564 g) gold, 1,186,043 oz (36,885,937 g) silver, 27,542 lb (12,493 kg) copper, 27,984,562 lb (1,269,358 kg) lead, and 8,999,300 lb (4,082,014 kg) zinc.

Activity in the Clark Fork district led to mineral discoveries associated with the Blue Creek fault set to the southeast. During 1925-1927, the Broken Hill mine, owned by Broken Hill Silver-Lead Mining Co., produced 273 tons (248 t) of ore containing 942 ounces (29,299 g) silver, 53,057 lb (24,066 kg) lead, and 176,632 lb (80,119 kg) zinc. In 1966, 93 tons (84 t) of ore having 292 oz (9,082 g) of silver, 12,800 lb (5,806 kg) of lead, and 34,700 lb (15,740 kg) of zinc was produced. The Blue Creek mine, operated by Blue Creek Mining

Co., had production of at least 300 tons (272 t) of ore prior to 1950, and 9 tons (8 t) between 1963 and 1965. The 9 tons (8 t) contained 40 oz (1,244 g) silver, 2,500 lb (1,134 kg) lead, and 3,070 lb (1,393 kg) zinc. The property, which extends into the study area, is now held by the Lucky Star Mining Co. Both the Broken Hill and Blue Creek mines are idle, but maintained.

Price increases for copper and silver, and interest in disseminated deposits, resulted in widespread prospecting in the vicinity of the study area during the early 1960's. Several discoveries were made, but most significant was the Mount Vernon, or Spar Lake, deposit on the Daniel Lee and Ape property of Bear Creek Mining Co., a subsidiary of Kennecott Copper Corp. The property is adjacent to the northeast side of the study area. The deposit is a zoned, stratabound concentration of disseminated sulfides. The American Smelting and Refining Co., under a working agreement with Bear Creek Mining Co., is preparing to mine the property. The proximity of the Spar Lake deposit to the area, the widespread occurrence of the host formation in the area, and additional discoveries have been stimulating mineral location and exploration activities in the study area. A stratabound disseminated sulfide occurrence in Star Gulch was prospected in 1968 by Bear Creek Mining Co., and a deposit underlying Squaw Peak was drilled in 1974 by Day Mines, Inc. Another deposit at Ross Point was drilled in 1975 by Cities Service Mineral Corp.

## PREVIOUS STUDIES

First reconnaissance mapping in the study area was by Calkins and MacDonald (1909) in northwestern Montana. Anderson (1930, 1947) reported on the geology and ore deposits of the Clark Fork district, and Lorain (1946) also investigated the district. Gibson (1948) mapped geology and examined mineral properties in the Libby quadrangle, and Harrison and Jobin (1963) mapped the Clark Fork quadrangle. Crowley (1963) described mines in Sanders County, and Johns (1970) reported on the geology and mineral deposits of Lincoln and Flathead Counties.

## PRESENT INVESTIGATION AND ACKNOWLEDGMENTS

U.S. Bureau of Mines studies were made during 1974 and 1975 by Nicholas Zilka, assisted by Thomas Hamilton and Mike McCarthy. Records of mineral location and assessment work were obtained from the Bonner, Lincoln, and Sanders County courthouses in Sandpoint, Idaho, and Libby and Thompson Falls, Mont. Production statistics were obtained from U.S. Bureau of Mines files and the literature. The Bureau's analytical work was directed by H. H. Heady, U.S. Bureau of Mines, Reno, Nev.

We are grateful for the cooperation of the claimholders and local residents. The information provided by Bear Creek Mining Co., American Smelting and Refining Co., Day Mines, Inc., and Cities Service Minerals Corp. is especially appreciated.

## MINERAL COMMODITIES AND ECONOMIC CONSIDERATIONS

Mineral commodities found in or adjacent to the Scotchman Peak study area are gold, silver, copper, lead, and zinc.

Although most domestic production of copper is from large, low-grade disseminated deposits, dependence on domestic resources will likely increase as foreign resources become less available. South America has been the largest copper import source to date. In domestic developments, however, the enormous materials handling involved in mining disseminated deposits causes land-use conflicts to be major obstacles. The price of domestic copper in January 1978 was $0.63/lb ($1.40/kg). Silver was $4.93/oz ($0.16/g) (Engineering and Mining Journal, February 1978). A large portion of domestically consumed silver is imported from Canada.

Domestic consumption of lead, zinc, and silver exceeds production. The price of lead was $0.330/lb ($0.73/kg) and zinc was $0.305/lb ($0.67/kg) in March 1976 (Engineering and Mining Journal, February 1978).

Lead, zinc, and silver have been produced from the Blue Creek and Broken Hill mines on the Blue Creek fault zone at the southeast edge of the study area. Additional reserves and resources exist in the fault zone. Transportation costs will hinder development of the small lead-zinc-silver deposits in and near the study area. These reserves are too small to justify building a smelter; the nearest smelter is at Smelterville, Idaho, about 100 mi (160 km) away. However, construction of a custom mill, with resultant low-unit concentrate shipment costs, may be feasible.

Other metallic commodities in the study area are too sparsely distributed to have economic potential.

## METHODS OF EVALUATION

All known mines and prospects in the study area were examined. Locations from county records, descriptions in various publications, and information from mining companies and local residents were used. Mines and prospects were mapped when warranted. Samples were taken from all prospects and mine workings whether mineralized material was apparent or not.

A total of 256 lode samples averaging about 5 lb (2.3 kg) each was taken. In the laboratory, samples were pulverized and checked for the presence of radioactive or fluorescent minerals. All samples were fire assayed for gold and silver. The amounts of other metallic elements were determined by atomic absorption, colorimetric, or X-ray fluorescent methods. At least one sample from each property was analyzed by a semiquantitative spectographic method.

Categories of resources used for this study follow those outlined by the U.S. Bureau of Mines (1976), and the U.S. Geological Survey (1976). *Resources* are concentrations of naturally occurring materials from which commodities may be extracted, either currently or in the future. *Reserves* are part of the total resources and refer to mineralized material (ore) that can be mined and marketed under prevailing economic conditions. *Measured reserves* or *resources* are those computed from sample analyses and measurements from closely spaced sample sites. *Indicated reserves* or *resources* are computed partly from sample analyses and measurements, and partly from reasonable geologic projections. *Inferred reserves* or *resources* are estimates based on relatively few sample sites and measurements, and on geologic evidence and projection. *Paramarginal resources* either border on being economic grade or are not exploitable because of legal or political circumstances. *Submarginal resources* require more than 1.5 times the current price or a major cost-reducing advance in mining and extractive technology. Undiscovered resources include *hypothetical resources* in known mining districts and *speculative resources* in undiscovered districts.

## MINING CLAIMS

Courthouse records indicate that approximately 439 claims have been located within or along the edge of the study area; the first was located in 1887. Some claims have been relocated under different names. Most of them are grouped in three areas—Goat Mountain, Blue Creek, and Squaw Peak. There are patented claims near but not in the study area.

## MINERALIZED AREAS

Mineral location and mining activity in the study area has centered on and near three major geologic features—the Hope fault, the Blue

Creek fault set, and the Precambrian Revett Formation. The areas and mining properties (pl. 3) are described in order of apparent decreasing importance. Those occurrences that either have no mineral potential or are not well enough exposed to determine potential are tabulated.

## OCCURRENCES RELATED TO THE REVETT FORMATION

Stratabound copper deposits, where mineralization is related to metasedimentary formations, occur in a belt about 120 mi (190 km) long and 40 mi (64 km) wide that extends from British Columbia to the Coeur d'Alene mining district in Idaho. Stratabound copper sulfides occur in all formations of the Precambrian Belt Supergroup, but those of significance are in the Revett Formation.

An economic deposit was discovered in the late 1960's by Bear Creek Mining Co. on Mount Vernon, adjacent to the northeast boundary of the study area. American Smelting and Refining Co. is making feasibility studies and preparing to mine the deposit using room-and-pillar methods. Two long adits have been driven into the north and south sides of Mount Vernon and closely spaced holes have been drilled. The deposit is zoned and has a semigradational transitional boundary going from sulfide-rich to barren. Using a 0.5-percent copper cut-off grade, the ore body is about 8,500 ft (2,590 m) long, 1,800 ft (550 m) wide, and 50 ft (15 m) thick. It has an average grade of 0.79 percent copper and 1.67 oz silver per ton (57 g/t) (American Smelting and Refining Co., oral commun., 1974).

No economically minable stratabound deposits have been delineated within the study area, but significantly mineralized stratigraphic sections of the Revett Formation occur at Squaw Peak, Star Gulch, and Ross Point.

The surface expression of stratabound deposits is extremely subtle. Oxidation products are only occasionally found along fracture planes.

The copper sulfides occur as disseminations, discrete blebs, bedding plane concentrations, and fracture fillings. Most common are disseminated grains ranging in size from dust particles to 1/64 in. (from micrometer size to 0.4 mm). Sedimentary structures and sulfide concentration are closely related. Sulfide minerals are concentrated in the basal portions of graded beds, crossbedding, cut-and-fill structures, and individual quartzite beds overlying argillite beds. Grain size of the sulfide minerals is directly proportional to the grain size of the host rock. Many areas of stratabound sulfide deposits contain sulfide-bearing veins.

The primary mineral is bornite but chalcocite, chalcopyrite, covellite, and galena occur. Secondary minerals are brochantite, malachite, azurite, and limonite.

*Bee and Boo groups.*—The Bee group of 24 claims and Boo group of 31 claims inside the study area (pl. 2, No. 18) were located in 1968 by Bear Creek Mining Co. The property is in secs. 1 and 12, T. 27 N., R. 34 W., sec. 6, T. 27 N., R. 33 W., and sec. 31, T. 28 N., R. 33 W., at the head of Star Gulch. Access is by trail.

No workings other than discovery pits are on the property. Exploratory drilling by Bear Creek Mining Co. disclosed a stratabound copper-sulfide occurrence in lithostratigraphic units 6 and 8 near the bottom of the Revett Formation section. The beds within the claims strike northeast and dip moderately southeast. The southern part of the occurrence crops out within the study area. Geochemical sampling by the U.S. Geological Survey indicates that the occurrence extends for a considerable distance to the north, but does not crop out.

Within the study area the copper-sulfide occurrence consists of two sequences of mineralized beds—a lower zone and an upper zone—separated by a large, barren sequence (fig. 1). The zones are crosscut to the east and west by normal faults trending northeast and dipping steeply southeast. The faults have significant displacement.

The lower zone is composed of a mineralized medial part 1-14 ft (0.3-4.3 m) thick bounded on top and bottom by 5-15 ft (1.5 to 4.6 m) of less mineralized beds. The zone averages 27 ft (8.2 m) in width and it can be traced on the surface intermittently for approximately 7,000 ft (2,000 m). Bornite, chalcopyrite, limonite, and brochantite occur as disseminated blebs and grains in quartzite. Thirteen samples collected by the U.S. Bureau of Mines from leached outcrops in the middle of the zone average 85 ppm (parts per million) copper. Three composite samples from the outer parts averaged 354 ppm copper. Average threshold value for copper in the area is 15 ppm (p. 67). Only trace amounts of silver were detected. The lower zone within the study area represents an estimated potential of 35 million tons (32 million t) of rock with an unknown metal content (7,000-ft length by 27-ft width by 2,900-ft average depth—amount removed by erosion. Surface samples average 0.04 percent copper but, because of leaching, they do not indicate the percentage of copper at depth.

The upper zone has a mineralized medial part 3 ft (0.9 m) thick bounded on top and bottom by 2–5 ft (0.6–1.5 m) of less mineralized beds. This zone also can be traced on the surface in widely spaced outcrops for approximately 7,000 ft (2,000 m). Brochantite and limonite occur as disseminated blebs and grains in quartzite. The upper zone contains much less potential tonnage than does the lower zone. To the north and outside the study area, several million tons of inferred resources may occur in the lower and upper zones. Drilling is needed to accurately delimit the occurrence. Six samples taken across the medial section averaged 166 ppm copper. Three composite samples from the bounding beds averaged 18 ppm copper. Only trace amounts of silver were detected.

*Squaw Peak copper*—Four groups of adjoining claims, both inside and outside the study area, cover Squaw Peak in T. 27 N., R. 33 to 34 W. The M group (pl. 2, No. 17) of P. W. Laczay is on the west and northwest side, the Red Fir group (pl. 2, No. 20) of Brooks and Dettwiler is on the south, and the Frederick and Wind groups (pl. 2, No. 19) of Lynn Keith are on the northeast. A trail leads to Squaw Peak lookout from a road up Eddy Creek.

Three groups of old workings lie within the claims. The only workings in the study area were excavated in the 1930's by the Dixie Queen Mining Co. on the Ulley property, now part of the Frederick. An inclined, flooded shaft, apparently connected to a caved 40-ft (12-m) lower adit level, is on a fissure vein striking N. 40° W., and dipping 50° SW. The vein has an exposed length of 10 ft (3 m) and a 3- to 12-in. (8- to 30-cm) width at the surface. It is composed of 95 percent quartz and 5 percent combined magnetite, chalcopyrite, pyrite, malachite, and limonite, with traces of galena and sphalerite. Two samples taken across the vein averaged 0.7 oz silver per ton (24 g/t) and 0.4 percent copper. A grab sample from the ore bin contained 5.6 oz silver per ton (192 g/t) and 7.0 percent copper. Seven deep pits are on the slope between the shaft and ridgecrest on discontinuous, en echelon quartz fissure veins. Samples from them averaged 0.01 percent copper and trace gold, lead, and zinc.

Current interest is in sulfide-bearing beds of the Revett Formation underlying the area. Bedding strikes N. 10° E. and dips 45° SE., too steep for room-and-pillar mining methods. During the summer of 1974, Day Mines Inc. contracted the drilling of a 900-ft (274-m) hole on the south side of Squaw Peak as part of a lease option with International Minerals and Chemical Corp. The core contained minor amounts of copper. Further exploration is not planned.

The U.S. Bureau of Mines sampled sections of the exposed Revett Formation stratigraphic column at eight localities on Squaw Peak. Samples contained as much as 70 ppm copper and averaged 31 ppm. Grab samples were taken at selected sites. A sample from a sequence of beds in the S. ½ sec. 13 contained minor disseminated bornite and assayed 0.01 (100 ppm) percent copper. The sampled sequence may

*Data for samples shown in figure 1.*

| Sample | | | | Copper |
|---|---|---|---|---|
| No. | Type | Length (feet) | Description | (parts per million) |
| Z-165 | Chip | 4.0 | Across middle of upper zone | 120 |
| Z-246 | do | 4.0 | do | 400 |
| Z-257 | do | 14.0 | Across middle of lower zone | 500 |
| Z-258 | do | 10.0 | do | 100 |
| Z-259 | do | 10.0 (composite) | Across outer portions of lower zone | 20 |
| Z-260 | do | 5.0 | Across middle of lower zone | 200 |
| Z-261 | do | 40.0 (composite) | Across outer portions of upper zone | 20 |
| Z-262 | do | 30.0 (composite) | do | 10 |
| Z-263 | do | 60.0 (composite) | do | 20 |
| Z-264 | do | 5.0 | Across middle of upper zone | 20 |
| Z-265 | do | 5.0 | do | 20 |
| Z-266 | do | 15.0 | do | 30 |
| Z-267 | do | 5.0 | do | 400 |
| Z-268 | do | 46.0 (composite) | Across outer portions of lower zone | 450 |
| Z-269 | do | 15.0 | Across middle of lower zone | 800 |
| Z-270 | do | 6.0 | do | 800 |
| Z-271 | do | 24.0 (composite) | Across outer portions of lower zone | 300 |
| Z-300 | do | 1.5 | Across middle of lower zone | 500 |
| Z-301 | do | 4.5 | do | 200 |
| Z-302 | do | 5.0 | do | 100 |
| Z-303 | Chip | 5.0 | Across middle of lower zone | 400 |
| Z-304 | do | 2.5 | do | 100 |
| Z-305 | do | 5.0 | do | 1100 |
| Z-306 | do | 15.0 | do | 400 |
| Z-307 | do | 6.0 | do | 600 |

be the same as that drilled on the south side of Squaw Peak. Stream-sediment samples taken by the U.S. Geological Survey around the peak contain anomalous copper values.

*John Francis group.*—The John Francis group consists of 32 claims, both inside and outside the study area, in secs. 11, 14, and 23, T. 28 N., R. 34 W. (pl. 2, No. 10). It extends from the top of the Ross Point ridge to South Fork Ross Creek. The property is claimed by F. McKay and H. Tauscher of Spokane, Wash. Cities Service Mineral Corp. has a lease-option on the property, and holds numerous claims (RP claims) adjacent and to the east. Access is by logging road up Dry Creek from Montana Highway No. 202.

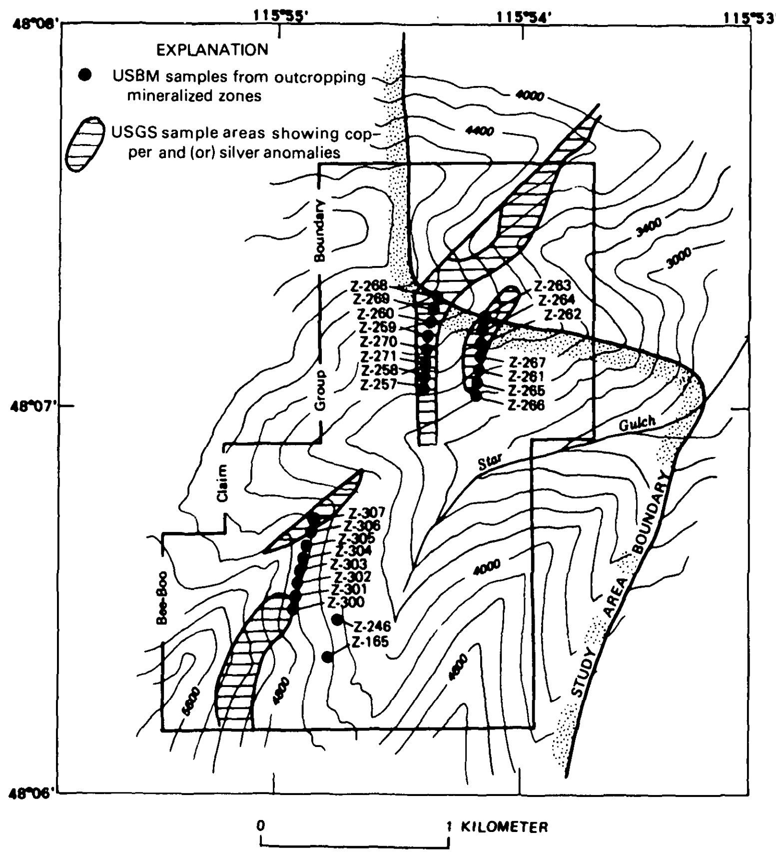


FIGURE 1.—Localities of U.S. Bureau of Mines samples on the Bee and Boo claims.

Three adits and a large pit were excavated in the early days of the district to develop a sheeted-zone deposit (fig. 2). The zone is subsidiary to a fault about 200 ft (61 m) to the south; the fault is bounded on the north by the Revett, St. Regis, and Wallace Formations and on the south by the Revett Formation.

The sheeted zone strikes N. 40° to 50° W. and dips 65° SW. to vertical. The zone, as determined on the basis of intermittent exposures, ranges from 5 to 16 ft (2–5 m) in width, has a strike length of at least 1,500 ft (460 m), and is continuous over an elevation difference of 750 ft (230 m). The zone is terminated by a fault along South Fork Ross Creek. The extension of the zone on the west side of the fault was not found, but float indicates it may have been offset about 1,000 ft (300 m) to the south. The zone is composed of 75 percent sulfide-bearing quartz veins and veinlets and 25 percent country rock fragments and gouge. Sulfides are pyrite, pyrrhotite, and chalcopyrite. Hematite, limonite, and malachite occur locally. Samples across the zone averaged 0.07 oz silver per ton (2.4 g/t)

*Data for samples shown in figure 2*

[Tr, trace; N, none detected; Na, not analyzed. All samples are chip samples collected across fissure vein]

| No. | Sample Length | | Gold | Silver | | Lead | Zinc | Copper |
|---|---|---|---|---|---|---|---|---|
| Z- | ft | (m) | oz/ton | oz/ton | (g/t) | (percent | (percent) | (percent) |
| 175 | 3.5 | (1.1) | N | 0.2 | (6.9) | NA | NA | 0.29 |
| 176 | 5.0 | (1.5) | Tr | .1 | (3.4) | NA | NA | .14 |
| 177 | 3.5 | (1.1) | N | .3 | (10.3) | NA | NA | .81 |
| 178 | 6.0 | (1.8) | Tr | .1 | (3.4) | Tr | 0.2 | .32 |
| 179 | 8.0 | (2.4) | N | .2 | (6.9) | NA | .1 | .37 |
| 181 | 6.0 | (1.8) | N | N | | Tr | Tr | .06 |
| 182 | 6.0 | (1.8) | N | N | | N | N | .01 |
| 183 | 4.0 | (1.2) | N | .1 | (3.4) | Tr | Tr | .23 |
| 184 | 4.0 | (1.2) | N | Tr | | Tr | Tr | .05 |
| 185 | 4.0 | (1.2) | N | Tr | | 0.02 | .04 | .01 |
| 186 | 11.0 | (3.4) | N | N | | Tr | Tr | .07 |
| 187 | 1.5 | (.5) | N | N | | Tr | Tr | Tr |
| 188 | .8 | (.2) | N | N | | Tr | Tr | Tr |
| 189 | 2.0 | (.6) | N | N | | Tr | Tr | Tr |

and 0.13 percent copper. Indicated and inferred submarginal resources between the top adit and South Fork Ross Creek are 430,000 tons (390,000 t); average width sampled was 4.7 ft (1.4 m).

Because of the proximity of the Spar Lake ore body, to the John Francis claims, the stratabound sulfide occurrence in the Revett Formation is of greater significance than the fissure vein. During the summer of 1975, Cities Service Minerals Corp. drilled two holes in the area east of Ross Point on claims adjacent to the study area. Only the upper part of the Revett section was drilled. Each hole encountered sections of mineralized Revett Formation, but only the hole nearest the study area boundary encountered significant amounts. An ore body was not found. U.S. Bureau of Mines samples from exposed parts of the Revett Formation stratigraphic section on the west side of Ross Point within the John Francis claims contained 30-160 ppm copper and averaged 71 ppm copper. Average threshold value for copper for the area is 15 ppm (p. 67). Copper content increases down section, with highest sample values occurring at the bottom of the exposed Revett section along South Fork Ross Creek and Ross Creek. Copper values are comparable on both sides of the fault (pl. 1). The sampled part of the Revett section just above

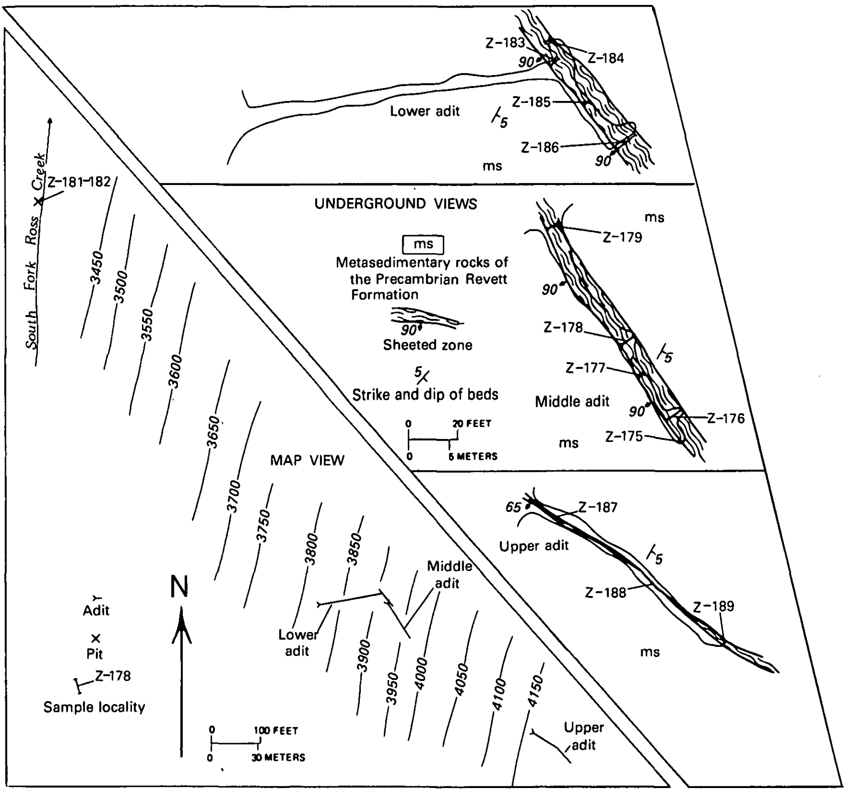


FIGURE 2.—Surface map and underground views of John Francis group of claims, secs. 11, 14, and 23, T. 28 N., R. 34 W.

the South Fork and south of the fault contained as much as 0.2 percent lead. If the zoning displayed by the Spar Lake deposit, where the ore body is surrounded by two copper-lead bearing zones (the inner more copper-rich) is characteristic of depsits in the area, a disseminated copper deposit may exist near this low-grade copper- and lead-bearing zone. This occurrence is in a similar situation to the Bee and Boo claims in Star Gulch and the Rock Creek deposit in the Cabinet Mountains where the deposits are near the bottom of the Revett section. Drilling of the lower Revett section is needed to define the occurrence. Samples taken from the lower 300 ft (91 m) of the exposed St. Regis Formation averaged a highly anomalous 140 ppm copper. Stream sediment samples taken from the area by the U.S. Geological Survey contained anomalous copper values. A good exploration target exists on the property.

## OCCURRENCES RELATED TO THE BLUE CREEK FAULT

The Blue Creek fault and several subparallel faults that are entirely within the Precambrian Belt Supergroup trend north and extend from the Hope fault to the Spar Creek fault, a distance of 10 mi (16 km) (pl. 1). The faults are generally not traceable on the surface but are usually exposed in appropriately located underground workings. Because the large displacement has produced considerable impervious and nonreactive gouge, the mineral deposits do not occur along the major faults of the zone but along crosscutting shears within the faults. There, deposits have been emplaced by a combination of replacement and fissure-filling. The deposits consist of veins that pinch and swell along and downdip and are not individually extensive, but collectively they comprise a zone that is significant.

The veins are composed of quartz, pyrrhotite, and arsenopyrite and minor sphalerite, galena, pyrite, and chalcopyrite. The sulfides are mixed but more segregated than those in the Goat Mountain deposits. Silver is generally present, but gold is notably absent. Limonite is the most abundant secondary mineral. The host rocks are sericitized and chloritized.

Descriptions of the Blue Creek and Broken Hill properties, which are related to the Blue Creek and subparallel faults, follow. Four other properties, described in table 1, have no potential. Of the six properties, two are situated within the study area and four are adjacent. The properties outside were investigated as possible indicators of the mineral potential along the 7 mi (11 km) of fault zone within the study area. The faults represent a good exploration target for small, high-grade deposits.

*Blue Creek mine.*—The Blue Creek, or Scotchman, mine straddles the boundary of the area and is in secs. 3 and 4, T. 27 N., R. 34 W., at an elevation of 3,150 ft (960 m) (pl. 2, No. 12). It is owned by the Lucky Star Mining Co. The property consists of six patented and three unpatented claims. Complete records are lacking, but at least 300 tons (270 t) of ore averaging 11 percent lead and 9 percent zinc was shipped prior to 1950. During 1963–65, 9 tons (8 t) containing 40 oz (1,244 g) silver, 2,500 lb (1,134 kg) lead, and 3,070 lb (1,394 kg) zinc was produced.

The main working is a 420-ft-long (128-m) crosscut connecting to a 1,480-ft-long (451-m) drift (fig. 3). The drift is caved 550 ft (168 m) from the north portal where it crosscuts an old stream channel filled with unconsolidated gravel.

The mine is on a fault near the Blue Creek fault. It trends N. 20° W. and dips steeply southwest. The zone is about 60 ft (18 m) wide and is exposed in the adit for about 1,100 ft (330 m). It consists of two large bounding faults separated by moderately fractured country rock (argillite and quartzite of the Precambrian Revett Formation) striking N. 30° E. and dipping 22° SE.

TABLE 1.—*Miscellaneous prospects related to the Blue Creek and subparallel faults*

| Map No. (pl. 2) | Prospect | Summary | Number and type of workings | Sample data |
|---|---|---|---|---|
| 11 | Oakland | A 6-in. (15 cm)-wide shear zone crops out for 20 ft (6.1 m) in argillite. The zone strikes N. 10° W., dips 63° NE., and is composed of 45 percent quartz, 45 percent gouge, and 10 percent arsenopyrite, galena, pyrite and chalcopyrite. | Two pits | Three samples across zone; as much as 0.18 oz gold, per ton (6.2 g/t), 0.1 oz silver per ton (3.4 g/t), and 0.2 percent lead. |
| 14 | Lucky Lady | A shear zone averaging 7 in. (18 cm) in width strikes N. 10° W. and dips 70°-85° SW. in argillite and quartzite. The zone is exposed for 340 ft (103.6 m) and contains disseminated grains and blebs of pyrite, galena, and sphalerite. | One adit, 520 ft (158.5 m) long. | Seven samples across zone; averaged 0.4 oz silver per ton (13.7 g/t), 0.4 percent lead, 0.3 percent zinc, and 0.02 percent copper. |
| 15 | Badger | A poorly exposed fault zone trends N. 20° W. in argillite. | At least five pits. | Three samples; no values. |
| 16 | Ryan | A northwest-striking fault zone is exposed by the workings for about 500 ft (152.4 m). Quartz fills fractures and lines voids in the zone. Country rock is argillite striking N. 15° W. and dipping 34° NE. | Two caved adits, 30 and 100 ft (9.1 and 30.5 m) long; six pits. | Four samples of quartz; averaged 0.02 oz gold per ton (0.7 g/t) 0.07 percent lead, and 0.01 percent copper. |

*Data for samples shown in figure 3*

[Tr, trace; N, none detected; NA, not analyzed. All samples are chip samples]

| Sample | | | | Gold | | Silver | | Lead | Zinc | Copper |
|---|---|---|---|---|---|---|---|---|---|---|
| No. | Length ft | (m) | Locality | oz/ton | (g/t) | oz/ton | (g/t) | | | |
| Z-83 | 18.0 | (5.49) | Across fault ------ | N | | N | | 0.02 | 0.04 | 0.01 |
| Z-84 | 22.0 | (6.71) | do ---------- | N | | N | | .08 | .05 | .02 |
| Z-85 | 30.0 | (9.14) | do ---------- | N | | N | | .13 | .15 | .05 |
| Z-86 | 19.0 | (5.79) | do ---------- | N | | N | | .02 | .03 | .02 |
| Z-87 | 22.0 | (6.71) | do ---------- | N | | 0.1 | (3.4) | | | |
| Z-88 | 5.0 | (1.52) | do ---------- | Tr | | Tr | | .02 | .03 | Tr |
| Z-89 | 18.0 | (5.49) | do ---------- | Tr | | .2 | (6.9) | .09 | .14 | .01 |
| Z-90 | 5.0 | (1.52) | do ---------- | -- | | .1 | (3.4) | .05 | .07 | .01 |
| Z-91 | 5.0 | (1.52) | Across mineralized shear ---------- | 0.01 | (.3) | N | | .31 | .67 | .02 |
| Z-92 | 4.0 | (1.22) | Across fault ------ | .10 | (3.4) | 1.2 | (41.1) | 3.00 | 2.83 | .09 |
| Z-93 | 16.0 | 4.88) | do ---------- | N | | .1 | (3.4) | .28 | .75 | .05 |
| Z-94 | 12.0 | (3.66) | Across mineralized shear ---------- | .06 | (2.1) | .8 | (27.4) | 2.74 | 2.52 | .11 |
| Z-95 | 37.0 | (11.28) | Across fault ------ | N | | N | | .12 | .07 | .03 |
| CCP-201-203 | 5.0 | (1.52) | Across mineralized shear ---------- | NA | | NA | | 3.92 | 3.07 | NA |
| CCP-203-204 | 3.0 | (.91) | do ---------- | NA | | NA | | .37 | 1.80 | NA |
| CCP-205-206 | 6.0 | (1.83) | do ---------- | NA | | NA | | 1.15 | 4.60 | NA |
| CCP-207 | 1.8 | (.55) | do ---------- | NA | | NA | | 3.31 | 6.04 | NA |
| CCP-208-209 | 5.0 | (1.52) | do ---------- | NA | | NA | | 5.10 | 4.35 | NA |

Mineral deposition occurred mainly along a shear zone that strikes N. 30° W., dips 53° SW., and crosscuts the fault in the south drift. The zone is as much as 10 ft (3 m) wide and is exposed for 275 ft (84 m). The ore occurs as numerous small veins and lenses 1-12 in. (2.5-30.5 cm) wide of quartz and calcite containing sulfides. The veins are parallel, and many are banded. Sulfide minerals are pyrite, arsenopyrite, pyrrhotite, sphalerite, galena, and chalcopyrite. Any one of the sulfides may predominate in a particular vein or lens. The sulfides are very fine grained, which along with the arsenic content, may hinder beneficiation.

The mineralized shear zone has been stoped for 40 ft (12.2 m) along strike and 35 ft (10.7 m) updip. Samples across the zone averaged 2.52 percent lead and 3.03 percent zinc. The CCP series of samples, included above, were taken by the U.S. Bureau of Mines and U.S. Geological Survey in 1951 under the Defense Minerals Administration. Assuming a depth of mineralization of one-half the strike length, and accounting for material mined out, indicated resources are 7,100 tons (6,400 t) of vein material. Average vein width is 5.2 ft (1.6 m).

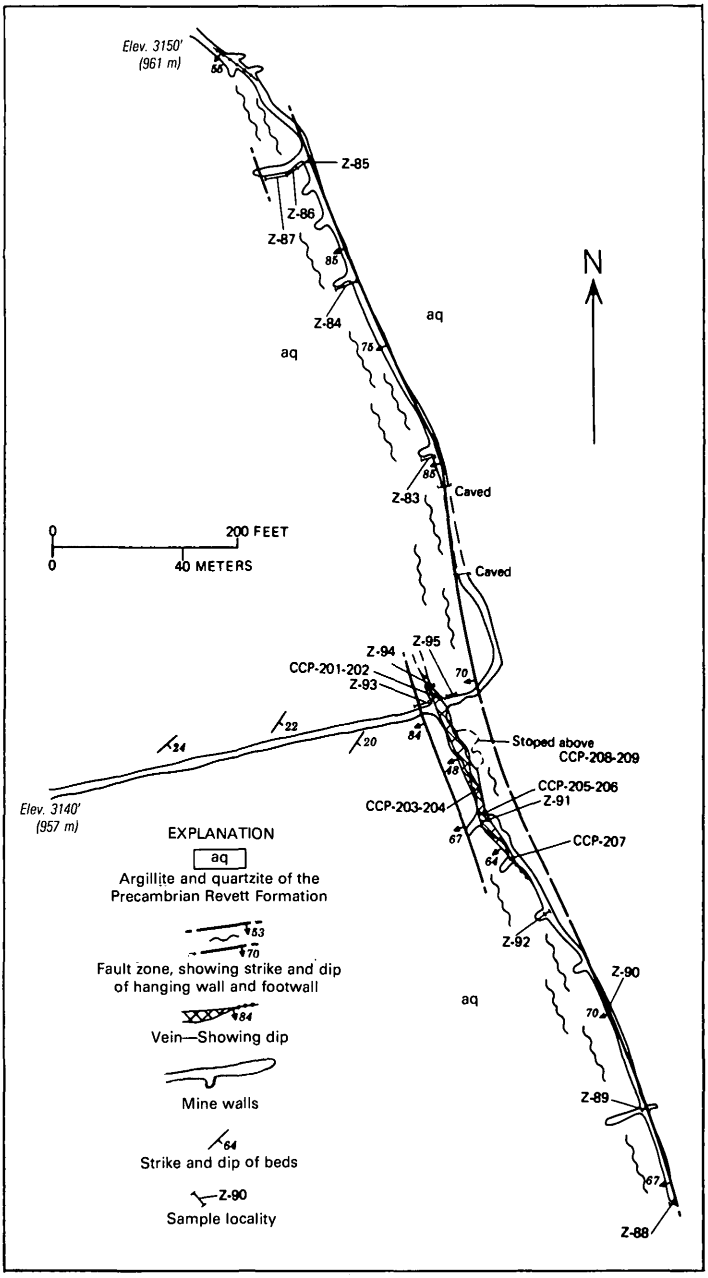


FIGURE 3.—Blue Creek mine, secs. 3 and 4, T. 27 N., R. 34 W.

Samples across other parts of the fault average 0.15 percent lead, 0.19 percent zinc, and 0.03 percent copper.

A smaller mineralized shear zone, which is exposed for 50 ft (15.2 m), occurs in the northern part of the drift. It strikes N. 55° W., dips 55° SW., and is composed of country rock fragments cemented by quartz. No potentially valuable sulfides were found.

Several pits and a 15-ft (4.6-m) adit are northwest and just across the creek from the main adit. They are on discontinuous quartz veinlets and blebs along minor faults related to the Blue Creek fault. Samples from these workings contained only traces of lead and zinc.

*Broken Hill mine.*—The Broken Hill mine development is on two patented claims outside the study area and in the SW1/4 in or out of study area NE1/4 of sec. 10, T. 27 N., R. 34 W., at an elevation of 4,200 ft (1,280 m) (pl. 2, No. 13). Access is by a well-graded, single-lane road. The development consists of an open cut, two underground levels totaling 1,320 ft (402 m), several cabins, and an ore bin. The two levels (fig. 4) are connected by a 116-ft (35-m) ore chute and manway. Silver-lead-zinc ore has been stoped throughout the workings and removed through the lower adit. The steep dip of the deposit and the nature of the wallrock allowed for shrinkage stoping.

Adits were driven to crosscut and then drift on a mineralized shear zone exposed in the open cut on the surface. The shear zone lies within a fault, which strikes N. 19° W. and dips 55°–78° SW. The fault has a gradational boundary on the Broken Hill property rather than major bounding faults as in the Blue Creek mine, but it is probably the same fault. Country rock is argillite, argillaceous quartzite, and quartzite in the Precambrian Revett Formation with a N. 45° W. strike and variable dip.

The mineralized shear zone has an average attitude of N. 25° W., it is vertical where strong, but weakens where merging with the fault. The zone is widest, 30 in. (76 cm), in the upper adit and narrowest, 1 in. (3 cm), in the lower adit. It has an exposed strike length of 190 ft (58 m), and apparently pinches out at both ends. Mineralization resulted in fissure-filling stringers of quartz or sulfides, or both, along shear planes. Distribution of the stringers is variable. Sulfides in order of abundance are galena, pyrite, sphalerite, pyrrhotite, and chalcopyrite.

Most of the ore above the upper level has been mined out and little is thought to occur below the lower level. The ore remaining is between levels (20 percent mined out) in the narrower parts of the zone. Average width of the zone remaining is about 6 in. (15 cm). Samples taken across the zone over a 4-ft (1.2-m) mining width averaged trace gold, 0.4 oz silver per ton (14 g/t), 1.3 percent lead, 1.8 percent zinc, and trace copper. About 5,900 tons (5,300 t) of measured submarginal resources exist between the levels.

Minor subsidiary mineralized shear zones, as much as 1 in. (3 cm) wide, are exposed in the adit but they lack continuity. Samples across them contained as much as 0.4 oz silver per ton (13.7 g/t), 1.7 percent zinc, and 1.3 percent lead. Samples from portions of the fault contained as much as 0.57 percent lead and 0.45 percent zinc (table 2).

### OCCURRENCES RELATED TO GRANODIORITE INTRUSION AND THE HOPE FAULT

Occurrences north of and related to the Hope fault (pl. 1) are concentrated near Goat Mountain in Precambrian Belt Supergroup rocks. The deposits have been emplaced by a combination of replacement and fissure-filling along minor faults and joints. Cretaceous (?) and Tertiary (?) granodiorite intrusives were probably the source of mineralizing fluids. Large faults, especially the Hope, do not contain ore deposits, because displacement produced sufficient gouge to impede circulation of mineral solutions. Ore-bearing shears cross-cutting large faults, as in the Blue Creek fault zone, are not found. The mineralized faults and joints occur parallel to the Hope fault, or perpendicular to it, and along variously oriented bedding planes. The veins pinch and swell along strike and down dip, and are not individually extensive. Structures trending northwest and parallel to the Hope fault are more pronounced and more mineralized.

The veins are composed of quartz and pyrrhotite with minor amounts of pyrite, galena, sphalerite, arsenopyrite, chalcopyrite, and calcite. The sulfide minerals are intermixed. The sphalerite is black (blackjack) rather than the usual brown. Gold is not common in the veins, but when present it occurs alone, not mixed with the sulfides. Silver content is proportional to lead content. Limonite is the predominant secondary mineral, but marcasite locally replaces pyrrhotite. Wallrock alteration included sericitization and chloritization.

Nine mineral properties were examined; seven are within the study area and two are just outside. Those outside the area are geologically representative of ore deposits in the area, and their distribution is indicative of the probability of other deposits occurring. The Goat Mountain area appears to have little potential for discovery of mineral resources.

*Regal group.*—The Regal group of six claims (pl. 2, no. 1) was first located in 1926. A road was built up Regal Gulch from the Lightning Creek road in 1927 by the Regal Mining Co., and although repaired in recent years, it is now impassable. Only assessment work is being done.

*Data for samples shown in figure 4*

[Tr, trace; N, none detected. All samples are chip samples]

| Sample | | | | Gold | | Silver | | Lead | Zinc | Copper |
|---|---|---|---|---|---|---|---|---|---|---|
| Z-No. | Length ft | (m) | Locality | oz/ton | (g/t) | oz/ton | (g/t) | (percent) | | |
| 96 | 4 | (1.22) | Across mineralized zone | Tr | | 0.9 | (30.9) | 1.76 | 2.94 | Tr |
| 97 | 3 | (.91) | Across pillar in stope | 0.02 | (0.7) | .8 | (27.4) | 2.62 | 14.50 | Tr |
| 98 | 4 | (1.22) | Across mineralized shear | Tr | | .3 | (10.3) | .21 | .12 | Tr |
| 99 | 11 | (3.35) | do | N | | .2 | (6.9) | .18 | .09 | Tr |
| 04 | 4 | (1.22) | do | N | | .1 | (3.4) | .22 | .54 | Tr |
| 05 | 4 | (1.22) | Across fault zone | N | | N | | .17 | .05 | Tr |
| 06 | 4 | (1.22) | Across mineralized shear | Tr | | .1 | (3.4) | 1.72 | .46 | Tr |
| 07 | 4 | (1.22) | Across fault zone | N | | N | | Tr | Tr | Tr |
| 08 | 4 | (1.22) | do | N | | Tr | | .57 | .45 | Tr |
| 09 | 8 | (2.44) | do | N | | .1 | (3.4) | Tr | Tr | Tr |
| 10 | 3 | (.91) | Across mineralized zone | N | | .2 | (6.9) | .80 | .23 | Tr |
| 11 | 3 | (.91) | do | Tr | | .2 | (6.9) | 1.02 | .29 | Tr |
| 12 | 11 | (3.35) | Across fault zone | N | | N | | Tr | Tr | Tr |
| 13 | 15 | (4.57) | do | N | | N | | Tr | Tr | Tr |
| 14 | 25 | (7.62) | do | N | | Tr | | Tr | Tr | Tr |
| 15 | 4 | (1.22) | Across mineralized zone | .03 | (1.0) | .6 | (20.6) | 1.17 | 1.65 | Tr |
| 16 | 12 | (3.66) | Across fault zone | N | | .1 | (3.4) | Tr | Tr | Tr |
| 17 | 4 | (1.22) | Across mineralized zone | N | | N | | .07 | .05 | Tr |
| 18 | 3 | (.91) | Across mineralized shear | .01 | (.3) | .4 | (13.7) | 1.33 | 1.68 | Tr |
| 19 | 3 | (.91) | Across mineralized zone | .02 | (.7) | 1.5 | (51.4) | 3.53 | 9.57 | Tr |

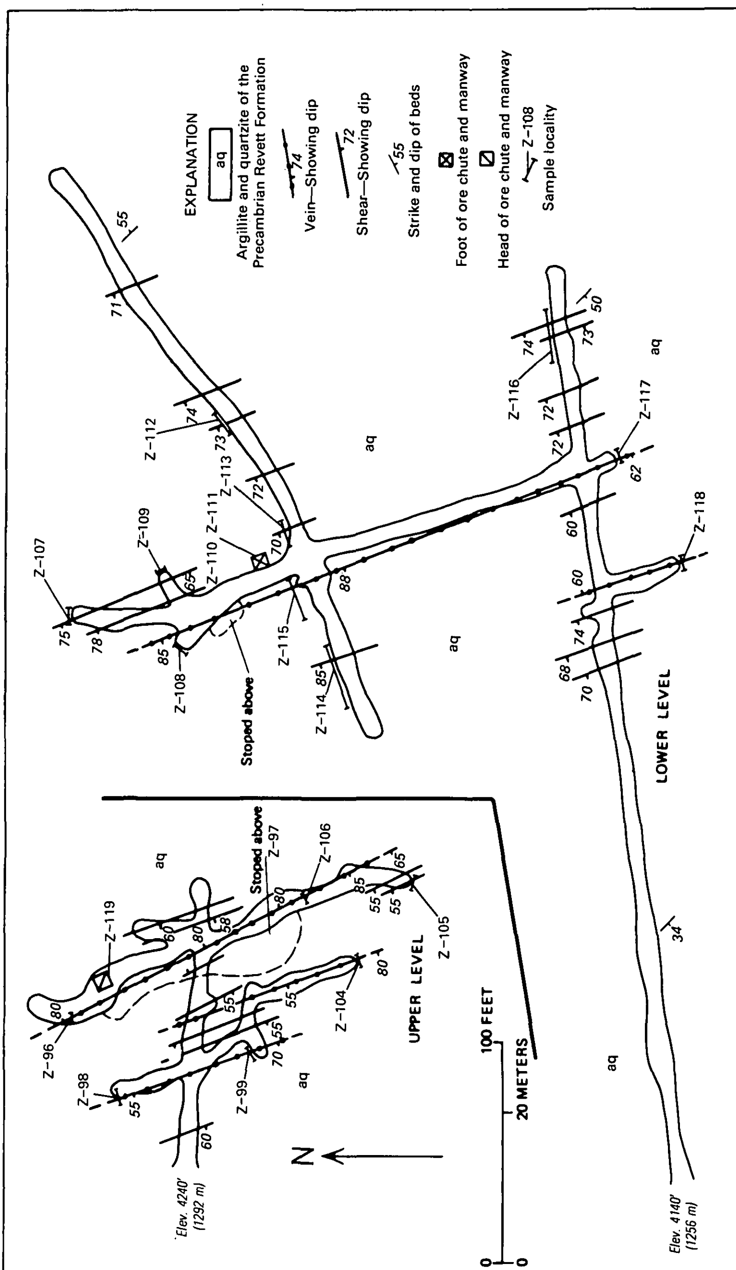


FIGURE 4.—Broken Hill mine, SW ¼ NE ¼, sec. 10, T. 27 N., R. 34 W.

TABLE 2.—*Miscellaneous prospects related to granodiorite intrusion and the Hope fault*

| Pl 1 Map No. | Prospect | Summary | Number and type of workings | Sample data |
|---|---|---|---|---|
| 2 | Dubia | Small sulfide-bearing fissure veins occur in argillite and quartzite. Largest outcropping vein is 3 in. (8 cm) wide and cointains 5 percent pyrite. | Several caved pits | One sample from large vein; negligible assay values. |
| 6 | Gabriel | A N. 50° E.-trending adit crosscuts six northwest-striking, southwest-dipping, quartz-bearing shears. | One adit, 25 ft (7.6 m) long. | Five samples across shears; as much as 0.1 oz gold per ton (3.4 g/t) and 0.2 oz silver per ton (6.9 g/t). |
| 7 | Lucky Strike | A 0.5- to 18-in. (1 to 46 cm) wide fissure vein is exposed in the workings for 95 ft (29.0 m) along a N. 47° W. strike and for at least 200 ft (61.0 m) down a 41° SW dip. Host rock is phyrrhotite-bearing argillite and quartzite, striking N. 50° W. and dipping 40° NE. Vein contains 50 percent quartz, 40 percent gouge, 10 percent pyrrhotite, and minor galena, sphalerite, pyrite, marcasite, and chalcopyrite. Several smaller veins occur. | Three adits, 400 (121.9 m), 35 (10.7 m) and 10 ft (3.0 m) long; four pits; two cabins; 12-in. (30 cm) steel flume, pelton wheel. compressor. | Ten samples of veins; negligible assay values. |
| 8 | McWilliams | Fissure veins are in gray argillite and quartzite containing as much as 10 percent pyrite. Veins contain pyrite, galena, arsenopyrite, and chalcopyrite. | Three caved adits, 140 (42.7 m), 140 (42.7 m), and 70 ft (21.3 m) long; one trench 30 ft (9.1 m) long. | Three samples from dumps; as much as 0.3 oz silver per ton (10.3 g/t), 0.4 percent lead, and 0.2 percent zinc. |
| 9 | Homestake | Thin galena and pyrite stringers occur locally in a zone of widespread fracturing. Quartzite strikes N. 75° E. and dips 20° SE. | Three adits, 156 (47.5 m), 21 (6.4 m), and 10 ft (3.0 m) long. | Six samples from zone; as much as 1.0 oz silver per ton (34.3 g/t) and 1.7 percent lead. |

Considerable development has been done on the property. An open, 140-ft-long (43-m) adit is beside the creek at an elevation of about 4,200 ft (1,300 m). A caved adit and collapsed shop building are 70 ft (21 m) downstream from the open adit. A dam just above the adits connects by flume to a pelton-wheel-driven compressor on the north bank of the creek at 3,800-ft (1,200-m) elevation. A bunkhouse is adjacent to the compressor house, and an adit has been started across the creek.

The upper adits were driven on a fissure vein striking N. 40° to 60° W. and dipping 48°-65° NE. in quartzite. The country rock strikes an average of N. 30° E. and dips 20° SE. The vein occurs on both sides of a lamprophyre dike in the fissure, but only on one side at a time, and is larger on the footwall side. Stringers also extend into and across the dike. Three veins along slippage joints in bedding planes occur as branches to the fissure vein in both the hanging wall and footwall, but are larger in the footwall.

The fissure vein in the open adit (fig. 5) pinches and swells, and is 2-12 in. (5-30 cm) wide. It is composed of quartz and 2 percent combined pyrrhotite, pyrite, galena, and chalcopyrite. Samples taken across it averaged 0.4 oz silver per ton (13.7 g/t), 0.3 percent lead, and trace gold, zinc, and copper. The largest bedding plane vein is near the portal and is 8-18 in. (20-46 cm) wide. These veins are composed of quartz, 8 percent pyrrhotite, 3 percent sphalerite, 3 percent galena, and minor pyrite, arsenopyrite, and chalcopyrite. A silver- and lead-rich pocket occurs at the intersection of the main vein and one of the subsidiary faults (sample Z–70).

The adit 70 ft (21 m) downstream is caved but on the same structure. Anderson (1930, p. 109) reported that the fissure vein and dike have the same character as in the adit above, and that sulfides are confined to bedded seams branching from the fissure vein. Samples from the adit dump averaged 0.01 oz gold per ton (0.3 g/t), 0.4 oz silver per ton (13.7 g/t), and trace lead, zinc, and copper.

An adit across the creek from the compressor house exposes two quartz veinlets, one-half inch (1.3 cm) wide. It may represent original intentions to intersect the main fissure vein at depth. A sample across the face contained no values.

No resources are estimated for the property. Assays indicate a good potential for discovery of gold, silver, copper, lead, and zinc ore in small pockets.

*Goat Mountain group.*—Interest in the Goat Mountain property (pl. 2, Nos. 3, 4) has centered on a number of bedding plane and fissure veins that crop out at an elevation of about 4,000 ft (1,200 m)

*Data for samples shown in figure* 5

[Tr, trace; N, none detected. All samples are chip samples]

| Sample | | | | Gold | | Silver | | Lead | Zinc | Copper |
|---|---|---|---|---|---|---|---|---|---|---|
| Z- No. | Length ft | (m) | Locality | oz/ton | (g/t) | oz/ton | (g/t) | (percent) | | |
| 69 | 0.5 | (.15) | Across fissure vein | 0.01 | (.3) | 0.4 | (13.7) | 0.19 | 0.02 | 0.01 |
| 70 | .1 | (.03) | Across bedded vein | .01 | (.3) | 3.4 | (116.6) | 2.99 | .29 | Tr |
| 71 | 1.0 | (.30) | Across fissure vein | .02 | (.7) | .7 | (24.0) | .57 | .01 | .01 |
| 72 | 1.1 | (.34) | Across lamprophyre dike | N | | N | | N | N | N |
| 73 | 1.0 | (.30) | Across fissure vein | N | | N | | .07 | N | N |
| 74 | .2 | (.06) | do | .02 | (.7) | .7 | (24.0) | .35 | .01 | Tr |
| 75 | 1.5 | (.46) | Across bedded vein | .02 | (.7) | 6.2 | (212.6) | 9.54 | 2.73 | .09 |
| 76 | .7 | (.21) | do | .10 | (3.4) | .3 | (10.3) | .17 | .01 | .03 |

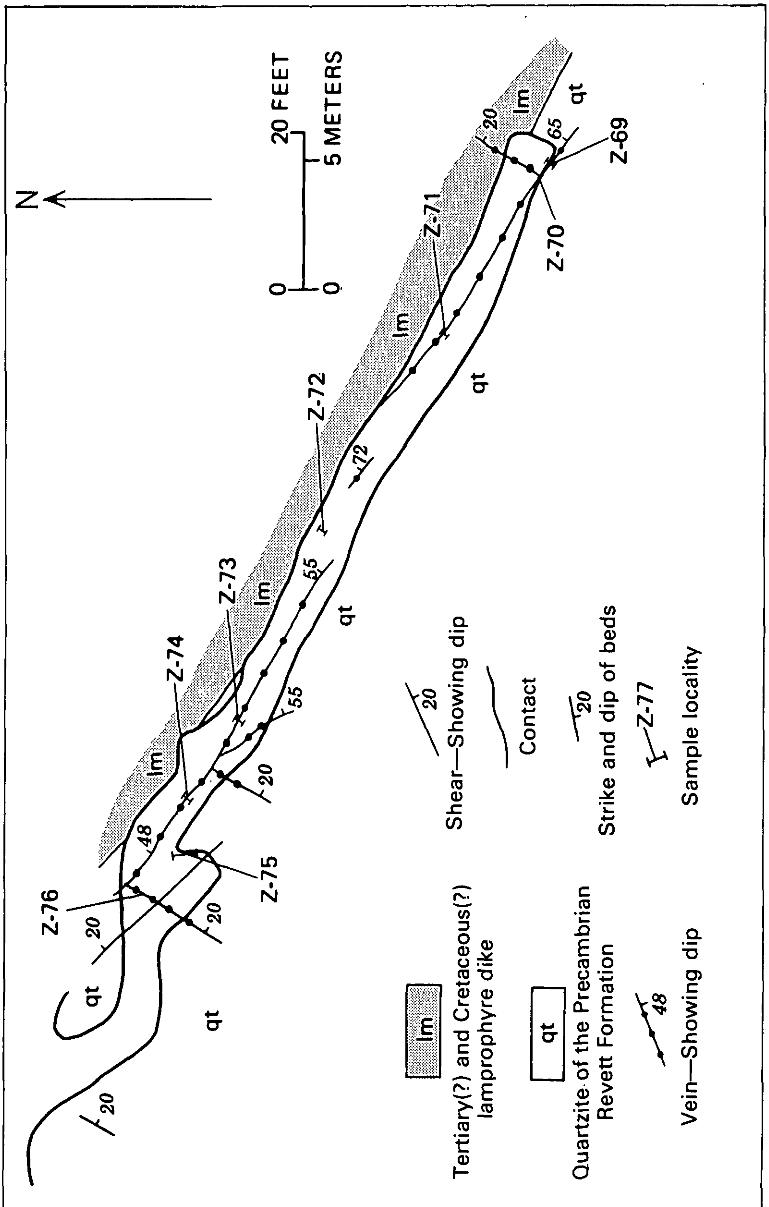


FIGURE 5.—Regal group, upper adit, sec. 17, T. 56 N., R. 35 W.

in the center of NE 1/4 sec. 24, T. 56 N., R. 2 E. The deposit was first claimed in 1916. Access is from the Goat Mountain trail.

Most of the early work consisted of the excavation of a 900-ft (270-m)-long adit by Interstate-Sullivan Mining Co. The portal is beside the Lightning Creek road at an elevation of 2,400 ft (730 m) (pl. 2, No. 3). A 100-ft (30-m)-long crosscut was driven northeast about 600 ft (180 m) from the portal. This attempt to crosscut the bedding plane veins at depth failed. Geometric projection of the adit trend, and dip of the veins, indicates that intersection would require that the adit be about 6,000 ft (1,800 m) long and that the veins extend downdip an unlikely 4,000 ft (1,200 m). The adip does intersect joint sets that strike N. 50°-60° E., two fissure-filling quartz veinlets that strike N. 45°-50° W., and northwest-trending nephelinite dikes. Country rock is argillite, siltite, and quartzite of the Revett Formation that strikes N. 30°-45° E. and dips 12°-20° SE. The quartz veinlets contain small amounts of pyrite, arsenopyrite, limonite, and chlorite. Samples from across the structures assayed negligible values.

In 1926 and 1927, operations were transferred to the outcrops (pl. 1, No. 4) by a new organization, the Goat Mountain Mining Co. The company drove a 200-ft-long (61-m) adit, trending N. 40° E., to crosscut and then drift upon the bedding plane and fissure veins exposed immediately upslope. A cabin, compressor, pump, and engine remain on the dump. Bedding plane veins conform to the attitude—N. 55°-65° W., 21°-27° NE.—of the pyrrhotite-bearing argillite, siltite, and quartzite country rock. These veins occur as replacements along slippage joints in the bedding planes. The fissure veins strike N. 45°-55° W. and dip 50°-60° SW. Both types of veins are longitudinally discontinuous and they pinch and swell from 1 to 18 in. (3 to 46 cm) in thickness, and average 5 in. (13 cm) in thickness. The veins contain as much as 5 percent combined pyrite, pyrrhotite, galena, sphalerite, and chalcopyrite in a gangue of quartz and fragments of country rock. Samples across the veins in and above the adit contained as much as 0.9 oz silver per ton (28 g/t) and 2.47 percent lead. Assays indicate that a few small, high-grade pockets occur.

Several additional discontinuous veins occur near and between the two main adits. The 10- and 37-ft (3- and 11-m) adits, which are 0.4 mi (0.6 km) south of the Interstate-Sullivan adit, were driven on fissure-filling quartz veins trending N. 40° W. and dipping to the northeast. Samples from the veins averaged 0.4 percent lead. A 20-ft (6-m)-long adit, which is 400 ft (120 m) vertically above the Interstate-Sullivan adit, is on a quartz vein that strikes N. 60° E. and dips 40° SE. A sample across this pyrite-bearing vein contained trace silver. Samples from four undeveloped veins elsewhere contained trace silver. Samples from four undeveloped veins elsewhere on the property contained trace silver, lead, zinc, and copper.

*Ponderosa group.*—The Ponderosa property has been worked several times and covers much of the SE 1/4 sec. 24, T. 56 N., R. 2 E. (pl. 2, no. 5). There are three groups of workings (fig. 6).

The upper group of workings is at an elevation of about 3,700 ft (1,100 m) and consists of a 10-ft (3.0-m) -long drift, a shaft, and two caved crosscuts. The drift follows a discontinuous, 3-ft (0.9-m)

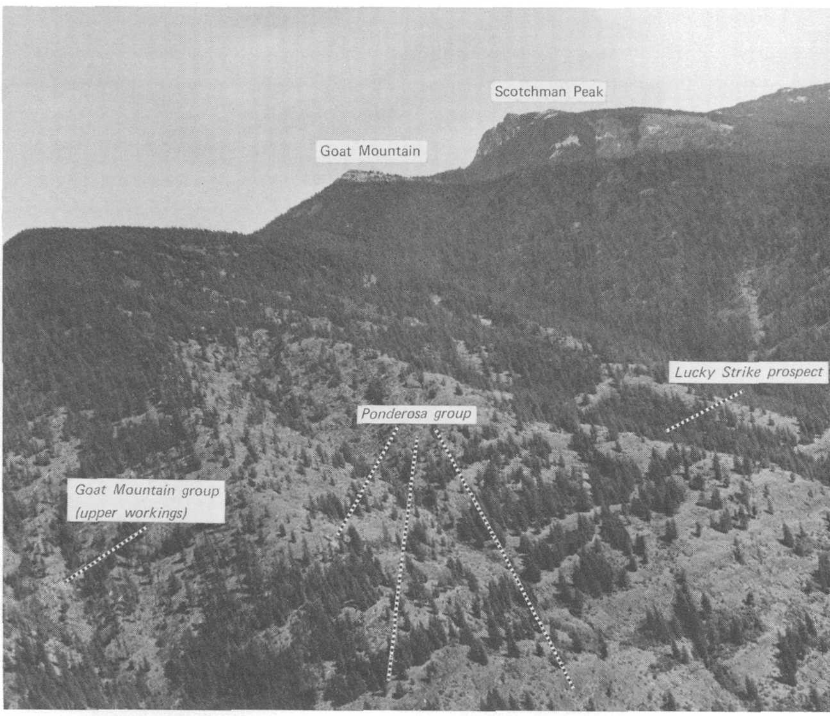


FIGURE 6.—Ponderosa group, SE ¼ sec. 24, T. 56 N., R. 2 E., and nearby prospects.

fissure vein striking N. 50° W. and dipping 60° SW. in argillite. The vein is composed of 65 percent vuggy quartz, 30 percent country rock, and 5 percent limonite boxwork. A sample from across the vein contained 0.01 percent lead and trace copper and zinc. A separate, 2-ft (0.6-m)-wide fissure vein with the same attitude is exposed in the shaft. This vein is composed of vuggy quartz and 1 percent combined galena, pyrite, and limonite. A sample taken across the vein contained 0.1 oz silver per ton (3.4 g/t), 0.03 percent lead, and trace zinc. Two adits, both caved at the portal, probably crosscut the veins below the outcrops. Samples of vein material on the dumps contained no values.

The middle group is at an elevation of approximately 3,400 ft (1,000 m) and consists of a caved variably trending adit, and a sloughed pit. The adit reportedly (Anderson, 1930, p. 112) was on the intersection of a 12-in. (30-cm) bedded vein and a fissure vein. Vuggy quartz containing minor pyrrhotite and galena occurs on the dump. A sample of the quartz assayed 0.04 percent lead.

The lower group of workings is at an elevation of 3,200 ft (970 m) and consists of one adit 15 ft (5 m) long and one adit 30 ft (9 m) long adit. The adits follow the largest two of six outcropping veins. The veins parallel the bedding of the gray argillite and quartzite country rock and strike N. 30° E. and dip 16° NW. They are 4-12 in. (10-30 cm) wide, have strike lengths not exceeding 50 ft (15 m), and are offset by minor shears trending N. 70° W. Composition is about 92 percent quartz, 5 percent galena, 2 percent pyrite and pyrrhotite, 1 percent limonite, and traces of chalcopyrite and bornite. Samples across the veins contained as much as 2.6 oz silver per ton (89.1 g/t), 4.08 percent lead, and trace copper.

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