STUDIES RELATED TO WILDERNESS

WILDERNESS AREAS

SCAPEGOAT, MONTANA

GEOLOGICAL SURVEY BULLETIN 1385-B

Mineral Resources of the Scapegoat Wilderness, Powell and Lewis and Clark Counties, Montana

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With a section on GEOPHYSICAL SURVEYS

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An evaluation of the mineral potential of the area

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1974

UNITED STATES DEPARTMENT OF THE INTERIOR

ROGERS C. B. MORTON, *Secretary*

GEOLOGICAL SURVEY

V. E. McKelvey, *Director*

Library of Congress catalog-card No. 74-600101

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Stock Number 2401-02516

STUDIES RELATED TO WILDERNESS

WILDERNESS AREAS

Under the Wilderness Act (Public Law 88-577, Sept. 3, 1964) certain areas within the National forests previously classified as "wilderness," "wild," or "canoe" were incorporated into the National Wilderness Preservation System as wilderness areas. The act provides that the Geological Survey and the Bureau of Mines survey these wilderness areas to determine the mineral values, if any, that may be present. The act also directs that results of such surveys are to be made available to the public and submitted to the President and Congress.

This bulletin reports the results of a mineral survey of the Scapegoat Wilderness, Montana. Work began in the area prior to its wilderness designation.

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MINERAL RESOURCES OF THE SCAPEGOAT WILDERNESS, POWELL AND LEWIS AND CLARK COUNTIES, MONTANA

By MELVILLE R. MUDGE, ROBERT L. EARHART, and KENNETH C. WATTS, JR., U.S. Geological Survey, and by ERNEST T. TUCHEK and WILLIAM L. RICE, U.S. Bureau of Mines

SUMMARY

A mineral survey of the Scapegoat Wilderness was made by the U.S. Geological Survey and the U.S. Bureau of Mines during the summer of 1970; the U.S. Geological Survey made an aeromagnetic survey in 1966 and a gravity survey in 1970. The area, about 375 square miles, lies about 45 miles northwest of Helena and about 50 miles northeast of Missoula, Mont. Sedimentary rocks of Precambrian Y (Belt Supergroup), Cambrian, Devonian, and Mississippian ages crop out in the area. The Precambrian rocks have been intruded by diorite sills of Precambrian Z age, monzonite and andesite sills of pre-Tertiary age, and aplite dikes of probable Cretaceous age. In addition, there are small exposures of tuff of Tertiary age. In places the rocks, except for the tuff, have been broken by thrust and normal faults and are folded.

The mineral-resource potential of the area was evaluated by detailed examination of the rocks and mining claims, by geological mapping, by geochemical sampling, and by aeromagnetic and gravity surveys. Foot traverses along most ridges and streams in the area resulted in the collection of 3,321 samples, of which 402 are stream pebbles, 523 are water, 690 are stream sediments, and 1,706 are outcrop samples. South of the area, aeromagnetic and gravity data reflect intrusive igneous bodies, some of which contain ore deposits. However, similar geophysical anomalies were not found in the Scapegoat Wilderness. A large positive magnetic anomaly southwest of Scapegoat Mountain is interpreted to indicate a deeply buried (10,500±1,200 ft below ground surface) pluton. Other magnetic trends in the area are related to exposed Precambrian sills.

Copper is the only mineral commodity found that has possible economic importance. Other metallic commodities, such as silver, lead, and zinc, are locally present in low concentrations that are not economically significant. Copper is in quartz-carbonate veins and in green beds in the Precambrian sedimentary rocks.

The copper-bearing quartz-carbonate veins are in the southernmost part of the area—at Mineral Hill, at Bugle Mountain, and in the upper reaches of Copper Creek. They are of hydrothermal origin.

Scattered copper minerals in green to greenish-gray clastic Precambrian rocks are widespread in the Scapegoat Wilderness, but are of insufficient grade and size for exploitation. The copper minerals are commonly in thin strata in green sequences in the Spokane and Empire Formations and in the Snowslip Formation, and locally they are in similar beds in the Helena Dolomite, and in the Shepard, Mount Shields, and McNamara Formations.

County records show that 131 mining claims have been located in the area, but none are known to have produced ore. Most claims are located on and adjacent to veins explored for copper on the southwest edge of the study area. The veins are in the area that extends from Copper Creek to Mineral Hill, a distance of 10 miles. The larger vein deposits are not economically minable but are a potential resource of copper and are likely to be further explored. High-grade samples containing 18.2 and 45.2 percent copper, from the Porto Rico mine at Mineral Hill and a group of prospects at Bugle Mountain, respectively, indicate that small shoots of high-grade ore are present.

The Bugle Mountain group and the Fisher group prospects are contiguous and appear to have more potential than other prospects in the area. Shear zones at these prospects may be as much as 800 feet long, and attendant mineralized rock may be as much as 35 feet thick. Resources at these two prospects are estimated to total about 400,000 tons containing 1-1.8 percent copper. A much larger resource, about 1 million tons, may be present if the mineralized country rock is persistent along the shear zones. The grade of the material is too low for mining to be economically feasible at the present time.

INTRODUCTION

The Scapegoat Wilderness, formerly known as the Lincoln Back Country Area, covers about 375 square miles of rugged mountainous terrain in Lewis and Clark and Powell Counties, Mont. (fig. 1). It is in parts of the Helena, Lolo, and Lewis and Clark National Forests. The Continental Divide defines the northwest edge of the area to Scapegoat Mountain, where the divide then extends southeast across the middle of the area and becomes part of the southeast boundary (fig. 2). The streams southwest of the divide are tributaries of the Blackfoot River, whereas those northeast of the divide are tributaries of the Dearborn and Sun Rivers. The northwest edge of the area borders the Bob Marshall Wilderness (fig. 1).

Scenery in much of the Scapegoat Wilderness is spectacular, as streams and glaciers have carved deep canyons in Precambrian and Paleozoic rocks. Total relief is about 4,400 feet, from an elevation of 5,000 feet along the Blackfoot River to about 9,400 feet on Red Mountain; most ridges and peaks rise above 7,500 feet. The scenic high ridges and peaks are almost barren and expose layers of reddish-brown, grayish-green, and yellowish-gray bedrock. The Paleozoic carbonate rocks, in particular, form precipitous cliffs of more than 1,000 feet. The lower slopes and valleys are more gentle, but locally the streams contain numerous falls and rapids. Slopes and valleys are mostly covered by timber and brush. Timberline is at an elevation of about 8,500 feet.

Access to the Scapegoat Wilderness is by horse trail except near Benchmark Guard Station, where a gravel road extends to the north

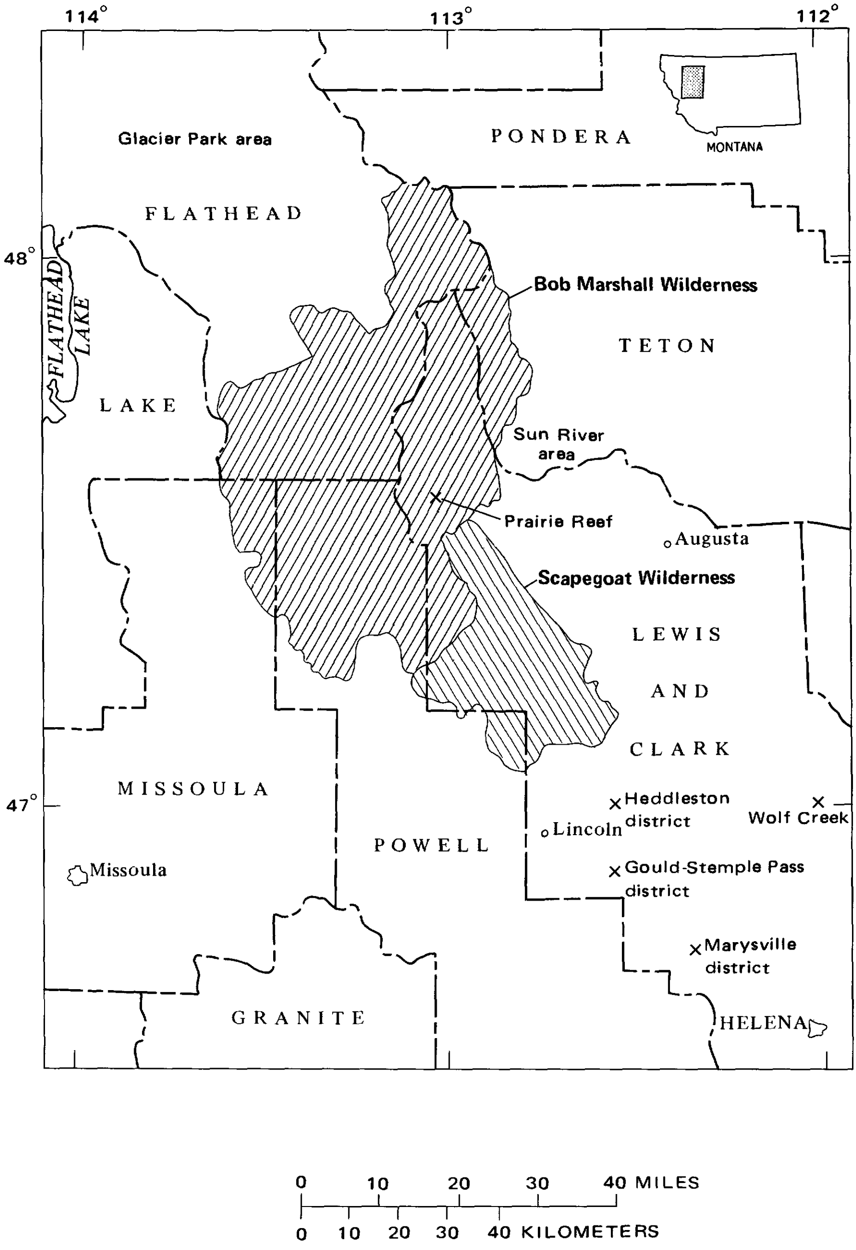


FIGURE 1.—Location of Scapegoat Wilderness and Bob Marshall Wilderness in northwestern Montana.

boundary, and at the head of Copper Creek, where a jeep trail extends to the south boundary. Elsewhere to the east and south, gravel roads terminate 2-3 miles from the boundary. Access from the west is only by a horse trail from the Bob Marshall Wilderness. Travel in the area is by horseback or on foot along marked trails that have been built along most valleys and some ridges.

A variety of maps covers the area. Planimetric maps at a scale of 1 : 125,000 cover the three national forests. Recently compiled 7½-minute topographic maps at a scale of 1 : 24,000 cover the area south of lat 47° 15′ N. Similar maps are being prepared by the U.S. Geological Survey for the northern part. Complete coverage of the area is on substandard Coopers Lake (1900), Ovando (1902), and Saypo (1905) 30-minute (1 : 125,000-scale) topographic maps. The base for plate 1 consists of parts of these three quadrangles combined and enlarged to a scale of 1 : 96,000.

PREVIOUS GEOLOGIC STUDIES

Most previous geologic studies in and adjacent to the Scapegoat Wilderness were limited in scope. Walcott (1906, 1908, 1910) made stratigraphic studies on the Precambrian and Cambrian rocks. Clapp and Deiss (1931) studied the Belt rocks in and adjacent to the area, and Clapp (1932, 1934) published the first geologic map of the area and briefly described the stratigraphy and structure. Metalliferous deposits just south of the area were briefly described by Pardee and Schrader (1933). The Coopers Lake, Ovando, and Saypo quadrangles were mapped by C. F. Deiss in the late 1930's and early 1940's but were never published; he did write many reports on stratigraphy, structure, and paleontology that included parts of the Scapegoat Wilderness (Deiss, 1933, 1939, 1943). Devonian rocks in the lower reaches of the Dearborn River canyon were studied by Sloss and Laird (1946). Glacial deposits in the drainages of the Blackfoot River were discussed by Alden (1953).

More recent studies have been mostly in and adjacent to the northern part of the area. Theses on stratigraphy and structure of small areas were written by Viele (1960), Knapp (1963), Lange (1963), Melson (1964), Sommers (1966), and Funk (1967). Detailed stratigraphic studies of Precambrian rocks in the northern part of the area were published by McGill and Sommers (1967). Similar studies by Mudge (1966b, c; 1972) on Precambrian and Paleozoic rocks, including a geologic map, concerned the very northern part of the area. A reconnaissance study of the geology, geophysics, and geochemistry on the southeastern part of the Lewis and Clark Range was made by Mudge, Erickson, and Kleinkopf (1968). The geophysical data in that report cover all the Scapegoat Wilderness; the aeromagnetic map is included in the present report.

A mineral survey of the Mission Mountains Primitive Area on the Montana-Idaho border by Harrison, Reynolds, Kleinkopf, and Pattee (1969) included a study of Precambrian rocks, like those exposed in the Scapegoat Wilderness. In addition, Harrison and Grimes (1970) discussed the mineralogy and geochemistry of the Belt rocks in the Mission Mountains.

PRESENT STUDIES AND ACKNOWLEDGMENTS

The purpose of the mineral survey is to appraise the mineral resources of the wilderness area. U.S. Geological Survey fieldwork was done between late June and September 1970 by Mudge, Earhart, and Watts assisted full time by Robert Coolidge and Ronald Hooper and part time by William Crim, David Grimes, Mark Teets, and Gustavo Gonsalves. Don Peterson devoted 2 weeks during the period to the gravity survey. Stream sediments, water, and pebbles of altered rock were collected systematically by a field party headed by Watts, who also studied and sampled outcrops along streams. Two field parties headed by Mudge and Earhart made foot traverses along most ridges and closely examined the rocks, collected samples, and geologically mapped the area at a scale of 1 : 62,500; the resulting map (pl. 1) is published at a scale of 1 : 96,000. The studies were greatly aided by helicopter transporation which shuttled the field parties to and from dropoff and pickup points. The total number of samples collected by members of the U.S. Geological Survey is 3,219, of which 402 are stream pebbles, 523 are water, 679 are stream sediment, and 1,615 are outcrop samples. Also discussed are samples previously collected by Mudge and R. L. Erickson—88 outcrop samples, 35 stream-sediment samples, and 7 pebbles. Analyses of other samples east and south of the area were discussed by Mudge, Erickson, and Kleinkopf (1968) and therefore are not summarized in this report. The present report is slightly modified from the open-file report (Mudge and others, 1971).

All samples were prepared and analyzed in three truck-mounted laboratories established at the field headquarters. Water samples were analyzed for copper and molybdenum by A. P. Marranzino, J. G. Viets, and J. R. Hassemer. All other samples were analyzed in a mobile spectrographic laboratory for 30 elements and were scanned for radioactivity by D. J. Grimes and R. T. Hopkins, Jr. Gold was determined by atomic absorption methods by S. K. McDanal; mercury was analyzed by a mercury detector by J. G. Viets, J. R. Hassemer, W. D. Crim, and J. Reynolds. Citrate-soluble heavy metals and copper were determined on all stream sediments by cold-extraction methods by J. A. Thomas and C. Huffman, Jr., in the U.S. Geological Survey laboratories in Denver, Colo. In the same laboratories, all samples above 0.1 ppm (part per million) mercury were rechecked by J. G. Frisken, J. D. Hoffman, and V. Mello. All sample data were checked by Helen E. Eichler and Christine

McDougal before being entered into computer storage. L. O. Wilch, S. K. McDanal, and J. M. Botbol, with Mudge and Earhart, planned the type of data to be stored in and retrieved from the computer. We are deeply grateful to these colleagues whose enthusiastic cooperation greatly benefited the mineral appraisal of the Scapegoat Wilderness.

The U.S. Bureau of Mines searched for records of mining claims in the courthouses of Lewis and Clark and Powell Counties during the spring of 1970. Field investigations were made during the summer by Ernest T. Tuchek, William L. Rice, David W. Lockard, Eldon C. Pattee, and Mark H. Hibpshman.

All claims, prospects, and mines listed in courthouse records were examined in the Scapegoat Wilderness. Field studies included studying geologic features that control the concentration of metals, sampling visibly altered rocks or rocks that displayed evidence of possible metallic minerals, and mapping some prospects and mines. An economic evaluation was made on those prospects which yielded highly anomalous concentrations of valuable metals.

A total of 102 samples was collected by Bureau of Mines personnel and analyzed by spectrographic, petrographic, fire-assay, or chemical methods. Most of the spectographic analyses were made in the U.S. Geological Survey mobile laboratory. Petrographic studies were made by James A. Canwell, Western Field Operation Center, Bureau of Mines. Gold-silver fire assays were performed by the Bureau's Reno Metallurgy Laboratory. Chemical analyses were made by various commercial laboratories.

We are also grateful to many people outside the Geological Survey and Bureau of Mines for their aid during this study. In particular, Bill Worf, H. D. Powell, Jr., Henry Greitl, and Neal Pederson, U.S. Forest Service, were very cooperative during the survey and provided radios for contact with fire lookouts and fire guards.

GEOLOGY

GEOLOGIC SETTING

Scapegoat Wilderness is in the southwestern part of the northern disturbed belt of Montana, a belt that contains many northwest-trending closely spaced thrust faults, some folds, and some high-angle normal faults. The wilderness area contains four major fault blocks (fig. 2); the northeast three are thrust-fault blocks and the southwest one is a normal-fault block (pl. 1). Each block contains sedimentary rocks of the Belt Supergroup of Precambrian age as well as sedimentary rocks of Cambrian and Devonian age. Fault block II (fig. 2) also contains sedimentary rocks of Mississippian age. Diorite sills of Precambrian age and monzonite and andesite sills of pre-Tertiary age occur locally within the Precambrian sedimentary rock sequence. Thin aplite dikes of probable Cretaceous age crosscut the sills and sedimentary rocks in the southern part of the area. Remnants of tuff of Tertiary age are exposed in the valley of Landers Fork. Poorly consolidated gravels of Tertiary or Quaternary age form Lone Mountain and are locally exposed beneath glacial deposits in stream banks along the East Fork Blackfoot River. Most valley sides and floors are mantled by alluvial, glacial, and colluvial deposits. Landslide deposits are common adjacent to outcrops of Cambrian rocks. Structural deformation of the area is related to a Tertiary orogeny which resulted in many thrust and normal faults and folds.

PRECAMBRIAN ROCKS

The oldest and most widespread rocks in the Scapegoat Wilderness belong to the Belt Supergroup of Precambrian Y age. The lower part of the supergroup is not exposed in or near the area. The rocks are divided into nine formations, which are, from oldest to youngest, Spokane and Empire, Helena, Snowslip, Shepard, Mount Shields, Bonner, McNamara, and Garnet Range (table 1). Belt rocks are about 4,600 feet thick in the northeastern part of the area but thicken to more than 32,000 feet in the southwestern part. In the northeastern part of the area, the Garnet Range and, locally, the McNamara and part of the Bonner were eroded prior to deposition of Middle Cambrian rocks. Nevertheless, as shown in figure 2, each formation thins markedly to the northeast. All units are composed mostly of argillites, siltites, and quartzites, except the Helena Dolomite and Shepard Formation, which are mostly carbonate rock. The quartzites are commonly fine grained, but locally one or more beds are medium to coarse grained. The clastic rocks are mostly reddish brown but have interbeds of greenish-gray, gray, and, locally, yellowish-gray tints. The only megascopic fossils are stromatolites—cabbage-shaped colonies of algae that lived on mud flats and in very shallow marine water.

The green to gray clastic rocks and the carbonate rocks locally contain pyrite, which is mostly in the form of cubic crystals. Rarely the red clastic rocks contain goethite pseudomorphic after pyrite.

Radiometric ages of 1,020-1,135 m.y. (million years) were determined by potassium-argon and rubidium-strontium isochron methods on samples from strata between the upper part of the Spokane and Empire Formations and the middle of the McNamara Formation in and adjacent to the northern part of the area (Obradovich and Peterman, 1968); the ages were discussed by Mudge (1972). The Garnet Range Formation and Pilcher Quartzite in the Alberton region of western Montana were dated as 930 m.y. (Obradovich and Peterman, 1968).

SPOKANE AND EMPIRE FORMATIONS

The Spokane and Empire Formations crop out along the southern part of the area, west and south of Evans Peak, along the east side of

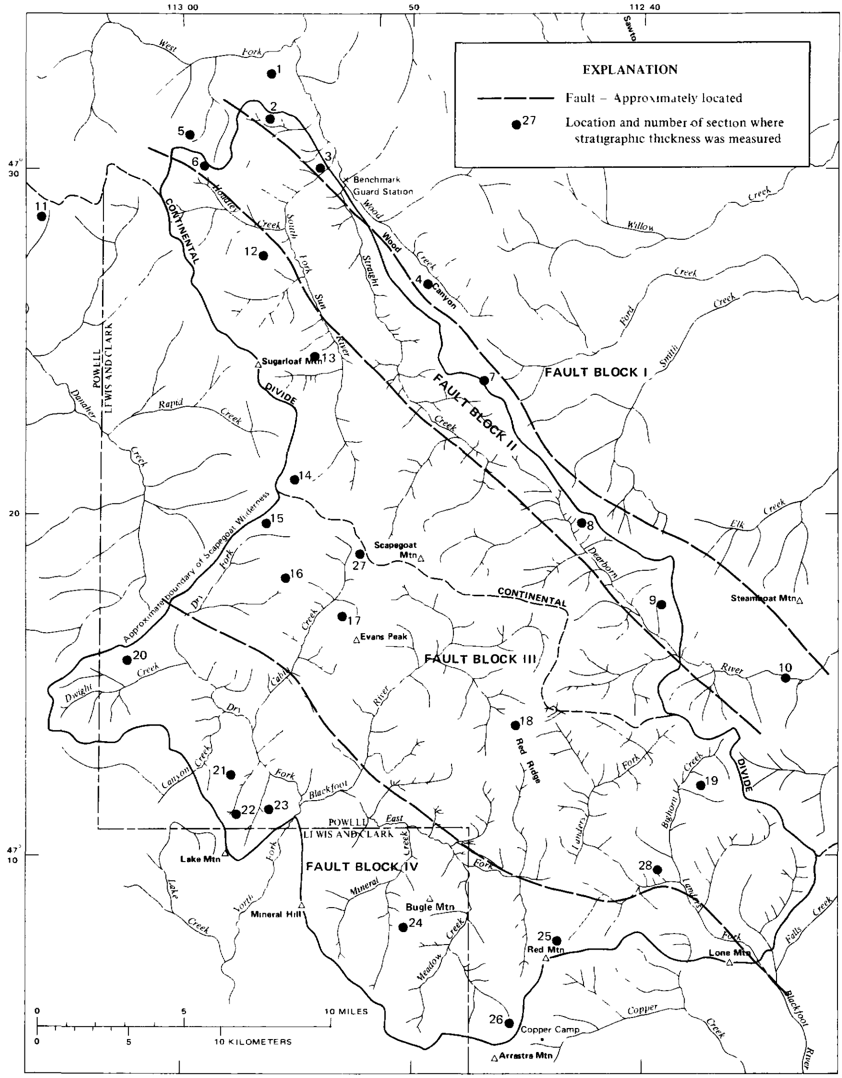


FIGURE 2.—Locations (above) and approximate thicknesses (right) of units in fault blocks in the Scapegoat Wilderness. All thicknesses south of lat 47°15′ were measured from unpublished 1 : 24,000-scale geologic maps; thicknesses north of lat 47°15′ were measured from a 1 : 62,500-scale geologic map or were measured on the ground.

the upper reaches of Bighorn Creek, and in the northeastern part of the area (pl. 1). As much as 8,575 feet of strata comprising these formations is exposed in and adjacent to the southern part of the area (fig. 2). Total thickness of the two formations is much greater than that given because the base of the Spokane is not exposed.

Approximate thickness, in feet, of geologic units in Scapegoat Wilderness

[Locations shown on map]

Geologic unit	Fault block I	Loc.	Fault block II	Loc.	Fault block III	Loc.	Fault block IV	Loc.
Mississippian rocks	([1])	----	([1])	8	----------	----	----------	----
Devonian rocks	----------	----	----------	9	[2]1,200	([2])	----------	----
Cambrian rocks	----------	----	2,235	10	2,650	28	----------	----
			[3]1,950	6	1,725	27	----------	----
			[4]1,800	7	1,850	14	----------	----
Garnet Range Formation.	----------	----	----------	----	[5,6]825-985	11	[6]1,600	20
					[6]475	13	----------	----
McNamara Formation	[3,6]0-400	2	[3,6]400	5	[5]2,655-3,070	11	2,100	20
					2,600	13	----------	----
					2,175	17	----------	----
Bonner Quartzite	[3,6]0-700	2	[3]700	5	[5]1,265	11	1,900	21
					1,575	12	----------	----
					1,500	15	----------	----
					1,400	17	----------	----
Mount Shields Formation.	[3]1,820	2	[3]1,650	5	[5]2,730	11	6,100	21
	[5,6]505-570	4	----------	----	3,700	15	----------	----
					2,325	18	----------	----
Shepard Formation	[3]815	3	[3]775	5	[5]1,980	11	2,350	22
	[5]285-365	4	----------	----	1,500	17	----------	----
					860	18	----------	----
Snowslip Formation	[3]350	3	[3]1,200	5	[5]2,235	11	3,600	23
	[5]230	4	----------	----	2,100	15	2,325	24
	[3]700	1	----------	----	1,800	17	----------	----
Helena Dolomite	[3]625	2	[3]775	5	[5,6]1,480	11	5,450	25
					3,100	16	----------	----
					3,600	19	----------	----
Empire and Spokane Formations.	[5,6]335	4	----------	----	----------	----	[6]8,575	26

[1]Complete section not present in Scapegoat Wilderness area.
[2]Section measured east of Scapegoat Wilderness at Monitor Mountain.
[3]Mudge (1966b).
[4]Deiss (1939).
[5]McGill and Sommers (1967).
[6]Incomplete thickness because of pre-Middle Cambrian erosion or faulting.

FIGURE 2.—Continued.

The Empire Formation is not easily defined in the Scapegoat Wilderness, and therefore it is combined with the Spokane Formation as a single map unit. In the type area near Marysville, Mont., the Empire as defined by Walcott (1899) and Barrell (1907) and as discussed by Knopf (1963) is mainly greenish-gray argillite but has some purplish-weathering dark-red argillite and siltstone that are stratigraphically above the Spokane and below the Helena; dark-red color is the main criterion that distinguishes the Empire from the underlying and overlying formations. In the Scapegoat Wilderness, beds of grayish-green siltite, argillite, and quartzite, locally interbedded with reddish-brown and purplish-gray rocks, underlie the Helena Dolomite in some places. Very likely they are laterally equivalent to the Empire Formation farther south, in the Helena-Marysville area; but even there, the gradational contact was difficult to map, and the two formations were therefore combined into one map unit by Knopf (1963). About 2,000 feet of dominantly grayish-green strata beneath the Helena at the south end of Bugle Mountain is lithologically similar to the Empire described by Knopf (1963). However, just east of Red Mountain only 700 feet of

TABLE 1.—*Rock units in the Scapegoat Wilderness*

Quaternary		Alluvial, glacial, colluvial, and landslide deposits	
Tertiary		Gravel	
		Tuff	
Mississippian	Upper Mississippian	Castle Reef Dolomite	Sun River Member
	Lower Mississippian		Lower member
		Allan Mountain Limestone	Upper member
			Middle member
			Lower member
		Three Forks Formation	
Devonian	Upper Devonian	Jefferson Formation	Birdbear Member
			Lower member
	Middle Devonian	Maywood Formation	
Cambrian	Upper Cambrian	Devils Glen Dolomite	
		Switchback Shale	
	Middle Cambrian	Steamboat Limestone	
		Pagoda Limestone	
		Dearborn Limestone	
		Damnation Limestone	
		Gordon Shale	
		Flathead Sandstone	
Precambrian Y	Belt Supergroup	Garnet Range Formation	
		McNamara Formation	
		Bonner Quartzite	
		Mount Shields Formation	
		Shepard Formation	
		Snowslip Formation	
		Helena Dolomite	
		Empire and Spokane Formations	

dominantly grayish-green strata lies beneath the Helena, and just south of Evans Peak reddish-brown strata underlie the Helena. Apparently, from one exposure to another these strata change abruptly in color; there is no evidence of an unconformity at or near the base of the Helena.

Some of these changes in color may be the result of metamorphism caused by a Precambrian Z diorite sill that intruded strata of the Spokane and Empire Formations everywhere except in the northwest corner of the area. Beds adjacent to the sill are altered to maroonish-gray, olive-green, and medium-gray hornfels. In the southern part of the area the sill is about 3,000 feet below the Helena; as much as 1,000 feet of strata above the sill and 5,900 feet of strata beneath it have been altered to hornfels. West of Evans Peak the sill is in the uppermost beds of the Spokane and Empire Formations; adjacent strata above and below the sill, including the lower part of the Helena, have been metamorphosed. Along the east side of the upper reaches of Bighorn Creek the sill inflects across the strata of the Spokane and Empire Formations toward the north to a position just below the Helena Dolomite; all exposed strata of the Spokane and Empire have been changed to hornfels.

The Spokane and Empire Formations consist mostly of pale-reddish-brown strata that locally have some grayish-green to gray beds in the upper part. The rocks are thinly bedded siltites containing some interbedded argillites and very fine to medium-grained quartzites. Minute crossbeds and ripple marks are locally in the beds of quartzite and siltite. In places the siltite beds contain very thin laminae of argillite.

The upper part of the Spokane and Empire is calcareous; the amount of carbonate increases upward, so the strata grade into the Helena Dolomite. Thin beds of dolomitic siltite, flat-pebble conglomerate, and gray poorly sorted calcareous quartzite are locally in the transitional sequence.

This gradational contact is here placed at the base of calcareous siltite and quartzites that weather light brown; these lower beds of the Helena contain considerably more carbonate than the underlying pale-olive-weathering beds of the Spokane and Empire. At Evans Peak, however, the contact is sharp and distinct because beds of stromatolite rest in sharp contact on beds of red-brown siltite.

HELENA DOLOMITE

The Helena Dolomite crops out in the southern part of the area, along the Blackfoot River, on both sides of the upper reaches of Dry Fork, at Evans Peak (fig. 3), in the upper reaches of Landers Fork, east and south of Bighorn Creek, and in the northernmost part of the area (pl. 1). The Helena is 5,450 feet thick in the southern part of the area

FIGURE 3.—Evans Peak (high peaks at left) and ridge extending north (right), showing exposures of Helena Dolomite (p€h) and Snowslip (p€sn) and Shepard (p€s) Formations.

but thins to 625 feet in the northern part (fig. 2). It is 575 feet thick in the Dearborn River canyon, about 5 miles east of the wilderness boundary. The Helena weathers a distinct light brown and forms even-bedded ledges.

The lower part of the Helena is mostly thin yellowish-gray to light-gray beds of dolomite, dolomitic siltite, and some calcareous quartzite. A calcareous sandstone unit locally present at the base of the Helena is about 3 feet thick in the northern part of the area (Mudge and others, 1968, p. E10) and 4-6 feet thick in the southern part, but it is absent at Evans Peak and in the upper reaches of Bighorn Creek. The beds of dolomitic siltite are yellowish gray and locally maroonish and purplish gray. In places beds of stromatolitic and oolitic limestone occur in the lower part of the formation, but they are more common in the middle and upper parts.

The middle and upper parts, which constitute most of the Helena, are mostly thin even beds of medium- to dark-gray dense dolomite and some dolomitic limestone and limestone; they weather yellowish gray to light brown. The middle part is characterized by beds of dolomite containing some beds of stromatolitic and oolitic limestone and flat-pebble conglomerate. The upper part of the Helena is similar to the middle part except that the upper part contains some moderately thin beds of dark-gray dolomitic mudstone. Beds are mostly less than 1 foot thick, and most oolitic limestone and flat-pebble conglomerate beds are less than 8 inches thick. The conglomerates consist of angular randomly oriented to shingled dolomite fragments derived mostly from stromatolite colonies. The thickest beds of stromatolitic limestone (3½ ft) are in the northernmost part of the area. The oolitic beds consist of medium- to fine-grained mostly spheroidal oolites and some clear quartz grains. In the southern part of the area some carbonate beds contain horizontal and vertical dark-gray ribbons (molar-tooth structure) like those described by O'Connor (1967) from the southern end of the Mission Mountains, Mont.

Joints filled with calcite and, locally, with barite are locally abundant in the middle and upper parts of the Helena and are as much as 10 inches wide.

The contact between the Helena Dolomite and Snowslip Formation is mostly gradational through a sequence of strata as much as 200 feet thick. The gradational sequence of beds is best developed in exposures between Evans Peak and Bighorn Creek. The amount of carbonate decreases upward from beds of dolomite through beds of dolomitic mudstone and dolomite to beds of siltite that contain little dolomite. The contact is placed at the top of the dominant dolomitic mudstone sequence, beneath yellowish-gray-green calcareous siltstones that have interbedded coarse-grained sandstone. In the southern part of the area the contact is gradational through less than 50 feet of beds of silty dolomite. The contact west of Bighorn Creek and in the northernmost part of the area is sharp and distinct because red-brown siltite and quartzite overlie thick beds of dolomite.

SNOWSLIP FORMATION

The Snowslip Formation is well exposed on ridges in the southern part of the area, west and north of Evans Peak (fig. 3), between the North Fork Blackfoot River and the upper reaches of Landers Fork, in the area east of Bighorn Creek, and in the northeastern part of the area (pl. 1). The Snowslip comprises the crest and north slope of Red Mountain. The formation is about 3,600 feet thick in the southern part of the area but thins to 350 feet in the northeastern part (fig. 2).

The Snowslip consists mostly of beds of siltite that are typically reddish brown, but it includes lenticular grayish-green intervals that range in thickness from a few inches to as much as 100 feet (fig. 4). The stratigraphic position of the grayish-green sequences differs from one exposure to another; they appear to be more common and thicker in the lower half of the formation. Along strike the color changes abruptly without a change in lithologies. Also, the color locally transgresses obliquely across the bedding.

Although the Snowslip consists mostly of siltite, it contains some locally calcareous lenticular beds of argillite and quartzite (fig. 4). The beds of siltite and argillite are finely micaceous and thinly laminated to very thinly bedded (as much as 2 in. thick); many beds contain very thin laminae and cross laminae. Some pairs of laminae show graded bedding from silt to fine sand. The quartzite beds, as much as 6 inches thick, are composed mostly of very fine to medium-grained micaceous quartz sand; some beds show graded bedding. Crossbedding, mud cracks, and ripple marks are common features, and angular mud chips are in some beds of siltite. Salt-crystal casts are in the middle of the Snowslip in exposures on the ridge south of Meadow Creek. Iron-cross twin pyritohedrons were observed at sample localities L102a, L159a, and L198c (pl. 2). Elsewhere the pyrite is mostly cubic.

Beds of stromatolite, oolitic limestone, and flat-pebble conglomerate, as much as 18 inches thick, occur locally at various stratigraphic positions in the formation. The thickest stromatolitic limestone beds are in the northeast part of the area. West of the upper reaches of Dry Fork many of them are heavily iron impregnated. The oolitic limestone consists of large oolites and some scattered quartz grains. The conglomerates, composed of angular fragments of limestone as much as 2 inches across, are commonly associated with stromatolite beds and very likely were derived from them.

The lower part of the Snowslip is gradational with the underlying Helena Dolomite, and it is best exposed from Evans Peak to Bighorn Creek and in the area north of Mineral Hill. In these areas the lower 100 feet of the Snowslip contains beds of calcareous grayish-green siltite and some argillite, stromatolitic and oolitic limestone, fine-grained quartzite, and coarse-grained oolitic quartzite. The amount of

FIGURE 4.—Part of the Snowslip Formation exposed on the ridge just southeast of the North Fork Blackfoot River at sample localities L177-L178 (pl. 2). Light beds are grayish-green siltite and quartzite; dark beds are reddish-brown siltite and quartzite.

carbonate increases toward the base of the formation. The beds of coarse-grained oolitic quartzite, as much as 3 feet thick, are characteristically pinkish gray to reddish gray. They are composed of rounded to subrounded grains of quartz, red siltite and argillite, and oolites. Some angular fragments of argillite, one-half inch across, are along bedding planes.

The contact between the Snowslip and the overlying Shepard Formation is conformable and is commonly sharp but locally gradational. In most places a zone of yellowish-gray dolomitic siltite and thinly interbedded stromatolitic limestone of the Shepard lies in sharp contact on reddish-brown siltites of the Snowslip. In the western part of the area beds of yellowish-gray siltite and interbedded reddish-brown siltite of the Shepard are gradational with those of the Snowslip, and the contact is placed at the base of the lowest yellowish-gray unit.

SHEPARD FORMATION

The Shepard Formation is easily recognized on the ridges, where it forms a distinctive grayish-yellow band between the dominantly reddish-brown Snowslip and Mount Shield Formations. The Shepard crops out between Canyon Creek and the North Fork Blackfoot River, east of the lower reaches of Mineral and Meadow Creeks, north and west of Evans Peak (fig. 3), between the North Fork Blackfoot River and Landers Fork, in small areas just west and east of Bighorn Creek, and in the northern part of the wilderness area (pl. 1). The Shepard is about 2,350 feet thick in the southern part of the area but thins to about 815 feet in the northeastern part (fig. 2). An exposure of the formation along Wood Canyon was described in detail by McGill and Sommers (1967, fig. 2a).

The Shepard is mostly thinly laminated dolomitic siltstone interbedded with thin beds of fine-grained sandstone and quartzite, argillite, dolomite, limestone, oolitic and stromatolitic limestone, and flat-pebble conglomerate. It is mostly gray to yellowish gray but has greenish-gray and reddish-brown beds in the middle part. Oolitic beds 4-6 inches thick and beds of stromatolitic limestone and flat-pebble conglomerate as much as 15 inches thick are common in the lower part of the formation; they are similar to those in the underlying formations. Lenticular very thinly laminated and cross-laminated glauconitic siltites and quartzites occur locally in the middle and upper parts of the Shepard. Load casts, ripple marks, filled mud cracks, and minute cross-laminations are common, especially in the upper part.

The contact between the Shepard and the overlying Mount Shields Formation is gradational through about 100 feet of beds of yellowish-gray siltite and some layers of very thinly bedded reddish-brown quartzite and siltite. The contact is placed at the top of the uppermost yellowish-gray unit.

MOUNT SHIELDS FORMATION

The Mount Shields Formation is a thick almost entirely bright-reddish-brown unit that forms all of Red Ridge and parts of adjacent ridges to the west (pl. 1). It is also exposed in the western part of the area, west of the North Fork Blackfoot River; in a narrow band south of Scapegoat Mountain which trends east to the Dearborn River and then bends northwest and extends to the northwest corner of the mapped area; and in the Straight Creek-Deadman Hill area (pl. 1). The Mount Shields is at least 6,100 feet thick in the southwestern part of the area but thins to the north to about 1,820 feet in the Deadman Hill area. On the west side of Wood Canyon it was described in a measured section by McGill and Sommers (1967, fig. 2a).

The Mount Shields consists of bright-reddish-brown very micaceous mudstone and quartzite containing a thin widespread sequence of greenish-gray to gray beds in the upper part. In most places the formation is lithologically divisible into two units; the lower part of the formation is mostly quartzite, and the upper part is mostly mudstone. Mudge (1966b) mapped these two units as part of the now abandoned Hoadley Formation in the northernmost part of the area. Northwest of the area Sommers (1966, p. 26-27) divided the formation into three members. His lower and upper members correlate with the units of Mudge (1966b); his middle member is a thick (550 ft) prominent quartzite unit similar to a quartzite sequence in the southwestern part of the Scapegoat Wilderness that extends as far east as Red Ridge.

The lower part of the Mount Shields is mostly beds 2-6 inches thick of very fine grained quartzite that is locally interbedded with very thin sequences of siltite and argillite. The quartzite beds form prominent red hillside ledges, especially in the northern outcrop area. The beds characteristically contain ripple marks, cross-laminations, mud-crack fillings, angular unoriented fragments of very dark red brown mudstone, load casts, and some raindrop impressions, rill marks, and flute casts. Salt-crystal casts are in the upper part of this sequence in the Deer Creek area (Mudge, 1966b).

In the southern part of the area a quartzite sequence 500-1,000 feet thick near the middle of the Mount Shields is well exposed on Red Ridge and thickens to the west. The sequence consists of even-bedded quartzite beds less than 2 feet thick, locally separated by reddish-brown mudstone. Most quartzite beds are fine to medium grained, but a few are very coarse grained and poorly sorted. The beds vary from pinkish gray to reddish brown; the light-colored beds resemble some strata in the Bonner Quartzite. Some beds are mottled pinkish gray or yellowish gray and contain crossbeds, ripple marks, and angular mud chips.

The upper part of the Mount Shields is mostly bright-reddish-brown mudstone but contains some interbedded quartzite; many beds are locally mottled yellow. A widespread grayish-green unit, 30-50 feet thick is present 200-300 feet below the top of the formation. In the Red Ridge area the unit consists of light-greenish-gray to yellowish-green siltite and argillite. Farther west the unit contains many very thinly bedded very fine grained quartzites. In the area northeast of Scapegoat Mountain the unit contains two sequences of dark-gray fissile shale interbedded with gray to greenish-gray mudstone and thinly bedded quartzite.

Salt-crystal casts are widespread in thinly bedded red-brown siltite and very fine grained quartzite about 100 feet below the greenish-gray sequence. They are also at or near this horizon to the north in the Sun River area (Mudge, 1972), to the west in the Camp Creek area (Sommers, 1966; McGill and Sommers, 1967), and farther to the north in the Glacier Park area (Willis, 1902; Fenton and Fenton, 1937; Childers, 1963; Smith and Barnes, 1966). In the Helena area, to the south, they are in the upper part of the Marsh Formation (Knopf, 1963), a term now abandoned (Harrison, 1972), which is laterally equivalent to the upper part of the Mount Shields.

Rocks of the Mount Shields lie conformably beneath the Bonner Quartzite. In the northern part of the area the contact between the two formations is sharp; elsewhere, quartzite beds of Bonner lithology are interbedded with mudstones of Mount Shields lithology through a sequence 30-50 feet thick. The contact is placed at the top of the uppermost mudstone; all rocks above it are quartzite of the Bonner.

BONNER QUARTZITE

The Bonner Quartzite forms smoothly rounded high knobs on the ridges in the northern and western parts of the area, just northeast, east, and south of Scapegoat Mountain, and on Red Ridge (pl. 1). Large residual boulders are scattered over much of the outcrops. The Bonner is 1,900 feet thick in the southwestern part of the area but thins to 700 feet in the northern part (fig. 2). In the type area, near Missoula, it is 800 feet thick, according to Nelson and Dobell (1961, p. 201); however, about 5 miles to the southwest they noted that it is more accurately 1,-500 feet thick. In the Sun River area the Bonner was formerly referred to as the lower member of the Ahorn Quartzite by Deiss (1943) and Mudge (1966b, c).

The Bonner consists of quartzite beds, 1-3 feet thick, that are mostly well indurated. The beds consist of fine- to medium-grained subrounded to rounded quartz and subordinate amounts of feldspar. Most beds range from pink through pale red and gray to pinkish gray. Many are mottled light grayish orange to pale reddish brown. They are commonly crossbedded and locally contain ripple marks. In many places they contain fracture fillings of white quartz and, locally, barite.

The contact between the Bonner and the overlying McNamara Formation is conformable and poorly exposed in the area. In most places where the contact was observed it is sharp and distinct—greenish-gray mudstone of the McNamara rests on quartzite of the Bonner. However, in exposures along the boundary west of Scapegoat Mountain, northwest of the area at Camp Creek (Sommers, 1966), and near Prairie Reef (Mudge, 1972), the contact is transitional over an interval of about 30 feet—quartzite is interbedded with the lower mudstones of the McNamara.

McNAMARA FORMATION

The McNamara Formation is poorly exposed in the vicinity of Scapegoat Mountain, between Landers Fork and Bighorn Creek, and in the westernmost and northwestern part of the area (pl. 1). It is 400 feet thick in the northern part of the area, just east of Nineteen mountain (Mudge, 1966b), where much of the formation was eroded prior to deposition of the Middle Cambrian Flathead Sandstone. In the western part of the area the entire formation is present, and it is overlain by the Garnet Range Formation. East of Sugarloaf Mountain the McNamara is about 2,600 feet thick (fig. 2), which is similar to the thickness (2,653 ft) measured by Sommers (1966) along the strike of the formation in the Camp Creek section, west of the area. In the southwesternmost part of the wilderness area the formation is about 2,100 feet thick (fig. 2).

The McNamara is divisible into two distinctive lithologic units of nearly equal thickness. The lower unit is composed of siltite and argillite and some quartzite and sandstone. The beds are mostly grayish green to gray and locally have some maroonish-gray tints. The quartzite and sandstone beds are very thinly bedded, fine to medium grained, poorly sorted, micaceous, and locally ripple marked and crossbedded. Thin beds of fine- to medium-grained greenish-gray glauconitic sandstone are common in the upper part of the unit. In most places the middle and upper parts contain small nodules and lentils of pinkish-gray to red-brown vuggy jasperoid, some of which contain barite.

The upper unit of the McNamara consists of reddish quartzite and interbedded siltite, closely resembling the lower part of the Mount Shields Formation. The beds of quartzite are mostly less than 6 inches thick, very fine to fine grained, micaceous, minutely crossbedded, and locally ripple marked.

The contact between the McNamara and the overlying Garnet Range Formation is in a sequence of transitional beds less than 50 feet thick. The uppermost reddish-brown beds of the McNamara contain some medium-gray to pale-olive strata like those in the Garnet Range. The contact is placed at the top of the uppermost reddish-brown bed.

GARNET RANGE FORMATION

The Garnet Range Formation is the youngest unit in the Belt Supergroup in the Scapegoat Wilderness, and it is present only in the western part of the area (pl. 1); elsewhere, it was eroded prior to deposition of the Middle Cambrian Flathead Sandstone. Where present, the Garnet Range Formation ranges in thickness from 475 to as much as 1,600 feet (fig. 2); everywhere it is overlain unconformably by the Flathead Sandstone.

The Garnet Range consists of 2- to 5-inch beds of poorly sorted very fine to fine-grained micaceous pale-olive to medium-gray well-indurated quartzite that are characteristically speckled by hematite, as are the sandstone beds of the Flathead Sandstone. The beds are crossbedded and ripple marked, and they weather into large slabs of even thickness. They contain greenish-gray angular fragments of mudstone. To the west Sommers (1966, p.43) noted that chlorite makes up as much as 20 percent of the matrix of the rock.

CAMBRIAN ROCKS

Cambrian rocks were divided into eight formations (table 1) in the Lewis and Clark Range by Deiss (1939), but they are shown as a single unit on plate 1. They crop out on both sides of Dry Fork, between Bighorn Creek and Landers Fork, at Scapegoat Mountain (fig. 5), at

FIGURE 5.—East face of Scapegoat Mountain. All light-colored cliff-forming rocks are Cambrian. Most of the tree-covered area in front of the cliffs is underlain by the McNamara Formation, whose lowermost beds are exposed in the lower left-hand corner of the photograph. €d, Dearborn Limestone; €p, Pagoda Limestone; €st, Steamboat Limestone; €s, Switchback Shale; €dg, Devils Glen Dolomite.

Sugarloaf Mountain, at Hoadley Reef and Nineteen mountain, and along the ridges between the South Fork Sun River and Wood Creek (pl. 1). These rocks range in thickness from 1,800 feet in the northeastern part of the area to about 2,650 feet in the southeastern part (fig. 2). Cambrian rocks in and adjacent to the area were described in detail by Deiss (1939) and Mudge (1972) and briefly by Mudge, Erickson, and Kleinkopf (1968). Therefore, they will be only briefly discussed in this report.

The Flathead Sandstone, the basal Middle Cambrian unit, rests unconformably on several Precambrian units from the Garnet Range Formation on the west to the middle part of the Mount Shields Formation on the east. The angularity of the unconformity is most evident when stratigraphic sections are compared from one ridge to another, especially in the northern part of the area (pl. 1). It is apparent also in the vicinity of Suglarloaf Mountain, where the Garnet Range Formation is locally absent. The Flathead is a poorly sorted poorly indurated yellowish-gray to gray quartz sandstone that locally grades into a well-indurated quartzite; it contains some quartz pebbles as much as 4 inches across. The sandstone is characteristically mottled by brown iron-oxide stains. The formation, ranging in thickness from about 80 to 115 feet (Deiss, 1939, p. 31-37), consists of beds 2 inches to 2 feet thick.

The rest of the Cambrian sequence (table 1) consists of two mudstone units (Gordon and Switchback) and five carbonate units (Damnation, Dearborn, Pagoda, Steamboat, and Devils Glen). The carbonate units form steep, nearly vertical cliffs, whereas the mudstone units form low-angle slopes (fig. 5). At Scapegoat Mountain (fig. 5) the thickest unit is in the Devils Glen Dolomite (350 ft), which forms the peak of the mountain (Deiss, 1939, p. 31). Cliff-forming units are the Pagoda Limestone (about 300 ft thick) overlain by the Steamboat Limestone (about 255 ft thick). All carbonate formations are thin bedded; most contain a thin calcareous shale unit.

DEVONIAN ROCKS

Devonian rocks crop out north of Dry Creek, along Bighorn Creek, on top of Scapegoat Mountain, on the west flank of Steamboat Mountain, at and northeast of Crown Mountain, and at Patrol Mountain (pl. 1). Complete thicknesses of these rocks were not obtained because in most places the rocks are folded and faulted. At Monitor Mountain, just east of the area, they are about 1,200 feet thick (Sloss and Laird, 1946). To the northeast, in the Sun River area, they are 950 feet thick (Mudge, 1966a).

Devonian rocks, although divisible into the Maywood, Jefferson, and most of the Three Forks Formations, (table 1), are mapped as a single unit on plate 1. The Maywood, about 200 feet thick, consists of interbedded grayish-green and minor grayish-red dolomitic mudstone in the lower part and thinly bedded dark-gray limestone in the upper part. The Jefferson Formation, about 700 feet thick, consists of an unnamed lower member, about 500 feet thick, and the Birdbear Member, about 200 feet thick (Mudge and others, 1968, p. E12). The unnamed lower member contains moderately thin grayish-brown sugary-textured beds of limestone, dolomitic limestone, and dolomite. Locally, one or more sequences of evaporite-solution breccia contain angular fragments of dolomite, some of which are 1 foot or more across. The Birdbear Member is mostly very thin beds of pale-yellowish-brown finely crystalline dolomite that pinch and swell. The Three Forks Formation, about 300 feet thick, contains thin beds of gray limestone in the lower part, thick massive evaporite-solution breccia in the middle part, and the green mudstone and yellowish-brown siltstone containing a thin black shale in the upper part. The black shale is about 11 feet thick at Crown Mountain and 20 feet thick at Monitor Mountain (R. C. Gutschick, written commmun., 1965). The contact between the Devonian and Mississippian rocks is at the base of a yellowish-brown siltstone unit above the black shale; it represents a minor disconformity.

MISSISSIPPIAN ROCKS

Mississippian rocks (Madison Group) are present along the east border of the area at the head of Bighorn Creek, in the Dearborn River and Straight Creek areas, and at Crown Mountain (pl. 1). Complete sections of the Madison Group, about 1,225 feet thick, are present to the northeast in the Sun River area (Mudge and others, 1962), where the group is divided into two formations of about equal thickness that contain five members (table 1). In the Scapegoat Wilderness the Castle Reef Dolomite is the only formation present in most thrust-fault blocks. However, an erosional remnant of the Allan Mountain Limestone crops out in the vicinity of Crown Mountain. The Allan Mountain limestone is mostly very thinly bedded dark-gray limestone containing dark-gray chert lentils and nodules in the middle part and thick-bedded medium-gray limestone in the upper part. The Castle Reef Dolomite is mostly thick-bedded medium- to light-gray dolomite that contains some interbedded dolomitic limestone in the lower and middle parts; the upper part is the Sun River Member, which consists of very light gray moderately thick bedded dolomite.

TERTIARY ROCKS

An unknown thickness of light-gray fine-grained siliceous tuff of Tertiary age crops out in Landers Fork in the southern part of the area. The tuff consists of shards and subhedral to euhedral crystals of light-gray to amber quartz and sanidine and minor mafic minerals; locally, fragments of limestone country rock are included. The tuff is highly porous and easily weathered. It is similar in composition and texture to a crystal tuff south of Lincoln, Mont. (Melson, 1964), which is in an upper rhyolite series of middle Tertiary volcanic rocks; the tuff mapped in the Scapegoat Wilderness is probably the same age.

PREGLACIAL GRAVEL

Deposits of gravel of either late Tertiary or early Quaternary age are at Lone Mountain and locally along the East Fork Blackfoot River. They are overlain unconformably by glacial till; at Lone Mountain, the till rests unconformably on the flanks of the gravel deposit. At Lone Mountain the gravel is as much as 2,250 feet thick, but elsewhere it is less than 100 feet thick. The deposits consist of poorly sorted mainly pebble and cobble quartzite gravel in a sandy silt matrix. In places the deposits are well cemented. Boulders as much as 1 foot across occur locally in the Lone Mountain deposit.

SURFICIAL DEPOSITS

Surficial deposits of Pleistocene and Holocene ages mantle the floors and sides of most valleys (pl. 1). Till is in the upper reaches of the more extensive drainages and forms moraines along parts of many large valleys. Alluvium, some of which is glacial outwash, is along most streams. Alluvial fans are common where small streams emit onto broad valley floors. Talus deposits lie along the bases of cliffs, whereas colluvial deposits mantle most hillsides. Landslide deposits are most common in the western part of the area, especially in Cambrian carbonate rocks.

IGNEOUS ROCKS

Various kinds of igneous rocks ranging in age from Precambrian to Cretaceous (?) crop out in the Scapegoat Wilderness; they cover only a small fraction of the area. Most igneous rocks form sills that crop out in the southern, west-central, and northern parts of the area; a few dikes are in the southern part of the area.

PRECAMBRIAN SILLS

Sills of Precambrian Z age are widespread in and adjacent to the area (pl. 1). In the southern part of the area thick diorite sills intrude the Spokane and Empire Formations, and in the northern part, at Wood Canyon, a diorite sill intrudes the Spokane and Empire Formations and inflects upward across the Helena Dolomite into the Snowslip Formation (Knapp, 1963; Mudge and others, 1968). The sills are as much as 900 feet thick along the south boundary of the area, but elsewhere they are 200-500 feet thick. Mica and (or) hornblende from samples from the northern part of the Scapegoat Wilderness and adjacent areas have been dated as late Precambrian in age (750±25 m.y.) by potassium-argon methods (J. D. Obradovich, oral commun., 1966).

The sills range in composition from diorite to gabbro and, locally, to monzonite. The sill at Wood Creek (Knapp, 1963) has an average composition of 42 percent finely to coarsely crystalline plagioclase, 18 percent hornblende, 20 percent clinopyroxene, 10 percent magnetite, and 10 percent combined quartz and feldspar. Magnetite in the sills appears to be a late magmatic mineral, as much of it is interstitial and is locally concentrated in thin layers.

CRETACEOUS (?) APLITE DIKES

Nearly vertical west-striking aplite dikes are locally exposed in the southern part of the Scapegoat Wilderness at Mineral Hill and Daly Peak (pl. 1). The dikes are presumably Cretaceous in age, as are similar aplite dikes in the Southern Elkhorn Mountains south of Helena, Mont. (Klepper and others, 1957), and in the northern part of the Boulder batholith (Knopf, 1963). The dikes are light gray, fine grained, and equigranular. The most abundant mineral is quartz; muscovite, biotite, and orthoclase are also present.

An aplite dike a short distance south of the peak of Mineral Hill intrudes diorite and is 20 feet thick; elsewhere, the dikes are 3-6 feet thick. At Mineral Hill the diorite wallrock is sheared, chloritized, and epidotized and contains veinlets of calcite, siderite, and quartz.

PRE-TERTIARY SILLS

Several dark-greenish-gray to pinkish-gray sills of pre-Tertiary age are exposed in the vicinity of Red Mountain in the southern part of the Scapegoat Wilderness (pl. 1). They have a fine-grained porphyritic texture and are intermediate in composition between diorite sills of Precambrian age in the Scapegoat Wilderness and trachyandesite sills of Late Cretaceous-early Tertiary age in the Sun River area to the north (Mudge, 1966b). These differences in composition and texture suggest that the sills of uncertain age are probably unrelated to either the Precambrian or the Upper Cretaceous-lower Tertiary sills. Similar sills were mapped in the area west of Wolf Creek, Mont., and were assigned a probable Late Cretaceous age by Schmidt and Strong (1968).

A very late Jurassic or very early Cretaceous age may be appropriate for these sills because their composition is like that of igneous pebbles and cobbles found in Lower Cretaceous conglomerates in the Sun River area by Mudge and Sheppard (1968).

The sills range in thickness from 2 to about 200 feet, and they intrude the Helena Dolomite and the Snowslip Formation. They are laterally continuous over a very short distance in only a small part of the area, another feature that distinguishes them from other sills in and north of the area. Composition of the sills ranges from andesite where the sill is in the lower part of the stratigraphic section to monzonite where it is in the upper part. The groundmass is composed of plagioclase, orthoclase, and subordinate amounts of mafic minerals; phenocrysts are mostly hornblende and plagioclase, but biotite is the most abundant phenocryst mineral in the lowermost sill, and pink orthoclase is most abundant in the uppermost.

STRUCTURE

The moderately complex structure in the area consists of thrust and normal faults and a variety of folds (pl. 1). The thrust faults, folds, and some normal faults are probably Paleocene to late Eocene in age (Mudge, 1970, p. 379). The early Tertiary structures are part of the disturbed belt of northwestern Montana.

The thrust faults are mostly along the northeastern part of the area, but two of them are along the north side of the Blackfoot River; all trend northwest and dip southwest. The largest thrust fault in the area has translated rocks of the Precambrian Mount Shields Formation onto rocks of Paleozoic age (pl. 1 and fig. 6).

The normal faults trend northwest and northeast. The northwest- to east-trending normal faults along Bighorn Creek and Landers Fork form a graben and appear to be older than the thrust faults to the northeast. Small northeast-trending normal faults in the upper reaches of the Dearborn River displace thrust faults and are alined with the Scapegoat-Bannatyne trend, as discussed by Alpha (1955) and Mudge, Erickson, and Kleinkopf (1968). Northwest-trending normal faults on the west fork of Landers Fork have southerly dips and probably formed during or shortly after thrust faulting. A large rotational fault hinges in the upper reaches of the East Fork Blackfoot River; it trends northwest, dips southwest, and has a maximum stratigraphic displacement of about 19,000 feet at the western border of the area. It is

FIGURE 6.—View northwest of a ridge just south of Straight Creek, showing strata of the Mount Shields Formation (p€ms) in thrust-fault contact on strata of Mississippian age (Ms). €s, Cambrian rocks; Ds, Devonian rocks.

FIGURE 7.—Folded Cambrian rocks on the south side of Scapegoat Mountain. View northwest.

possibly the youngest structure in the area, as it truncates some thrust and northeast-trending normal faults.

Axial traces of folds in the area trend both north and northwest. The largest fold is a broad open syncline that enters the area from the northwest and continues across the area through Scapegoat and Sugarloaf Mountains. On the south edge of Scapegoat Mountain, overturned folds (fig. 7) are in Cambrian rocks; farther south, Precambrian strata are locally overturned (pl. 1). In the northeastern part of the area, a northwest-trending open anticline and syncline are in thrust plates that have been folded. Two small north-trending anticlines and a syncline are in the area between Dry Fork and Cabin Creek. A northeast-trending syncline is in the graben between Bighorn Creek and Landers Fork.

GEOPHYSICAL SURVEYS

By DONALD L. PETERSON

INTRODUCTION

Aeromagnetic and gravity surveys were made in the Scapegoat Wilderness and adjacent areas of Montana to support geological and geochemical investigations.

The aeromagnetic data are from a more widespread survey flown in 1964 by the U.S. Geological Survey (fig. 8). Total-intensity magnetic measurements were made with a continuously recording ASQ10 fluxgate magnetometer installed in a Convair aircraft. The survey was flown at a barometric elevation of 9,000 feet above sea level except for deviations to 10,500 feet to clear mountain peaks. Flightlines were flown in an east-northeast direction at a spacing of 2 miles.

During July and August 1970, approximately 140 gravity stations were established by helicopter, and gravity measurements were made with LaCoste-Romberg and Worden gravity meters. These data were supplemented with data from previous surveys (Mudge and others, 1968) in compiling the Bouguer gravity map (fig. 9). Vertical and horizontal positions of stations south of lat N. 47°15′ are from control points marked on topographic maps at scales of 1 : 24,000. North of lat 47°15′ N., where maps are of poor quality, vertical and horizontal positions were determined by photogrammetric methods supplemented by topographic surveys. The gravity stations were terrain corrected for a distance of 167 kilometers by a method described by Plouff (1966). The topographic relief for most of the area is extreme, and the largest terrain correction exceeded 40 milligals. A density of 2.67 grams per cubic centimeter was assumed for the rock between sea level and station elevations in reducing the data to the complete Bouguer anomaly. The gravity data are referenced to airport base station WA 124 at Great Falls, Mont. (Woollard, 1958).

MAGNETIC AND GRAVITY SURVEYS

The magnetic and Bouguer gravity maps (figs. 8 and 9) reflect the major distortions of the earth's magnetic and gravity fields in the Scapegoat Wilderness. These fields are produced by surface and subsurface geologic phenomena.

For a discussion of geophysical anomalies and geologic features outside the boundary of the Scapegoat Wilderness see Mudge, Erickson, and Kleinkopf (1968), Smith (1970), and Kleinkopf and Mudge (1972). The total-intensity magnetic map (fig. 8) displays mainly three kinds of patterns: a large isolated positive anomaly near Evans Peak, low-amplitude positive and negative anomalies, and gradient zones extending across the area. The south half of the Bouguer gravity map (fig. 9) consists of a broad east-west gravity maximum which is nearly at right angles to the structural trend of the thrust belt. Superimposed on the maximum are anomalies of lesser magnitude. The regional gravity field over the north half of the mapped area is more negative than that over the south half and has mostly northwesterly and northerly trends. Patterns in the north and south areas are separated by an irregular gravity gradient.

The positive magnetic anomaly (1, fig. 8) near Evans Peak has an amplitude of about 200 gammas and trends northeast. The depth of burial of the mass causing the anomaly was computed, by methods of Vacquier, Steenland, Henderson, and Zietz (1951) and Zietz and

Henderson (1956), to be 10,500±1,200 feet below the ground surface (Mudge and others, 1968). The average susceptibility contrast of 0.001 centimeter-gram-second units (determined using the method of Vacquier and others, 1951) suggests that the rock causing the anomaly is quartz monzonite. The magnetic anomaly lies on the axis of the broad gravity maximum and is also coincident with a prominent northwest salient and a 5-milligal closure of the gravity contours. Exposed bedrock in the area of the anomaly is mostly Precambrian sedimentary rocks of the Belt Supergroup that are in westerly dipping thrust plates. A preliminary analysis of a magnetic profile across the area (Mudge and others, 1966) suggested that the anomaly near Evans Peak might represent part of a large gabbroic batholith extending 60 miles northwest of the Evans Peak area. A study of both the magnetic and gravity anomalies, however, suggests that the mass is a much smaller, buried pluton whose composition is less mafic than gabbro.

Superimposed on the magnetic anomaly near Evans Peak is a sharp low-amplitude positive magnetic anomaly trending southeast. This anomaly correlates with a diorite sill of Precambrian age (pl. 1)

About 14 miles southeast of Evans Peak is another low-amplitude positive magnetic anomaly (2, fig. 8), indicated by a southeast salient in the contours. This anomaly nearly coincides with a gravity anomaly that has about 15 milligals of positive closure. These anomalies may reflect a diorite sill of Precambrian age exposed nearby or, possibly, a small buried stock.

Magnetic and gravity gradients trend northwest and are coincident along the south edge of the area. The magnetic gradient has an amplitude of about 200 gammas, and the gravity gradient has an amplitude of about 15-20 milligals. These gradients reflect a major normal fault whose downthrown block is to the south. Other small magnetic (3, fig. 8) and gravity maximums correspond mostly to surface exposures of Precambrian diorite sills in the southern part of the area (pl. 1).

Two small sharp positive magnetic anomalies in the northern part of the mapped area (4 and 5, fig. 8) probably correspond to northwest-trending sills mapped by Mudge (1966b). The northeast sill (4) is trachyandesite of Late Cretaceous or early Tertiary age, whereas the southwest sill (5) is diorite of Precambrian age. Anomaly 4 can be traced southeastward for 8 miles or more.

A positive southeast magnetic trend (6, fig. 8) is coincident with the westward-dipping South Fork thrust-fault zone (Mudge and others, 1968). The gravity data show a gradient with two small positive closures along the fault zone.

Geophysical anomalies in the Scapegoat Wilderness that may indicate mineralized igneous rocks are those that reflect sills and buried

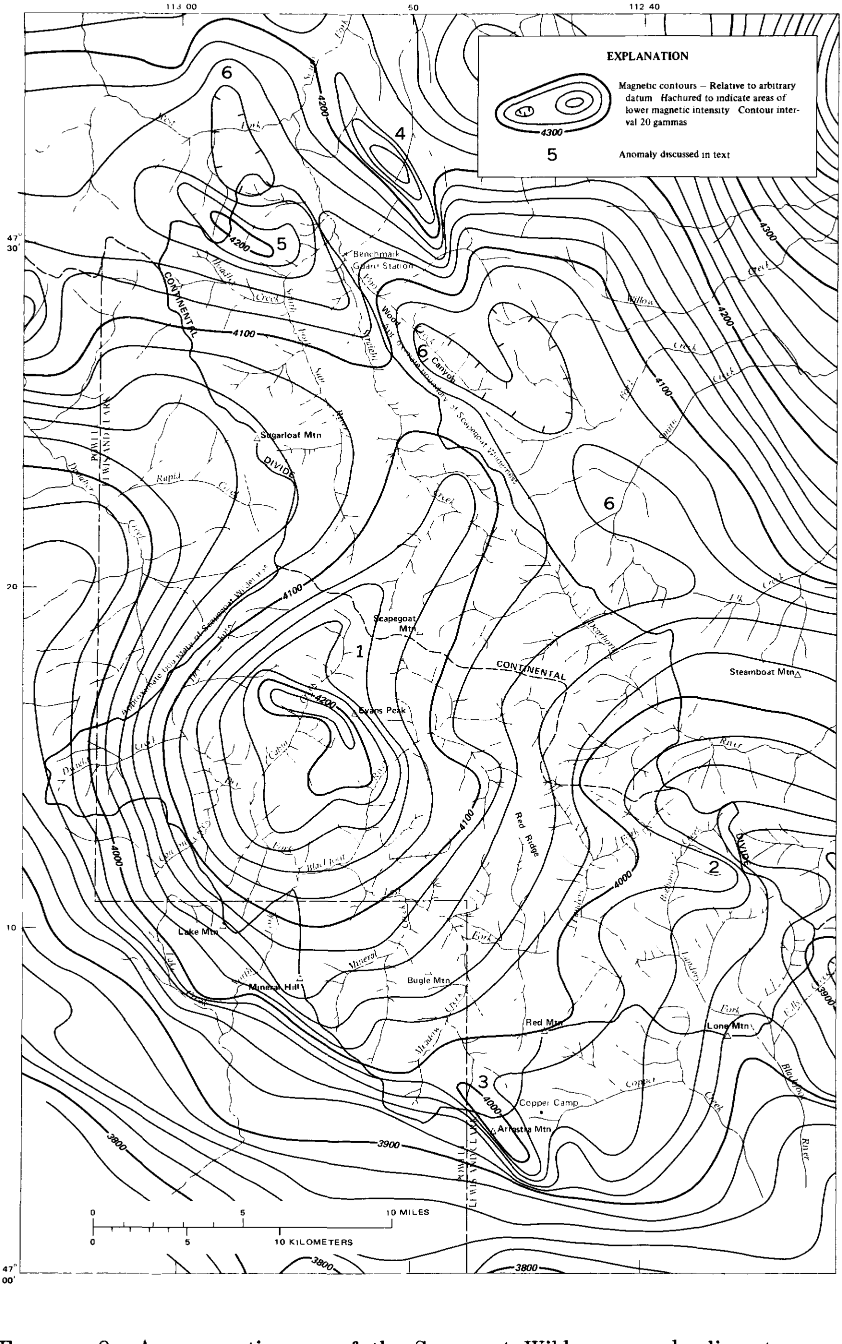


FIGURE 8.—Aeromagnetic map of the Scapegoat Wilderness and adjacent areas. Aeromagnetic contours compiled by M. D. Kleinkopf in 1966. From Mudge, Erickson, and Kleinkopf (1968, pl. 2).

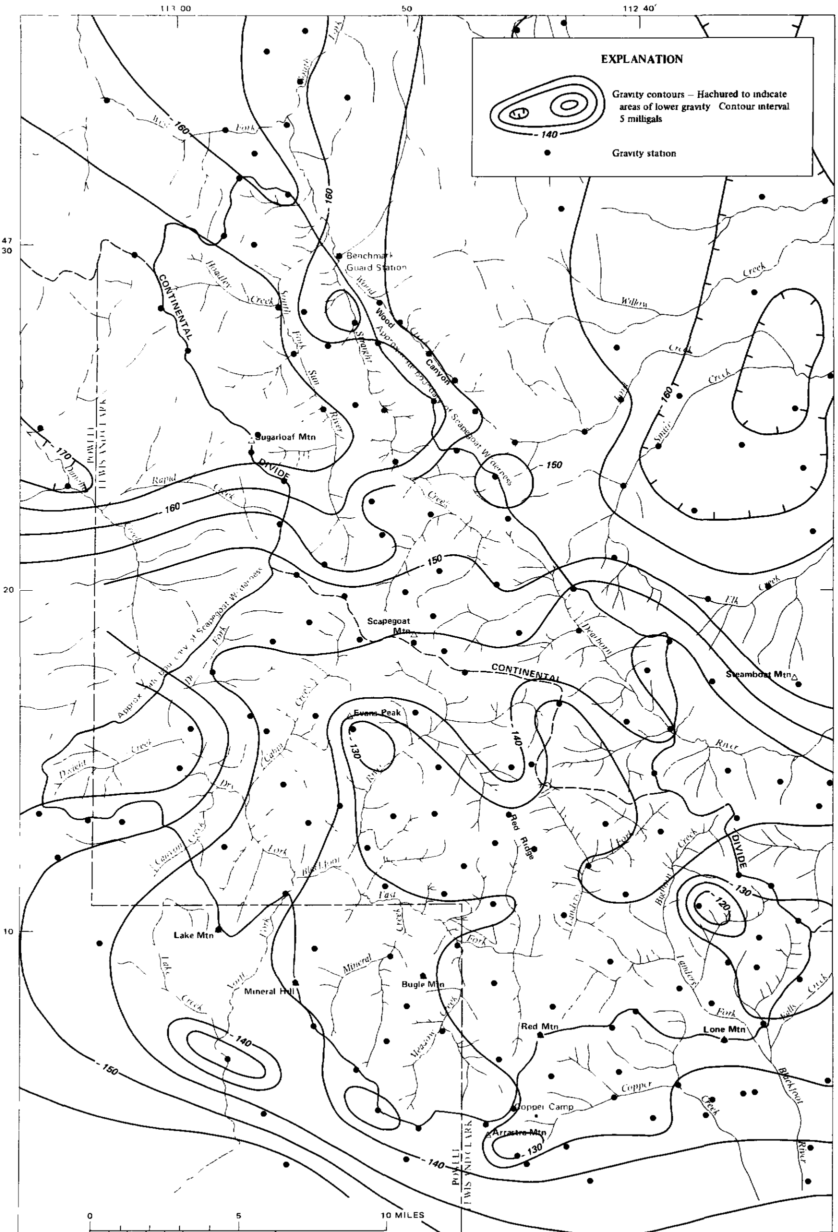


FIGURE 9.—Gravity map of the Scapegoat Wilderness and adjacent areas.

plutons. Because none of the exposed sills contain economic concentrations of valuable minerals, the buried sills are not likely to be favorable host rocks. Computed depths of burial of the inferred plutons are far too great for the plutons to be of possible economic importance.

MINERAL RESOURCES

Copper is the only mineral commodity of possible economic importance in the Scapegoat Wilderness; however, the results of the investigation indicate that the area probably does not contain large copper deposits. Other metallic mineral commodities are locally present in low concentrations that are not economically significant. The area contains large deposits of limestone and building stone, but these commodities are readily available elsewhere nearer to markets. There are no indications of fossil fuels or geothermal energy in the area. The southern part of the wilderness area contains several abandoned mineral prospects but no currently producing or developing mines. Exploration activities, including outcrop testing and subsurface investigations, have been conducted in recent years by private firms and individuals; however, no mining or exploration was evident in the area during the present investigations.

During the last 110 years, mining activity has occurred south of the Scapegoat Wilderness, and much prospecting has been done east of the area. Some mines and prospects east of the wilderness area were discussed by Mudge, Erickson, and Kleinkopf (1968). The mining districts and some outlying mines south of the wilderness area were discussed in detail by Pardee and Schrader (1933) and by Sahinen (1959, p. 136), so they are only briefly summarized here. The most productive district is the Marysville, about 32 miles southeast of the wilderness area. Mining began in 1876 and about $35,150,000 (based on metal prices prevailing between 1876 and 1956) in gold and silver, appreciable amounts of lead, and some copper and zinc were produced (Sahinen, 1959, p. 136). Except for placer deposits, most of the ore is in fissure veins in a quartz diorite stock and adjacent metamorphosed Belt rocks.

In the Gould-Stemple Pass district, about 20 miles south of the wilderness area, mining began in 1884 with the discovery of the Jay Gould mine, which by 1915 had produced gold and minor amounts of silver having an estimated value of $2½ million, based on metal prices prevailing between 1894 and 1915 (Pardee and Schrader, 1933). A small amount of gold was produced after 1922, and the total estimated value of production from the district is at least $3 million (Pardee and Schrader, 1933). Gold and silver ores containing some copper and lead and very little zinc were mined from veins in the Granite Mountain quartz diorite and adjacent metamorphosed Belt rocks. Placer deposits in McClellan Gulch, about 6 miles west of Stemple Pass, produced about $7 million worth of gold (based on prevailing gold prices) between 1864 and 1875 (Pardee and Schrader, 1933).

In the Heddleston district, about 12 miles southeast of the wilderness area, mining began in 1889 and continued intermittently through World War II, especially in the Mike Horse mine. Lead, some silver and gold, and small but appreciable amounts of copper were mined mostly from breccia and veins in a diorite porphyry body. A porphyry copper deposit has been found in the area north of the Mike Horse mine by Anaconda Co.

Closer to the wilderness area, high-grade gold placer deposits were mined in Lincoln Gulch, about 6 miles south of the boundary. About $7 million worth of gold was obtained from these gravels between 1865 and 1871 (Pardee and Schrader, 1933). After 1865, a gold lode deposit, the Blackfoot mine, was discovered in Lincoln Gulch near its confluence with the Blackfoot River. It contained gold in quartz-carbonate veins in a diorite host rock; the placer gold in Lincoln Gulch was probably from a similar source. Keep Cool and Liverpool Creeks, about 6 miles southeast of the Scapegoat Wilderness, contain very small gold placer workings, but the deposits were reported to be irregular and low grade (Pardee and Schrader, 1933).

ECONOMIC CONSIDERATIONS

The only commodity known to be of economic importance in the study area is copper. Trace amounts of gold and silver occur in the mineralized rock, but they could be produced only as a byproduct from copper mining.

The following data provide basic information for evaluation of the economic potential of the copper resources. Copper production in the United States for 1969 was 1,558,000 short tons, whereas consumption was 2,040,000 short tons. The excess consumption amounted to 482,000 short tons. The average price per pound of refined copper was 47.4 cents. Five western States supply 94 percent of mine output. U.S. reserves are estimated at 85 million short tons of copper from ores averaging 0.8 percent copper. The forecast of domestic consumption is an increase at an annual rate of between 3.7 and 5.2 percent. If the forecasted consumption does not exceed the low estimate, the copper needed for the period 1969-2000 can be met from known reserves. A higher demand will necessitate copper acquisition from other sources. Solutions for the probable imbalance may be met by a price increase to cover costs of mining submarginal reserves, discovery of new ore bodies, and (or) increased use of substitute materials (U.S. Bur. Mines, 1970).

The Copper Belt, along the southern end of the study area, could become an active site for future development and production under a more favorable economic environment. The small vein-type deposits in the study area would require about 4 percent copper to be minable under present conditions. The deposits along bedding planes would require more than 1 percent copper over a minimum thickness of about 5 feet and should contain minimum reserves of ½ to 1 million short tons in order to be economic at present conditions.

METHODS OF EVALUATION

Evaluation of the mineral resources of the Scapegoat Wilderness is based on analyses of rock and stream samples, results from geologic mapping, detailed study of mineral occurrences, and aeromagnetic and gravity surveys. Collection localities for samples are shown on plate 2; the analyses were included in an open-file report (Mudge and others, 1971), and a computer tape of them is available (Mudge and others, 1973).

Foot traverses, in most places less than a mile apart, were made along ridges and streams. The rock samples include fresh and unaltered rocks, altered rocks, veins, veinlets, and fault gouge or breccia. The outcrops were inspected carefully for scattered pyrite or chalcopyrite, minute amounts of malachite, galena, iron stains, or black streaks.

The stream traverses were made primarily to obtain stream-sediment and water samples, but close attention was given to the stream pebbles and to outcrops along the streams. Samples were taken at intervals of 1 mile or less along most larger streams; at least one sample was obtained at the mouth of each short tributary. Where possible, a significant amount of clay- and silt-sized material was included in the pound or more of sediment sample. Rock fragments in gravel bars were examined, and those fragments showing staining, alteration, or veining, or those having a high porosity, were sampled. Fourteen pan-concentrate samples were taken at selected localities along Bighorn Creek; none of these contained highly anomalous amounts of valuable elements. A few samples were obtained from streams outside the wilderness area, and some of these sample localities are shown on plate 2. A geochemical survey east and south of the area was discussed by Mudge, Erickson, and Kleinkopf (1968). Water samples were analyzed for copper and molybdenum by the colorimetric method, but the results of the tests are not included in this report; instead, the few samples that contained detectable amounts of these elements are discussed in the following paragraphs. (The lower limit of detection for copper is 0.002 ppm and for molybdenum is 0.004 ppm.) The spectrographic analyses of stream-pebble samples were not included on the computer tape because they were used as a field guide for the type of rock and possible mineralization in a specific drainage. The probable source of pebbles of mineralized rock was subsequently located during the field studies.

Sample data were evaluated by comparing the analytical results of the elements in each sample with geometric mean values of the elements in all samples of a similar rock type. The frequency distribution of values for each element was determined from each of the rock types in a formation and was subsequently summarized by rock type independent of formation. The frequency distribution of copper and lead shown in table 2 was used to plot the histograms shown in figures 10 and 11. With the exceptions discussed in the following paragraphs, the values that were sufficiently high were classified as anomalous. The determination of an anomalous value is dependent on rock type and type of sample as well as on the analytical results. For example, outcrop samples from green-bed Belt rocks have a geometric mean value of 33 ppm copper; therefore, green clastic rocks containing 50 ppm copper or more are considered in this report as anomalous (fig. 10). The mean copper content of Precambrian diorite sills is about 300 ppm; therefore, 500 ppm copper or more is considered anomalous for this rock type. Anomalous values for the other elements were determined in the same manner as the anomalous copper values. It follows that the geochemical maps (figs. 13, 14, 17, and 18) should be evaluated in the context of the geologic map (pl. 1).

Also, the amount of copper in a stream sediment sample must be evaluated in regard to the geology in the drainage (figs. 13 and 14). As shown on the first histogram in figure 10, if we include all stream-sediment samples as one statistical population, then any samples that contain 50 ppm or more copper are anomalous. However, this threshold for determining what is truly an anomalous content is too high or too low in view of certain geologic considerations. For example, sediment from streams draining diorite sills normally contains 50-100 ppm copper. In contrast, sediment from streams draining copper-bearing green beds rarely contains more than 30 ppm copper.

Again using copper as an example, values less than 50 ppm may be anomalously high for some rock types. Carbonate rocks characteristically contain 15 ppm copper or less (fig. 10); a few contain more than 30 ppm copper. Although 30 ppm or more copper may be anomalous, by the definition above, for carbonate rocks, rocks containing less than 50 ppm copper are considered unimportant from a resource-potential viewpoint regardless of the rock type. By excluding rock samples with less than 50 ppm copper from the geochemical map (fig. 13), the copper occurrences of possible importance are more readily apparent.

Aeromagnetic and gravity data have proved useful in delineating possible buried plutons in nearby areas (Mudge and others, 1968). The most productive districts south of the area are associated with quartz diorite and quartz monzonite stocks which are readily defined by aeromagnetic data. However, stocks and other similar-type intrusives

TABLE 2.—*Frequency distribution of copper and lead, in*

[Data from Mudge and others (1971, table 3). *f*, frequency (number of samples reported to contain each amount); c.f., amounts below the sensitivity limit; G, more than amount

Spectrographic results (ppm)	Stream sediments			Clastic rocks		
	f	c.f.	Percent c.f.	*f*	c.f.	Percent c.f.
Copper						
N	1	1	0.15	39	39	4.41
L	33	34	5.07	67	106	11.99
5	20	54	8.05	57	163	18.44
7	42	96	14.31	55	218	24.66
10	78	174	25.93	93	311	35.18
15	136	310	46.20	81	392	44.34
20	122	432	64.38	92	484	54.75
30	121	553	82.41	117	601	67.99
50	51	604	90.01	47	648	73.31
70	23	627	93.44	38	686	77.61
100	23	650	96.87	35	721	81.57
150	15	665	99.11	27	748	84.62
200	-----	-------	99.11	16	764	86.43
300	4	669	99.72	10	774	87.56
500	1	670	99.85	11	785	88.80
700	1	671	100.00	10	795	89.93
1,000	-----	-------	----------------	18	813	91.97
1,500	-----	-------	----------------	17	830	93.89
2,000	-----	-------	----------------	12	842	95.25
3,000	-----	-------	----------------	6	848	95.93
5,000	-----	-------	----------------	14	862	97.51
7,000	-----	-------	----------------	10	872	98.64
10,000	-----	-------	----------------	7	879	99.43
G10,000	-----	-------	----------------	-------	-------	----------------
15,000	-----	-------	----------------	2	881	99.66
G15,000	-----	-------	----------------	-------	-------	----------------
20,000	-----	-------	----------------	2	883	99.89
G20,000	-----	-------	----------------	1	884	100.00
Lead						
N	15	15	2.24	266	266	30.12
L	78	93	13.86	259	525	59.45
10	169	262	39.05	147	672	76.10
15	172	434	64.68	59	731	82.78
20	132	566	84.35	57	788	89.24
30	75	641	95.53	30	818	92.64
50	23	664	98.96	21	839	95.02
70	3	667	99.40	19	858	97.17
100	2	669	99.70	6	864	97.85
150	2	671	100.00	7	871	98.64
200	-----	-------	----------------	-------	871	98.64
300	-----	-------	----------------	2	873	98.87
500	-----	-------	----------------	2	875	99.10
700	-----	-------	----------------	1	876	99.21
1,000	-----	-------	----------------	3	879	99.25
1,500	-----	-------	----------------	3	882	99.89
2,000	-----	-------	----------------	1	883	100.00
3,000	-----	-------	----------------	-------	-------	----------------
5,000	-----	-------	----------------	-------	-------	----------------
7,000	-----	-------	----------------	-------	-------	----------------
10,000	-----	-------	----------------	-------	-------	----------------
15,000	-----	-------	----------------	-------	-------	----------------

parts per million, in stream-sediment and rock samples

cumulative frequency; percent c.f., cumulative frequency in percent; N, looked for but not found; L, detected but in shown, --, element not looked for or analysis not made]

Carbonate rocks			Green clastic rocks			Red clastic rocks		
f	c.f.	Percent c.f.	*f*	c.f.	Percent c.f.	*f*	c.f.	Percent c.f.
				Copper—Continued				
161	161	26.18	22	22	3.83	24	24	9.60
90	251	40.81	35	57	9.93	27	51	20.40
47	298	48.45	26	83	14.46	21	72	28.80
49	347	56.42	22	105	18.29	28	100	40.00
59	406	66.01	54	159	27.70	32	132	52.80
47	453	73.65	51	210	36.59	34	166	66.40
41	494	80.32	45	255	44.43	31	197	78.80
29	523	85.04	74	329	57.32	31	228	91.20
22	545	88.62	34	363	63.24	6	234	93.60
18	563	91.55	32	395	68.81	6	240	96.00
9	572	93.01	28	423	73.69	5	245	98.00
7	579	94.15	25	448	78.05	-------	-------	98.00
4	583	94.80	14	462	80.49	-------	-------	98.00
5	588	95.61	10	472	82.23	-------	-------	98.00
4	592	96.26	11	483	84.15	-------	-------	98.00
6	598	97.24	12	495	86.24	-------	-------	98.00
5	603	98.05	16	511	89.03	2	247	98.90
2	605	98.38	16	527	91.82	1	248	99.20
1	606	98.54	11	538	93.74	-------	-------	99.20
1	607	98.70	6	544	94.79	-------	-------	99.20
1	608	98.86	13	557	97.05	1	249	99.60
-------	-------	98.86	8	565	98.44	1	250	100.00
1	609	99.02	6	571	99.49	-------	-------	-------
5	614	100.00	-------	-------	-------	-------	-------	-------
-------	-------	-------	2	573	99.84	-------	-------	-------
-------	-------	-------	1	574	100.00	-------	-------	-------
-------	-------	-------	-------	-------	-------	-------	-------	-------
-------	-------	-------	-------	-------	-------	-------	-------	-------
				Lead—Continued				
214	214	34.80	153	153	26.66	96	96	38.40
91	305	49.60	153	306	53.32	95	191	76.40
92	397	64.56	99	405	70.57	39	230	92.00
51	448	72.85	36	441	76.84	13	243	97.20
44	492	80.00	51	492	85.73	2	245	98.00
41	533	86.67	26	518	90.26	3	248	99.20
21	554	90.08	16	534	93.05	1	249	99.60
15	569	92.52	17	551	96.01	1	250	100.00
6	575	93.50	4	555	96.71	-------	-------	-------
5	580	94.31	7	562	97.93	-------	-------	-------
3	583	94.80	-------	-------	97.93	-------	-------	-------
5	588	95.61	2	564	98.28	-------	-------	-------
6	594	96.59	2	566	98.63	-------	-------	-------
6	600	97.57	1	567	98.80	-------	-------	-------
4	604	98.22	3	570	99.32	-------	-------	-------
2	606	98.55	3	573	99.84	-------	-------	-------
-------	-------	98.55	1	574	100.00	-------	-------	-------
3	609	99.04	-------	-------	-------	-------	-------	-------
3	612	99.53	-------	-------	-------	-------	-------	-------
1	613	99.69	-------	-------	-------	-------	-------	-------
1	614	99.85	-------	-------	-------	-------	-------	-------
1	615	100.00	-------	-------	-------	-------	-------	-------

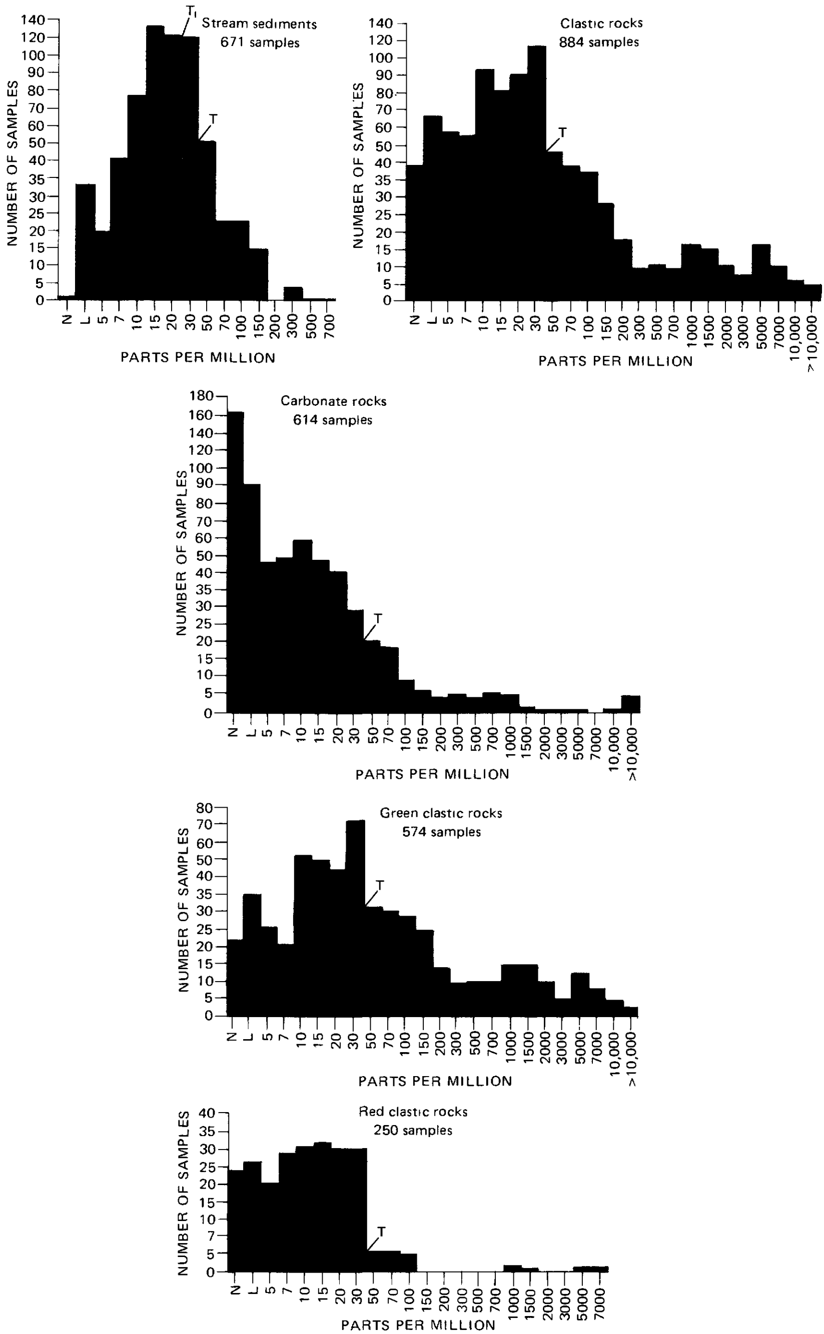


FIGURE 10.—Frequency distribution of copper in stream-sediment and rock samples. T indicates threshold of selected anomalous values; T_1 indicates T for copper in drainages with copper-bearing green beds.

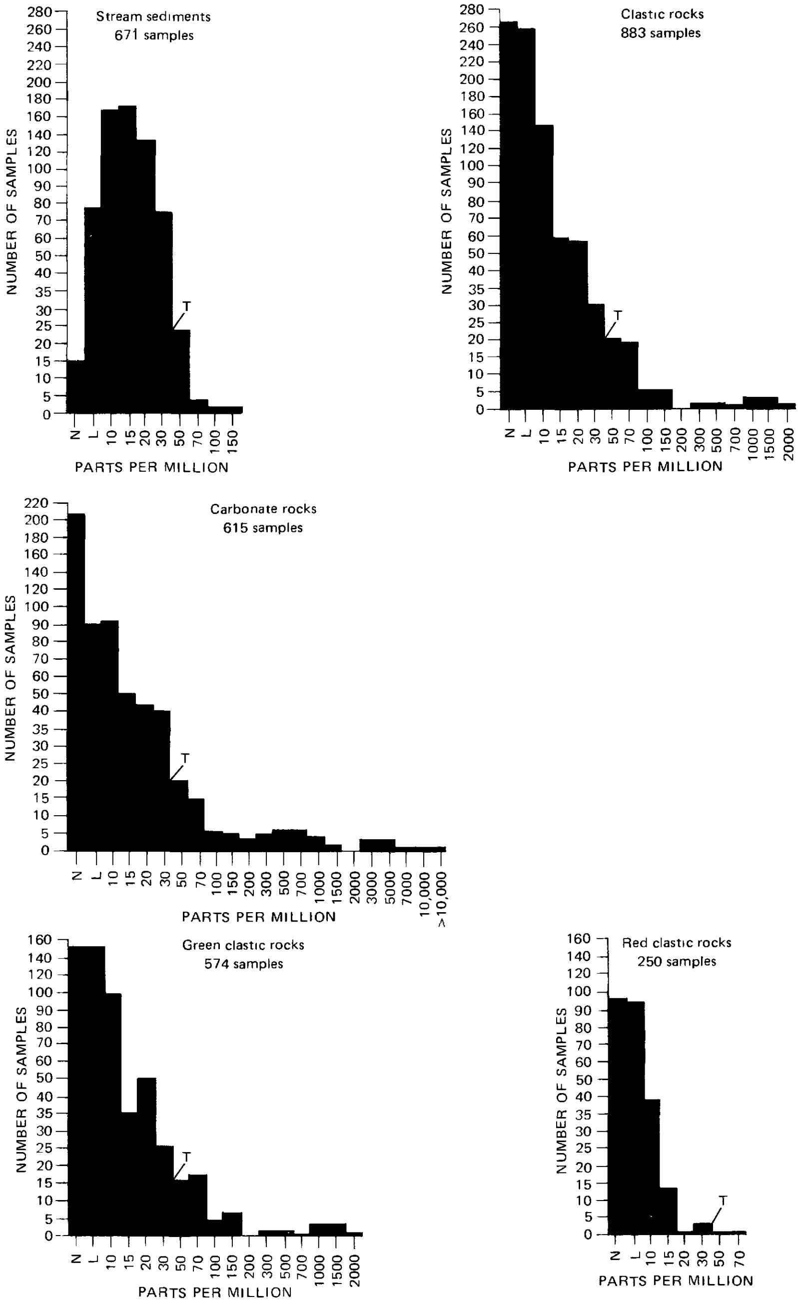


FIGURE 11.—Frequency distribution of lead in stream-sediment and rock samples. T indicates threshold of selected anomalous values. Statistical data are listed in table 2.

are not exposed in the wilderness area, and because the existing aeromagnetic map (Mudge and others, 1968) did not show evidence of near surface buried intrusives, a more detailed aeromagnetic map was not deemed necessary (fig. 8). The gravity map in Mudge, Erickson, and Kleinkopf (1968), however, was of a broad reconnaissance nature, and thus a more detailed gravity map was compiled for this study (fig. 9).

GOLD

Evidence of gold deposits and gold mining or prospecting activity was not found in the Scapegoat Wilderness. Quartz-carbonate veins similar to those in Lincoln Gulch are in the vicinity of Mineral Hill in the southern part of the wilderness area; however, the veins are not anomalous in gold. All samples of stream sediment, pebbles, and outcropping rock were analyzed for gold by both spectrographic and atomic absorption methods. Spectrographic results indicate either that gold is absent or that it is present in less than detectable amounts in all samples. (The lower detection limit is 10.0 ppm by semiquantitative spectrography and 0.02 ppm by atomic absorption.) Weakly anomalous gold values were obtained by the atomic absorption method on six stream-sediment samples (634, 636, 639, 643, 644, 645) from the Hoadley Creek drainage in the northwestern part of the area (pl. 2). These samples contained 0.1-1.0 ppm gold—the highest gold values found in the area. The bedrock source of this gold is unknown.

Except for the quartz-carbonate veins in the vicinity of Mineral Hill, targets for gold exploration, such as quartz veins and zones of hydrothermal alteration, are rare or absent throughout most of the area. The low gold values in the Hoadley Creek samples probably do not indicate a gold deposit. Based on present knowledge, there does not appear to be a potential for gold deposits in the Scapegoat Wilderness.

SILVER

Weakly anomalous amounts of silver are widely distributed in the rocks of the central and southern parts of the Scapegoat Wilderness (fig. 12). All samples were analyzed for silver by the spectrographic method, and the results indicate that silver is closely associated with copper but occurs in subordinate quantities (table 3). In some vein deposits silver occurs with antimony and zinc in tetrahedrite, and in other veins and in green-bed copper deposits it is probably included in the bornite and (or) chalcocite lattice.

Veins containing minor amounts of silver, a quarter of an inch to 2 feet wide, are exposed in the southern part of the area. The veins are nearly vertical, and they strike westward; they are described in greater detail under the discussion on copper. A selected sample (CC3) from a copper-bearing quartz-carbonate vein at the Copper Camp mine, which is less than a mile outside the southern boundary, contained 300 ppm silver (1 ppm = 0.001 percent = 0.029 troy oz per short ton); however,

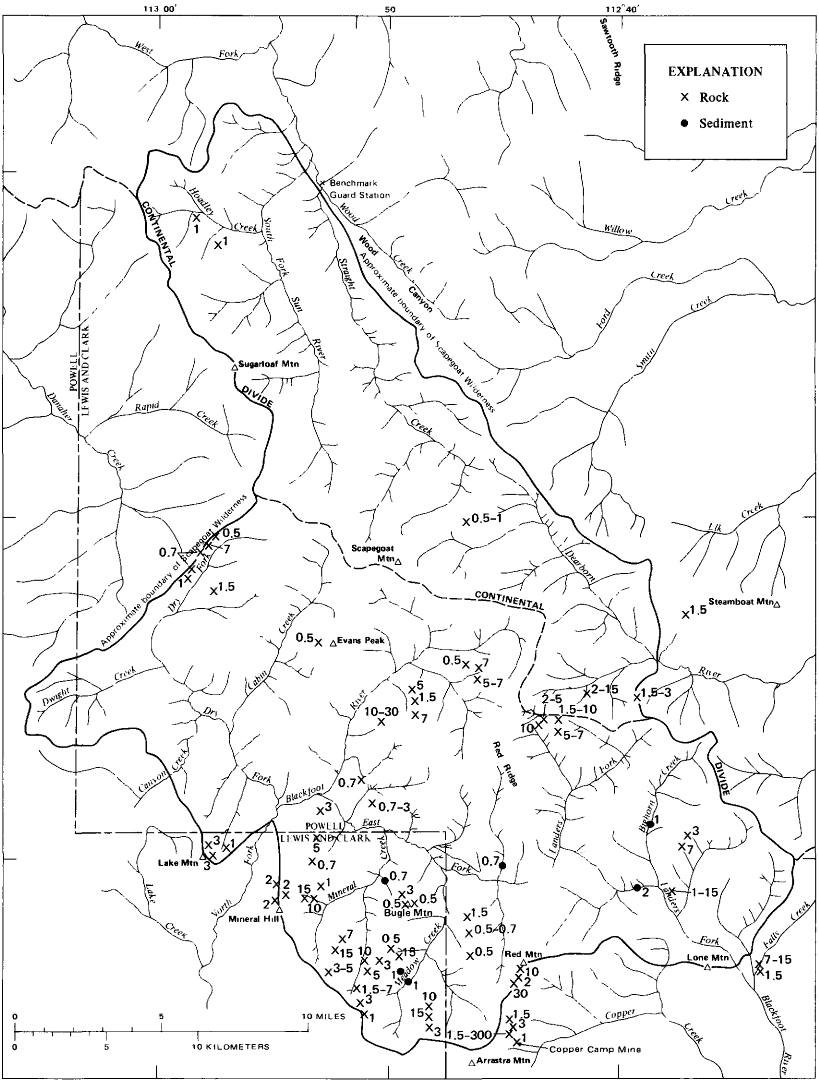


FIGURE 12.—Rock samples containing 0.5 ppm or more silver.

similar veins (B14A and B84) in the vicinity of Bugle Mountain and Mineral Hill in the southern part of the wilderness area contained a maximum of 15 ppm silver.

Minor amounts of silver are common in copper-bearing green beds of the Belt rocks in the vicinity of Red Mountain and east of the North Fork of the Blackfoot River. Samples B44A and L161 from the Snowslip Formation contained 30 ppm silver; elsewhere, this type of occurrence commonly contains 0.5-10.0 ppm silver.

TABLE 3.—*Copper and silver content of channel and chip samples in or near copper-bearing green beds*

[N.d., not detected]

Sample	Location (grid, pl. 2)	Length (ft)	True thickness (ft)	Copper (ppm)	Silver (ppm)	Description
				Snowslip Formation		
B342C-1	33,100 N. 167,680 E.	3.1	3.1	1,500	1.5	Green quartzite and siltite; uppermost of three copper-bearing green-bed sequences; mineralized rock traced laterally for 195 ft; sample is from eastern part.
B342C-2	33,100 N. 167,680 E.	3.2	3.2	1,500	1.5	Same beds as above; sample taken 150 ft northwest of B342C-1.
B342C-3	33,100 N. 167,680 E.	2.2	2.2	2,000	3.0	Same beds as above; sample taken 45 ft northwest of B342C-2; full thickness of mineralized sequence not exposed.
B343C-1	33,010 N. 167,810 E.	2.6	2.6	1,500	3.0	Green quartzite with laminae of siltite and argillite; middle copper-bearing green-bed sequence, 40 ft stratigraphically below uppermost sequence; mineralized rock traced laterally for 156 ft; sample is from eastern part.
B343C-2	33,010 N. 167,810 E.	1.3	1.3	1,500	2.0	Same beds as above; sample taken 97 ft northwest of B343C-1; full thickness of mineralized sequence not exposed.
B343C-3	33,010 N. 167,810 E.	2.6	2.6	1,000	1.5	Same beds as above; sample taken 55 ft northwest of B343C-2.
B345C-1	32,800 N. 167,980 E.	3.8	3.8	10	N.d.	Green siltite; green-bed sequence between middle and lowermost copper-bearing sequences.
B347C-1	32,630 N. 168.150 E.	2.5	2.5	50	N.d.	Green argillite; lowermost copper-bearing green-bed sequence; mineralized rock discontinuous laterally for 125 ft; sample is from middle part.
B347C-2	32,630 N. 168,150 E.	2.6	2.6	700	.7	Same beds as above; sample taken 60 ft east of B347C-1.
B347C-3	32,630 N. 168,150 E.	3.0	3.0	700	.5	Same beds as above; sample taken 65 ft northwest of B347C-1.
				Mount Shields Formation		
L276b	29,390 N. 165,060 E.	39.0	20.0	150	1.0	Green siltite and argillite; ½-in. bed in middle of chip sample contains 3.3 percent copper.
L276c	29,390 N. 165,060 E.	38.0	20.0	150	N.d.	Same beds as above; sample taken 5 ft north of L276b.
L318	29,710 N. 165,490 E.	56.0	25.0	700	.5	Same beds as above; sample taken about 700 ft northeast of L276b.
L318a	29,710 N. 165,490 E.	2.0	2.0	5,000	3.0	Same beds as above; sample taken in middle of sample L318.
L318b	29,710 N. 165,490 E.	---------	---------	30	N.d.	Red siltite beneath L318 green-bed sequence.
L319	30,290 N. 165,190 E.	39.0	18.0	700	1.0	Same beds as L276b; sample taken about 2,100 ft north of L276b.

Analyses of stream-sediment samples did not delineate any areas that are anomalous in silver (fig. 12). Five widely distributed samples (42, 52, 81, 102, and 467) contained 0.7-1.0 ppm silver, and one sample (447), from a small tributary of Landers Fork in the southeastern part of the area, contained 2 ppm silver; other stream-sediment samples contained less than 0.5 ppm silver.

If copper ore were to be mined in the area, silver might be recovered as a byproduct; however, no potential deposits in which silver might be of chief economic value are known in the area, and none are indicated by sample data.

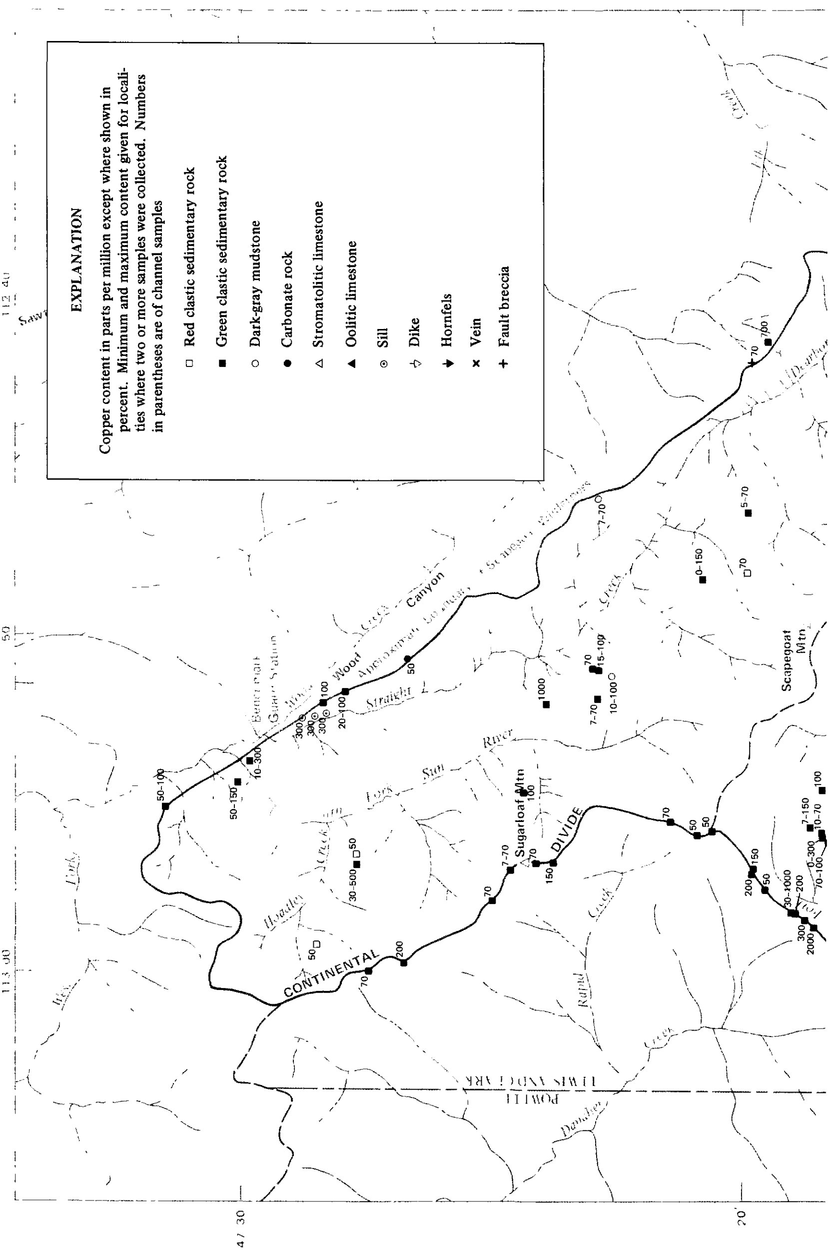
COPPER[1]

In the Scapegoat Wilderness, copper occurs in veins and in green beds in the Precambrian sedimentary rocks. The vein deposits are in the southern part of the area, and the copper-bearing green beds are in several Precambrian formations widely distributed throughout the area (fig. 13). In addition to these occurrences, some of the rock types in the area have high background amounts of copper. Diorite commonly contains 200-500 ppm copper, oolitic or stromatolitic limestone contains about 100 ppm, and glauconitic quartzite commonly contains 30-100 ppm. Some oolitic and stromatolitic rocks contain visible copper minerals, but the mineralization is very weak and highly localized.

Maps showing the distribution of copper (figs. 13 and 14) illustrate the excellent correlation between areas where rocks have a high content of copper and areas where stream sediments have a high content of copper. Diorite that contains 200-500 ppm copper has evidently contributed copper to stream sediments in such drainages as Bighorn Creek, tributaries of Cabin Creek, and the upper part of Dry Fork—the sediment samples contain 30-150 ppm copper. Diorite may also have contributed copper to stream sediments in streams between Red Mountain and Mineral Hill, but the copper could also be derived from veins and green beds. Stream-sediment samples from that area contain 30-700 ppm copper, but most contain 100-150 ppm. Sample 94, which contains 700 ppm copper, is from a tributary of Mineral Creek that drains an area mantled by Quaternary glacial and talus deposits; the high copper is probably from one or more quartz-carbonate veins buried by the surficial deposits. Stream sediments elsewhere in the area contain generally 30-50 ppm and rarely 70 ppm copper that has been derived from copper-bearing green beds (fig. 10). Cold-extractable copper in stream sediments is anomalous (5 ppm or more) in the same drainages as those shown in figure 14. The maximum amount of cold-extractable copper in a stream sediment is 200 ppm (sample 94).

Water samples from all flowing streams in the area were analyzed for copper. The highest copper value obtained in the area is 0.006 ppm from sample 205A in the Dearborn River. In Mineral Creek the highest amount of copper in the water is 0.004 ppm (samples 10A, 94A, and 97A). Most water samples in the Scapegoat Wilderness do not contain detectable amounts of copper (0.002 ppm).

[1]After this report was prepared, a source of copper contamination in the spectrographic analytical procedure was discovered. Duplicate analyses by atomic absorption indicate that the contamination is not reflected in copper values of 100 ppm or more. Contamination is reflected in approximately one-third of the samples reported herein as having less than 100 ppm copper. Because the presence and amount of contamination are erratic, values of less than 100 ppm copper shown in figures 13 and 14 and in other illustrations that show copper results may or may not be valid.


EXPLANATION
Copper content in parts per million except where shown in percent. Minimum and maximum content given for localities where two or more samples were collected. Numbers in parentheses are of channel samples
□ Red clastic sedimentary rock
■ Green clastic sedimentary rock
○ Dark-gray mudstone
● Carbonate rock
△ Stromatolitic limestone
▲ Oolitic limestone
⊙ Sill
Dike
Hornfels
× Vein
+ Fault breccia
CONTINENTAL DIVIDE
Sugarloaf Mtn
Scapegoat Mtn
Canyon
Wood
Straight
River
Creek
Rapid
Hoadley
47°30'
20'
113°30'
50'
113°40'

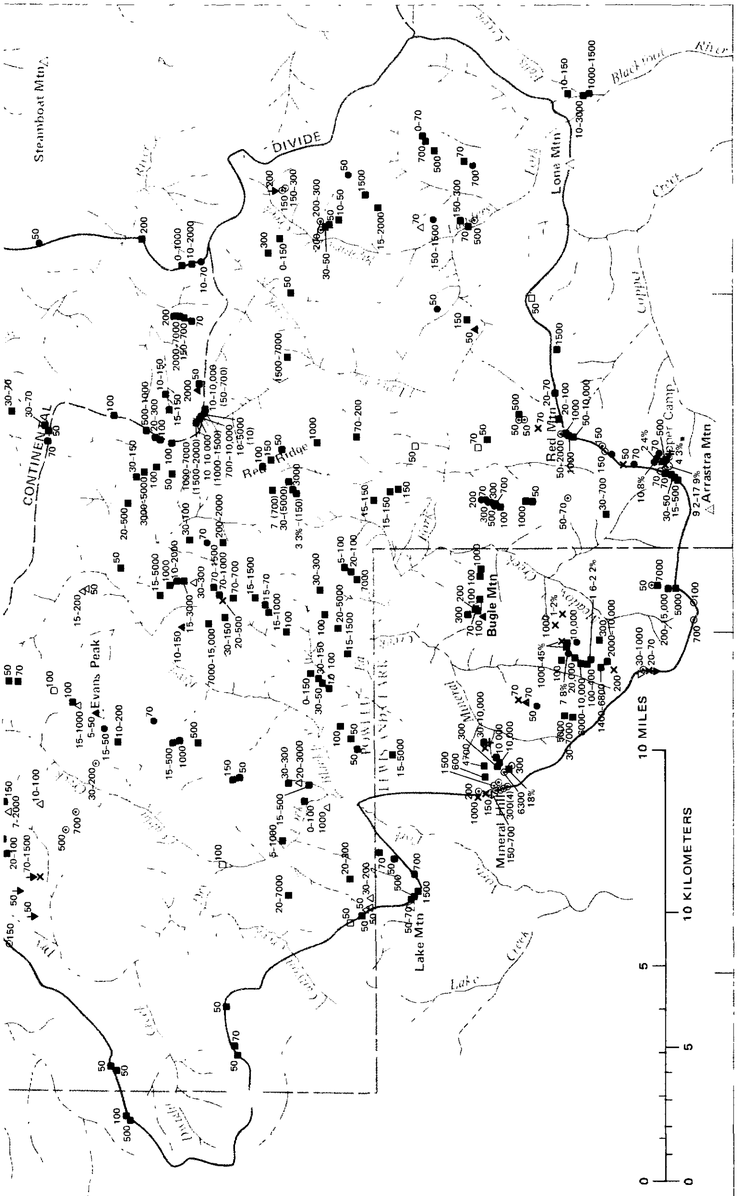
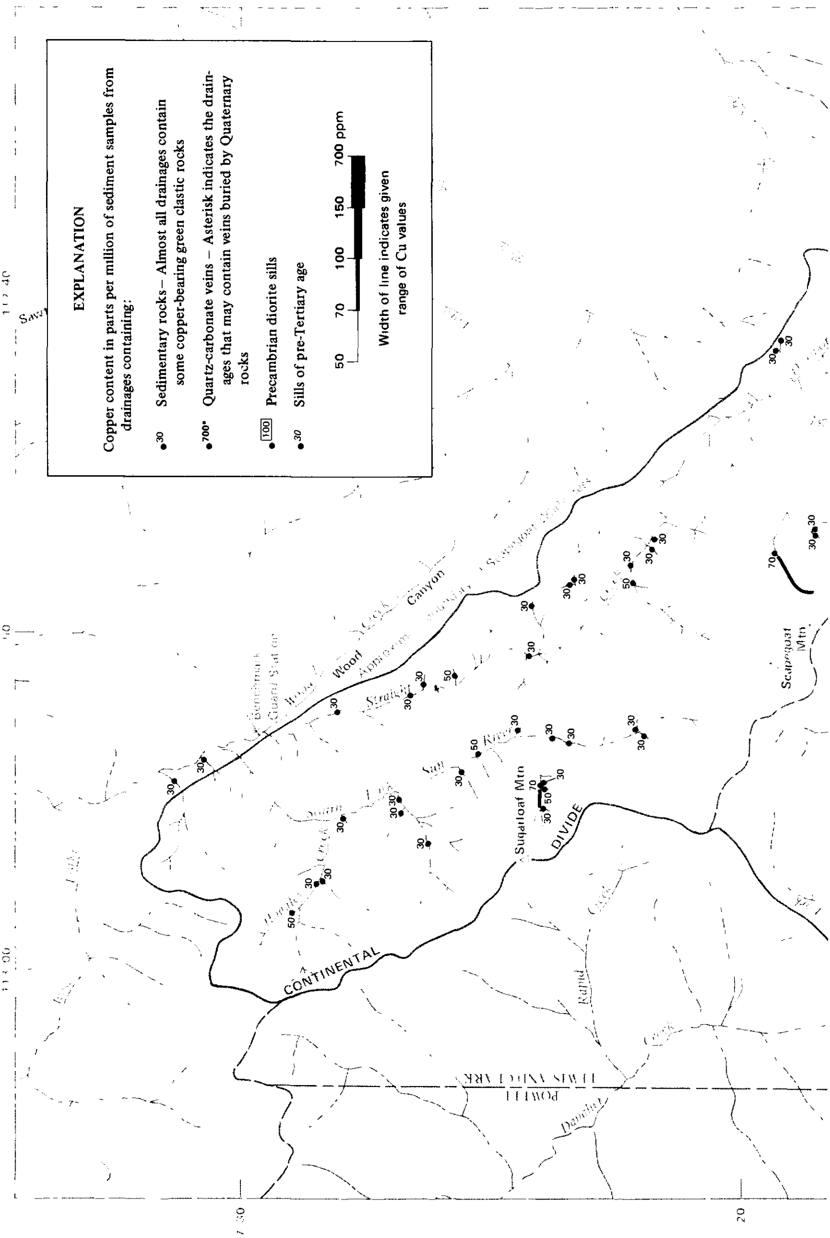


FIGURE 13.—Rock samples containing 50 ppm or more copper.


EXPLANATION
Copper content in parts per million of sediment samples from drainages containing:
•30 Sedimentary rocks – Almost all drainages contain some copper-bearing green clastic rocks
•700* Quartz-carbonate veins – Asterisk indicates the drainages that may contain veins buried by Quaternary rocks
•100 Precambrian diorite sills
•30 Sills of pre-Tertiary age
50 70 100 150 700 ppm
Width of line indicates given range of Cu values
CONTINENTAL DIVIDE
Sugarloaf Mtn
Scapegoat Mtn
Wood
Canyon
Creek
Rapid
47 30
20

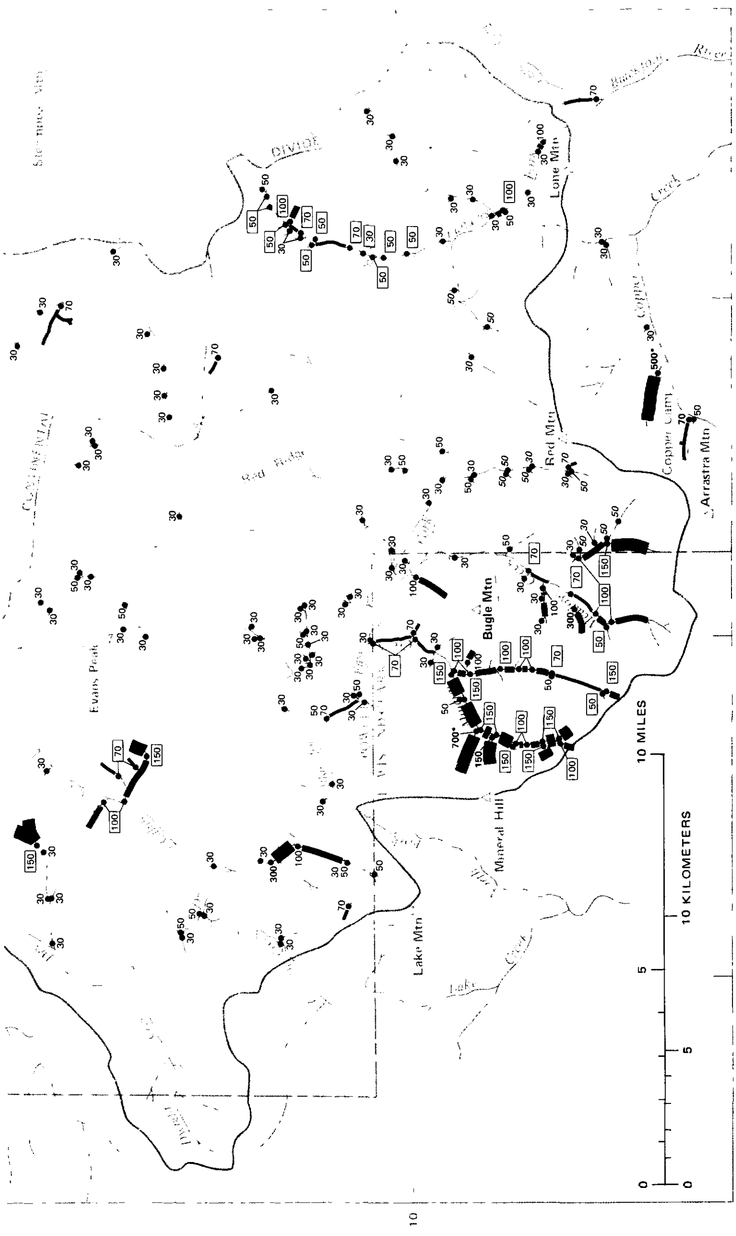


FIGURE 14.—Stream-sediment samples containing 30 ppm or more copper.

VEIN DEPOSITS

Numerous copper-bearing veins cut the Belt strata and diorite at several places in the southern part of the area. The veins have been prospected at Mineral Hill and Bugle Mountain in the Scapegoat Wilderness and at Copper Camp one-half mile east of the area. The near-vertical veins, which crop out only at these three localities, appear to be part of a vein system that trends N. 60° W. and extends for about 9 miles from Copper Camp to Mineral Hill. Surface observations and surface sampling indicate that only at Bugle Mountain do there seem to be significant amounts of copper, and even there the chances for a minable deposit are remote.

The vein system, which strikes subparallel to the strike of the strata, cuts the upper part of the Empire and Spokane Formations and the lower part of the Helena Dolomite. The wallrocks of the veins consist of siltite, dolomitic siltite, and very fine grained quartzite, and they contain copper minerals near the vein contacts, which are commonly sheared. At two places displacement of the wallrocks indicates that at least part of the veins occupies west-striking faults (fig. 15).

The width of the veins ranges from one-fourth inch to 2 feet, and both the width and the tenor vary greatly over short distances within the mineralized localities. Between the prospected areas the veins pinch out or are not exposed. The vein system, in which the distribution of copper minerals is erratic, is 110 feet wide at the prospected area on Bugle Mountain. Elsewhere, the width is difficult to determine because of poor exposures, but it probably is highly variable.

The metallic minerals in the veins are, in order of decreasing abundance, bornite (which locally makes up 40 percent of the vein material), malachite, chalcopyrite, pyrite, and chalococite. The veins also contain galena, sphalerite, and minor amounts of molybdenite at Copper Creek and trace to minor amounts of tetrahedrite at Copper Creek and Mineral Hill. The nonmetallic minerals are, in order of abundance, calcite, quartz, siderite, and barite. The metallic and nonmetallic minerals vary in relative abundance and are locally absent. Copper minerals in the wallrocks consist of bornite, malachite, and chalcopyrite and are commonly limited to within a few feet of the veins. They are locally abundant in fractures, along bedding planes, and in voids of the more porous rocks. At the Copper Creek prospect, copper minerals occur along some bedding planes for more than 100 feet beyond the vein and decrease in abundance away from the vein.

Several outcrop samples from the vein system contain high-grade copper (fig. 13). Although these are mostly selected samples, the analytical results and the distribution of the sample localities delineate the trend of the copper-bearing vein system. Samples of the veins contain as much as 18 percent copper (CC3), but material of this grade is

FIGURE 15.—High-angle normal fault in the lower part of the Helena Dolomite on the northwest side of the head of Copper Creek, near Copper Camp. The head of the pick lies across the fault zone. Drag-folded beds are to the right of the zone. A quartz carbonate vein to the left of the pick handle crosscuts the sheared carbonate beds in the fault zone. Dark areas along the zone are malachite-stained rocks.

highly localized in the vein system and is not present in quantity. The analytical results of representative samples are discussed in the section of this report describing individual prospects. The relatively large amounts of copper found in many of the stream sediments from the southern part of the area mostly reflect copper minerals associated with the quartz-carbonate vein system (fig. 13). Samples of sediments from streams draining the vein system contain 20-300 ppm copper; most have 100 ppm or more copper (fig. 14), compared with 5-20 ppm copper in stream-sediment samples elsewhere.

At Mineral Hill, an aplite dike about 20 feet wide strikes parallel to the vein system and contains visible but minor amounts of copper minerals. A similar dike was observed near the Klondike mine, a prospect near Mineral Hill. East of Mineral Hill, aplite dikes are rarely exposed, but where observed, they are only a few feet wide and do not contain visible copper minerals.

The economic potential of the vein system is based on surface investigations, because the underground working or prospects are caved or are otherwise unsafe to enter. At many localities the veins are poorly exposed, and their potential is difficult to assess. However, the lack of continuity and the narrow width of the veins, together with the apparent erratic distribution of anomalous minerals, indicate that the veins are probably not amenable to large-scale mining.

GREEN-BED COPPER OCCURRENCES

Weak copper mineralization in green to greenish-gray clastic rocks is widespread in the Scapegoat Wilderness, but the occurences contain insufficient grade and are too small for exploitation (fig. 13). The copper is most commonly in argillites, siltites, and quartzites of the Spokane and Empire Formations and the Snowslip Formation; it is also in the Helena Dolomite and the Shepard, Mount Shields, and McNamara Formations. Similar occurrences of copper in Belt rocks are widespread in northwestern Montana (Harrison and others, 1969; Harrison and Grimes, 1970; and Trammell, 1970). The copper minerals are, in order of abundance, malachite, bornite, azurite, chalcopyrite, and chalcocite. They are mostly along fractures and are commonly along bedding planes and in the intergranular voids of porous rocks, where the abundance of copper minerals increases proportionately to the grain size of the rocks. The copper-bearing strata commonly range in thickness from less than 1 inch to about 1 foot; rarely they are as much as 3 feet thick. Lateral continuity of anomalous amounts of copper ranges from a few inches to nearly 200 feet. In a few places, copper minerals are near the same stratigraphic horizon for about 1 mile but are not necessarily continuous over that distance. Lateral continuity of copper minerals is most widespread in porous beds. Minor, but anomalous, amounts of silver are associated with the copper; the silver is probably in the lattice of the copper minerals.

Selected samples of the mineralized green beds commonly contain as much as 1.5 percent copper; however, chip samples taken across zones as much as 3.2 feet thick are more representative of green-bed copper content and contain a maximum of only 0.2 percent copper (table 3). One selected sample (L276) from a green bed less than 1 inch thick in the Mount Shields Formation contained 3.3 percent copper, but a 39-foot chip sample across the green-bed section containing the thin mineralized bed had only 150 ppm copper.

A section of green beds containing abundant visible copper minerals is in the Snowslip Formation about 1 mile north of Red Ridge, which is in the east-central part of the area (pl. 1) about 11 miles north of the copper-bearing veins at Copper Camp. Here, three closely spaced green-bed sequences were tested by nine chip samples; a green bed intermediate between the middle and lower copper-bearing intervals was also sampled (table 3). The uppermost sequence (fig. 16) is 3.2 feet thick and can be traced laterally for 195 feet. Three chip samples (B342C-1, 2, 3) from this sequence contained 0.2, 0.15, and 0.15 percent copper; one

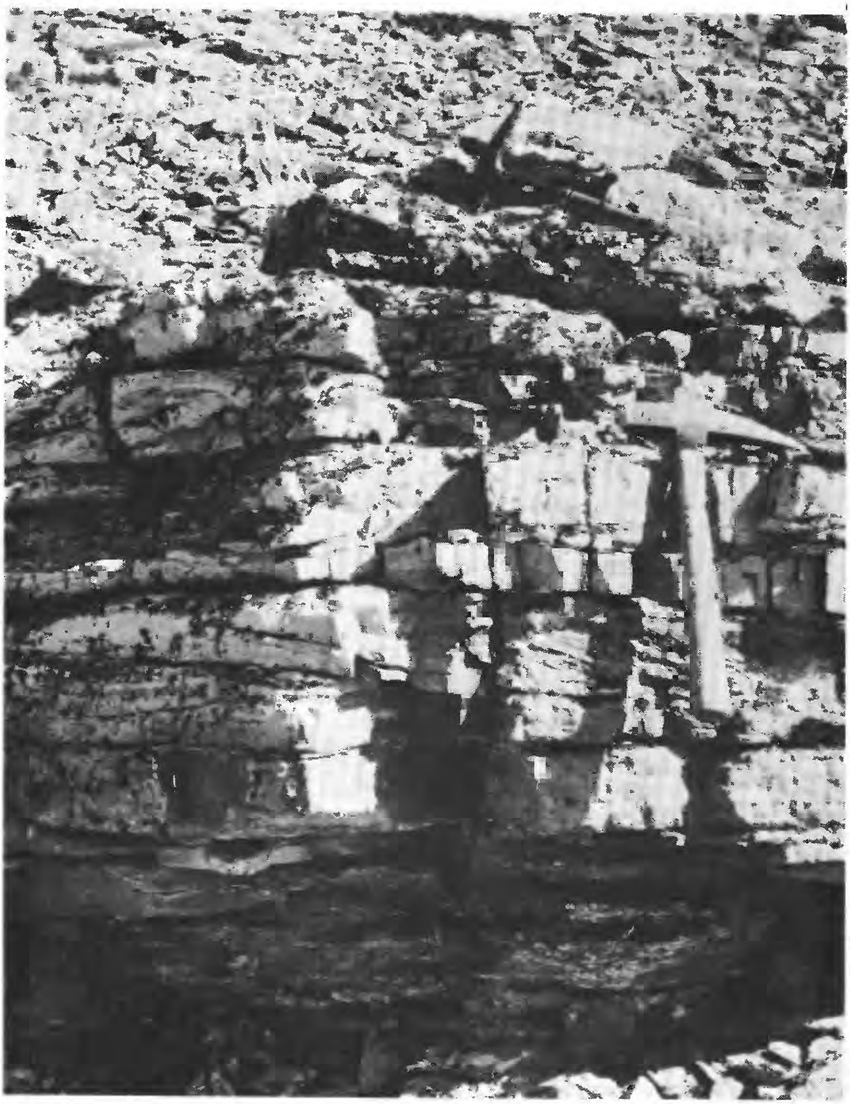


FIGURE 16.—A sequence of greenish-gray copper-bearing quartzites, about 3.2 feet thick, in the Snowslip Formation on the ridge at the head of the west fork of Landers Fork (chip sample B342, pl. 2). The underlying beds are thin-bedded siltite and argillite. Note thickness of individual beds and crossbedding.

sample contained 3 ppm silver, and the others each contained 1.5 ppm silver. The host rock is greenish-gray medium-grained crossbedded quartzite that displays graded bedding and contains thin layers of siltite. Bornite and malachite are in intergranular voids and in small crosscutting fractures. The middle mineralized green sequence is about

40 feet stratigraphically below the upper sequence, is 2.6 feet thick, and can be traced laterally for 156 feet. The lithology is similar to that in the upper sequence. Two of the three chip samples (B343C-1, 2) contained 0.15 percent copper, and the third (B343C-3) contained 0.1 percent; silver content ranged from 1.5 to 3 ppm. The lowermost copper-bearing green-bed sequence is about 50 feet stratigraphically below the middle zone, is 2.6 feet thick, and extends discontinuously for 125 feet. The copper minerals are in small fractures and along bedding planes in siltite and argillite. Three chip samples (B347C-1, 2, 3) contained 0.07, 0.07, and 0.005 percent copper, and silver content ranged from not detectable to 0.7 ppm. Each chip sample was taken over the thickness of the green-bed sequence near the middle and ends of the copper occurrence. One chip sample (B345C-1) from a green bed intermediate between the middle and lower mineralized sequences contained only 10 ppm copper.

In the extreme southeast part of the area, bornite, chalcopyrite, malachite, and azurite fill voids in the matrix of a gray fine-grained calcareous sandstone at the base of the Helena Dolomite. This occurrence warrants special mention because of its stratigraphic equivalence to a weakly mineralized lead-zinc belt in the vicinity of Wood Canyon, which is less than a mile northeast of the Scapegoat Wilderness (Mudge and others, 1968). The mineralized sandstone is poorly exposed in streambanks along Bighorn Creek about three-fourths of a mile north of its junction with Landers Fork and on Landers Fork about one-fourth of a mile below the confluence. In Bighorn Creek the sandstone is about 5 feet thick and locally crops out along strike for 1,000 feet. Six grab samples over this interval (B471, B471A, B471B, B471C, B472, B472A) contained 0.1-0.3 percent copper and 1.5-15 ppm silver. Three samples (B480, B480A, B480B) from sandstone exposures at Landers Fork ranged in copper content from 150 to 300 ppm and in silver content from not detectable to 15 ppm. However, large boulders of sandstone and siltite considerably richer in copper were found a short distance downstream from the outcrops. Although the contact at the base of the Helena Dolomite is well exposed on the ridges about 2 miles north of the Landers Fork mineral locality, the sandstone unit is absent, and the rocks in the vicinity of the contact contain no visible copper minerals.

The presence of copper minerals in green quartzites, siltites, and argillites included in alternating red and green rock sequences and the near exclusion of copper minerals from the same rock types in the red beds of those sequences suggest that the origin of the copper may be closely related to the processes affecting the color of the rocks. The fact that the coloration boundaries locally transect bedding planes and that abrupt lateral changes in color are common suggests that, for the most part, the alternating color pattern is a postdepositional feature which may have been the result of fluctuating oxidation-reduction conditions during the accumulation of the sedimentary pile, probably late in the diagenesis of the rocks. A comparison of the amounts of iron and copper in the red and green beds of varied lithologies suggests that, in general, red beds may have been depleted and green beds enriched in these elements. However, the evidence for this depletion and enrichment is inconclusive because direct comparison of the abundance of critical elements in red and green rocks of the same lithologies and grain sizes has not been made. Such studies may be helpful in determining the origin of the copper deposits, but they were not within the scope of the present investigations.

Since the copper minerals were emplaced, the host rocks have been subjected to tectonic activity, regional metamorphism, weathering, and, rarely, contact metamorphism. Deformation associated with tectonic activity and metamorphism had had no noticeable effects on the redistribution or concentration of the copper minerals. Faults that transect the green beds are devoid of copper minerals, and there is no apparent relationship between the copper occurrences and the troughs or crests of folds.

Replacement of chalcopyrite by bornite in some samples is indicated by a core of chalcopyrite surrounded by bornite. We do not know when in geologic time the bornite formed. In recent time, however, the rate of erosion has exceeded the rate of oxidation, and the presence of supergene copper minerals in the outcrops suggests that enriched zones at depth would not contain significantly higher grade copper than that found at the surface.

In summary, copper-bearing green clastic rocks are in several formations in the Scapegoat Wilderness, but they are most common in the Spokane and Empire and Snowslip Formations (table 2 and fig. 13). Green-bed sections of the Spokane and Empire Formations are limited to the southern part of the Scapegoat Wilderness, whereas green beds in the Snowslip Formation are widely distributed. Copper content of ore grade is present in beds no more than a few inches thick. Conversely, green-bed sequences that are thick enough to be minable do not have sufficient grade to be considered a resource under foreseeable economic and technologic conditions.

LEAD AND ZINC

Ores of lead or zinc were not found in the Scapegoat Wilderness. About half a mile northeast of the area, a belt of weak lead-zinc mineralization is in calcareous sandstone at the base of the Helena Dolomite, in the Flathead Sandstone, and in Devonian rocks (Mudge and others, 1968), but similar occurrences were not found in the wilderness area.

The quartz-carbonate veins in the southern part of the area contain as much as 1.5 percent lead and 0.15 percent zinc, but these metals are erratically distributed in the vein system. Trace to minor amounts of lead and zinc were locally detected in thin stromatolitic beds of the Helena Dolomite and the Shepard Formation; the maximum values are 0.3 percent lead and 0.1 percent zinc. In a few places, traces of galena were observed in silty dolomite near the base of the Helena Dolomite and in limestone of Cambrian age; the lead values are commonly less than 0.1 percent, and the maximum value is 0.5 percent (fig. 17). Most stream sediments contain 10-30 ppm lead (fig. 11); only five contain 100 ppm or more lead, and these are widely distributed (fig. 17). Only one stream sediment (sample 533) contained more than 200 ppm zinc.

OTHER COMMODITIES

Several other commodities are present in above-normal concentrations in the Scapegoat Wilderness, but none of them have economic potential. The quartz-carbonate veins in the southern part of the area locally contain trace to minor amounts of barium, antimony, bismuth, cadmium, molybdenum, and arsenic, but the occurrences are much too small and low grade to be of economic importance.

The Precambrian clastic rocks locally contain 3,000-5,000 ppm barium and rarely as much as 3 percent barium. The barium is in the matrix of the rocks and in stringers and veinlets. Although the barium content of the clastic rocks is abnormally high (Goldschmidt, 1958), it is not economically significant.

All rock and stream-sediment samples were analyzed spectrographically for molybdenum, and all water samples were tested chemically for it. Molybdenum in sparse amounts was found in 40 widely scattered rock samples but in only 13 water samples. Most rock samples containing molybdenum also contain anomalous amounts of copper or lead. The molybdenum content is 5-30 ppm in most samples but is as much as 500 ppm in two samples (fig. 19)—one (sample CC5) from a copper-bearing 4- to 6-inch-thick quartz-carbonate vein at the head of Copper Creek, just outside the wilderness area, and the other (sample B368A) from a very thin bed of gray-green copper-bearing argillite in the Snowslip Formation exposed south of the Dearborn River.

Mercury was detected in anomalous amounts (0.10 ppm or more) in widely scattered rock and stream-sediment samples in the area, especially south of the Continental Divide (fig. 18). In most rock samples the mercury appears to be associated with copper and (or) lead; in some it may reflect the pyrite in carbonate rocks. Although most anomalous rock samples contain 0.10-0.65 ppm mercury, some contain 1.0 to more than 10.0 ppm. The samples with values of more than 1.0 ppm are CC5 (more than 10 ppm), CC3 (1.1 ppm), L6 (1.5 ppm), B12 (1.0 ppm), B87

(2.5 ppm), B190 (1.0 ppm), B480A (5.0 ppm), B480B (3.6 ppm), and B311 (6.0 ppm). The anomalous amounts of mercury in stream-sediment samples are mostly between 0.10 and 0.18 ppm (fig. 18). The sediment samples that contain more than 0.18 ppm mercury are 5 (0.45 ppm), 35 (0.22 ppm), 39 (0.24 ppm), 42 (0.50 ppm), 70 (0.22 ppm), 81 (0.40 ppm), 94 (0.35 ppm), and 282 (0.24 ppm). Some samples of stream sediment derived from carbonate rock are anomalous in mercury but not anomalous in copper or lead; they may reflect a concentration of pyrite. Gold was not detected in any of the rock or stream-sediment samples high in mercury.

The citrate-soluble heavy-metal content of stream sediments shows a spotty pattern of anomalous values (9 ppm or more). The highest contents are in the Mineral Creek drainages (fig. 20). The highest concentrations shown in figure 20 are for samples 94 (70 ppm), 5 (20 ppm), 42 (35 ppm), and 533 (20 ppm). All but sample 533 are from streams draining areas that contain cupriferous rocks. Sample 533 was collected just below a diorite sill outcrop.

The Precambrian diorite sills locally contain 11 percent iron, much of which is in magnetite. However, the iron occurrences in the diorite sills are too small and low grade to be considered an iron resource.

The area contains large deposits of limestone, which may be suitable for the manufacture of cement, and deposits of sand and gravel, but these raw materials are readily accessible in other areas closer to markets.

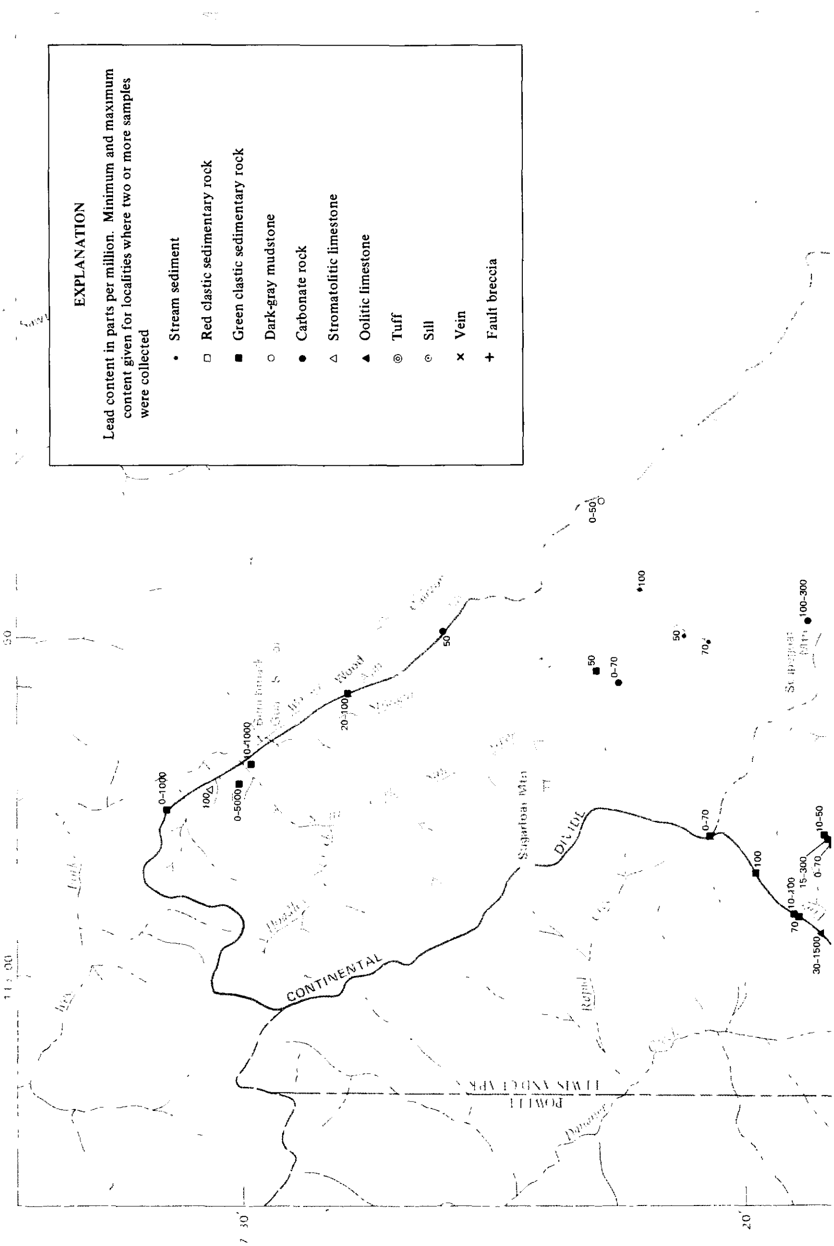
Deposits of high-quality ornamental stone were not found in the area. Parts of the Garnet Range Formation could be used for flagstone, and some of the quartzite and dolomite units in the other formations may be suitable for building stone, but superior products are readily available in more accessible areas.

MINING CLAIMS

According to Lewis and Clark and Powell County records, 131 mining claims were located in the study area. Most of them are in the southern part of the area and in the vicinity of Welcome Pass on the east border (fig. 21). The earliest claims were located in the 1800's. Inasmuch as many of the claims are old and lack evidence of excavations, they were not positively identified on the ground. Some were not found. The most recent prospecting activty has been in the southern part of the area.

MINES, PROSPECTS, AND MINERALIZED AREAS

Most mining claims and workings within the study area are located along a northwest-trending belt of copper mineralization which extends about 10 miles from the upper part of the Copper Creek area northwestward to Mineral Hill (fig. 21). Three distinctly mineralized


EXPLANATION
Lead content in parts per million. Minimum and maximum content given for localities where two or more samples were collected
Stream sediment
Red clastic sedimentary rock
Green clastic sedimentary rock
Dark-gray mudstone
Carbonate rock
Stromatolitic limestone
Oolitic limestone
Tuff
Sill
Vein
Fault breccia
0-1000
100
0-5000
10-1000
20-100
50
0-50
100
50
0-70
50
70
100-300
0-70
100
10-50
15-300
0-70
10-100
70
30-1500
CONTINENTAL
DIVIDE
Sugarloaf Mtn
POWELL
LEWIS AND CLARK
47°30'
20'

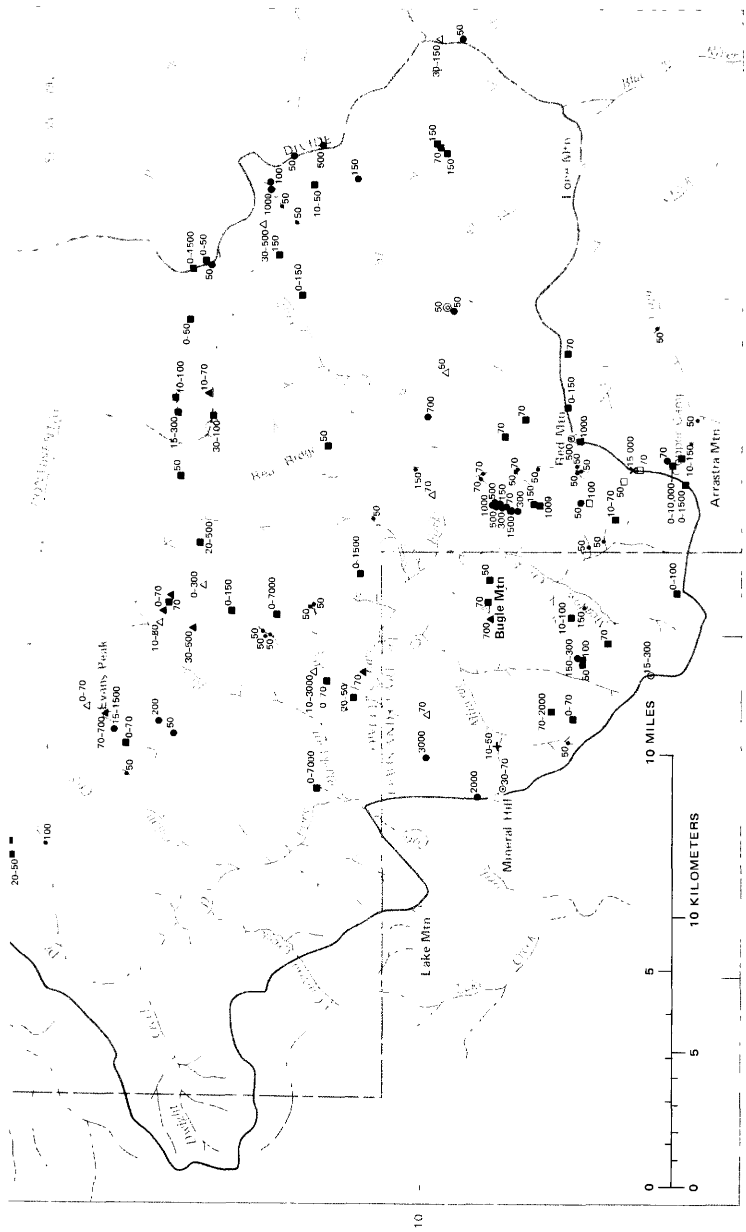
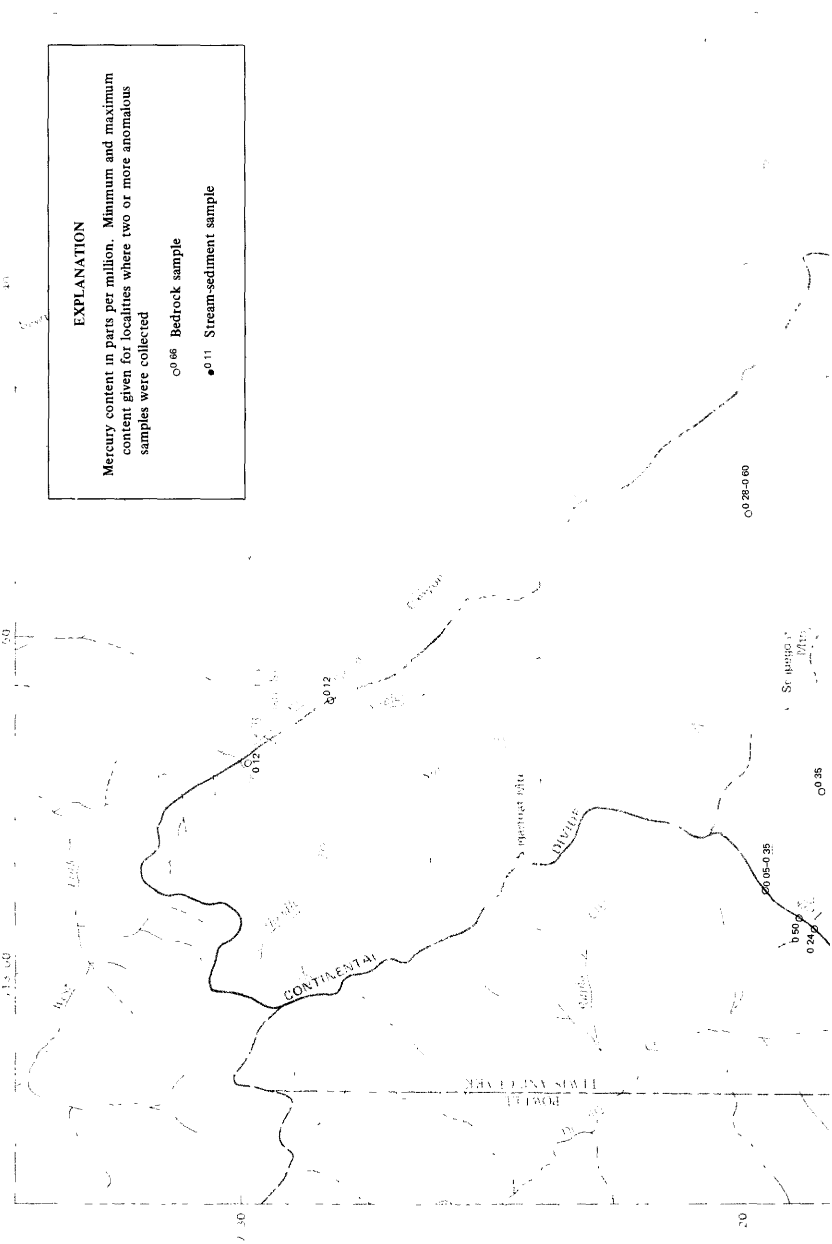


FIGURE 17.—Rock and stream-sediment samples containing 50 ppm or more lead.


EXPLANATION
Mercury content in parts per million. Minimum and maximum content given for localities where two or more anomalous samples were collected
○0 66 Bedrock sample
●0 11 Stream-sediment sample
0 28-0 60
0 12
0 12
0 35
0 05-0 35
0 50
0 24
CONTINENTAL
DIVIDE
47 30
20

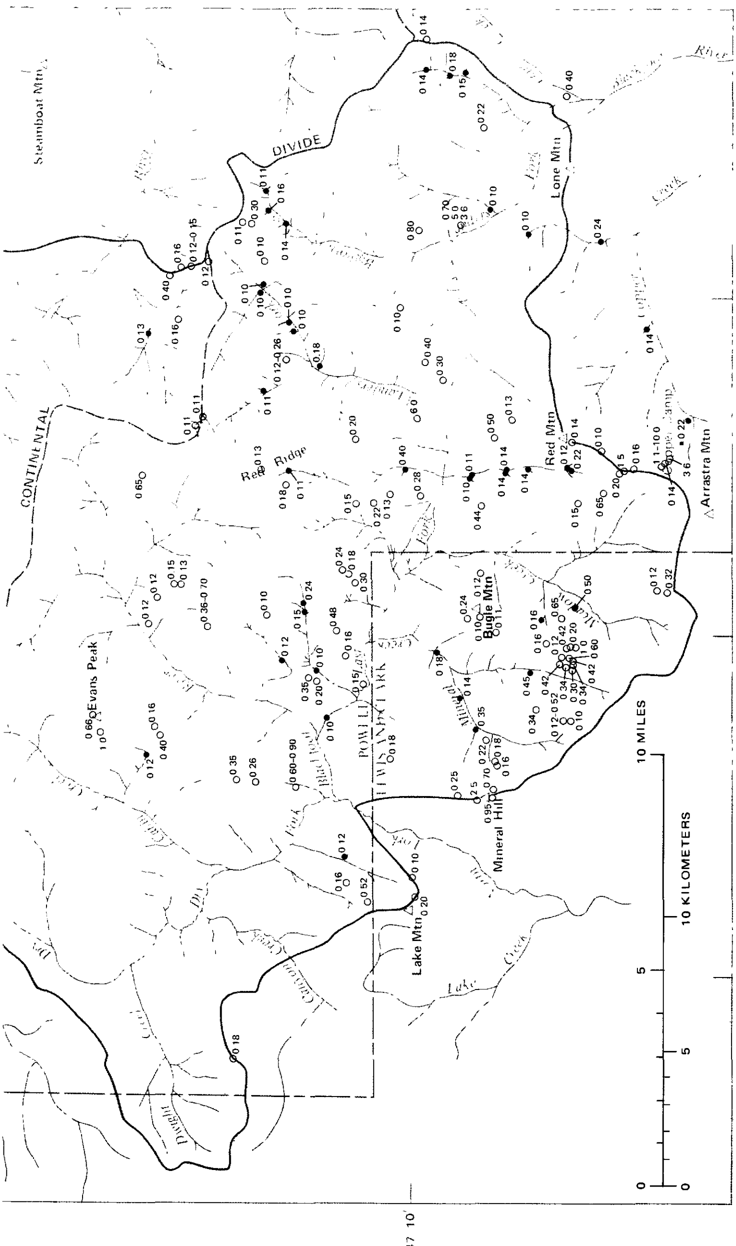


FIGURE 18.—Rock and stream-sediment samples containing 0.10 ppm or more mercury.

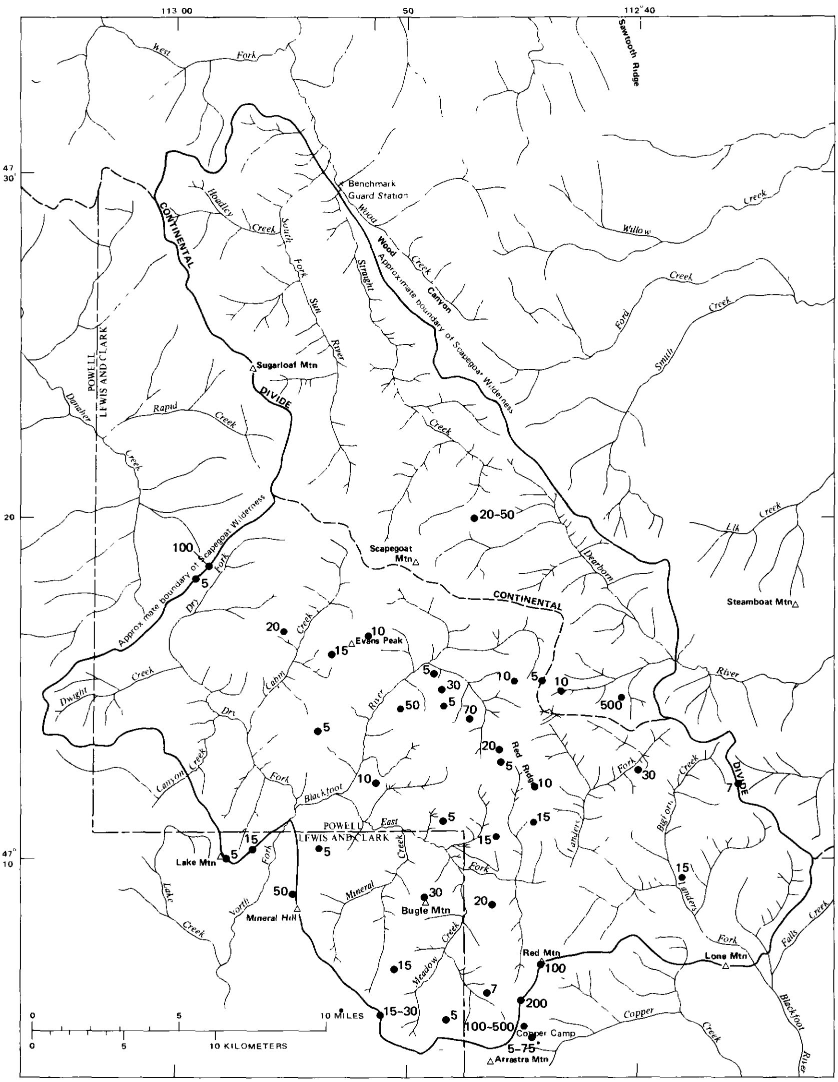


FIGURE 19.—Rock samples containing 5 ppm or more molybdenum.

areas along this belt are upper Copper Creek, Bugle Mountain, and Mineral Hill. The belt roughly parallels the contact between the Spokane and Empire Formations and the Helena Dolomite.

Mineralization is structurally controlled; it is in west-trending veins and veinlets in argillite and in normal faults in the upper part of the Spokane and Empire formations and the basal part of the Helena Dolomite. The veins and veinlets contain quartz, calcite, chalcopyrite,

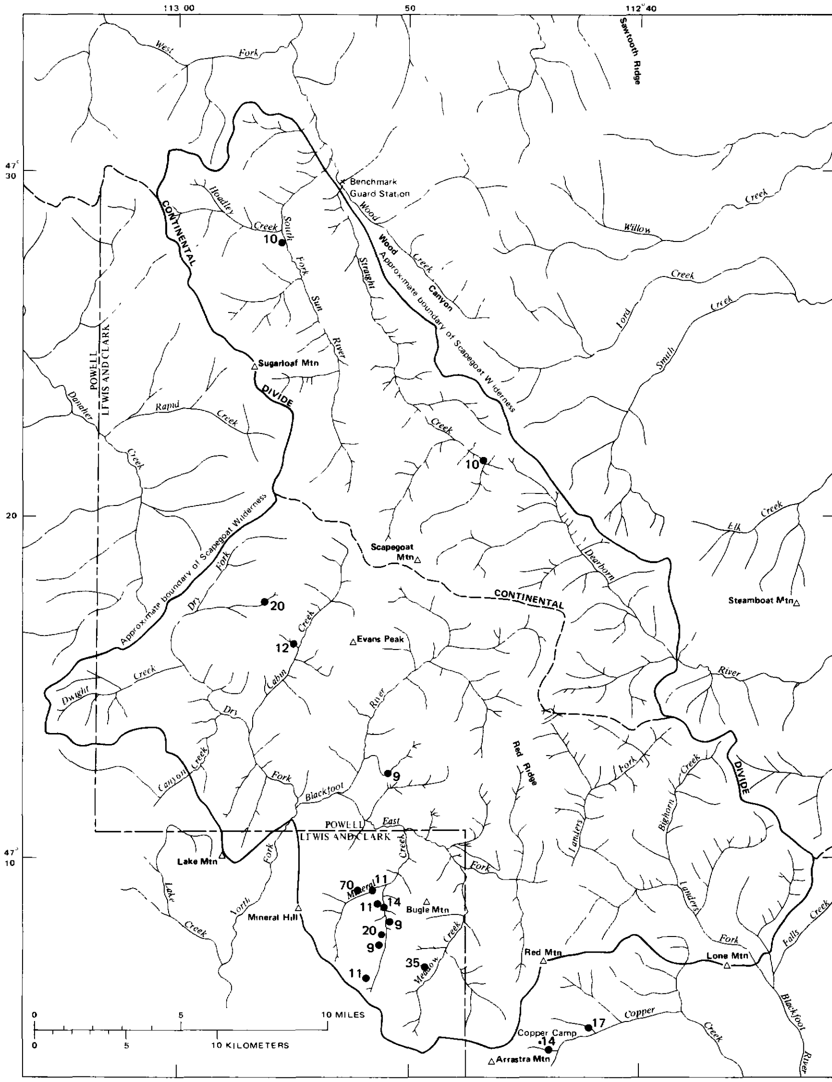


FIGURE 20.—Stream-sediment samples containing 9 ppm or more citrate-soluble heavy metals.

chalcocite, and bornite. Malachite and minor azurite stains fractures, bedding, and cleavage planes. Copper minerals are in the country rock to a small extent, but most are in veins and veinlets separated by barren country rock.

Interest in the belt has existed since the 1800's, as indicated by claim records and numerous old prospect pits, caved adits, and shafts on Mineral Hill, on Bugle Mountain, and in the upper Copper Creek area.

Only the Copper Creek area, which is about one-half mile outside of the wilderness boundary, has a history of past production. Small tonnages of copper ore were reportedly shipped from this area during 1917, 1919, and 1920.

During the mid-1960's, Bear Creek Mining Co. located claims on Bugle Mountain, leased others at Copper Camp, and reportedly did a considerable amount of exploration work.

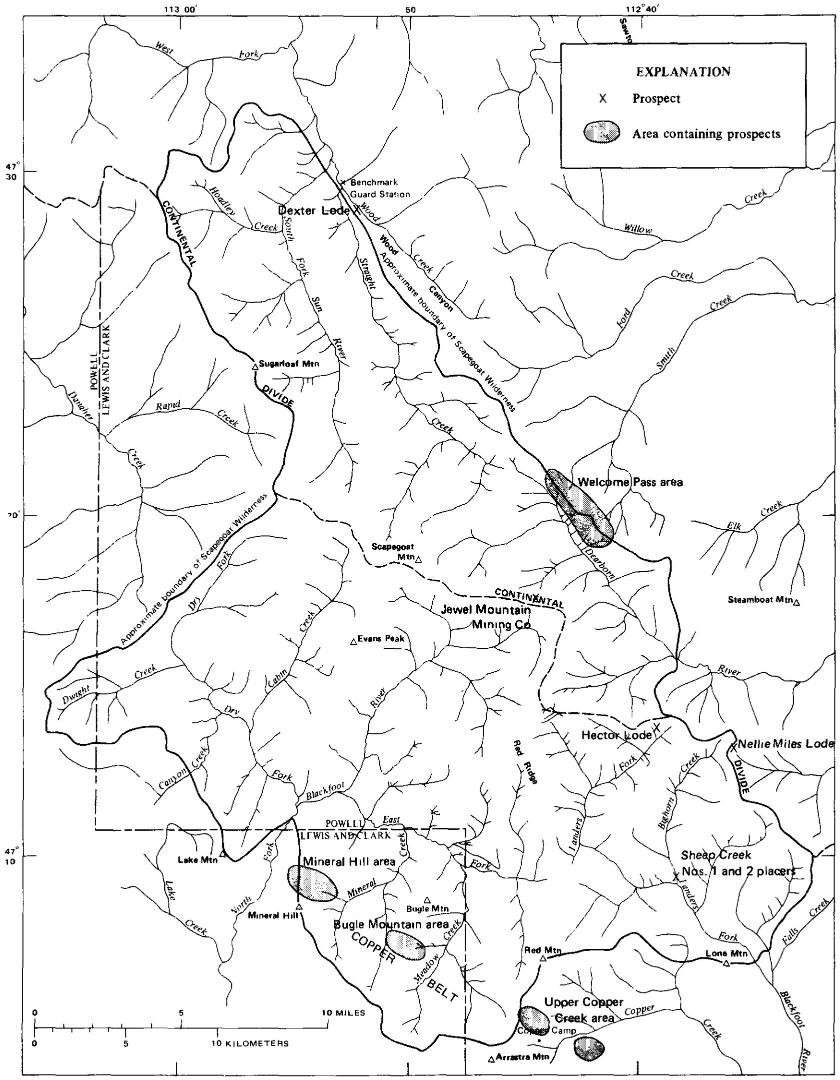


FIGURE 21.—Prospects and claimed areas in and near the Scapegoat Wilderness.

Two groups of mining claims are located in the vicinity of Welcome Pass along the northeast side of the area (fig. 21). However, field investigations did not disclose any significant mineralization in this vicinity.

Other mining claims are sparsely scattered throughout the study area. Those found and examined did not show significant mineralization.

MINERAL HILL AREA

The Mineral Hill area is on the southwest boundary of the wilderness area (fig. 21). Most of the workings are in unsurveyed secs. 17, 18, and 19, T. 16 N., R. 10 W., on the east flank of Mineral Hill between 6,000 and 7,800 feet elevation.

Powell County records show that possibly 20 mining claims were located before 1920 on the east side of Mineral Hill. Only two, the Porto Rico and Klondike, were positively identified on the ground. Production records are not available from these or other properties in the Mineral Hill area.

PORTO RICO PROSPECT

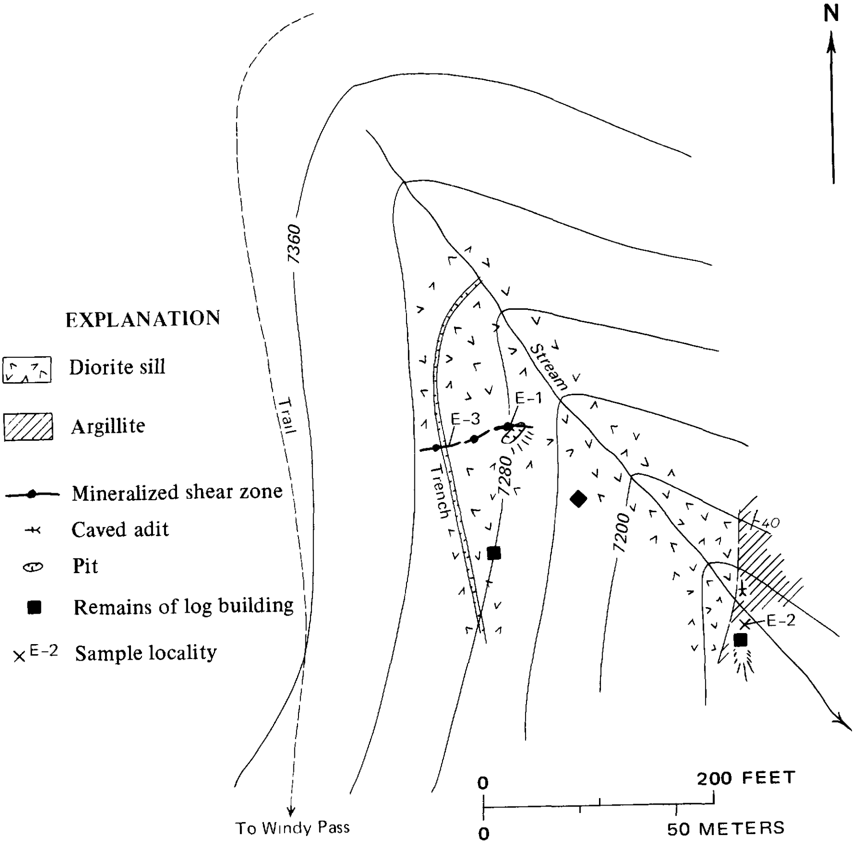
The Porto Rico prospect is in the NE¼ sec. 19, T. 16 N., R. 10 W., about 3,500 feet southeast of Mineral Hill summit. A horse trail which leads to Windy Pass skirts the north and west sides of the workings (fig. 22).

A northwest-trending diorite sill of Precambrian age is a major geologic feature in the area (pl. 1). It is several hundred feet thick and lies entirely within the Spokane and Empire Formations.

The principal working is an adit, now caved, which appears to have been driven along the upper contact of the sill partly in green argillite of the Spokane and Empire Formations. Brecciated argillite on the dump contains copper minerals and indicates that the mineralization is along a shear zone. The breccia consists of angular bleached argillite fragments cemented by brownish calcite, chalcocite, and bornite. A select sample of breccia (E-2) from the dump assayed 18.20 percent copper, 0.02 ounce gold per ton, and 3.1 ounces silver per ton (fig. 22).

A pit 25 feet long, 10 feet wide, and 3 feet deep is about 300 feet northwest of the caved adit. A shear zone, 3 feet wide, is exposed in diorite on one side of the pit. This zone contains numerous small quartz stringers and is highly oxidized, as shown by the abundance of clay, hematite, and limonite. A 3-foot chip sample (E-1) taken across the shear zone assayed 0.63 percent copper, a trace gold, and 0.2 ounce silver per ton (fig. 22).

The shear zone is also exposed 70 feet west of the pit in a shallow trench. The trench is 350 feet long, 2 feet wide, and 2-2½ feet deep. A 3-foot chip sample (E-3) taken across the shear zone contained 0.03 percent copper and no gold or silver.



Sample	Length (feet)	Copper (percent)	Gold (oz per ton)	Silver (oz per ton)
E-1	3	0.63	Tr.	0.2
E-2	Select, dump	18.20	0.02	3.1
E-3	3	.03	N.d.	N.d.

FIGURE 22.—Map and assay data, Porto Rico prospect area. N.d. not detected; tr., trace. All samples were also assayed for lead, but none was detected.

The select sample indicates that some high-grade rock was intersected in the adit. The extent of this material is not known.

KLONDIKE PROSPECT

The Klondike prospect is in the SW¼ sec. 17, T. 16 N., R. 10 W., within a narrow canyon about 1 mile north of Windy Pass.

Copper minerals are in argillite in the lower part of the Helena Dolomite near its northwest-trending contact with a siliceous dike. The mineralized rock, as much as 60 feet wide, is intermittently exposed along a distance of 500 feet near the contact.

The caved portal of the Klondike adit is near the creek; the dump has been washed away. The adit was driven in argillite which crops out for 350 feet along the north side of the creek (fig. 23). The rock is mostly grayish blue but has some brown and green interbeds. The beds in the vicinity of the prospect strike generally N. 55° W. and dip 25° NE.; however, beds northwest of the adit dip more steeply. This increase in dip and the moisture at the portal indicate the presence of a fault parallel to the adit. East-trending quartz veinlets ⅛ to ¼ inch wide are in some beds of argillite west of the probable fault. The veinlets contain chalcocite, pyrite, and bornite. Locally, joints, fractures, and bedding planes are heavily coated by malachite.

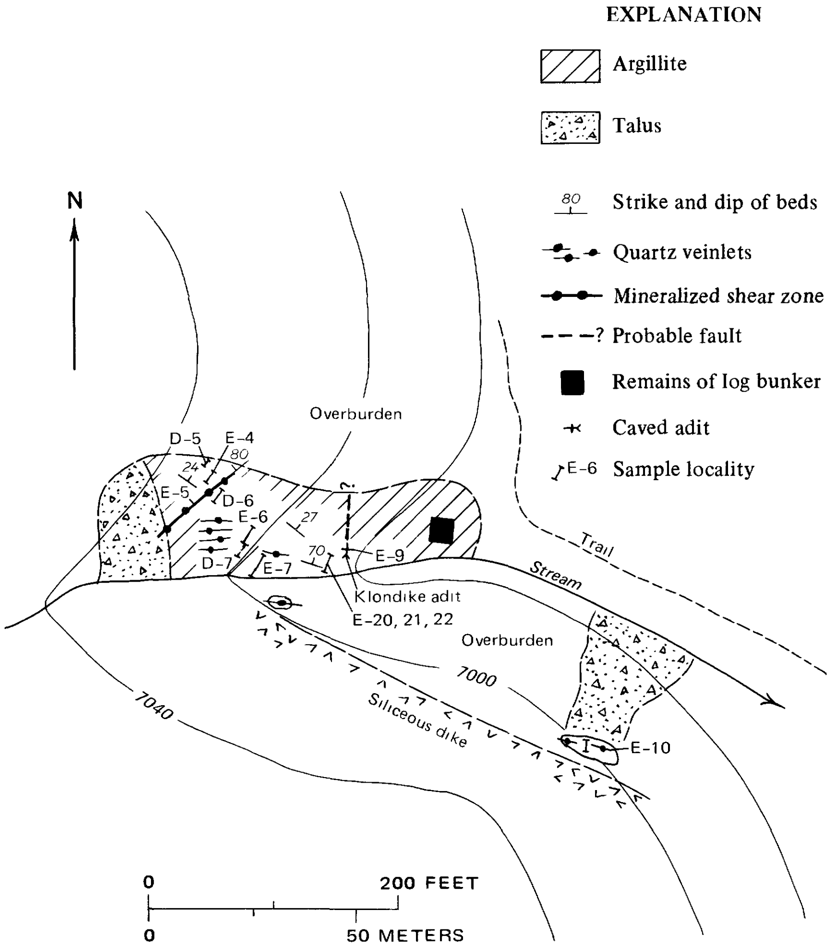
A line of chip samples was taken stratigraphically down an outcrop near the portal, and a second line was taken stratigraphically down the argillite to the west (fig. 23). The line near the portal consisted of three samples (E-20, 21, 22) which totaled 18.5 feet in length and contained an average of 0.15 percent copper (weighted by length). The second line consisted of six samples (E-4, 6, 7, and D-5, 6, 7) which totaled 59.5 feet in length and contained an average of 0.38 percent copper (weighted by length). A chip sample (E-5) across a quartz vein about 150 feet northwest of the portal contained 0.16 percent copper and 0.08 percent lead. The vein strikes N. 50° E. and dips 80° NW., and the mineralogy of the vein is similar to that of the narrow east-trending veinlets.

Copper-bearing quartz veinlets in argillite also were observed in two expsosures on the south side of the creek. A sample (E-10) taken from one of the exposures at a point 285 feet southeast from the portal contained 0.33 percent copper and no lead.

The copper content of the visible outcrops indicates that the deposit is not economic. A relatively large resource of low-grade mineralized rock—about 700,000 tons containing 0.3 percent copper—may be present.

MINERAL HILL PROSPECT

A trench and pit in a cirque on the east side of Mineral Hill in SE¼ sec. 18, T. 16 N., R. 10 W., are about 2,000 feet north of the Porto Rico prospect. The workings are about 1,000 feet northwest of the trail that leads through Windy Pass and skirts the Porto Rico and Klondike prospects. The trench is 18 feet long, 3 feet wide, and 2 feet deep and exposes a bed of mineralized argillite in the Spokane and Empire Formations. The bed is 1.7 feet thick and can be traced for about 200 feet; it strikes about N. 40° W. and dips 32° NE. (fig. 24). It is light gray, highly siliceous, and much harder than the nonmineralized argillite that is stratigraphically above and below it. Chalcocite and bornite fill small fractures, and malachite and azurite coat joints and bedding

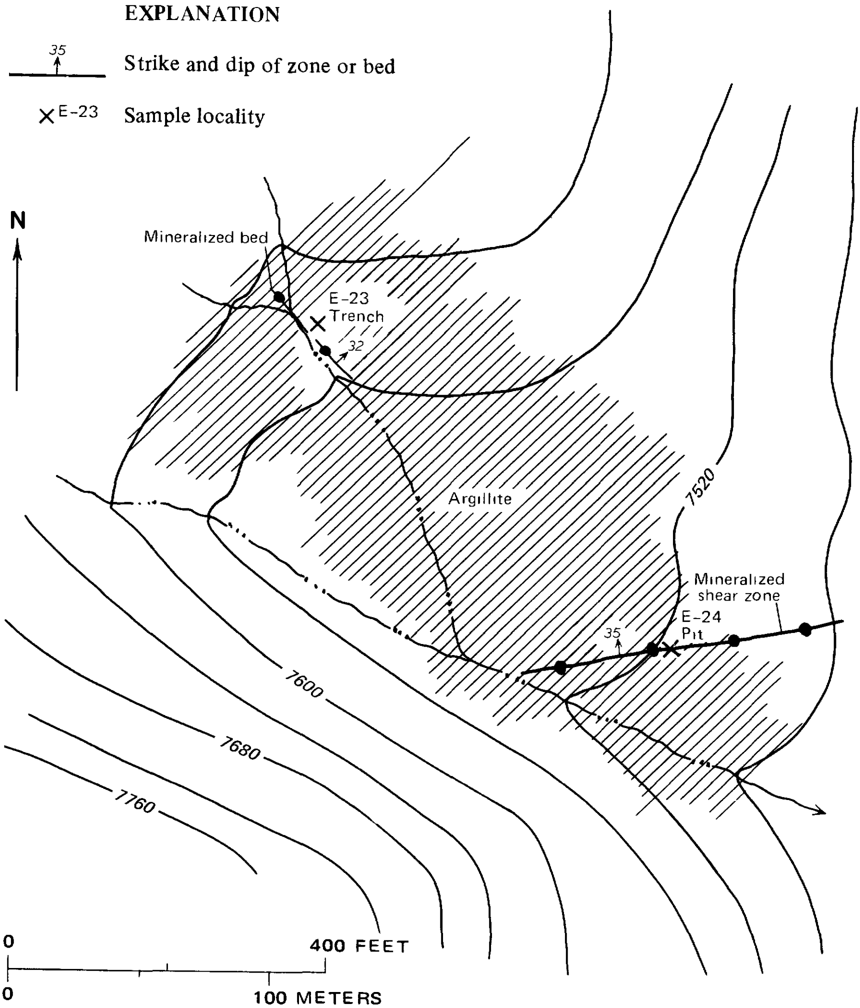


Sample	Length (ft)	Copper (percent)	Lead (percent)
E- 4	9.0	0.44	0.04
5	1.8	.16	0.08
6	6.5	.30	N.d.
7	20.0	.63	.08
9	Grab	.01	N.d.
10	6.0	.33	N.d.
20	4.5	.22	<.01
21	6.0	.10	<.01
22	8.0	.15	<.01
D- 5	5.0	.17	N.d.
6	12.0	.19	.05
7	7.0	.17	<.01

FIGURE 23.—Map and assay data, Klondike prospect area. N.d., not detected.

planes. One sample (E-23) taken across the bed assayed 0.06 percent copper and < 0.01 percent lead (fig. 24).

About 600 feet southeast of the trench, a pit 6 feet across and 5.5 feet deep exposes a copper-bearing shear zone in green argillite. The highly sheared zone is 5.5 feet wide, can be traced for more than 380 feet,



Sample	Length (ft)	Copper (percent)	Lead (percent)
E-23	1.7	0.06	<0.01
E-24	5.5	.47	<.01

FIGURE 24.—Map and assay data, Mineral Hill Prospect area.

strikes N. 80° E. and dips 35° N. The shear planes are heavily coated by malachite containing specks of chalcocite and bornite. One sample (E-24) taken across the zone assayed 0.47 percent copper and <0.01 percent lead.

The deposit is too low in grade to be economically minable but is a potential resource of copper.

BUGLE MOUNTAIN AREA

The Bugle Mountain mineralized area is near the common corner of unsurveyed secs. 22, 23, 26, and 27, T. 16 N., R. 10 W. The most highly mineralized zone is in the basal part of the Helena Dolomite and is at an elevation of about 7,000 feet on the east side of the ridge connecting Bugle Mountain with Daly Peak (pl. 1). The slopes are covered by trees suitable for mining timber. Water, however, would be a problem and would need to be pumped from Meadow Creek, a vertical distance of about 1,000 feet.

The route to the area from Lincoln, Mont., is 30 miles northwestward by State Highway 200 and graveled roads to the Salmon Creek school near Coopers Lake, then about 7 miles by pack trail into Meadow Creek basin, and then 1.5 miles northward cross-country to the ridgetop. Mineral development of this area would necessitate about 7 miles of new road over rough rocky terrain.

Records at the Powell County courthouse indicate that three lode claims were located in the Bugle Mountain-Daly Peak area during the early 1900's. Old workings were found but could not be correlated with these old claims. During the mid-1960's, Bear Creek Mining Co. located 80 contiguous mining claims and conducted detailed exploration work in this area. These claims have since lapsed.

BUGLE MOUNTAIN GROUP

The Bugle Mountain group of claims is about 2½ miles southwest of Bugle Mountain (fig. 21) in unsurveyed secs. 22, 23, 26, and 27, T. 16 N., R. 10 W. The claims are at elevations between 6,000 and 7,000 feet on the crest and east slope of the ridge between East Fork Mineral Creek and Meadow Creek.

The group contains 80 contiguous lode claims, staked in September 1965 by Bear Creek Mining Co. Apparently no assessment work was filed subsequent to location, but some exploration work was conducted. Old workings are present in the area, and the older exploration probably was done at the same time as that at the Porto Rico and Klondike prospects, which were worked in the late 1800's and early 1900's.

The Spokane and Empire Formations and the Helena Dolomite crop out at the Bugle Mountain claims. The lower part of the Helena Dolomite is mostly thinly bedded well-fractured light-gray to tan calcareous siltstone. Light-colored calcareous rocks of the underlying Spokane and Empire Formations grade downward into beds of red and green argillite. The bedding strikes N. 55°-65° W. and dips 25°-20° NE.

Copper minerals appear to be confined to the east-trending zone that parallels the bedding in the Helena Dolomite.

Two types of copper occurrences are present: (1) malachite, bornite, and chalcopyrite which fill some thin fractures and which occur at stringers and blebs along bedding planes in calcareous rocks, and (2) massive malachite, bornite, and covellite which are in quartz-calcite fissure veins.

Copper in fracture fillings, stringers, and blebs is restricted to zones or stratigraphic intervals in fine-grained calcareous rocks. The copper-bearing zones are about 5-30 feet thick, and they are separated by a few feet to several tens of feet of barren rock. The mineralized rock is well-fractured thinly bedded to finely laminated gray to tan calcareous siltite and argillite. Malachite, bornite, and chalcopyrite are present as 1/16- to ¼-inch-thick fillings and as pinpoint to ⅛-inch irregular blebs on fractures. Iron and manganese oxides impart brown and black stain to the rock adjacent to and along the mineralized fractures.

The fissure veins are sparsely to heavily mineralized. Malachite, bornite, and a small amount of covellite occur as stringers of variable width and as irregular masses in banded quartz-calcite veins. The veins have an average thickness of about 10 inches; they strike mostly east and dip steeply north or south.

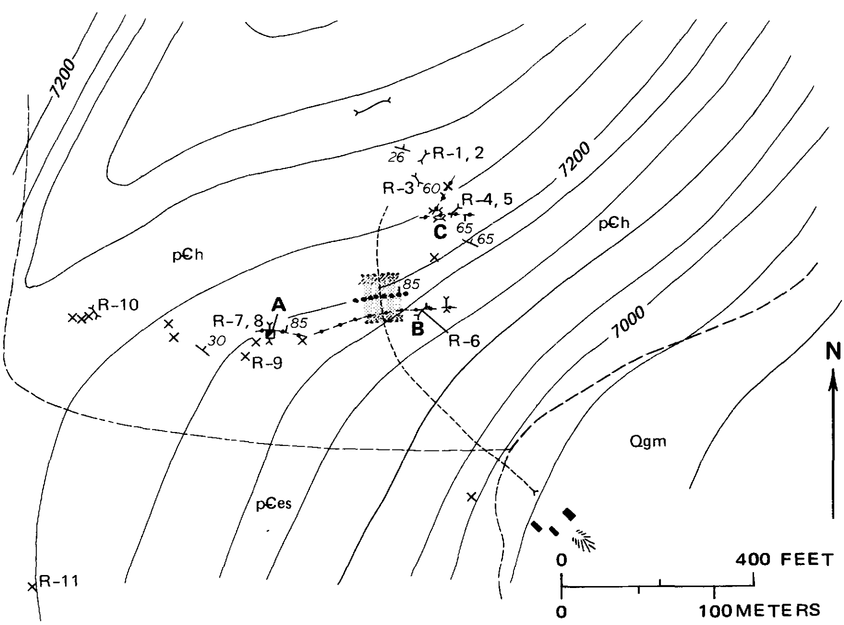
The workings consist of a caved shaft, an adit, and about 20 shallow pits, trenches, and opencuts that are largely sloughed. The pits and trenches are scattered over a 500- by 1,000-foot area on the Meadow Creek side of the ridge. Although bedrock exposures in the surface workings are poor, mineralized rock on dumps indicates that both types of copper occurrences were found.

The shaft (loc. A, fig. 25) is collared on the floor of a 12-foot-deep trench and is caved about 10 feet below the collar. The shaft (fig. 26) was sunk on a 14-inch-thick banded quartz-calcite fissure vein that strikes west and dips 85° N. A shallow sloughed pit 65 feet to the east has similar vein material on the dump. Bedrock exposed in the trench is profusely fractured thinly laminated mottled gray calcareous argillite. Malachite crusts and fillings and sparse small blebs of bornite are along the fractures and some bedding planes. A 10-foot-long chip sample (R-7) taken normal to bedding in the west wall of the trench assayed 1.99 percent copper; a 1.4-foot-long chip sample (R-8) across the quartz-calcite vein assayed 0.32 percent copper.

A small pit 70 feet southwest of the shaft exposes a 4-foot-thick section of calcareous argillite that has sparse malachite on fracture planes. A 4-foot chip sample (R-9) from the pit wall assayed 0.59 percent copper.

A shallow partly sloughed 4- by 20-foot trench, 370 feet west of the shaft, exposes well-fractured thinly bedded gray to tan calcareous argillite that has 1/16-inch-thick malachite in many fractures and bedding planes. A 4-foot stratigraphic section of rock contains copper minerals. A grab sample (R-10) across 8 feet of the dump assayed 2.37 percent copper. The mineralized zone exposed here may be an extension of that exposed by the shaft and trench.

A small dump containing a few hundred pounds of massive



EXPLANATION

- Qgm — Quaternary glacial deposits
- p€h — Precambrian Helena Dolomite
- p€es — Precambrian Empire and Spokane Formations
- Contact
- 30 — Strike and dip of beds
- Vein
- × Pit
- Cut or trench
- Shaft
- Adit
- Fault zone at adit level
- Mineralized zone at adit level
- Building
- R-6 Sample locality
- Dump
- A Area discussed in text

FIGURE 25.—Map (above) and assay data (right), area of Bugle Mountain prospects. N.d., not detected; tr., trace. All samples were also assayed for lead, but none was detected.

malachite-bornite copper ore adjoins two caved prospect pits at locality B (fig. 26). These workings are about 350 feet east of the shaft and probably explored the same east-trending fracture zone. A grab sample (R-6) across 4 feet of the dump assayed 45.2 percent copper and 3.4 ounces silver per ton.

At locality C (fig. 25), 450 feet northeast of the shaft, a 22-foot stratigraphic section of mineralized rock and three copper-bearing veins are exposed by a 45-foot-long opencut. The cut trends east-west and was excavated parallel to the contour of the slope. The rock is well-fractured thin-bedded gray to tan calcareous siltite that breaks out in rectangular blocks along joints. The bedding strikes N. 65° W. and dips 30° NE. Sparse to moderate amounts of malachite and bornite are present as hairline 1/16-inch-thick stringers and coatings along joints, fractures, and bedding planes.

The veins are mostly quartz and calcite and contain copper minerals occurring as irregular ¼- to ½-inch stringers and small irregular blebs. The veins appear to vary widely in thickness in a few feet along strike, and one is offset by faults (fig. 27).

The lower (southernmost) vein is exposed in the walls of the lower bench of the opencut; it strikes east and dips 65° S. The vein is 10 inches thick on the east end and pinches westward to less than 6 inches within 8 feet along strike.

The middle vein, where exposed in the east wall of the lower bench, is a 3-foot-wide mineralized shear zone filled by horses of country rock and subordinate amounts of thin irregular bands and lenses of quartz, calcite, malachite, and bornite. The zone strikes eastward and dips 60°-65° S.; 8 feet to the west it narrows to 12-14 inches and is offset three times in 20 feet vertically by bedding-plane faults that have displacements of 1-3 feet (fig. 28). A chip sample (R-5) across the vein ex-

FIGURE 25.—Continued.

Sample	Length (ft)	Copper (percent)	Silver (oz per ton)
R-1	5.4	1.12	0.2
2	4.0	.76	.1
3	1.4	1.16	.2
4	22.0	.72	Tr.
5	4.0	1.11	.1
6	Grab	45.2	3.4
7	10.0	1.99	.2
8	1.4	.32	N.d.
9	4.0	.59	.1
10	Grab	2.37	N.d.
11	Grab	1.35	.3

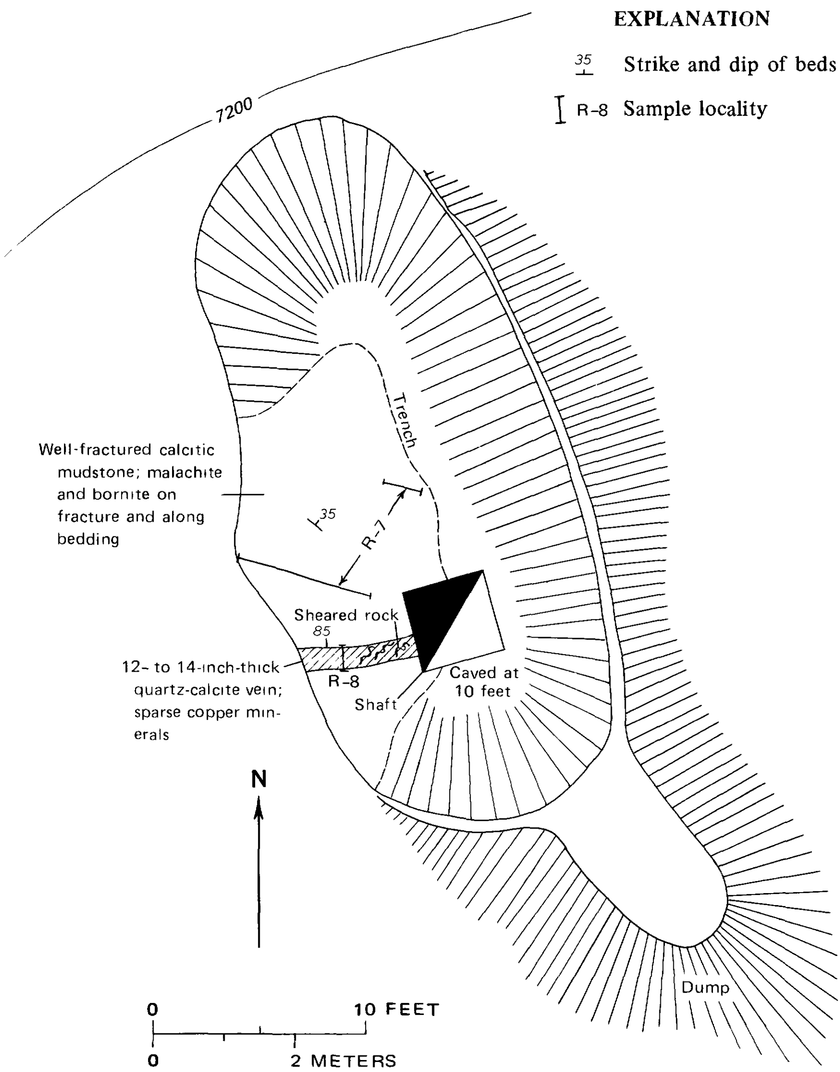


FIGURE 26.—Trench and shaft (loc. A, fig. 25), Bugle Mountain group of prospects.

posed in the east wall contained 1.11 percent copper. A second chip sample (R-4), representing a 22-foot stratigraphic section of calcareous siltstone near the offset vein exposed in the west wall, assayed 0.72 percent copper.

An 8-inch-wide quartz-calcite vein containing sparse to moderate amounts of copper minerals is poorly exposed in the north wall of the upper bench (fig. 27). The vein strikes N. 25° E. and dips 60° NW.; a caved pit 60 feet along the projected strike to the northeast has similarappearing vein material on the dump and may be on the same structure.

A shallow 5- by 25-foot partly caved trench 140 feet north of locality C (fig. 25) exposes dense, hard, moderately fractured gray limestone that contains chalcopyrite. The copper minerals occur as hairline to 1/16-inch-thick fillings along fractures and bedding planes. A chip sample (R-1) across a 5.4-foot stratigraphic section of rock in the trench wall assayed 1.12 percent copper. A 4-foot chip sample (R-2) across the most prominent fractures and normal to the bedding assayed 0.76 percent copper.

A 735-foot-long adit, driven northwest to north, explores a copper-bearing zone assumed to be related to shears exposed on the surface between localities A and B (fig. 25). Copper minerals, primarily bornite and smaller amounts of malachite and chalcopyrite, are in thin seams and along joints, fractures, and bedding planes in fine-grained calcareous rocks. The copper minerals are concentrated in a nearly east-trending belt that is crosscut by the adit between 500 and 600 feet

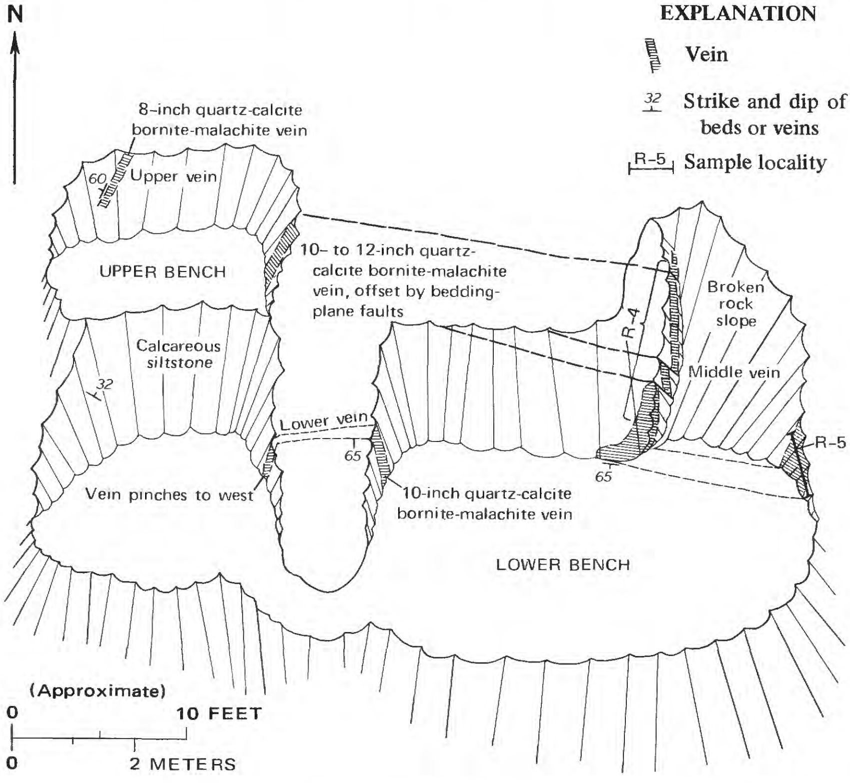


FIGURE 27.—Opencut (loc. C, fig. 25), Bugle Mountain group of prospects.

from the portal (fig. 29); the sedimentary rocks are mineralized on both sides of a 2-foot-wide fault zone that strikes N. 79° E. and dips 80°-85° N. Analyses of 46 closely spaced samples from this 35-foot stratigraphic section of mineralized bedrock show an average of 0.5 percent copper.

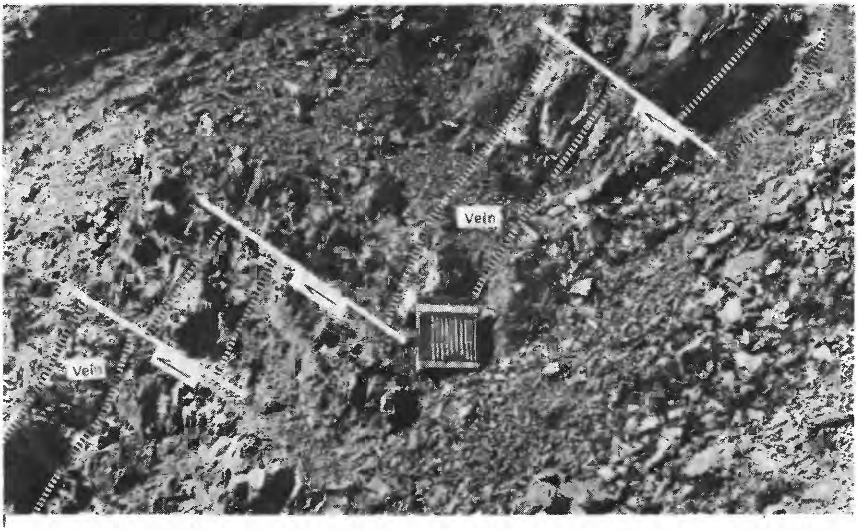


FIGURE 28.—Middle vein, offset by faults, exposed in west wall of opencut (loc. C, fig. 25), Bugle Mountain group of prospects. Arrows show direction of movement.

In summary, the workings show five zones or favorable stratigraphic intervals of calcareous rocks that contain copper minerals in an area about 1,000 feet long and 500 feet wide. Three of the mineralized zones are associated with well-developed fractures. One mineralized zone was projected over a strike distance of about 800 feet and was prospected at three places: at localities A (shaft) and B and at a site 370 feet west of the shaft (fig. 25). Three other zones are partly exposed on the surface, and the fifth is exposed in the adit. If we limit resource estimates to the five zones, make only moderate projections along bedding, and assume a lateral continuity of copper distribution (in contrast to the distribution pattern in other areas described in this report), there are about 300,000 tons of rock containing 1.8 percent copper. However, our most optimistic estimate suggests the possibility of a larger tonnage. The shear zones at localities A, B, and C in figure 25 may extend downward to the mineralized rock exposed in the adit. The resulting resources would be about 1 million tons of rock containing 1 percent copper, assuming a 20-foot-wide continuously mineralized zone along the shears. Even these resources are not economically minable, but they are marginal.

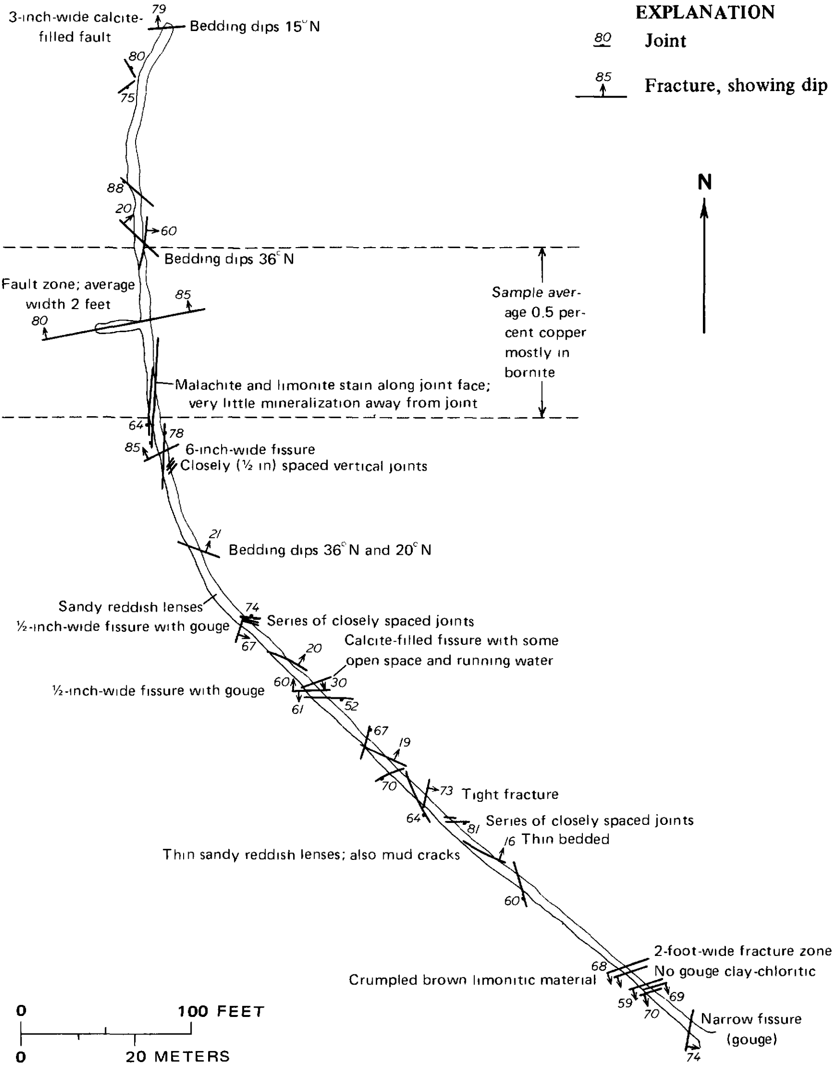


FIGURE 29.—Adit (fig. 25), Bugle Mountain group of prospects. Adapted from map provided by private source.

FISHER GROUP PROSPECT

The Fisher group of workings is on the southern fringe of the main Bugle Mountain mineralized area (fig. 21) in unsurveyed secs. 27 and 34, T. 16 N., R. 10 W., and on top of the ridge connecting Bugle Mountain and Daly Peak.

Three groups of workings contain 11 pits and 1 caved adit (fig. 30). The main pits are in the northernmost group and were recently excavated. One lies within the boundary of Cloud No. 1 lode, which is part of the block of claims located by Bear Creek Mining Co. in the 1960's.

The main pits and associated diggings are in a line which trends N. 65° W., approximately parallel to the strike of the exposed argillite. A mineralized zone can be projected along the line for an inferred length of 500 feet and an inferred average thickness of 10 feet. In the pits the

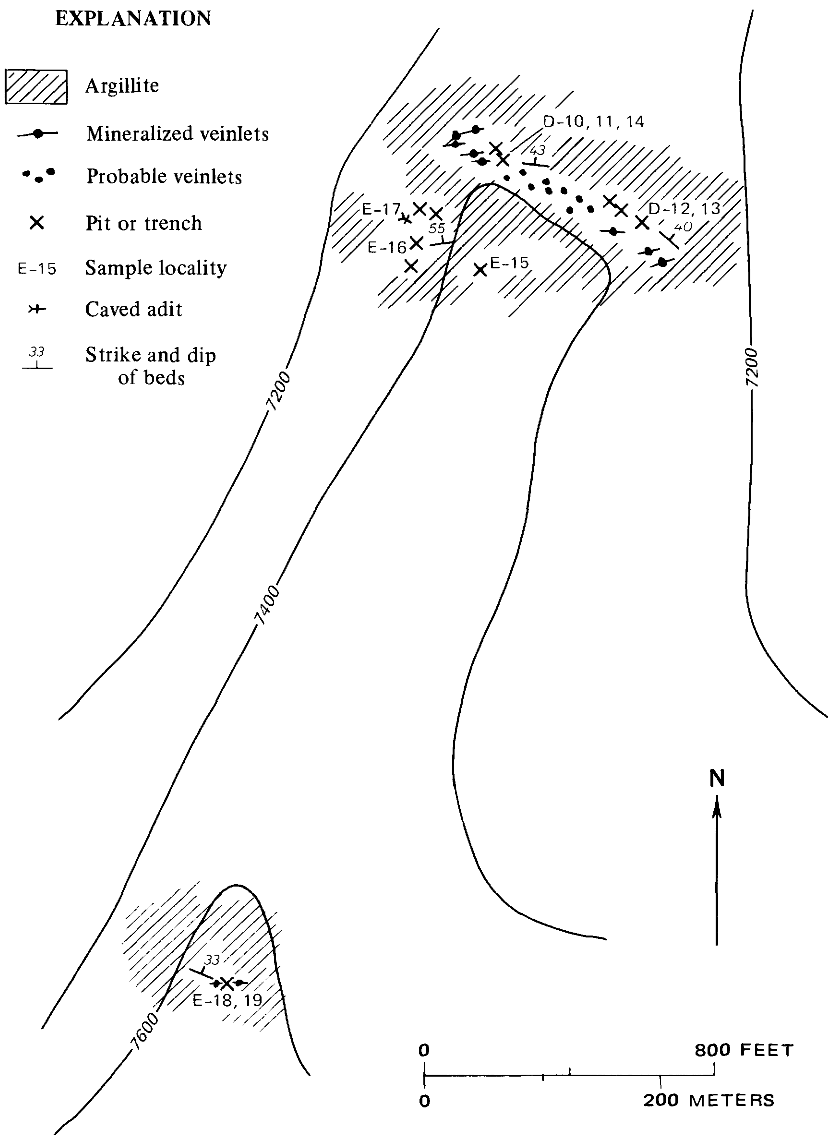


FIGURE 30.—Map (above) and assay data (right), Fisher group prospects. N.d., not detected.

bedding of the light-green to buff argillite of the Spokane and Empire Formations strike N. 85° W. and dips 43° N. Narrow veinlets as much as one-eighth inch wide strike N. 65° E. and dip 43° S. in the argillite. The veinlets are composed mostly of quartz with some chalcocite and bornite. The bedding planes and joints are coated by malachite.

At the northwest end of the zone, two chip samples (D-10, 11) totaling 12 feet in length were cut perpendicular to the bedding in one of the main pits (fig. 30). The samples assayed 0.59 and 0.96 percent copper, < 0.01 percent lead, no gold, and a trace of silver. A third sample (D-14), 7 feet long, was cut perpendicular to the veinlets in the same pit. It assayed 0.48 percent copper, 0.01 percent lead, and no gold or silver. Near the southeast end of the zone, two chip samples (D-12, 13) totaling 9 feet in length were cut perpendicular to the bedding in the second main pit. The samples contained 1.62 and 2.22 percent copper, <0.01 percent lead, no gold, and an average of 0.76 ounce silver per ton.

A caved adit and five shallow pits are about 300 feet southwest of the mineralized zone. The adit was probably not more than 40 feet long. Argillite sloughed from the north wall of the caved adit at the portal contained the only visible mineralized rock, which consisted of small fractures filled by chalcocite, bornite, and pyrite. A grab sample (E-17) contained 0.04 percent copper, 0.71 percent lead, and no gold or silver.

A cut 30 feet long and 10 feet wide, 80 feet south of the adit, exposes green micaceous argillite. No copper minerals were visible in the cut, but the assay results from a chip sample (E-16) cut perpendicular to the bedding planes showed 0.01 percent copper, 0.06 percent lead, and no gold or silver.

The dump of a small pit 270 feet southeast of the adit consists of green siliceous argillite; no rock was observed in place. Some pieces are thickly coated by hematite. A select grab sample (E-15) from the dump contained <0.01 percent copper, <0.01 percent lead, and no gold or silver.

Figure 30.—Continued.

Sample	Length (ft)	Copper (percent)	Lead (percent)	Gold (oz per ton)	Silver (oz per ton)
E-15	Grab	<0.01	<0.01	N.d.	N.d.
16	9.5	.01	.06	----------	----------
17	Grab	.04	.71	----------	----------
18	Grab	.68	<.01	----------	----------
19	Grab	.14	<.01	----------	----------
D-10	5.5	.59	<.01	----------	----------
11	6.5	.96	<.01	----------	----------
12	4.0	1.62	<.01	----------	0.2
13	5.0	2.22	.01	----------	1.2
14	7.0	.48	.01	----------	N.d.

One shallow pit, 6 feet across, is about 2,300 feet south of the main mineralized zone (fig. 30). A 3- to 4-inch-thick quartz lens which conforms to bedding of the green argillite is exposed in the pit. The lens is within a 1.5-foot-thick bed of argillite containing pyrite crystals and some knife-edge streaks of bornite parallel to the bedding. A sample of the argillite bed (E-18) contained 0.68 percent copper and < 0.01 percent lead. A sample of the quartz lens (E-19) contained 0.14 percent copper and < 0.01 percent lead. Neither sample contained gold or silver.

The main mineralized zone is estimated optimistically to contain about 100,000 tons of material that would assay about 1 percent copper. A deposit of that size and grade is not considered to be economically minable at this location.

UPPER COPPER CREEK AREA

The Upper Copper Creek area is just outside the southern boundary of the study area in unsurveyed sec. 4, T. 15 N., R. 9 W. Good roads extend to a point about 1½ miles east of the area. The remaining 1½ miles is a very rough trail.

Shear zones exposed near the crest of a ridge strike N. 70° W. and dip north; they contain quartz, calcite, and copper sulfides. The country rock is red and green argillite of the Spokane and Empire Formations. The copper occurs as massive chalcocite and bornite in a quartz and calcite gangue and as small fracture fillings within a shear zone. As noted on page B46, the mineralization does follow some bedding planes for more than 100 feet beyond the vein.

Small tonnages of copper ore were reportedly shipped from the area during 1917, 1919, and 1920. These ore-bearing veins do not appear to extend across the boundary ridge into the study area. These deposits, however, appear to be in the same belt that extends northwestward to Mineral Hill.

MISCELLANEOUS CLAIMS AND PROSPECTS

During 1904 and 1905, 15 mining claims were located in the vicinity of Welcome Pass. Because of many years of inactivity, only six claims—Sheep Creek No. 1 and No. 2, Jessie, Roosevelt, Cinnamon, and Babe—were identified. Three lode claims in other areas—the Jewell Mountain Mining Co., the Hector, and the Nellie Miles—were identified in the field and examined. Few workings are present on these claims, and mineralized rock found was insignificant (table 4).

SHEEP CREEK NOS. 1 AND 2 PLACERS

The Sheep Creek claims were located by Carlin J. and Pauline B. Alt in 1964 on Bighorn Creek about 1,500 feet above its confluence with Landers Fork in unsurveyed sec. 8, T. 16 N., R. 8 W. Access from Lincoln, Mont., is by 16 miles of road, which ends at Indian Meadows, then by 7 miles of good pack trail. The claims are contiguous and cover about

TABLE 4.—*Description of miscellaneous claims and prospects*

Prospect	Location	Summary remarks	Number and type of workings	Sample data
Jessie	NE¼ sec. 4, T. 18 N., R. 9 W.	Country rock is limestone of Devonian age. One pit exposes a 3-ft-thick bed of fractured limestone that has hematite and limonite staining along fractures. Second pit is sloughed, and no mineralization was noted.	Two pits	One chip sample contained <0.01 percent lead and a trace gold.
Roosevelt	At Welcome Pass, sec. 3, T. 18 N., R. 9 W.	No workings were observed within the claimed area. Country rock in Welcome Pass vicinity is green argillite of Precambrian Mount Shields Formation.	None	Two reconnaissance chip samples across green argillite escarpment contained <0.01 percent copper and a trace gold.
Cinnamon	NE¼SE¼ sec. 14, T. 18 N., R. 9 W.	No workings were observed within the claimed area. Samples were taken from an iron-oxide-stained bold limestone outcrop 320 ft long by 150 ft high. Limestone is Mississippian age.	None	Three samples taken from face of outcrop contained <0.01 percent lead and a trace gold.
Babe	Center sec. 13, T. 18 N., R. 9 W.	Two trenches were dug in limestone beds of Mississippian age near thrust-fault contact with Precambrian Mount Shields Formation. Iron-oxide stains and coats some of the fractured limestone.	Two trenches	Two samples, one from each trench, contained 0.05 percent lead and a trace gold.
Jewell Mountain Mining Co.	NE¼ sec. 28, T. 17 N., R. 9 W.	The pit explores a greenish-gray sandstone bed of Precambrian McNamara Formation in which white and red chalcedony fills some of the vugs.	One pit	A sample, taken from pit contained <0.01 percent copper.
Hector	Sec. 17, T. 17 N., R. 8 W.	Apparently, a 0.6-ft-thick quartz-barite vein conforms to country-rock bedding. Country rock is argillite and siltstone of Precambrian Snowslip Formation. Bedding strikes N. 70° W. and dips 25° N.	One sloughed pit	A sample taken from vein contained no detectable metals.
Nellie Miles	Sec. 22, T. 17 N., R. 8 W.	A weakly mineralized contact zone is between gray massive Devonian limestone and red argillite of Precambrian Spokane and Empire Formations. A vuggy iron-oxide-stained quartz vein up to 0.4 ft thick is along contact. Contact zone can be traced for 1,000 ft.	Two trenches	Two samples were taken from contact zone. One sample contained a trace gold.

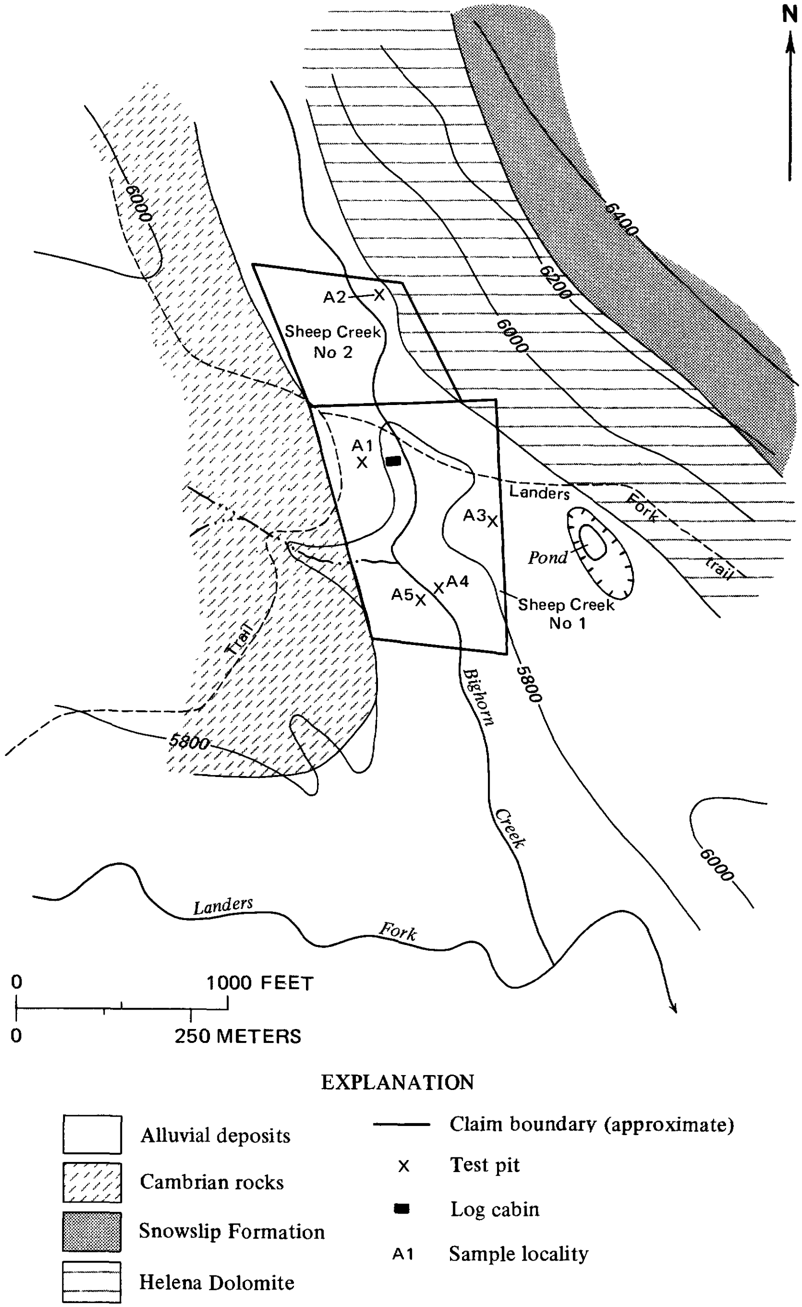


FIGURE 31.—Sheep Creek Nos. 1 and 2 placer area.

26 acres. A 15-foot by 30-foot log cabin and adjacent horse corral are located on the Sheep Creek No. 1 placer (fig. 31). The cabin is in very good repair. No other physical improvements were observed on the claims.

The claims lie on the Bighorn Creek valley floor, which is covered with a veneer of reworked glacial deposits. The creek meanders and has a braided channel. Much of the alluvium is poorly sorted, which indicates deposition during floods.

Samples were collected from five sites. Sites A1, A2, and A3 are existing test pits. Sites A4 and A5 are located on the banks of the present stream channel. Other test pits have been recorded, but they could not be located on the ground. It is assumed that high water during spring runoff filled these test pits.

At each sample site, one level 15-inch gold pan of material was collected per foot of depth and concentrated by hand panning. Results are shown in table 5. No gold was found in any of the samples. The concentrates were examined petrographically for other potentially valuable minerals; however, only the common rock-forming minerals were observed. None were present in sufficient concentrations to be a potential resource.

TABLE 5.—*Sample data for Sheep Creek Nos. 1 and 2 placers*

Sample Site	Number of Samples	Sample interval (ft)	Gold value (cents per yard)	Remarks
A1	7	0-7	Nil	Existing sidehill cut with a 7-ft face exposure. Poorly indurated pebble gravel with a limy clay coating.
A2	3	0-4	Nil	Existing pit 6 ft by 6 ft by 4 ft deep. Poorly indurated pea gravel and silt.
A3	3	0-3	Nil	Existing sidehill cut with a 3-ft face exposure. Predominantly angular argillite talus.
A4	6	0-6	Nil	Collected from bank of existing creek channel. Unconsolidated sandy gravel.
A5	4	0-4	Nil	Do.

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