STUDIES RELATED TO WILDERNESS

NORTH ABSAROKA STUDY AREA MONTANA

GEOLOGICAL SURVEY BULLETIN 1505

Mineral Resources of the North Absaroka Wilderness Study Area, Park and Sweet Grass Counties, Montana

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

A. Geological and geochemical investigations of the North Absaroka wilderness study area, Park and Sweet Grass Counties, Montana

B. Geophysical interpretations

C. Economic appraisal of the North Absaroka wilderness study area, Park and Sweet Grass Counties, Montana

D. Geothermal resource

STUDIES RELATED TO WILDERNESS—WILDERNESS AREAS

GEOLOGICAL SURVEY BULLETIN 1505

An evaluation of the mineral potential of the area

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STUDIES RELATED TO WILDERNESS STUDY AREAS

In accordance with the provisions of the Wilderness Act (Public Law 88-577, September 3, 1964) and the Joint Conference Report on Senate Bill 4, 88th Congress, the U.S. Geological Survey and U.S. Bureau of Mines have been conducting mineral surveys of wilderness and primitive areas. Studies and reports of all primitive areas have been completed. Areas officially designated as "wilderness," "wild," or "canoe" when the Act was passed were incorporated into the National Wilderness Preservation System, and some of them are presently being studied. The Act provided that areas under consideration for wilderness designation should be studied for suitability for incorporation into the Wilderness System. The mineral surveys constitute one aspect of the suitability studies. This report discusses the results of a mineral survey of some national forest lands in the North Absaroka study area, Montana, which is being considered for wilderness designation. The area studied is in Park and Sweet Grass Counties in the south-central part of Montana.

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STUDIES RELATED TO WILDERNESS

MINERAL RESOURCES OF THE NORTH ABSAROKA WILDERNESS STUDY AREA, PARK AND SWEET GRASS COUNTIES, MONTANA

By U.S. GEOLOGICAL SURVEY and U.S. BUREAU of MINES

SUMMARY

A mineral survey of the North Absaroka wilderness study area, covering about 542 mi^2 (1,403 km^2) of the Gallatin National Forest in southern Montana, was conducted by the U.S. Geological Survey and the U.S. Bureau of Mines in 1973 and 1974. The area is a proposed addition to the Beartooth and Absaroka primitive areas, which adjoin the study area to the southeast and south, respectively. The U.S. Geological Survey investigations included geologic mapping, examination of mineralized areas, geochemical sampling, and geophysical surveys; the U.S. Bureau of Mines searched courthouse claim records, evaluated claims and mineralized areas, and compiled production records. The results of these studies indicate that the area contains identified resources and potential undiscovered resources of gold, silver, copper, molybdenum, nickel, lead, zinc, platinum-group metals, uranium, iron, and manganese. The area also contains small amounts of tungsten, arsenic, bismuth, thorium, and chromium. The potential for geothermal resources is low, and the possibility of a coal, oil, or gas resource is remote.

The North Absaroka study area is in the western part of the Beartooth uplift, a major fault-bounded structural block. Precambrian crystalline rocks occupy most of the north and east parts of the area, and Tertiary igneous rocks of the Absaroka-Gallatin volcanic province cover most of the remainder. Sedimentary rocks of Paleozoic and Mesozoic ages overlie Precambrian rocks near the northern boundary, and they occur in a discontinuous east-trending belt across the central part of the area. The Precambrian rocks have been subjected to several periods of folding, faulting, metamorphism, and igneous intrusion in Precambrian time. After a long period of crustal stability during later Precambrian, Paleozoic, and Mesozoic time, the Laramide orogeny in late Mesozoic to early Tertiary time resulted in the Beartooth uplift, large intrusive centers and the extensive volcanic field of the Absaroka-Gallatin volcanic province. Regional uplift in late Tertiary time was followed by glaciation and erosion that produced the present topography.

Geophysical investigations, consisting of airborne magnetic and gravity surveys, show magnetic highs associated with Tertiary intrusive centers. Other magnetic and gravity anomalies may reflect buried plutons of Precambrian or Tertiary age.

Mineral deposits in or peripheral to the North Absaroka study area are of diverse types and metal suites, clustered mainly in four areas or districts. Deposits in the Emigrant–Mill Creek and Boulder (Independence) districts are associated with intrusive rocks of

Tertiary age and show a close spatial relationship with the intrusive centers, whereas those in the Sheepeater (Jardine) district and the Stillwater–Natural Bridge area are in Precambrian rocks (pl. 1).

Approximately 3,500 lode claims and 580 placer claims have been located in or peripheral to the study area since it was opened to mineral entry in 1882. A total of 43 lode claims have been patented. Patented placer claims cover lower Emigrant and Sixmile Creeks and the headwaters of Boulder River. Geothermal lease applications have been filed for about 40 sections. The study area and the corridors contain about 1,100 prospects and small mines; approximately half are in the Boulder district and one-third are in the Emigrant–Mill Creek district. The remains of 10 small mills were also observed.

The Emigrant–Mill Creek mining district has, since 1863, produced about 40,000 oz (1.2 million g) gold, most from outside the study area. The productive part of the Sheepeater district (outside the study area) yielded 180,000 oz (5.6 million g) gold, 778,000 lb (352,900 kg) tungsten trioxide, and 12.6 million lb (5.7 million kg) arsenic trioxide, plus minor copper, lead, and silver.

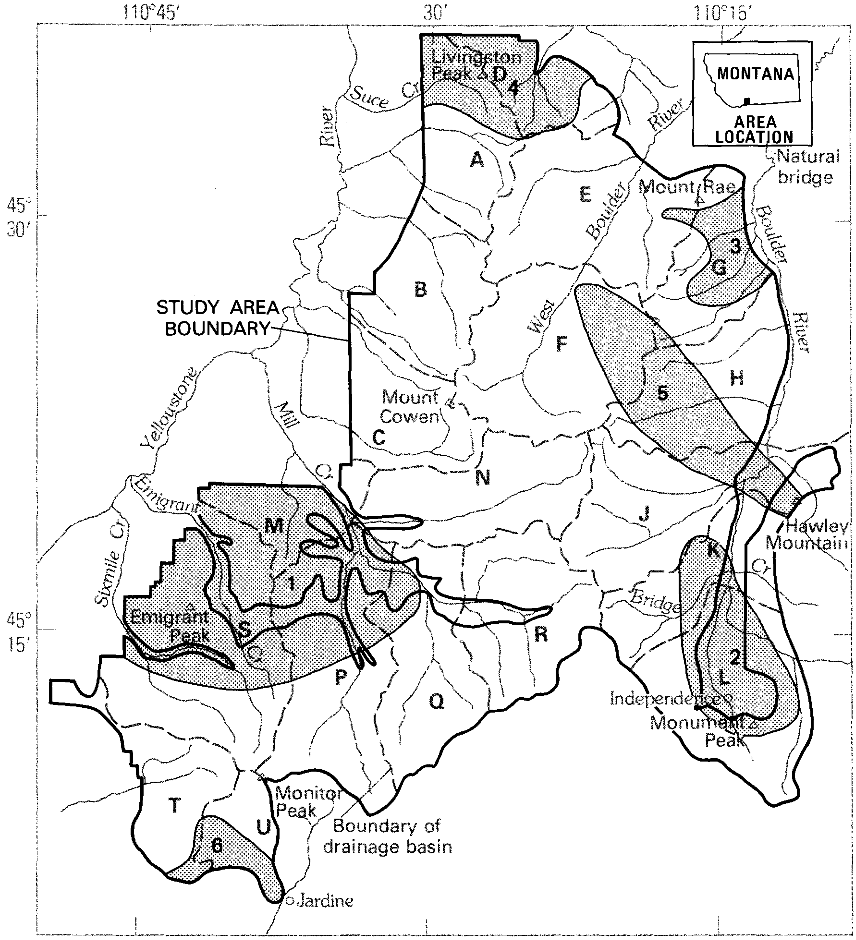
Mining of a small placer and stockpiling of development rock at a lode property were the only operations in or near the area during the present investigations. However, mining companies were conducting independent exploration and development programs in the Emigrant–Mill Creek, Sheepeater, and Natural Bridge districts.

Identified or potential undiscovered resources are concentrated in the six areas shown on figure 1. The Emigrant–Mill Creek area (fig. 1, area 1) contains an estimated 1.7 million tons (1.54 million t) of indicated and inferred silver, gold, lead, zinc, and copper resources in 13 vein deposits. The study area contains about 204,000 tons (185,000 t) of the estimated 1.7 million tons (1.54 million t); the remainder is in an excluded corridor containing roads and patented claims. A copper-molybdenum porphyry-type deposit, partly in the study area, is currently being explored and may contain a large tonnage of resources. Zinc-rich manganiferous bog deposits, also partly outside the area, probably contain about 230,000 tons (209,000 t) of resources. A mineral deposit in North Fork Sixmile Gulch is estimated to contain 175,000 tons (159,000 t) of iron- and gold-bearing material. The valleys of Emigrant and Sixmile Creeks may contain significant amounts of gold-bearing gravels. The Emigrant–Mill Creek area has a high potential for undiscovered copper and molybdenum resources, and a moderate potential for undiscovered gold, silver, lead, and zinc resources.

A deposit within the study area in the Boulder district (fig. 1, area 2) has an inferred resource of 11 million tons (10 million t) estimated to average 0.87 percent copper, 0.05 percent molybdenum, and 45.9 percent iron. Reconnaissance samples from patented claims indicate that the gold and silver content of intrusive rocks that extend into the study area may be a few hundredths of an ounce gold per ton (about 1 g/t) and several tenths of an ounce silver per ton (about 10 g/t). Another occurrence, exposed in a cirque wall, may have a few hundred thousand tons of gold-, silver-, and lead-bearing material. In addition to the identified resources, the district has a low to moderate potential for undiscovered resources of copper, gold, molybdenum, silver, lead, and zinc.

A vein deposit in the Stillwater–Natural Bridge area (fig. 1, area 3) contains an estimated 21,000 tons (19,000 t) averaging 0.1 oz gold per ton (3.4 g/t). A copper-nickel occurrence near the base of the igneous Stillwater Complex of Precambrian age has been explored at the edge of the study area, and extends into the area. Based on the possibility that copper-nickel occurrences are continuous along the base of the Stillwater Complex from the site of current exploration, the resource within the study area may exceed 300 million tons (270 million t) of copper-nickel-bearing rock. However, the extent of the mineralized zone in the study area cannot be verified from the results of the present studies. A high potential for undiscovered resources of platinum-group metals and chromium also exists along the base of the complex in the study area.

The Livingston Peak area (fig. 1, area 4) has a low to moderate potential for undiscovered copper resources. The Hawley Mountain–West Boulder area (fig. 1, area 5) has



0 5 10 MILES
0 5 10 KILOMETERS

FIGURE 1.—Map showing areas of identified or potential undiscovered mineral resources in the North Absaroka wilderness study area. In order of relative importance (1, most important), they are: 1, Emigrant-Mill Creek area; 2, Boulder (Independence) district; 3, Stillwater-Natural Bridge area; 4, Livingston Peak area; 5, Hawley Mountain-West Boulder area; and 6, area adjacent to the Sheepeater (Jardine) district. Capital letters indicate drainage basins.

a low potential for undiscovered molybdenum and uranium resources, and the area adjacent to the Sheepeater (Jardine) district (fig. 1, area 6) has a low potential for undiscovered gold, tungsten, and arsenic resources. Claims in the Mt. Cowen area and Silver Lake district have low potential for undiscovered resources of copper, molybdenum, and uranium.

Mineral production from the North Absaroka study area has been minor, considering the amount of prospecting and claim locating. Several factors have hindered development of the mineral potential. The area is extremely rugged and has severe winters, numerous avalanches, high spring runoff in the narrow canyons, and a resulting prospecting season of only a few months per year. The refractory nature of the deposits prohibited free-milling of the gold ore. Relatively inexpensive metallurgical methods are now available to treat the ores, which could lead to development of the mineral deposits in and peripheral to the study area.

Geological and Geochemical Investigations of the North Absaroka Wilderness Study Area, Park and Sweet Grass Counties, Montana

By J. E. ELLIOTT, D. L. GASKILL, *and* W. H. RAYMOND,
U.S. GEOLOGICAL SURVEY

MINERAL RESOURCES OF THE NORTH ABSAROKA WILDERNESS STUDY AREA, PARK AND SWEET GRASS COUNTIES, MONTANA

GEOLOGICAL SURVEY BULLETIN 1505-A

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GEOLOGICAL AND GEOCHEMICAL INVESTIGATIONS OF THE NORTH ABSAROKA WILDERNESS STUDY AREA, PARK AND SWEET GRASS COUNTIES, MONTANA

By J. E. ELLIOTT, D. L. GASKILL, and W. H. RAYMOND,
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INTRODUCTION

The purpose of this mineral survey is to evaluate the resources of the North Absaroka study area, an area of approximately 540 mi^2 (1,400 km^2) in Park and Sweet Grass Counties, Mont. This area has been proposed as an addition to the Beartooth and Absaroka Primitive Areas that have been studied previously by the U.S. Geological Survey and U.S. Bureau of Mines. It is not the same as, nor is it contiguous with, the North Absaroka Wilderness area in northwestern Wyoming.

LOCATION AND GEOGRAPHY

The study area is in south-central Montana just north of Yellowstone Park (fig. 2). The town of Gardiner is near the southwest corner and Livingston is near the northwest corner of the area. On the southwest, west, and north sides, the area is bordered by the valley of the Yellowstone River and on the northeast side it is bordered by the Boulder River. To the south the area adjoins the Absaroka study area, which includes the Absaroka Primitive Area, and to the southeast it adjoins the Beartooth study area, which includes the Beartooth Primitive Area.

Geographically the study area is at the north end of the Absaroka Range and includes a small part of the west end of the Beartooth Mountains; the Boulder River marks the boundary between the two ranges. The north half of the study area resembles the Beartooth Mountains in topography, drainage, and geology, whereas the south half is more similar to the Absaroka Range.

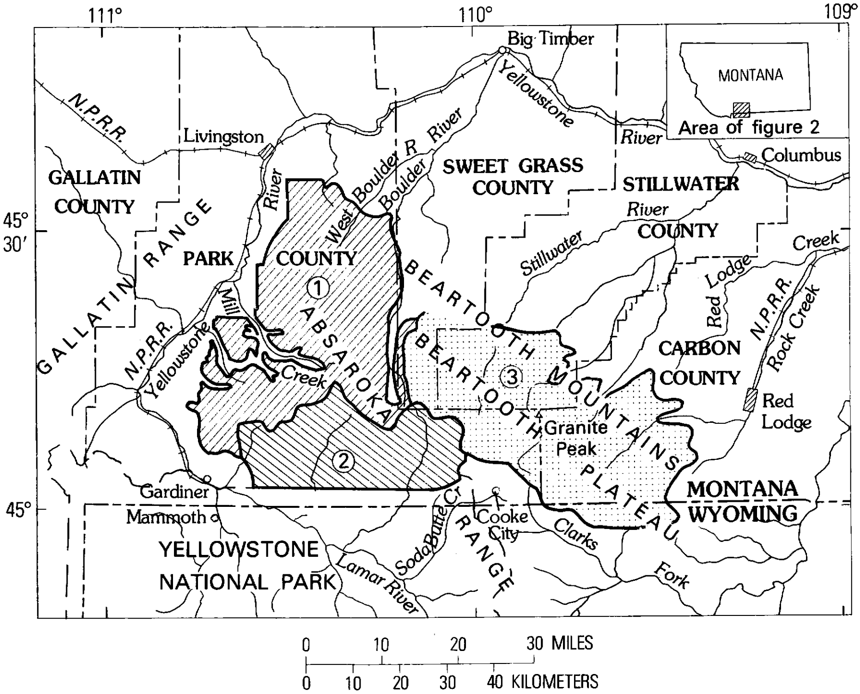


FIGURE 2.—Location of study areas in south-central Montana. 1, North Absaroka wilderness study area (this report); 2, Absaroka Primitive Area and vicinity (Wedow and others, 1975); 3, Beartooth Primitive Area and vicinity (Simons and others, 1973).

The area is drained by tributaries of the Yellowstone River (fig. 2). The northeastern, eastern, and southeastern parts of the area, about half the total area, are drained by the north-flowing Boulder and West Boulder Rivers, which join northeast of the study area and enter the Yellowstone River at Big Timber. The northwestern, western, and southwestern parts of the study area are drained by predominantly west flowing streams most of which join the Yellowstone River in Paradise Valley. Approximately one-third of the study area is drained by the northwest-flowing Mill Creek and its tributaries. The study area has a maximum north-south length of about 35 mi (56 km) and east-west width of about 25 mi (40 km).

Nearly all of the study area has extremely high relief and rugged topography. Much of the scenic western part is visible from U.S. Highway 89 along the Yellowstone River between Gardiner and Livingston, and the northern part is visible from Interstate 90, east of Livingston. The highest and most spectacular peak in the area is Mount Cowen (11,207 ft; 3,416 m), in the west-central part of the area (fig. 3). More than 25 other peaks have elevations in excess of 10,500 ft (3,200

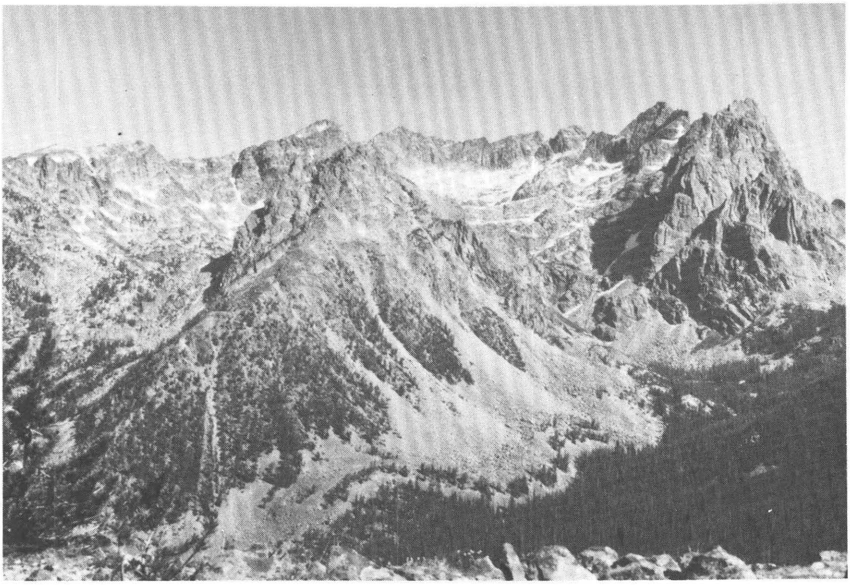


FIGURE 3.—The south side of Mount Cowen, the highest peak in the North Absaroka study area and type area of the Mount Cowen Gneiss (Reid and others, 1975), viewed from ridge between Elbow Creek (foreground) and East Fork Mill Creek. Occurrences of molybdenum and uranium were found at locality C2571 in the cirque at the right side of scene.

m), and numerous peaks, ridges, and high plateaus are over 10,000 ft (3,050 m) high. Much of the area is above timberline (approximately 9,000 ft, or about 2,740 m) and displays a variety of striking alpine features and scenery. The area is deeply dissected by streams, and valleys of major trunk streams are at elevations of about 5,000–7,000 ft (1,520–2,130 m). Maximum relief in the area is about 6,000 ft (1,830 m), and local relief of about 2,950–4,900 ft (900–1,500 m) over a horizontal distance of 1–2.5 mi (1.6–4 km) is common. The general topography is illustrated by a physiographic map of the study area (fig. 4).

Access to the boundaries of the study area is by secondary roads except for most of the south boundary, which is accessible only by trail. Most of the east boundary of the study area can be reached from the Boulder River road, which is a good gravel road to the vicinity of the Box Canyon guard station and continues upstream as a jeep trail. A good gravel road follows the West Boulder River to the boundary along the north side. Gravel roads parallel the boundary from West Boulder River to near Livingston, and a gravel road leads to the Pine Creek recreation area on the northwest boundary of the study area. The Mill Creek area is accessible by good gravel roads along Mill Creek, West Fork Mill Creek, and East Fork Mill Creek and by numerous logging

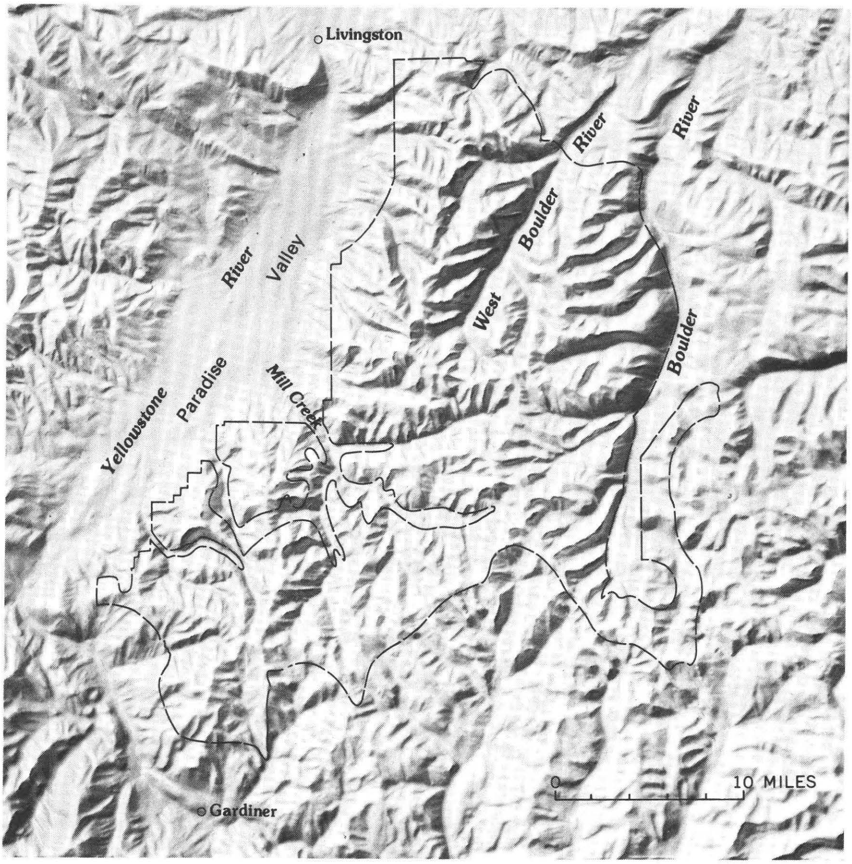


FIGURE 4.—Physiography of the North Absaroka study area, showing the topography and drainage. (From AMS map NL'12-8, Bozeman, Montana, Wyoming, 1958.)

roads connecting with these. A secondary road, in part paved, provides access at Chico, on lower Emigrant Creek. The southwest corner of the area is accessible from roads in the vicinity of Jardine.

A network of foot or horseback trails provides access to most of the study area. Most trails are in valleys, but a few are along ridge tops. The area may be traversed from east to west and north to south by trails that cross high mountain passes. In the least accessible part of the area, in the rugged northwest part north of East Fork Mill Creek and west of West Boulder River, trails are few and difficult to maintain.

Maps of the North Absaroka study area north of lat 45°30′ N. consist of 7½-minute topographic maps at a scale of 1:24,000, and the remainder of the area is shown by 15-minute quadrangle maps at a scale of 1:62,500. The base for plates 1, 2, and 3 was compiled from these topographic maps at a scale of 1:62,500. Topographic maps at a scale of

1:250,000 are also available, and the planimetric map of the Gallatin National Forest at a scale of 1:125,000 covers the entire area.

PREVIOUS STUDIES

The geology of the North Absaroka study area was mapped initially by Iddings and Weed (1894) for the Livingston Folio, scale 1:250,000. This reconnaissance work provided an understanding of the basic geologic framework of the area. Mineral deposits are shown on the Economic Sheet of the Folio but are not described. The earliest detailed work in the area was a study of the intrusive rocks of the Independence area by Emmons (1908).

Most of the geologic studies of the area have been done since 1930, many of them during the last 20 years. Wilson (1936) investigated the geology of the Mill Creek–Stillwater fault zone. The structural geology of the Livingston Peak area was described by Lammers (1937). The geology and ore deposits of the Jardine district, adjacent to the study area, were studied by Seager (1944). Some of the mines and mineral deposits in and adjacent to the study area were described by Reed (1950). Geology of the Livingston area and vicinity was studied by Richards (1957). Foose, Wise, and Garbarini (1961) discussed the structural geology of the Beartooth Mountains, including the North Absaroka study area. Theses by Fox (1960) and Basler (1965) described the geology of the Mill Creek and Emigrant Peak areas, respectively. Geologic study of the Independence area by Rubel (1964, 1971) was particularly helpful to us. Fraser, Waldrop, and Hyden (1969) mapped the geology of the Gardiner area at a scale of 1:24,000 and briefly described the area's mineral deposits. A reconnaissance geologic map of the Mount Douglas quadrangle was compiled by Page, Simons, and Dohrenwend (1973) at a scale of 1:62,500. Mapping and detailed geologic studies by Reid, McMannis, and Palmquist (1975) of the Precambrian geology of the North Snowy block of the Beartooth Mountains have been used extensively in the preparation of the geologic map of the North Absaroka study area (pl. 1) and in descriptions of Precambrian rocks. Unpublished mapping of the Emigrant and Mill Creek areas by W. J. McMannis was also included in our compilation.

PRESENT STUDIES AND ACKNOWLEDGMENTS

Geologic mapping and geochemical sampling were conducted during the summer months of 1973 and 1974. Fieldwork, in 1973, was by Elliott and Raymond, assisted by Kerwin Stark and John Robinson, and during 1974 was by Elliott, Raymond, and Gaskill, assisted by Stark, Gregory Wessel, and Ronald Schmiermund. Aeromagnetic surveys were flown in 1967 and 1972, and gravity surveys were conducted during 1973 and 1974.

Most of the fieldwork was accomplished by foot traverses supported by a helicopter for transportation to and from the study area. Horses were used for transportation and logistical support in 1973 and 1974. Streams were sampled systematically by traversing valleys and collecting sediment and rock samples, although most rock samples were collected on ridges during geologic mapping. Sampling was more intensive in and near known mineralized areas, where evidence of hydrothermal alteration was visible, or where the geologic setting was judged favorable for mineral deposits.

Geologic mapping was done on topographic maps, mostly at a scale of 1:62,500, and on color aerial photographs at a scale of 1:15,840. All of the study area had been mapped previously, and our mapping served mainly to modify some earlier maps and to extend the mapping into areas in which previous mapping was inadequate for this study.

Samples were analyzed in mobile field laboratories and in laboratories of the U.S. Geological Survey in Denver, Colo. Determinations of gold and mercury were made in the field by J. G. Viets, R. R. Carlson, and E. P. Welsch. Semiquantitative spectrographic analyses for 30 elements were done in the field by R. T. Hopkins, Jr., and W. D. Crim. Computer processing and manipulation of the large volume of geochemical and geologic data were facilitated with the help of C. M. McDougal, S. K. McDanal, R. J. Smith, and T. M. Billings. N. B. Anderson and W. E. Shipley aided in the preparation of illustrations.

Our work on the geology and mineral deposits of the North Absaroka study area was aided by several individuals. W. J. McMannis provided us with his unpublished mapping of the Emigrant and Mill Creek areas and information on Precambrian geology and mineralization in western parts of the study area. D. N. Rubel discussed the geology and mineralization of the Independence area with us in the field. K. L. Pierce assisted us on the glacial geology of the area. Information on mining claims and mineral deposits in or adjacent to the study area was provided by Kester Counts, Garland Counts, and Charles Rasnick. John L. McGillis, Duval Corporation, and Stan Ellingwood, Johns-Manville Corporation, gave information on the geology and mineralization of parts of the study area and adjacent areas in which their companies are conducting exploration programs.

The cooperation and assistance of U.S. Forest Service officials Kenneth A. Gallik and Lewis E. Hawkes, Forest Supervisors, Gallatin National Forest; Ralph Meyer, District Ranger, Livingston; John Inman, District Ranger, Big Timber; and David Morton, District Ranger, Gardiner, are gratefully acknowledged. Helicopter operations at the Livingston Municipal Airport were facilitated by Jack Michels. Don Conway, Chico Hot Springs, and David Zogbaum, Yellowstone Valley Guest Ranch, graciously permitted use of their properties as heliports during our fieldwork.

GEOLOGY

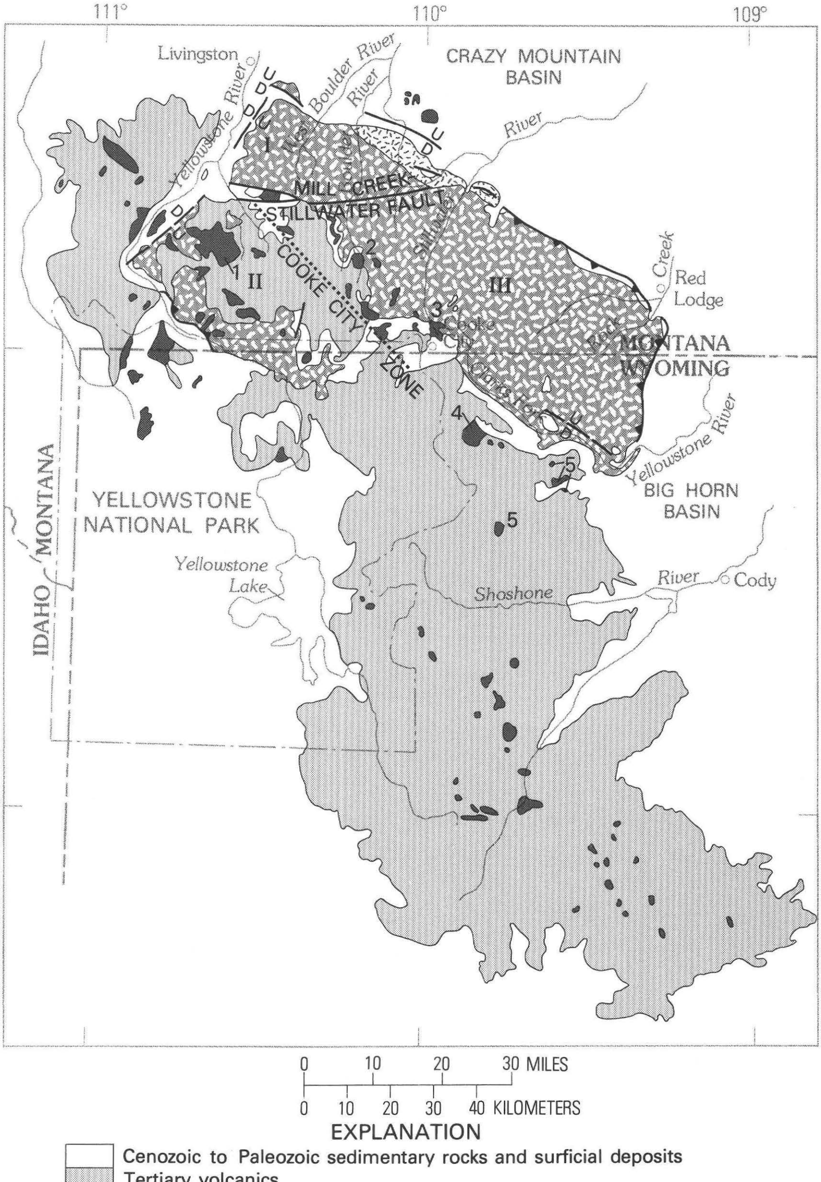
GEOLOGICAL SETTING

The North Absaroka study area is in the western part of the Beartooth uplift, a broad fault-bounded structural block in the Middle Rockies that rises abruptly from the Great Plains province to the north and east. No sharp topographic break exists along much of the southern part of the uplift. Precambrian crystalline rocks are exposed on most of the Beartooth uplift except for the southwestern and southern parts, where Paleozoic sedimentary rocks and Tertiary igneous rocks of the Absaroka-Gallatin volcanic province (Chadwick, 1970) overlie the Precambrian rocks (fig. 5).

The northwest-trending Beartooth uplift rises abruptly 4,000 to 5,000 ft (1,220 to 1,525 m) from lower areas to the west, north, and east. This uplift is about 70 by 40 mi (110 by 64 km) in extent and is roughly rectangular in shape. It is bounded on the north by the Crazy Mountain Basin, a northwesterly trending structural basin that is filled with sedimentary and volcaniclastic rocks, and on the west by Paradise Valley, the alluvium-filled valley of the Yellowstone River. The Gardiner thrust fault and the Yellowstone River form the southwest boundary. The southeast corner of the uplift is bordered on the east by the Bighorn Basin and on the south by the Clarks Fork Yellowstone River.

The Beartooth uplift is divided into the North Snowy, South Snowy, and Beartooth Plateau blocks by major structural zones (fig. 5). The amount and direction of tilting of these structural blocks are indicated by the attitude of the contact between Precambrian and the overlying Paleozoic sedimentary rocks. In both the North and South Snowy blocks, the surface of the Precambrian rocks slopes to the northeast, whereas in the Beartooth Plateau block this surface slopes to the southwest (Lammers, 1937).

This region has had a complex geologic history since early Precambrian time. Several periods of folding, faulting, metamorphism, and igneous intrusion took place during the Precambrian. During the Paleozoic and Mesozoic Eras, a thick pile of sedimentary rocks was deposited in shallow seas that covered the region. During a major period of crustal instability that began in the late Mesozoic and continued into the early Tertiary, the Beartooth uplift was formed, many intrusives were emplaced, and volcanic rocks of the Absaroka-Gallatin volcanic field were extruded. In late Tertiary time, the region was uplifted to approximately the present altitude. Glaciation and erosion during Quaternary time resulted in the development of the present topography (fig. 6).



EXPLANATION

Cenozoic to Paleozoic sedimentary rocks and surficial deposits

Tertiary volcanics

Tertiary intrusives

Precambrian Stillwater Complex

Precambrian rocks, excluding Stillwater Complex

U/D Fault—Dashed where inferred, dotted where concealed; U, upthrown side; D, downthrown side

Thrust fault—Sawteeth on upper plate

FIGURE 6.—Glacial U-shaped valley near the head of the Boulder River. View to south from vicinity of Baboon Mountain. Precambrian granitic gneiss and Paleozoic sedimentary rocks underlie the lower slopes and valley floor. Tertiary volcanic rocks are exposed along the upper slopes, ridges, and peaks.

ROCKS

Spanning two major geologic provinces—the Beartooth uplift and Absaroka-Gallatin volcanic province—the study area encloses a variety of rock types that formed over a considerable range of time. Igneous, sedimentary, and metamorphic rocks occur as representatives of all geologic eras: Precambrian, Paleozoic, Mesozoic, and Cenozoic. The geology of the study area is shown in plate 1, and a generalized map of the bedrock geology with Quaternary surficial deposits deleted is given in figure 7.

Metamorphic rocks of Precambrian age constitute the core of the Beartooth uplift and make up about 60 percent of the bedrock of the study area. Tertiary igneous rocks of the Absaroka-Gallatin province make up about 30 percent of the bedrock of the study area. Of this,

FIGURE 5 (facing page).—General geology of the Beartooth uplift and the Absaroka-Gallatin volcanic province. Structural blocks of the Beartooth uplift are the North Snowy (I), South Snowy (II), and Beartooth Plateau (III) blocks. The principal eruptive centers of the Eastern Absaroka belt in the volcanic province are: (1) Emigrant, (2) Independence, (3) Cooke City, (4) Crandall or Hurricane Mesa areas, and (5) Sunlight Basin and Sunlight mining region. Modified from Chadwick (1970, p. 268).

volcanic and volcaniclastic sedimentary rocks constitute about 20 percent of the area, and intrusive rocks about 10 percent. These rocks cover most of the southern part of the area and are not found north of about lat 45°22′ N. Sedimentary rocks of Paleozoic and Mesozoic age cover about 10 percent of the study area. Surficial deposits of Quaternary age—glacial deposits, alluvium, landslides, and talus—conceal bedrock in many places.

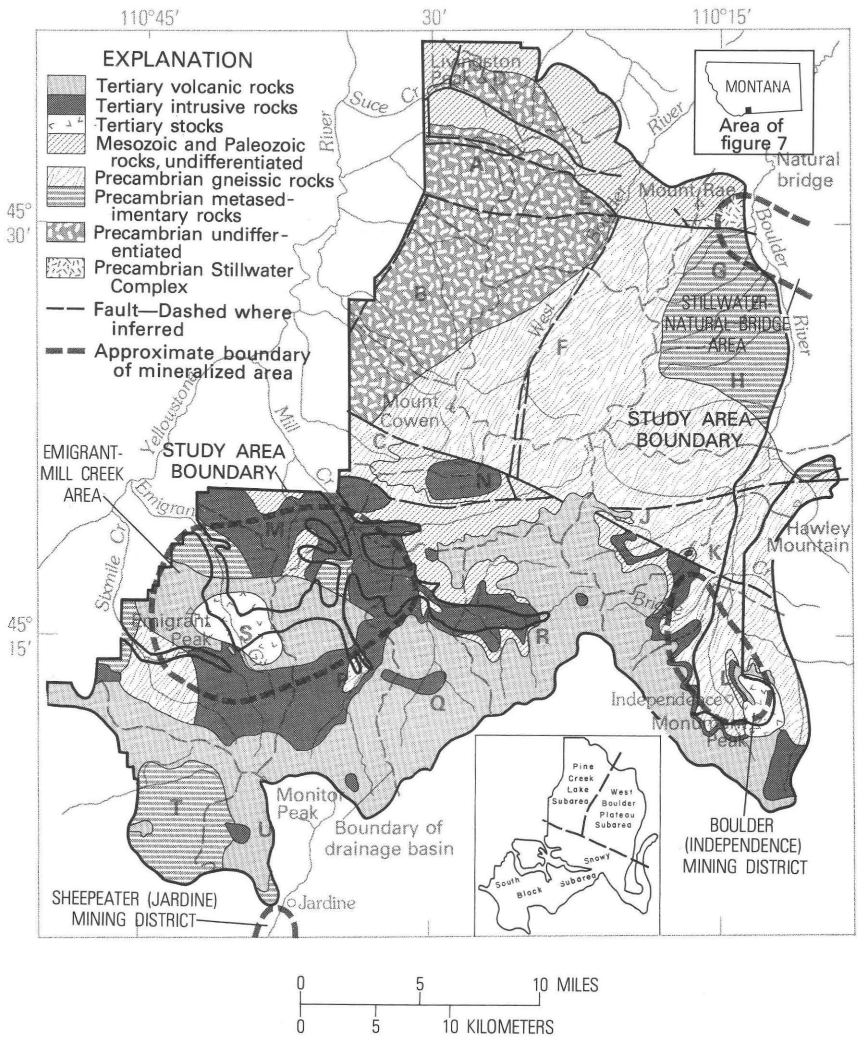


FIGURE 7.—Generalized geology of the North Absaroka wilderness study area, with detail of subareas and mineralized areas in or peripheral to the study area. Letter symbols, which correspond to sample number prefixes, indicate drainage basins.

PRECAMBRIAN ROCKS

Except for a few dolerite dikes, all of the Precambrian rocks are metamorphic and can be subdivided, with reasonable certainty into two groups: metasedimentary and metaigneous.

The metasedimentary rocks are the oldest in the area. Rocks in the North Snowy block have been dated radiometrically at more than 3,000 m.y. (million years) (Reid and others, 1975), and metasedimentary rocks in other parts of the study area probably are of equivalent age.

Metasedimentary rocks are widely distributed and constitute approximately one-third of the Precambrian exposures. Thick sequences occur in the area west of the West Boulder River and north of Mount Cowen, along lower Boulder River in the drainage areas of Weasel, Great Falls, Falls, and Froze-to-Death Creeks, in the vicinity of Sheep Mountain in the southwest corner of the study area, and along West Fork Mill Creek and the lower parts of Emigrant and Sixmile Creeks (pl. 1). The predominant rock types are schist, quartzite, and hornfels. Less abundant are para-amphibolite, marble, phyllite, and iron-formation.

The remaining two-thirds of the Precambrian terrain is chiefly igneous rocks. Granitic gneiss is predominant, but orthoamphibolites and mafic to ultramafic intrusives occur in significant quantities.

Granitic gneiss is predominant along both sides of the Boulder River south of Speculator and Hawley Creeks and extends westward to the West Boulder River and along the West Boulder Plateau. Granitic gneiss underlies approximately one-half of the area west of the West Boulder River and north of the Elbow Creek fault. Granitic gneiss is less common in the Precambrian rocks in the southwestern part of the area, but it occurs along Mill Creek, West Fork Mill Creek, and the upper parts of both forks of Sixmile Creek (pl. 1).

Mafic rocks of igneous origin include amphibolites, unmetamorphosed mafic dikes, and the Stillwater Complex. Amphibolites are most abundant in the northwestern part of the area, west of the West Boulder River and north of Mount Cowen, where they occur interlayered with gneiss, quartzite, marble, and schist and as dikes. East of the West Boulder River, amphibolites are scarce and occur only as dikes and irregular bodies. South of the Elbow Creek fault, amphibolites are common, mostly as dikes or sills in sequences of schist. Unmetamorphosed mafic dikes are few in number and are steeply dipping or vertical. The Stillwater Complex is exposed only in the extreme northeastern part of the study area.

Studies in the eastern part of the Beartooth Plateau block by a number of workers have indicated that the Beartooth Mountain range is part of an approximately 2,750-m.y.-old terrain that includes much of Wyoming and southeastern Montana (Gast and others, 1958; Giletti, 1968). Older ages of 3,120 and 3,140 m.y. have been measured by Catanzaro and Kulp (1964) and Nunes and Tilton (1971) on detrital cores of zircon crystals from metamorphic rocks. Nunes and Tilton (1971) concluded that the Stillwater Complex was emplaced about 2,750 m.y. ago, essentially concurrently with the major metamorphism of the region.

Detailed mapping in the eastern and southeastern Beartooth Mountains indicates that at least two and probably as many as four periods of deformation occurred during the 2,750-m.y. event, the so-called Beartooth orogeny (Rowan, 1969; Skinner and others, 1969). Mafic dikes that intrude granitic gneisses and associated rocks in the eastern Beartooth terrain are interpreted by Baadsgaard and Mueller (1973) as having been emplaced during three episodes approximately 2,550, 1,300, and 740 m.y. ago, respectively.

The most direct evidence bearing on the Precambrian history of the North Absaroka study area comes from a study of the geology of the North Snowy block by Reid, McMannis, and Palmquist (1975). They outlined a long and complex Precambrian history based on data obtained from U-Pb, Pb-Pb, K-Ar, and Rb-Sr age determinations, and they concluded that at least four orogenies widely separated in time and differing in grade of metamorphism and structural style occurred during Precambrian time. The first three orogenies were accompanied by widespread granitic intrusion. The occurrence of seven nonparallel sets of deformation structures in the rocks of the Pine Creek Lake area (pl. 1) provides evidence of seven superimposed deformational events spaced over 2,000 m.y. during the Precambrian. The deformation has been related to orogenic pulses that occurred between 3,000 and 1,200 m.y. ago. It is proposed "* * * that the nappe core and enveloping schists are a remnant of earliest supracrustal rocks (older than 3.1 b.y.) that were transported to deeper crustal levels and successively intruded by syntectonic stratiform injections of intermediate to granitic magma (at 3.0 b.y., 2.6 b.y., and 2.2 b.y.) and also by mafic injections as dikes and sills at about 2.2 b.y." (Reid and others, 1975, p. 117).

The Precambrian history may be summarized as follows (Reid and others, 1975, p. 127–128):

1. The deposition of muds, quartz sands, and dolomitic carbonates accompanied by the extrusion of basaltic tuffs and (or) flows occurred more than 3,200 m.y. ago.

2. The Pine Creek orogeny began about 3,100 m.y. ago. The grade of metamorphism achieved during the orogeny was to amphibolite-granulite facies. Folding resulted in the development of northwest-trending recumbent passive-flow folds. Tonalitic magma was intruded and solidified and subsequently metamorphosed to gneiss.

3. The Beartooth orogeny began about 2,700 m.y. ago. Rocks were metamorphosed to the andalusite-sillimanite facies of the Buchan type, indicative of a level shallower than that of the Pine Creek orogeny.

North-trending recumbent passive-flow folds were developed. Intrusion and solidificaton of granodioritic magma were followed by continued stress that produced gneiss.

4. An unnamed orogeny occurred about 2,200 m.y. ago, and the grade of metamorphism was of the Abukuma greenschist-amphibolite facies, indicative of even shallower crustal levels. Folding was of the recumbent passive-flow type with a northeast trend. Synkinematic felsic magma was emplaced and was followed by the intrusion of dikes, stocks, and sills of diabase. Continued stress produced gneiss and metadiabase.

5. Another unnamed orogeny occurred about 1,700 m.y. ago. Metamorphism was of a still shallower nature, resulting in a metamorphic grade of the albite-epidote hornfels facies. Folding along a northeast trend was renewed and was accompanied by leucocratic intrusions. North-northeast and west-northwest steep fault zones began to form.

6. The latest events occurred probably during a time span about 1,200 to 965 m.y. ago (Reid and others, 1975, p. 136) and included the intrusion of a small granodiorite pluton in the upper Davis Creek area, the development of northeast-trending folds and northwest-trending thrust faults, kink folds and shear fractures, and a small diabase intrusion in the upper Davis Creek area.

In order to describe the Precambrian rocks, we have divided the study area into three subareas: (1) the Pine Creek Lake subarea, bounded on the east by the West Boulder River and on the south by the Mill Creek fault; (2) the West Boulder Plateau subarea, bounded on the west by the West Boulder River, on the southwest by the Cooke City structural zone, and on the east and southeast by the boundaries of the study area; and (3) the South Snowy block subarea, bounded on the north by the Mill Creek fault and to the east by the Cooke City structural zone (pl. 1; fig. 5).

PINE CREEK LAKE SUBAREA

This subarea is the western part of the North Snowy structural block and is underlain mainly by rocks of Precambrian age. Geologic maps and detailed structural and petrographic studies of Reid, McMannis, and Palmquist (1975) have been used extensively in the following section.

These authors (1975) described and named seven formations of metasedimentary and metaigneous rocks that range in age from more than 3,000 m.y. to about 2,200 m.y. These formations are, from oldest to youngest, the Barney Creek Amphibolite, George Lake Marble, Jewel Lake Quartzite, Davis Creek Schist, Mount Delano Gneiss, Mount Cowen Gneiss, and Falls Creek Gneiss.

The Barney Creek Amphibolite, George Lake Marble, and Jewel Lake Quartzite are part of a nappe structure in the area of Pine Creek Lake and are included in the nappe core unit on plate 1. This triad of distinctly black-, brown-, and white-weathering units are the most easily identified rocks in the subarea.

The Barney Creek Amphibolite is black to dark gray, fine grained (less than 1 mm), finely laminated or schistose, mildly to strongly foliated, and includes intercalated gneiss, schist, and metadiabase. The unit is quite variable in thickness and commonly is about 200–790 ft (60–240 m) thick. The principal minerals are green hornblende, plagioclase, biotite, and quartz. Epidote and sericite are common alteration products. Minor minerals include garnet, clinozoisite, chlorite, apatite, magnetite, ilmenite, allanite, thorite, sphene, and pyrite. This unit was probably originally deposited as basalt flows and interbedded tuffaceous sediments.

The George Lake Marble is a brown-weathering, coarsely crystalline dolomitic and calcitic marble. Observed thickness of this unit ranges from 0 to 200 ft (0 to 60 m), but the rock is highly deformed and the original thickness is unknown. Intercalated quartzite is common. Tremolite is a common constituent of the marble. Minor minerals are diopside, quartz, phlogopite, talc, graphite(?), and apatite. This marble was probably originally deposited as impure dolomite and limestone in a marine environment.

The Jewel Lake Quartzite ranges from about 65 to 200 ft (20 to 60 m) in thickness but locally is thicker, probably as a result of structural duplication. The quartzite is white to pale or dark green in color and is micaceous; the green color is probably due to the occurrence of fuchsite (chromium mica). Quartz is granoblastic, fine to coarse grained (greater than 5 mm), and platy. Minor minerals include muscovite, plagioclase, biotite, sphene, zircon, apatite, leucoxene, allanite, pyrite, and opaques.

Another major sequence of quartzite occurs in a northeasterly-trending band parallel to and northwest of the nappe core group and separated from it by a gneiss-amphibolite sequence (pl. 1). This quartzite sequence consists of interlayered quartzite and amphibolite in layers about 6–20 ft (2–6 m) thick and was mapped as Davis Creek Schist (Reid and others, 1975). This change appears elsewhere, too however, the sequence includes very little schist, so it is shown on plate 1 as a separate map unit. Stratigraphically, this sequence may be correlative with the Davis Creek Schist. Along the ridge crest northwest of Mount Delano, the quartzite sequence has an apparent thickness of approximately 6,500 ft (2,000 m).

The quartzite was originally deposited as quartzose sediments or possibly as chert that was intercalated with carbonate sediments, shale, and basaltic tuff. To the east and south these sediments intertongued with a sequence of quartz- and clay-rich sediments.

The Davis Creek Schist was named for the extensive exposures of schist along Davis Creek (pl. 1). In addition, numerous tonguelike remnants or tabular inclusions of similar schist occur within the adjacent Mount Delano Gneiss and Mount Cowen Gneiss. This unit is a fine- to medium-grained (1–5 mm), brown-weathering mica schist containing scattered plagioclase porphyroblasts. Several intercalated quartzite layers, a few marble lenses, and sheetform intrusions of gneiss occur in the Davis Creek Schist. Quartz is the major constituent; biotite is next in order of abundance. Minor minerals are green hornblende, cummingtonite, plagioclase, muscovite, chlorite, garnet, cordierite, and epidote. Accessories include graphite(?), ilmenite, zircon, magnetite, apatite, allanite, pyrite, thorite, and tourmaline. This unit was probably originally deposited as an impure quartz-clay sediment.

The Mount Delano Gneiss is a medium- to coarse-grained, strongly banded gray gneiss that varies from massive nonfoliated to strongly foliated. It ranges in composition from quartz diorite to quartz monzonite. Modal composition is indicated in figure 8. Typically, gneiss is interlayered with many sheetlike masses of amphibolite that parallel

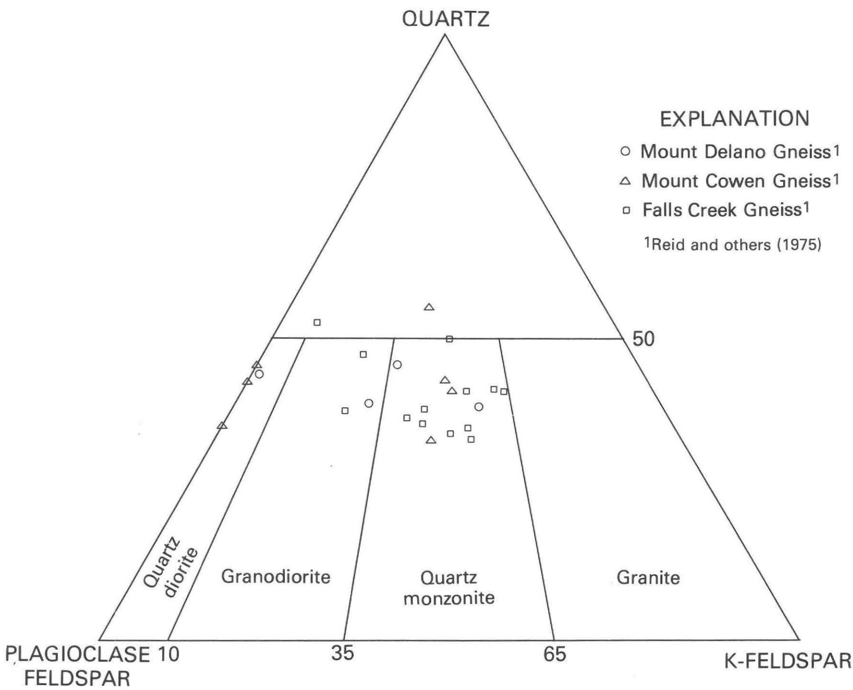


FIGURE 8.—Modal composition of gneissic rocks, North Absaroka wilderness study area.

the foliation of the enclosing gneiss (fig. 9). The amphibolite layers are generally about 6–20 ft (2–6 m) thick, and the ratio of amphibolite to gneiss in exposed sections is commonly 1:2 to 1:1 but is as much as 3:1 in certain sections. Schist inclusions or remnants also occur but are less abundant than amphibolite.

The typical mineral assemblage is plagioclase-biotite-quartz with a crystalloblastic-lepidoblastic texture. Most of the gneiss has little potassium feldspar and where present this mineral generally appears to have replaced other minerals. Evidence of moderate to strong shearing and alteration is common in thin sections. Minor minerals are epidote, muscovite, chlorite, and hornblende, and accessory minerals include apatite, ilmenite, graphite(?), magnetite, zircon, sphene, and pyrite.

Evidence of magmatic origin of this gneiss includes the presence of rotated xenoliths of older rocks, relict igneous textures, zircon morphology, and locally preserved cross-cutting contacts. An age of at least 3,000 m.y. is indicated by the $^{207}Pb/^{206}Pb$ ratio in zircon.

The Mount Cowen Gneiss is named for the highest peak in the study area where the rock is excellently exposed in the rugged crest, ridges, and cirques (fig. 3). This gneiss, the most abundant rock in the southeastern and eastern parts of the subarea, is generally coarse

FIGURE 9.—Interlayered gneiss (light colored) and amphibolite (dark colored) of the Mount Delano Gneiss (Reid and others, 1975) exposed on the south side of ridge approximately 2 mi (3 km) east of Mount Delano. The amphibolite contains abnormally high values of copper and several other elements compared with other rock types in the study area.

grained and gray and has an augen texture. Modally the composition ranges from granodiorite to quartz monzonite (fig. 8). This unit is commonly coarsely foliated and contains numerous small to large schist remnants or sheetlike inclusions, especially near the West Boulder River.

The augen are mostly potassium feldspar, although plagioclase also occurs. Flattened lensoid aggregates of granoblastic quartz are also common. Occurring in minor amounts are biotite, epidote, muscovite, and allanite. Alteration of plagioclase to sericite, clay, epidote, and carbonates and of biotite to sericite and chlorite was widespread. Accessory minerals are zircon, allanite, rutile, sphene, opaques, and garnet.

An age of 2,565 m.y. is indicated by the $^{207}Pb/^{206}Pb$ ratio in zircons. The contacts with older units show tectonically transposed intrusive relationships.

The Falls Creek Gneiss, the youngest of the major units described by Reid and others (1975), lies mostly east of the West Boulder River and will be described in the following section on the West Boulder Plateau subarea.

Amphibolites other than the Barney Creek Amphibolite, described as metadiabases (Reid and others, 1975), are very abundant in the Pine Creek Lake subarea, particularly in the northern part where they occur interlayered with gneiss (fig. 9) and quartzite. Dikes and irregular plutons of amphibolite are also common.

The amphibolites are fine to medium grained, dark green to black, and weather reddish brown. Lineation and foliation are strong but variable. The texture generally is crystalloblastic-nematoblastic, but relict diabasic and porphyritic textures are common locally. Where relict phenocrysts of plagioclase are abundant the texture is similar to leopard rock texture in metadolerites of the central and eastern parts of the Beartooth uplift (Prinz, 1964). Green hornblende is the dominant mineral, and brown hornblende also occurs as the major mineral in a few specimens. Plagioclase, second in abundance, commonly shows twinning and zoning suggestive of igneous origin. Pyroxene is uncommon but both augite and hypersthene are found in samples from amphibolite dikes. Other common minerals are quartz, biotite, chlorite, and epidote. Accessories include sphene, apatite, magnetite, and pyrite.

These amphibolites are mostly igneous in orgin and were originally emplaced as sills and, less commonly, as dikes, although some quartz- and garnet-rich amphibolite, interlayered with quartzite and schist, may be sedimentary in origin. They are mostly equivalent to the Archean ortho-amphibolites described by Prinz (1964) in the southern Beartooth Mountains. More than one intrusive event is indicated by cross-cutting relationships, the most common being dikes that cut sills. Original chilled contacts are represented by fine-grained borders of dikes and sills. The sills are probably late synkinematic in origin and were injected along active shear planes into rocks of moderate temperature (Reid and others, 1975).

Unmetamorphosed dolerite also occurs in the Pine Creek Lake subarea. One type is equivalent to the quartz dolerites and another to the alkalic olivine dolerite dikes described by Simons and others (1973) and Prinz (1964). The quartz dolerite dikes observed in this study have an ophitic to subophitic texture, and the principal minerals are plagioclase, pigeonite, and augite. Minor potassium feldspar and quartz are present as interstitial graphic intergrowths.

Other rock types occurring locally in the Pine Creek Lake subarea are pegmatites, mylonite, iron-formation (discussed in the section on mineral resources), quartz veins, and fault breccia.

WEST BOULDER PLATEAU SUBAREA

Rocks of the West Boulder Plateau subarea are mostly granitic gneiss. A large area of schist and hornfels is exposed in the northeastern part of the subarea and a small area of the Stillwater Complex in the northeast corner.

The major map unit in this subarea is the Falls Creek Gneiss, named (Reid and others, 1975) for exposures along Falls Creek (a tributary to the West Boulder River) and on the east side of the West Boulder River. The present study indicates that this unit is continuous to the east and south and is indistinguishable, at least during rapid reconnaissance, from granitic gneisses described by Simons and others (1973) to the east of the study area. Gneissic rocks south of Fourmile and Hawley Creeks (pl. 1) are similar, in general, to the Falls Creek Gneiss on the West Boulder Plateau.

Reid and others (1975) described the Falls Creek Gneiss as a gray to pink sheet-form unit that is generally strongly foliated. Composition is said to range from trondhjemitic to granodioritic. Modes were determined on stained slabs of several samples collected during the present study. These modes have been plotted on figure 8; they generally cluster in the quartz monzonite field. In general, the Falls Creek Gneiss is more leucocratic than either the Mount Cowen Gneiss or Mount Delano Gneiss; it commonly has a higher content of potassium feldspar and a lower content of mafic minerals, lacks the strong banding of the Mount Delano Gneiss, and lacks the augen texture of the Mount Cowen Gneiss. Cataclastic texture and other evidence of shearing are common. Major minerals are plagioclase, microcline, quartz, and biotite. Minor and accessory minerals include muscovite, chlorite, epidote, allanite, zircon, sphene, leucoxene, apatite, and magnetite. Small grains of disseminated magnetite are commonly visible in hand specimens.

Field relations indicate that the Falls Creek Gneiss intrudes Mount Cowen Gneiss. Potassium-argon determinations indicate an age of about 2,200 m.y. for the Falls Creek Gneiss (Reid and others, 1975).

The Falls Creek Gneiss is in contact with a major block of metasedimentary schist and hornfels along the lower part of Speculator Creek and near the headwaters of Weasel, Great Falls, Falls, and Froze-to-Death Creeks on the east side of the West Boulder Plateau (pl. 1). Exposures at the head of Weasel Creek indicate that gneiss is intrusive into hornfels. At the contact, rotated blocks of hornfels are enveloped in granitic gneiss and felsic pegmatite. To the east, away from the gneiss-hornfels contact, the hornfels grades into schistose rocks, and farther east schist grades into hornfels near the contact with the Stillwater Complex; this eastern zone of hornfels is wider and of a higher metamorphic grade than that developed adjacent to the Falls Creek Gneiss and has been mapped and described by Page and Nokleberg (1974) and Page, Simons, and Dohrenwend (1973). Their major map units are biotite-cordierite, anthophyllite-biotite-cordierite, and cordierite-orthopyroxene-biotite hornfels. Other units of limited extent are quartzite and iron-formation.

These metasedimentary rocks were probably deposited originally as impure quartzose sand, silt, and clay. Compaction and lithification were followed by several stages of metamorphism and folding including thermal metamorphism by the Stillwater Complex and the Falls Creek Gneiss. The hornfels near the base of the Stillwater Complex contains zircons with uranium-lead ages of 3,140 m.y. or older (Nunes and Tilton, 1971).

The northwest end of the Stillwater Complex is exposed in the northern part of the subarea; this major layered igneous intrusive continues to the southeast beyond the study area for approximately 26 mi (42 km). The Stillwater Complex has been studied by Hess (1960), Jackson (1961), Jones, Peoples, and Howland (1960), and many others. In the study area, the complex is bounded on the west and south by faults and is covered by Paleozoic sedimentary rocks to the north. Most of the exposures are of anorthosite and gabbro of the banded and upper zones. Norite and bronzite of the basal zone are exposed near the mouths of Falls and Great Falls Creeks on the west side of the Boulder River (Page and Nokleberg, 1974), but these units were not seen farther west along the projected strike.

SOUTH SNOWY BLOCK SUBAREA

Areas of exposure of Precambrian rocks in the South Snowy block subarea are relatively small and are isolated from the Precambrian terrain in the other parts of the study area (fig. 7). The largest outcrop area is in the southwest corner of the subarea that is drained by Bassett, Cedar, and North Fork Bear Creeks (pl. 1). Other areas of extensive exposure are in the lower parts of Sixmile and Emigrant Creeks and along Mill Creek and West Fork Mill Creek (pl. 1). Elsewhere, Precambrian rocks are covered by younger rocks, principally igneous rocks of Tertiary age. The Precambrian rocks of this subarea have been little studied in previous work, and correlation with the Precambrian rocks elsewhere in the study area is difficult.

Two major units, granitic gneiss and schist, have been mapped in this subarea (pl. 1). Included with the schist are quartzite, amphibolite, and phyllite. Mafic intrusives (amphibolite and dolerite) are common and intrude both gneiss and schist.

Gneissic rocks are exposed along Sixmile and North Fork Sixmile Creeks and in the upper parts of Mill and West Fork Mill Creeks (pl. 1). They are mainly gray to pink granitic gneiss with a granoblastic texture and foliation that is variable from weak to strong. The principal minerals are plagioclase, potassium feldspar, quartz, and biotite. In general, these gneisses resemble more closely the Mount Cowen Gneiss than either the Falls Creek Gneiss or Mount Delano Gneiss.

Schistose rocks similar to those described by Seager (1944) in the Jardine district are exposed over several square miles (kilometers) in the southwest corner of the subarea. Part of this southwest corner of the subarea was mapped and described by Fraser, Waldrop, and Hyden (1969). Mica schist is the dominant rock type, but quartzite and phyllite are common. Amphibolite, commonly cummingtonite schist, occurs locally. Quartz, biotite, and muscovite are the principal minerals.

Metasedimentary sequences consisting predominantly of schist also occur along lower Sixmile and Emigrant Creeks and West Fork Mill Creek (pl. 1).

Both metamorphosed and unmetamorphosed mafic dikes occur in this subarea. Some are sill-like masses, whereas others are clearly dikes. A major quartz gabbro dike with an east-west trend is well exposed north of Sheep Mountain (pl. 1).

PALEOZOIC ROCKS

The thickest and most complete sections of sedimentary rocks of Paleozoic age are in the northern part of the study area, where these rocks dip steeply north and northeast into the Crazy Mountain Basin. Paleozoic rocks are also exposed in a discontinuous band across the central part of the study area including the area of Chico Peak, along Mill, East Fork Mill, and Elbow Creeks, and on tributaries to the upper part of the Boulder River (pl. 1). Descriptions and thicknesses of Paleozoic and Mesozoic sedimentary rocks occurring in the study area are summarized in table 1.

The sedimentary Paleozoic rocks are mostly marine and were deposited in shallow seas that were part of the broad stable Wyoming shelf that persisted during Paleozoic and most of Mesozoic time (Foose and others, 1961). Two unconformities that represent at least one geologic period each occur between the Upper Ordovician Bighorn Dolomite and the Upper Devonian Jefferson Limestone and between the Pennsylvanian Quadrant Sandstone and the Middle Jurassic Piper Formation. Other unconformities represent time spans within the Ordovician and Mississippian and perhaps the Pennsylvanian Periods (Richards, 1957).

In the vicinity of Livingston, the Paleozoic sequence has a thickness of approximately 2,795 ft (850 m) (Richards, 1957). Limestone is the dominant rock type, followed by shale, dolomite, sandstone, and quartzite, in that order of abundance.

The distribution of rocks of Middle Cambrian age may be significant in regard to the occurrence of metallic mineral deposits. Rocks of this age are commonly hosts for epigenetic replacement and vein deposits that are associated with intrusive centers of Tertiary age. The Meagher Limestone and Wolsey Shale, in particular, are favorable hosts for replacement deposits of copper, gold, and other metals; for example, the pyritic gold-copper deposits of the Cooke City (or New World) mining district are localized in these rocks. These rocks are the hosts for mineral deposits on War Eagle Mountain and at the Ski Line claim in the Boulder district and for some deposits in the Emigrant–Mill Creek area.

MESOZOIC ROCKS

Rocks of Mesozoic age (here, Jurassic and Cretaceous) are limited almost entirely to the north edge of the study area (pl. 1). Most exposures are in one continuous band that overlies Paleozoic rocks and dips north or northeast beneath younger rocks. The maximum thickness of Mesozoic rocks in the study area is about 1,700 ft (520 m) on the northeast flank of Shell Mountain.

Brief descriptions of Jurassic and Cretaceous rocks are given in the generalized stratigraphic column in table 1. Both marine and continental rocks are represented, and shale is the dominant lithology, followed by sandstone, siltstone, mudstone, limestone, and conglomerate, in order of abundance.

Deposits of Late Cretaceous age are thicker than those of Early Cretaceous age in the Middle Rocky Mountains region, indicating the beginning of more rapid shelf subsidence and initiation of early Laramide crustal instability. This was also the beginning of volcanic and intrusive activity as well as doming and faulting along the perimeter of the Beartooth block (Foose and others, 1961).

TABLE 1.—*Generalized stratigraphic column of sedimentary rocks of Paleozoic and Mesozoic age exposed in the North Absaroka study area near Livingston, Park County, Montana (modified from Richards, 1957)*

[Wavy line, unconformity]

SYSTEM	SERIES		FORMATION	THICKNESS, FT (M)	DESCRIPTION
CRETACEOUS	Lower Cretaceous		Colorado Shale	815 (248)	Shale, silty and sandy in upper part; underlain by shale and thin beds of sandstone. About 30 ft (9 m) of flaggy siltstones and sandstones; basal part 30 ft (9 m) or less of gray shale.
			Kootenai Formation	300 (91)	Upper beds mostly concealed but include several lenticular beds of sandstone and some mudstone. Basal conglomerate as much as 130 ft (40 m) thick, contains pebbles of chert and quartzite.
JURASSIC	Upper Jurassic		Morrison Formation	400 (122)	Sandstone, massive near top and less massive in middle; lower part largely concealed, producing red soil.
		Ellis Group	Swift Formation	80 (24)	Sandstone, brown-weathering, calcereous, glauconitic and fossiliferous.
	Middle Jurassic		Rierdon Formation	95 (29)	Upper beds mostly concealed shale. Basal 10 ft (3 m) dense gray oolitic limestone.
			Piper Formation	240 (73)	Upper beds deeply weathered, probably red shale in large part. Gray dense limestone near middle. Greenish-gray shale in lower part on yellow basal sandstone.
PENNSYLVANIAN			Quadrant Sandstone	100 (30)	Sandstone, light-yellowish- to reddish-gray, fine-grained.
			Amsden Formation	140 (43)	Mostly concealed. Thin beds of red and gray limestone near middle lie above some red shale and siltstone.

MISSISSIPPIAN		Madison Limestone	860+ (260+)	Limestone, dense and finely crystalline, light- to medium-gray. Generally divisible in descending order into (1) about 340 ft (103 m) of dense light-gray limestone, partly brecciated and cherty; (2) about 180 ft (55 m) of light-gray dense limestone, includes several argillaceous and silty layers and several crinoidal limestones; (3) a 50-ft (15-m) zone of argillaceous limestone with bioherms; unit widespread in area; (4) about 235 ft (72 m) of thin-bedded to massive, variably argillaceous to sandy limestone; unit very fossiliferous, many beds have abundant crinoid stem fragments; (5) basal 55 ft (17 m) interbedded limestone and chert, making excellent marking beds.
DEVONIAN	Upper Devonian	Three Forks Shale	80 (24)	Largely concealed; yellow to brown soil formed from shale and thin orange dolomite.
		Jefferson Limestone	390 (119)	Limestone, gray to greenish-gray; limestone breccia in upper half; underlain by argillaceous and silty, brownish-gray limestone in the lower half.
ORDO-VICIAN	Upper Ordo-vician	Bighorn Dolomite	200 (61)	Upper few feet (meters) thin-bedded dolomitic limestone. Remainder is dolomite, cliff-forming, dense, light-gray and light-yellowish-gray.
CAMBRIAN	Upper Cambrian	Grove Creek Formation	50 (15)	Limestone and shale; limestone in part conglomerate with rounded pebbles.
		Snowy Range Formation	175 (53)	Shale; upper unit is limestone and shale; middle unit is limestone; basal unit is greenish-gray shale.
		Pilgrim Limestone	175 (53)	Upper two-thirds massive dense and finely crystalline mottled limestone. Lower one-third largely edgewise limestone conglomerate and limestone breccia that weather green.
	Middle Cambrian	Park Shale	380 (116)	Shale, greenish- and reddish-gray, and thin beds of gray crystalline limestone.
		Meagher Limestone	65 (20)	Shale, greenish-gray, and thin beds of dense gray limestone; make small ledges, weathers of light-yellowish-gray soil.
		Wolsey Shale	105 (32)	Shale, greenish gray, and a little thin-bedded limestone.
		Flathead Sandstone	0-75 (23)	Sandstone and quartzite, gray to reddish-gray; conglomerate near base.
PRECAMBRIAN		Gneiss, schist, granite		

CENOZOIC ROCKS

Rocks of Cenozoic age include Tertiary volcanic and intrusive rocks and Quaternary surficial deposits. Tertiary rocks are limited to the south half of the study area whereas Quaternary deposits are abundant throughout the area.

The Tertiary rocks are part of the Absaroka-Gallatin volcanic field that formed during early Tertiary time, concurrently with major uplift of the region. This extensive igneous activity probably lasted for 5 to 10 m.y. The bulk of the volcanic activity is thought to have occurred during the Eocene, approximately 50 to 45 m.y. ago (Smedes and Prostka, 1972); however, an older age is indicated for volcanic rocks of the Emigrant–Mill Creek area based on an age of 53.5±2.3 m.y. determined on biotite separated from andesite from West Fork Mill Creek (Chadwick, 1970). This may be the oldest volcanic unit in the study area. The ages of intrusive rocks have not been established; some, such as the Emigrant and Independence stocks, intrude volcanic rocks; however, some of the dacite porphyry bodies may be older than the youngest volcanic units. This is suggested by geologic relations and by an age of 49.0±1.7 m.y. for biotite from dacite porphyry of Arrow Peak (Chadwick, 1970). The Absaroka volcanic field or Absaroka-Gallatin volcanic province of Chadwick (1970) covers about 9,000 mi^2 (23,000 km^2), has a maximum thickness of about 4,920 ft (1,500 m), and is the largest volcanic pile of Eocene age in the Northern Rocky Mountains (Smedes and Prostka, 1972). The volcanic rocks are mostly andesite and dacite, and consist of pyroclastic and epiclastic volcanic material, lava flows, and genetically related intrusive rocks.

Eruptive centers are alined along two northwest-trending structural zones that extend for at least 150 mi (241 km) from the south end of the Absaroka Range in northwestern Wyoming to the vicinity of the Tobacco Root Mountains in southwestern Montana (Chadwick, 1970). One of these zones coincides with the Cooke City structural zone. Some of the intrusive centers are the eroded roots of volcanic cone complexes, and the intrusive rocks, at least in the Cooke City area (fig. 5), are variously older than, the same age as, or younger than surrounding volcanic and volcaniclastic rocks. Mineralization associated with the Tertiary igneous activity was concentrated in and around the intrusive centers and occurred late in the intrusive cycle or subsequent to the emplacement of intrusives.

By middle Eocene time the Beartooth block had obtained its present structural relief. However, it did not have its present topographic relief and was at a considerably lower elevation. Regional raising of the block, on the order of 4,000 to 6,000 ft (1,220 to 1,830 m), occurred during the Miocene and Pliocene (Foose and others, 1961, p. 1165). Subsequent erosional modification, principally by glaciers and streams, has resulted in the present topographic configuration.

TERTIARY VOLCANIC ROCKS

Extrusive rocks of the Absaroka-Gallatin volcanic field overlie Precambrian and Paleozoic rocks in the south half of the study area (pl. 1). They include volcanogenic deposits derived from several separate but nearly contemporaneously active volcanic centers. Smedes and Prostka (1972, fig. 3) included the volcanic rocks of the study area in the Washburn and Sunlight Groups of the Absaroka Volcanic Supergroup.

Five volcanic units are shown on plate 1. These units aggregate about 4,700 ft (1,430 m) in thickness in the study area but are deeply eroded, display considerable lateral variation and many unconformities, and locally interfinger with similar volcanogenic material from separate volcanic centers. The volcanic rocks are chiefly vent or near-source deposits mostly of intermediate composition but range from basalt to rhyodacite and consist of interlayered basaltic to rhyodacitic tuff breccias and ash, basaltic to latitic lava flows, and reworked volcanogenic rocks (lahars and epiclastic facies).

Perhaps the oldest volcanic rocks in the study area are represented by a complex of generally altered, andesitic and dacitic breccias associated with the Emigrant Peak intrusive center. According to Basler (1965), these rocks are monolithologic autobreccias and heterolithologic breccias that probably represent both material in a volcanic conduit and basal cone material that has been vented to the surface. The relation of these vent facies rocks to other volcanic rocks in the area is not clear. They are probably contemporaneous with and genetically related to some or all of the other volcanic rocks in the Mill Creek drainage basin.

Volcaniclastic rocks and lava flows of the Washburn and Sunlight Groups include a basal, mostly light colored volcaniclastic sequence of layered or crudely stratified rocks (the "early acid breccia" of Hague and others, 1899), and a predominantly dark colored volcaniclastic layered sequence (the "early basic breccia" of Hague and others, 1899). The basal sequence is approximately 900–1,500 ft (275–460 m) thick on the divides between the Boulder River, Hellroaring Creek, and Mill Creek drainages but may not be present in the western part of the study area. The overlying darker colored sequence has a maximum thickness of about 1,500 ft (460 m) in the area, and is well exposed in the cirque walls from the head of Wallace Creek northeast along the study area boundary to the head of Mill Creek and elsewhere. H. J. Prostka (*in* Wedow and others, 1975, p. B15) considered the basal, light-colored part of this volcaniclastic unit to be equivalent to the Cathedral Cliffs Formation of the Washburn Group and the darker colored upper part of this unit to be a basal clastic facies of the Mount Wallace Formation and hence a part of the Sunlight Group.

Lava flows in the lower part of the Mount Wallace Formation overlie and interfinger with the underlying volcaniclastic rocks. These lava flows were called the lower flow sequence of the Mount Wallace Formation by Wedow and others (1975). The lower flow sequence is about

1,300–1,500 ft (400–460 m) thick in the vicinity of Mount Wallace; it consists of thick to massive lenticular flows and flow breccias of andesite, trachybasalt, latite, and dacite (Smedes and Prostka, 1972).

The Slough Creek Tuff Member of the Mount Wallace Formation is a composite sheet of rhyodacitic to rhyolitic welded and nonwelded ash-flow tuffs (Smedes and Prostka, 1972; Wedow and others, 1975). The unit is about 400 ft (120 m) thick where it locally extends into the study area along the divide south and west of Passage Creek. It probably includes a massive, dense, siliceous, gray to yellowish-gray and pale-red, altered trachytic porphyry flow and associated crystal pumice biotite tuff, vitrophyric lapilli tuff, and other pyroclastic tuff breccias that cap Sliding Mountain north of Cedar Creek.

The upper flow sequence of the Mount Wallace Formation is represented by a thick dacitic porphyry flow that overlies the Slough Creek Tuff Member at one locality in the study area near the head of Passage Creek.

According to Rubel (1964, 1968, 1971) and Courtis (1965), a large stratovolcano was centered over the Tertiary stock of the Independence mining district. Another major volcanic center is probably represented by the Emigrant stock and surrounding Tertiary intrusive bodies. These two volcanic centers appear to be the source of most or all of the volcanic material in the study area. A late Paleocene or early Eocene age is indicated for the volcanic rocks of the Emigrant–Mill Creek area that are intruded by the Emigrant stock. Biotite separated from andesite from the West Fork Mill Creek has an age of 53.2±2.3 m.y. (Chadwick, 1970). Ash Mountain, several miles south of the study area near the Jardine mining district, is thought to be an eruptive center (Fraser and others, 1969) and a possible source for the Slough Creek Tuff Member (Wedow and others, 1975). Other Tertiary intrusive bodies in the southern part of the study area probably represent satellitic intrusions or vent areas on the flanks of the larger volcanoes. A protrusive body or plug near the head of Big Pine Creek, and a sequence of lava flows on the ridges east of Colley Creek may represent andesitic vents or lava domes. Most of the layered rocks in the basal, light-colored volcaniclastic, "early acid breccia" sequence dip away from and appear to have been derived from the Independence volcanic center, whereas layering attitudes and facies changes in the younger volcaniclastic rocks and flows indicate that they contain material derived from both the Independence and Emigrant volcanic centers. These volcanic deposits include ejecta that were erupted at many times during early or middle Eocene time (Smedes and Prostka, 1972).

TERTIARY INTRUSIVE ROCKS

Intrusive rocks of Tertiary age occur throughout the southern part of the study area, south of the Elbow Creek and Mill Creek–Stillwater faults, but are localized mainly near the Emigrant and Independence intrusive centers (pl. 1). These rocks occur as stocks, laccoliths, sills, dikes, and irregular-shaped bodies. The greatest concentration of intrusive rocks is in the Emigrant–Mill Creek mineralized area (fig. 5) and vicinity, where they are extensively exposed along Mill, West Fork Mill, Emigrant, Sixmile, and North Fork Sixmile Creeks.

Nearly all of the intrusive rocks were emplaced at hypabyssal or near-surface depths and have porphyritic textures and aphanitic groundmasses; only the Independence and Emigrant stocks and a small plug near the head of Mill Creek have phaneritic texture. The rocks range from basaltic andesite to rhyodacite in composition, but dacitic rocks are volumetrically the most important. Porphyritic types with aphanitic groundmasses include dacite porphyry, andesite porphyry, and rhyodacite porphyry. Phaneritic rocks (some with prophyritic textures) include syenogabbro, monzonite, granodiorite, granodiorite porphyry, and diorite porphyry. Miscellaneous types occurring locally are dacite, felsite, basaltic andesite, and intrusive tuff breccia.

The dacites are generally light colored in shades of gray, yellow, green, or brown and are rarely medium to dark gray or brown. Most are porphyritic, and the phenocryst content ranges from less than 5 percent to as much as 45 percent, and averages about 20 percent. The groundmass is usually aphanitic but locally is fine grained. Phenocrystic minerals are plagioclase, biotite, potassium feldspar, quartz, and occasionally hornblende. Sericite, chlorite, and(or) clay minerals are present commonly as alteration products. Dacites throughout the area are similar, with the exception of dacites of the Emigrant stock, which have some notable textural and mineralogical differences. These differences are considered in the following section on the Emigrant stock.

The dacitic intrusive bodies occur as sills, dikes, laccoliths, a stock, and irregular-shaped bodies, many of which may have been emplaced along faults. Wilson (1936) described four porphyry bodies in the Mill Creek area, which he named the Chico Peak, Fourmile Divide, Elbow Divide, and End Lookout bodies and which he believed to be localized by faults. Many sills were emplaced at the contact between Precambrian and Cambrian rocks; these relations are clearly exposed at several localities along Mill Creek.

The andesites are generally porphyritic with aphanitic groundmass and are light gray or green to dark gray in color. Hornblende is more common than in dacites, and potassium feldspar and quartz are rare or lacking as phenocrysts. Andesite porphyry is generally found on the fringes or outside of the Emigrant–Mill Creek mineralized area. It is a common rock type at Mineral Mountain, on the divide between Elbow Creek and East Fork Mill Creek, in the vicinity of Chico Peak, in the Boulder district, and southwest of Monitor Peak (pl. 1).

The Emigrant stock is located in the upper drainage basin of

Emigrant Creek and its tributaries (pl. 1) and is well exposed on the steep eastern slopes of Emigrant Peak (fig. 10) as well as on many ridges in the area. Locally relations are obscured by rock glaciers and talus.

The Emigrant Peak area has been mapped and described by Basler (1965). His area of study included the western part of the Emigrant stock as well as rocks bordering the stock to the west. Basler (1965) described both andesitic and dacitic rock types. The andesitic rocks, consisting of aphanitic andesite, andesite porphyry, and heterolithologic breccias make up most of Emigrant Peak and are older than and intruded by the dacites of the Emigrant stock. The andesitic rocks are thought to represent vent breccias and magma that solidified deep in the conduit of a volcano, but an extrusive origin for at least some of them cannot be ruled out. Basler (1965) recognized an older and a younger dacite. The older type makes up the bulk of the Emigrant stock and is cut by dikes and irregular bodies of the younger dacite.

Our fieldwork indicates that the Emigrant stock consists of at least three intrusive phases. Most of the stock consists of an older dacite porphyry that in part is intrusive tuff breccia. This porphyry also occurs as dikes that intrude the older andesitic rocks bordering the Emigrant stock. Intrusive breccias similar to those of the Emigrant stock also oc-

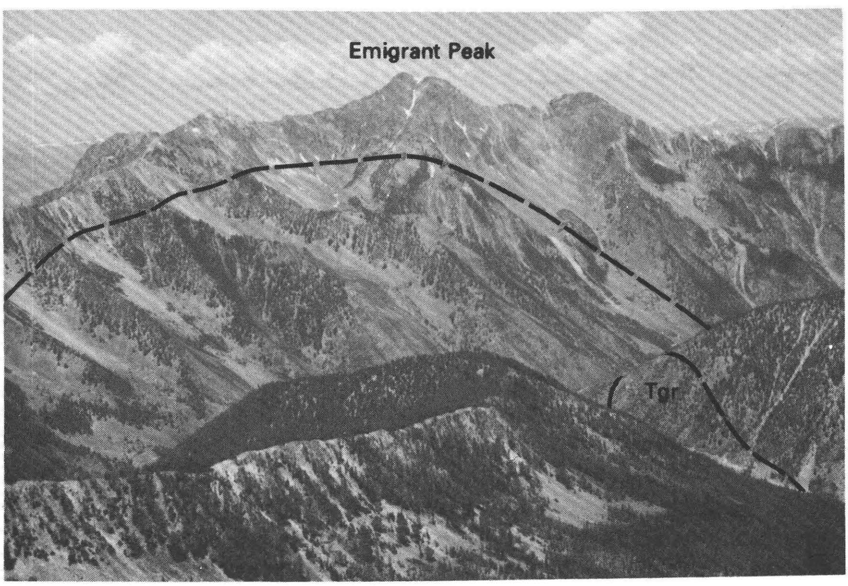


FIGURE 10.—Emigrant mining district, looking west; Emigrant Peak in middle background. Ridges in foreground and on right side are in pyritic zone of alteration. Approximate western limit of pyritic alteration on slopes of Emigrant Peak shown by solid line. Small stock of granodiorite porphyry (Tgr), the youngest phase of the Emigrant stock, is exposed on ridge and in valley on right side.

cur as dikelike bodies cutting dacite or andesite porphyry in the vicinity of Chico Peak, indicating the younger age of the Emigrant stock.

A younger dacite porphyry is present mostly as dikes and irregular bodies within the stock but is also found as dikes in the older andesitic rocks. The younger dacite porphyry typically contains more phenocrysts and more biotite as phenocrysts than the older dacite and has abundant quartz "eyes." This variety of dacite porphyry occurs elsewhere in the study area but is uncommon, and where present it is generally the youngest intrusive rock and is commonly spatially related to mineralized and (or) altered areas.

The youngest major phase of the Emigrant stock is granodiorite porphyry that occurs as a small pluton in the core of the stock and is exposed on upper Emigrant Creek (fig. 10). This rock is light gray and consists of 50–75 percent phenocrysts in a fine-grained groundmass. Plagioclase, orthoclase, quartz, and biotite occur as phenocrysts in decreasing order of abundance. The largest phenocrysts are of orthoclase in the range of ½ to 1 in. (1 to 2.5 cm). The rock is weakly altered, and chlorite and sphene replace hornblende and biotite. Veins of quartz and sulfide minerals, principally chalcopyrite, were noted in one locality.

In general, the dacites from the Emigrant stock differed from others in having a higher content of potassium feldspar and quartz in a fine-grained sugary-textured groundmass. Dacites from outside of the Emigrant stock have an aphanitic to very fine grained groundmass.

Mineralization and moderate to strong alteration in dacites was confined mostly to those of the Emigrant stock. These dacites exhibit evidence of argillic to sericitic alteration and are veined with quartz, which commonly contains sulfide minerals including pyrite, molybdenite, and chalcopyrite.

It appears that the Emigrant stock dacite is distinctly different from others occurring in the study area, from evidence of texture, mineralogy, and the effects of alteration and mineralization.

A major occurrence of phaneritic igneous rocks in the study area is in the Boulder (Independence) district (fig. 5; pl. 1). A compositionally zoned stocklike body exposed in the core of the partially eroded Independence volcano has been studied by Emmons (1908) and Rubel (1964, 1971). The following description of geologic relations and rocks is summarized from Rubel (1971).

The Independence volcano was a major eruptive center during the Eocene, and the rocks of the Independence stock are coarser grained intrusive equivalents, at least in part, of the volcanic flows and breccias in the surrounding terrain. Cross-cutting relationships indicate that the sequence of rocks in the core of the volcano, from oldest to youngest, is trachyandesite intrusive breccia, syenogabbro, monzonite, granodiorite, and granite dikes.

The oldest intrusive rocks of the Independence stock are trachyandesite breccias of Monument and Haystack Peaks (pl. 1). These appear to be gradational generally into syenogabbro but locally have been cut by stringers of the syenogabbro. The syenogabbro grades into monzonite, and the monzonite cuts the intrusive breccia. Monzonite interfingers with and is gradational with granodiorite north of Basin Creek. Granite dikes cut all the rocks of the core. The final phase of igneous activity is represented by a narrow zone of hydrothermally altered and sulfide-mineralized rock within the granodiorite near the north end of the stock.

The most abundant rock type, underlying more than half the area of the core, is monzonite. This rock type is commonly fine to medium grained, has a hypidiomorphic granular texture, and consists of plagioclase, potassium feldspar, pyroxene, biotite, and quartz. Granodiorite makes up less than one-third the total area of exposed rocks in the stock and is present in both fine- and coarse-grained varieties. The granodiorite has less pyroxene and plagioclase, and more potassium feldspar and quartz, than the monzonite. Syenogabbro makes up less than 20 percent of the exposed core rocks. It is dark colored and medium grained, and it has a hypidiomorphic granular texture. The predominant mineral is lathlike plagioclase, with interstitial pyroxene, biotite, magnetite, and potassium feldspar.

A small circular plug of diorite porphyry intrudes volcanic rocks near the headwaters of Mill Creek. The diorite porphyry is medium gray and has a faint porphyritic texture of sparse plagioclase phenocrysts in a fine- to medium-grained groundmass. Other essential minerals are augite and potassium feldspar. A radiating group of dark-colored dikes is present in the volcanic rocks surrounding the plug.

Dark-colored andesitic to basaltic dikes are common in the volcanic rocks. These medium- to dark-gray, olive or dark-greenish-gray rocks generally are porphyritic and have phenocrysts of plagioclase and pyroxene and (or) hornblende.

QUATERNARY SURFICIAL DEPOSITS

Glacial deposits, alluvial and lacustrine deposits, landslide and slump deposits, and other miscellaneous colluvial deposits of Quaternary age are shown as a single map unit on plate 1.

Evidence of glaciation in the study area includes U-shaped valleys (fig. 6), glacial striations and polish, morainal and till deposits, high-level erratics, and hanging valleys. Although during the maximum stages of glaciation all of the study area lay under ice except the highest peaks, ridges, and plateaus, glacial deposits are common only along the sides and bottoms of valleys.

Many of the larger stream valleys, in particular those of the West

Boulder and Boulder Rivers, have well-defined U-shaped profiles, indicating that they were occupied by valley glaciers. Well-developed lateral and terminal moraines occur for several miles (kilometers) along the West Boulder and Boulder Rivers northeast of the study area.

Prominent lateral moraines along South Fork Deep, Pine, and Strawberry Creeks and other streams entering Paradise Valley along the northwest boundary of the study area indicate that glaciers existed in these valleys (pl. 1). Moraines of both Bull Lake and Pinedale age are present (Horberg, 1940). Conspicuous morainal ridges occur also in the valley of Elbow Creek.

Lacustrine deposits of gravel, sand, silt, and clay in Emigrant Gulch near White City and at the junction of North Fork Sixmile and Sixmile Creeks were laid down in lakes formed when these streams were dammed temporarily by ice in the main Yellowstone valley during the Pleistocene.

No evidence of glaciation was found in some of the higher areas in the northeastern part of the study area, such as the West Boulder Plateau; this plateau is covered by felsenmeer similar to that noted by Simons and others (1973) in the Beartooth Primitive Area to the east.

Postglacial deposits of gravel, sand, and silt underlie relatively flat alluviated valley floors, and occur as alluvial fans and, less commonly, as stream terrace deposits throughout the area. These deposits are generally thin and limited in extent. The alluvial flats are best developed along major drainages such as the Boulder and West Boulder Rivers and Mill and Sixmile Creeks. Alluvial fans are most prominent below the mouths of hanging valleys; conspicuous examples are at the confluences of Weasel and Froze-to-Death Creeks with the Boulder River and of Basin Creek with West Boulder River (pl. 1).

Landslide and slump deposits occur in many parts of the study area, particularly in the volcanic terrain. Some landslides are more than 1 mi^2 (2.6 km^2) in area. Many small lakes and ponds have been formed as a result of landslides. For example, Thompson Lake, in the southwest quarter of the study area (pl. 1), is impounded behind a landslide that dammed Thompson Creek near its head. In the northern part of the study area, West Boulder River was dammed and the course of Lost Creek was altered by a large landslide that headed just east of their confluence. A group of small lakes, the Lost Lakes, formed at the head of the slide, and the lake impounded by the dam was subsequently silted to form West Boulder Meadows.

Large rock falls or slides also have dammed or diverted drainages. Beaver Meadows on the upper West Boulder River is behind a dam created by a large rock slide, and Trout Lake on the east side of the Boulder River near the Fourmile guard station was impounded by a very large rock fall or slide that also altered the course of the river (pl. 1).

Colluvial deposits including talus, soil, slope wash, and rock glaciers are common, particularly on the slopes of the higher peaks in the Precambrian terrain. Rock glaciers are particularly well developed on the east side of Emigrant Peak (fig. 10) and in the vicinity of Mount Cowen and The Needles.

STRUCTURE

The geologic structure of the study area is the cumulative result of two periods of major deformation, one of early Precambrian age and the other of Late Cretaceous–Eocene age (Laramide orogeny). Precambrian deformation extended over a time span of nearly 2 billion years, whereas the Laramide orogeny was much more shortlived.

The regional structure of the Beartooth Mountains is described by Foose, Wise, and Garbarini (1961). The northwest corner of the Beartooth structural block, which includes the study area, is bounded by faults on the southwest, west, and north sides. Part of the southwest edge of the Beartooth block is formed by the Gardiner reverse fault, along which structural relief is at least 11,800 ft (3,600 m) (Wilson, 1934). Along the west side, the block is bounded by high-angle normal faults, principally the Deep Creek and Luccock Park faults (Reid and others, 1975). As much as 15,000 ft (4,570 m) of structural relief separates uplifted basement rocks in the study area from those in the Gallatin Range westward across the Yellowstone Valley (Foose and others, 1961). The northern part of the Beartooth block has been uplifted along at least two high-angle faults, the Suce Creek and Davis Creek–Lost Creek faults, and structural relief between the Beartooth Mountains and the Crazy Mountain Basin is between 9,800 and 14,800 ft (3,000 and 4,500 m) (Foose and others, 1961).

Precambrian deformation produced a complex series of structures in the rocks of the Beartooth Mountains. These structures have been studied by Reid and others (1975) in the Pine Creek Lake subarea. Foliations in rocks of this subarea strike predominantly northeasterly, with steep dips to the west except at the north end, where foliations are approximately east-west with a northerly dip. This indicates isoclinal folding along northeast-trending axes through much of this subarea. A large nappe structure is well exposed in the area of Pine Creek Lake, in which the complex deformational history of this subarea is well displayed in the marble, quartzite, and amphibolite of the nappe core map unit.

The Mill Creek–Stillwater fault (Wilson, 1936), and its continuation to the west, as the Mill Creek fault, is a major structural zone that separates the North Snowy block from the other two structural blocks of the Beartooth uplift. Along the Mill Creek fault, Paleozoic sedimentary rocks and Tertiary dacite porphyry on the south are juxtaposed to

Precambrian and Cambrian rocks on the north, indicating an approximate vertical displacement of 3,300 ft (1,000 m) near the western border of the study area. The Mill Creek fault terminates at its intersection with Elbow Creek fault but probably was once continuous with the Mill Creek–Stillwater fault in the east half of the study area. The Mill Creek–Stillwater fault is exposed near the eastern boundary of the study area, where a minimum vertical displacement of approximately 1,600 ft (500 m) is indicated by stratigraphic offset. The apparent movement, down to the north, is opposite to that of the Mill Creek fault. This fault probably continues west along the valley of Fourmile Creek, where it is concealed by surficial deposits.

Within the North Snowy block, smaller structural blocks are delimited by other faults. These faults may be divided into three groups that strike west to west-northwest, north-northeast, and northeast respectively (Reid and others, 1975). Major faults that trend west to west-northwest include the Suce Creek, Davis Creek, Basin Creek–Lost Creek, Elbow Creek, and Mill Creek faults (pl. 1). Within the study area, all are steeply dipping and offset Precambrian units in a left-lateral sense. Major north-northeast-trending faults include the Deep Creek, Luccock Park, and West Boulder faults. All are steeply dipping and have a linear trace. Only one major northeast-trending fault, the Marten Peak, has been recognized; it dips moderately steeply to the northwest.

Many faults in the North Snowy block originated in Precambrian time and were reactivated during the Laramide orogeny (Reid and others, 1975). Faults along which major Laramide movement (mainly dip-slip) took place include the Suce Creek, Davis Creek, Lost Creek, Elbow Creek, Mill Creek, Deep Creek, and Luccock Park faults.

The Elbow Creek fault apparently had major vertical displacement during the Laramide. The total vertical displacement (including pre-Laramide movement) south of Mount Cowen is at least 3,300 ft (1,000 m); however, the movement was only about 400 ft (120 m) at Carbonate Mountain in the eastern part of the area. The Elbow Creek fault shows evidence of more recent movement than either the Mill Creek or Mill Creek–Stillwater faults but is covered by undisturbed volcanic rocks in the vicinity of Silver Pass; therefore, the movement must be prevolcanic.

The Cooke City structural zone (Foose and others, 1961) separates the South Snowy and Beartooth Plateau blocks. This zone is a prominent structural low in Precambrian basement rocks that trends southeastward across the Beartooth Mountains from the Mill Creek fault to the Clarks Fork Canyon in Wyoming. Structural downwarping of at least 2,100 ft (650 m) is indicated for this zone in the vicinity of Independence. Fractures are an important feature of this zone.

To the southeast, this zone is defined by northwest-trending faults in the Clarks Fork Canyon with vertical displacements of up to 3,300 ft (1,000 m) (Pierce, 1957). In the Cooke City area, many fractures and Precambrian mafic dikes have a northwest alinement.

Alinement of volcanic vents, dikes, and mineralized areas along the Cooke City zone suggests that the locations of volcanic and intrusive centers were controlled by the zone. Intersections of the Cooke City structural zone with the Mill Creek fault and other faults (now obscured by intrusives) were probably major factors in localizing the Emigrant stock and associated intrusives of the Emigrant and Mill Creek areas.

In the South Snowy block, structures in the Precambrian rocks are obscured by younger rocks but may have been similar to those of the North Snowy block. This inferred pattern of faults and structural blocks was disrupted by intrusive activity centered in the Emigrant–Mill Creek mineralized area, but nevertheless many mineralized fractures and mineral deposits have an overall northeasterly trend possibly reflecting a preexisting basement structural trend. Many of the presently observable structures in this area are the result of Laramide intrusive activity.

Paleozoic and Mesozoic rocks in the northern part of the study area are folded; at Lion Mountain, for example, a syncline and anticline are well exposed (pl. 1). This deformation was produced by compressive forces early in the Laramide orogeny, just prior to the major period of uplift and depression of crustal blocks (Foose and others, 1961).

MINERAL RESOURCES

SETTING

Previous work in the North Absaroka study area and vicinity, in particular Reed (1950), had indicated a variety of metallic mineral deposits occurring in various geologic settings. The majority of these deposits are clustered in four principal areas: the Emigrant–Mill Creek area, the Boulder (Independence) district, the Sheepeater (Jardine) district, and the Stillwater–Natural Bridge area (fig. 7). These areas contain the major types of mineral deposits suspected to occur in the study area. Although many of the previously reported deposits are outside the study area, they are discussed here because their characteristics have a bearing on the evaluation of mineralized and (or) altered zones within the study area.

Two of the mineralized areas, Emigrant–Mill Creek and Boulder, are grossly similar in that a similar suite of metals is found in similar types of deposits and in both areas the mineralization was related to igneous rocks of early Tertiary age. The other two areas, Sheepeater and Stillwater–Natural Bridge, are similar in that the mineral deposits in both are in rocks of Precambrian age; on the other hand, the metal suites and types and genesis of deposits in the two areas are very different.

The Emigrant–Mill Creek area (fig. 7) includes the Emigrant district (pl. 1) in the Emigrant Creek drainage area, the Sixmile subdistrict to the south along North Fork Sixmile and Sixmile Creeks, and the Mill Creek subdistrict to the north in the Mill Creek drainage area. The deposits of this area have been described by Reed (1950), and the geology and mineral deposits of parts of this area were investigated by Basler (1965, 1966) and Fox (1960).

The mineral deposits in this area are numerous and small, and the only significant production has been of gold. Metals known to be present include copper, molybdenum, gold, silver, lead, zinc, tungsten, bismuth, manganese, and iron. Stockwork, breccia-pipe, and vein-type mineral deposits are found within the Emigrant stock, whereas deposits outside of the stock are mostly of the vein and replacement types.

In the Emigrant–Mill Creek area, the Emigrant stock and several smaller satellitic dikes, sills, and laccoliths intrude Precambrian gneiss and schist, Paleozoic sedimentary rocks, and Tertiary volcanic rocks. The Emigrant stock is a large multiphase hypabyssal mass, principally dacitic in composition, whereas the satellitic intrusive bodies to the north, east, and south are of dacite or andesite porphyry.

The Emigrant stock was pervasively altered and mineralized. Pyritic alteration was widespread and locally intense, especially along upper Emigrant Creek (fig. 10). Alteration decreased in intensity outward from the stock, and in the satellitic intrusives was weak to nonexistent and mineralization occurred sparsely. Metals in and around the stock also appear to be zonally arranged: copper and molybdenum are concentrated near the center of the stock; gold is nearer the periphery; and lead, zinc, and silver are mostly near the periphery or outside of the stock. This zonation of metals is similar to that observed in the Cooke City (New World) district by Lovering (1929).

The mineral deposits of this area are the product of a hydrothermal system that may be spatially related to and somewhat younger than the Emigrant stock. The apparent zonation of metals and altered rock suggests that the system was centered in upper Emigrant Gulch, approximately coincident with the granodiorite porphyry phase of the stock.

Three types of fluid inclusions in quartz veinlets cutting the granodiorite porphyry were revealed in a preliminary examination. Type I inclusions contain two to four daughter minerals, one of which is always halite; these inclusions homogenize to a fluid in the temperature range of 285°C to 365°C. Type II inclusions contain none, one, or two daughter minerals and homogenize to a fluid near 450°C. Type III inclusions are similar to those of type II in having as many as two daughter minerals, but they homogenize to vapor near 450°C. The presence and abundance of halite in these inclusions indicates a moderate to high salinity. These data indicate that the inclusions formed at high temperatures and moderate to high salinities, and that they are in general similar to those inclusions occurring in porphyry copper deposits (Nash and Theodore, 1971; Moore and Nash, 1974).

Within the Emigrant–Mill Creek area, a general alinement of faults and mineral deposits suggests an overall northeast-trending structural control of the mineralization.

The Boulder (Independence) district is near the head of the Boulder River (fig. 7) and includes the area around Independence Peak as well as mineralized areas as far northwest as Carbonate Mountain (pl. 1).

The geology of the area is in general similar to that of the Emigrant–Mill Creek area and has been described by Rubel (1971). The eroded roots of the Independence volcano are exposed in the Independence Peak area. This volcano, which once stood high above the surrounding terrain and was the source of much of the volcanic flows and breccias during Eocene time, is represented by a compositionally zoned stock. Several nearby small plugs and sills of andesitic and dacitic composition probably are related to the Independence volcano. These rocks intrude Precambrian gneissic rocks, Paleozoic sedimentary rocks, and volcanic rocks, but sills are common only in Cambrian rocks. Volcanic rocks of Eocene age are exposed in the ridges and peaks south and west of the Independence Peak area.

The mineral deposits of the Boulder district have been described by Reed (1950) and Rubel (1964). The metals known to be present include gold, silver, lead, copper, and molybdenum, and the deposits comprise disseminated or stockwork, vein, and replacement types. Mineralization was probably related primarily, in time and space, to the eruptive center at Independence Peak; however, some mineralization seems to have been related to sills in the northwest quarter of the district.

Although no detailed work was done on the altered rocks associated with mineralized areas in the Boulder district, our field work suggests that the altered rocks are zoned and centered on the Independence area. Alteration near Independence Peak consisted of argillization, sericitization, and silicification, and the mineral deposits in this area consist of pyritic-quartz-gold ores that occur both as narrow veins and as disseminations in granodiorite and monzonite.

The mineral deposits, as well as the intrusive rocks, show a general northwest alinement that is coincident with the Cooke City structural zone. Northwest of Independence Peak, the mineralization was localized in Cambrian rocks, particularly the Meagher Limestone and Wolsey Shale.

The geologic environment, age of intrusive rocks, and suite of metals present are similar in the Boulder and Emigrant–Mill Creek areas. The main difference seems to be that the intrusive rocks of the Boulder area are more mafic and therefore perhaps less favorable in terms of mineral potential for such metals as copper and molybdenum.

The Tertiary mineralization was clearly related to eruptive centers associated with the Absaroka-Gallatin volcanic province. These centers are located along northwest-trending belts. The Eastern Absaroka belt (Chadwick, 1970) includes the Emigrant–Mill Creek area and the Boulder (Independence) district and extends as far southeast as the Sunlight mining region in Wyoming. The part of this belt between Cooke City and the Mill Creek area coincides with the Cooke City structural zone. The actual location of the eruptive centers may be controlled by the intersection of this northwesterly trending zone with other fracture zones of a northeasterly or westerly trend. For example, the Emigrant–Mill Creek area is located approximately at the intersection of the Cooke City structural zone and the Mill Creek–Stillwater fault zone.

Within each eruptive center, mineralization was more closely related to the younger and more silicic members of the intrusive sequence.

The Sheepeater (Jardine) district and the nearby Crevice Mountain district are near the southwest corner of the study area. Geologically these districts are similar, but the principal mineral production has been from the Jardine district. The mineral deposits of this area have been described by Seager (1944) and Reed (1950), and the genesis of the ores is discussed by Brown (1960).

The gold-arsenic-tungsten deposits of this district occur as replacement veins in schist and quartzite of Precambrian age. Arsenic occurs as arsenopyrite and tungsten as scheelite. The irregularly shaped ore bodies are the result of selective replacement of much deformed and sheared biotite-quartz schist and biotite quartzite and of quartz-cummingtonite schist or altered equivalents. The latter mode of occurrence is similar to that of the Homestake gold mine at Lead, S. Dak., as noted by Seager (1944). In the Jardine area, the Precambrian rocks have been folded into an asymmetrical faulted syncline that plunges gently south-southwest (Seager, 1944, p. 38–40). The ores are believed to be of magmatic hydrothermal origin and genetically related to a large pluton of Precambrian granite exposed on the south slopes of Crevice Mountain and beyond (Seager, 1944, p. 73; Brown, 1960).

Although these deposits have been worked principally for gold, they have also produced byproduct arsenic and tungsten and during World War II were mined principally for arsenic.

Hydrothermal alteration was mainly confined to the borders of economically important veins. Most alteration was of a high-temperature type that resulted in recrystallization of preexisting minerals. Chlorite appears to be closely associated with sulfide minerals and gold, but garnet and biotite are also characteristic of altered zones (Seager, 1944, p. 70).

The principal geologic controls of mineralization at Jardine appear to have been a major Precambrian granitic pluton, a lithology favorable for replacement, and a favorable structural environment.

The Stillwater–Natural Bridge area, as herein used (fig. 7), includes all the mineral deposits in and near the base of the Stillwater Complex. Most of the complex is east of and outside the North Absaroka study area, but it extends for a short distance into the northeast corner of the study area.

The major mineral resources of this area are restricted to and genetically related to the Stillwater Complex, a mafic and ultramafic stratiform igneous body that has an outcrop area about 28 mi (45 km) long and as much as 5 mi (8 km) wide along the northeast edge of the Beartooth Mountains. Only the northwest end of the exposed portion of the complex, about 3 mi^2 (8 km^2) in area, crops out in the study area, but the complex may be present in the subsurface farther northwest.

Mineral resources of the Stillwater Complex include chromium, nickel, copper, and PGM (platinum-group metals). The deposits are stratiform and have a great lateral continuity. Past production has been limited to chromium, principally at the Mouat and Benbow mines near Nye, Montana. The chromite deposits have been described by Howland (1955), Howland, Garrels, and Jones (1949), and Wimmler (1948). Exploration during the last 10 years has focused on the copper, nickel, and PGM deposits in the complex. The nickel-copper deposits are concentrated at the base of the complex as sulfide-rich zones in ultramafic rocks. These deposits are discussed by Roby (1949) and Dayton (1971). Platinum-group metals in association with mafic and ultramafic rocks near the base of the complex have been investigated by Page, Riley, and Haffty (1969).

Perhaps of greatest significance is the recent discovery by Johns-Manville Corporation (Engineering and Mining Journal, 1975) of major resources of PGM in a zone associated with mafic rocks a few thousand feet (meters) above the base of the complex on the West Fork of the Stillwater River. The significance of the discovery stems both from the rarity of PGM occurrences in the United States and the apparent richness of the deposit. This deposit has great continuity, as indicated by exposures over a vertical range of over 980 ft (300 m) and along strike for at least 4 mi (6.5 km) northwest of the original find (Engineering and Mining Journal, 1975). Later work has shown that the mineralized horizon, with important values, can be traced intermittently for a length of 24 mi (39 km) (Engineering and Mining Journal, 1976).

This discovery indicates that the Stillwater Complex may contain the largest resources of PGM in the United States. In addition, the Stillwater Complex contains about 80 percent of the chromium resources of the United States (Thayer, 1973) as well as major nickel and copper resources.

Both the basal sulfide and the PGM zones have great continuity along strike, and both extend into the study area along the west side of the Boulder River. The presence of the copper-nickel zone has been verified by exploration drilling, and the PGM zone has been located and sampled in surface exposures.

The Stillwater–Natural Bridge area also includes small quartz-gold veins in Precambrian hornfels near the base of the Stillwater Complex. Production from these deposits has been small, and their relationship, if any, to the Stillwater Complex is not clear.

METHODS OF EVALUATION

Samples of rocks and stream sediments from the study area were analyzed to determine the geochemical characteristics of known ore deposits and districts, the abundance or background level of certain elements in various rock types, and the possible presence of previously undiscovered mineral deposits or anomalous concentrations of metals of interest. The results of this geochemical study are used in combination with geologic mapping and geophysical investigations to evaluate the mineral resource potential of this area.

A total of 2,101 samples were collected, comprising 1,092 stream sediments, 944 rocks, 38 panned concentrates, and 27 soils. The analytical results were combined with those of Wedow and others (1975) and Simons and others (1973) to produce a data bank of 2,234 samples, of which 1,262 are stream sediment, panned concentrate, and soil, and 972 are rock.

A basic understanding of the geochemical as well as geologic characteristics of known mineral occurrences in or adjacent to the study area was essential to the search for new occurrences. Therefore, the geochemical program included the sampling of known deposits to determine the particular elements that occur in anomalous quantities in various types of deposits. This understanding of the geochemical signatures of known deposits can then be used to interpret metal anomalies in other parts of the area where no known deposits exist.

The sample localities are shown on plate 3. The total number of localities within the boundaries of the study area is about 1,560, and the approximate average spacing of sample sites is 2 to 3 per mi^2 (1 to 2 per km^2). More than one sample was collected at many localities, and therefore the average number of samples is at least 2 to 3 per mi^2 (1 to 2 per km^2).

For ease in locating sample sites on plate 3, we divided the study area into 19 parts corresponding to drainage basins. Each drainage basin is designated by a letter, which becomes part of appropriate sample numbers. For example, T6000A and T6000B would be the first and second samples collected at locality 6000 in the T drainage area. Samples collected during field investigations of the Absaroka Primitive Area

(Wedow and others, 1975) are indicated on plate 3 by R- and Q- prefixes followed by a three-digit number; those collected during the study of the Beartooth Primitive Area (Simons and others, 1973) are indicated by an S- prefix and a three- or four-digit number. An X-Y coordinate system (in meters; pl. 3) was used for recording and plotting sample locations. Grid lines E70000 and N30000 coincide with long 100°30′ W. and lat 45°15′ N., respectively.

The terms background, threshold, and anomalous are common in discussions of geochemical data. In this report, background is the normal range of analytically determined values for a particular element in a given kind of sample in a given area; background content ranges from the analytical detection limit to a maximum that is called the threshold value, and samples that contain more than threshold amounts of a particular element are termed anomalous.

Stream-sediment sampling was used as a tool both in reconnaissance to detect new deposits or mineralized districts and in detail to appraise known mineralized areas. Samples were collected from all streams, including major trunk streams and small tributaries. The approximate spacing of samples along streams is 0.5 to 1.0 mi (0.8 to 1.6 km). At each sample site an effort was made to collect a paper envelope full of silt- and clay-sized material from the active bed of the stream. The size of the sample varied from about 7 to 10 oz (200 to 300 g) dry weight. In many streams with high gradients, sufficient fine material was not available in the active channel for a sample; and in these cases the sediment sample was supplemented by or consisted wholly of overbank sediment or stream-bank soil.

Samples were collected in traverses of stream valleys, and in general, rock samples were collected during the same traverses, where outcrops occurred along the streams. Panned concentrates were also taken at widely spaced intervals from most drainage basins. Duplicate samples were taken at many sample sites at the same or a different spot in the stream bed to check on reproducibility of the sampling and analytical methods. The analytical results from duplicate samples collected at the respective sites were usually similar.

Rock samples were collected throughout the study area to search for new areas of metal concentration, to appraise known mineralized areas, and to determine the background level of various metals in different rock types. The spacing and number of samples varied; we took more samples closer together where mineralization was known or suspected to have occurred.

Most of the rock samples were collected from good exposures on ridges, and special effort was made to sample material that was visibly altered or mineralized or seemed likely to contain anomalous concentrations of metals. For example, quartz veins, fractures, and altered zones were sampled in preference to the host rocks in which they occurred. Therefore, the analytical results are generally not representative of a particular volume of rock but reflect the highest value detected at each sample site. Samples weighed from about 9 to 18 oz (250 to 500 g).

Panned concentrates were collected along major streams and all but three of the drainage areas. Most sample sites were along the middle or lower parts of trunk streams, thereby sampling major parts of the drainage basins. Except in the case of gold, analysis of panned concentrates added little if any information to what was available from the analysis of ordinary stream sediments.

Most of the samples were analyzed concurrently with the geochemical sampling program in mobile field laboratories located near the study areas. Rock samples were prepared by crushing and grinding. Stream-sediment and soil samples were dried and sieved, and the −80 mesh fraction was used for analysis. Aliquots were weighed for spectrographic analysis and the determination of gold and mercury by atomic absorption techniques. Tables 2 and 3 show lower limits of detectability for selected elements determined by the semiquantitative spectrographic method. The lower limit of detectability for gold is 0.1 ppm for a 0.2-oz (5-g) sample and 0.05 ppm for a 0.4-oz (10-g) sample; for mercury the lower limit is 0.02 ppm.

Uranium, thorium, and platinum-group metals were determined in U.S. Geological Survey laboratories, Denver, Colo.

Computerized statistical summaries were prepared for each element of interest and for various types of samples and rock types. Histograms were compiled (for example, figs. 11–20) and comparisons were made between rock and stream-sediment samples, altered and unaltered rocks, and various rock types of different geologic ages.

The principal aim of the computerized summaries and histograms was to determine the background value of various metals in rock and stream-sediment samples and thereby estimate the threshold and anomalous values for each metal. These threshold values are shown in table 4, together with medians for elements which occur in anomalous concentrations in the study area. After threshold values were estimated, computer-generated maps were plotted for copper, gold, lead, molybdenum, and silver to show the geographic distribution of anomalous values of these metals (figs. 14–18); distribution maps for uranium (fig. 19) and zinc (fig. 20) were prepared without computer aid. Anomalies for other metals are discussed in a later section.

Analytical data for selected elements in stream-sediment and rock samples that contain anomalous amounts of at least one element are shown in tables 3 and 4. All of the analytical data obtained by the U.S. Geological Survey have been placed on magnetic computer tape (Elliott and others, 1976) and are available through National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22151, at the expense of the user. The samples are identified by the field numbers shown on plate 3.

TABLE 2.—*Analyses for selected elements in 144 stream-sediment, panned-concentrate, and soil samples from the North Absaroka study area*

[Coordinates refer to grid shown on plate 3; numbers in parentheses after element symbols are the lower limits of analytical determinations; N, looked for but not detected; L, detected but below the limit of determination; B, not determined; H, interference. Other elements of interest looked for but not detected and their lower limits of determinations: As (200), Sn (10), and W (50). Mercury determined by mercury detector method (Vaughn and McCarthy, 1964)]

Sample	Coordinates (meters)		Semiquantitative spectrographic analyses (ppm)										Atomic Absorption (ppm)	
	N.	E.	Ag (0.5)	Be (1)	Bi (10)	Co (5)	Cr (10)	Cu (5)	Mo (5)	Ni (5)	Pb (10)	Zn (200)	Au (0.05)	Hg (0.02)
								Stream sediments						
A0089A	66200	69400	N	1.0	N	10	100	700	N	50	15	N	N	0.04
A0124A	63600	71600	N	L	N	50	150	150	N	70	15	L	0.20	.04
A0125A	63400	71000	N	L	N	50	150	150	N	150	20	N	N	.02
A0129A	59600	74400	N	N	N	50	150	150	N	100	70	N	N	.02
A0130A	59900	74500	N	N	N	20	150	100	N	70	100	N	N	.02
A0187A	57600	73200	N	L	N	50	150	100	N	100	20	200	N	.02
A2169A	58500	72600	N	L	N	20	150	150	N	100	15	N	N	.02
A2170A	58700	72500	N	L	N	50	150	150	N	100	20	N	N	H
A2171A	59000	71800	N	N	N	50	150	150	N	100	20	N	N	L
A2172A	59100	71700	N	N	N	70	150	150	N	70	20	N	N	.04
A2248A	49000	70000	N	L	N	20	150	150	N	70	20	L	N	H
B2225A	49800	71600	N	1.0	N	50	200	100	N	100	100	N	N	.04
B2230A	52000	71000	N	L	N	30	200	150	N	150	70	L	N	H
B2232A	52800	70600	N	L	N	30	200	150	N	100	30	N	N	.02
B2235A	54200	70600	N	L	N	50	150	150	N	100	30	L	N	H
B2237A	54500	70500	N	L	N	50	150	150	N	100	30	L	N	.04
E2059A	59200	81000	N	N	N	20	200	50	N	150	20	N	N	.06
E2062A	58900	79500	N	L	N	5	100	20	N	20	20	N	N	.16
E2065B	58900	79500	N	1.0	N	5	100	20	N	30	20	N	N	.06
E2210A	58300	75000	N	L	N	70	200	150	N	100	20	L	N	L

E2211A	54200	74500	N	2.0	N	50	150	100	N	70	100	L	N	.06
E2212A	54300	74300	N	2.0	N	50	150	100	N	100	100	L	N	H
F0012A	44700	75900	N	L	N	15	200	150	N	70	20	N	N	L
F2034A	52100	78700	N	1.0	N	15	200	70	10	70	70	N	N	H
F2036A	51100	78000	N	1.0	N	10	70	70	7	50	70	N	N	H
F2049A	51600	76700	N	1.0	N	20	150	10	N	70	20	N	N	.08
F2050A	51300	75800	N	L	N	20	150	50	N	100	20	N	N	H
F2051A	51200	75600	N	L	N	15	150	10	N	50	15	N	N	H
F2051A	51100	75100	N	L	N	15	150	20	N	100	20	N	N	H
F2054A	50800	74800	N	1.0	N	15	150	50	N	70	50	N	N	H
F2055A	50800	74600	N	1.0	N	20	150	70	N	100	50	N	N	H
F2056A	51100	75300	N	1.0	N	20	150	50	N	50	20	N	N	H
F2074A	48800	81700	N	1.0	N	7	70	10	7	20	70	N	N	H
F2079A	50700	74500	N	1.0	N	20	150	30	N	70	50	N	N	.04
F3274A	48300	82300	N	1.5	N	10	30	15	7	10	15	N	N	.06
F3274B	48300	82300	N	1.0	N	10	30	10	10	10	20	N	N	L
F6088A	49900	83600	N	3.0	N	30	150	30	15	70	30	N	N	.04
G0612A	58900	90400	N	N	N	50	1500	150	N	100	30	N	B	B
G3046A	57400	91200	N	N	N	30	500	50	N	100	15	N	3.0	.02
H0528A	47800	85300	N	2.0	N	10	50	15	10	15	20	N	N	.02
H0528B	47800	85300	N	2.0	N	10	30	15	7	15	20	N	N	.02
H0529A	48300	86000	N	1.5	N	15	100	20	7	50	20	N	N	.08
H0531A	48300	86800	N	1.0	N	15	100	20	7	70	15	N	N	.02
H0534A	48300	87600	N	1.0	N	15	100	15	7	50	10	N	N	.06
H0603A	45200	87200	N	1.0	N	30	200	20	5	50	20	N	B	B
H0604A	45400	93100	N	1.0	N	30	150	20	5	50	30	N	B	B
H1006A	52000	93900	N	N	N	50	700	150	N	200	10	N	L	H
H1007A	50700	94100	N	N	N	50	500	20	N	100	20	N	.15	.02
H1017J	42900	92300	.5	2.0	N	20	200	30	7	50	30	N	B	B
H1017K	42900	92300	N	1.5	N	20	300	30	5	50	30	N	B	B

TABLE 2.—*Analyses for selected elements in 144 stream-sediment, panned-concentrate, and soil samples from the North Absaroka study area*—Continued

Sample	Coordinates (meters) N.	E.	Semiquantitative spectrographic analyses (ppm) Ag (0.5)	Be (1)	Bi (10)	Co (5)	Cr (10)	Cu (5)	Mo (5)	Ni (5)	Pb (10)	Zn (200)	Atomic Absorption (ppm) Au (0.05)	Hg (0.02)
Stream sediments--continued														
H3234J	44800	85400	N	1.0	N	20	100	20	30	30	30	N	B	B
H3234K	44800	85400	1.0	1.0	N	20	70	15	30	20	50	N	B	B
H3236J	45900	88900	N	1.0	N	20	300	20	20	70	30	N	B	B
H3238J	45900	90600	N	L	N	20	300	10	7	30	20	N	B	B
H3280B	43300	89900	N	L	N	N	N	15	N	N	15	N	N	.20
J0322A	37200	88000	N	1.0	N	10	50	15	N	15	15	N	N	.20
J0607B	40500	92500	.7	1.0	N	30	150	30	N	30	30	N	B	B
J1019J	40800	92300	L	1.0	N	20	500	50	7	50	20	N	B	B
J2363A	36600	82500	N	N	N	10	100	30	N	30	15	N	.55	.10
K0606A	34100	90800	N	L	N	30	70	30	7	30	20	N	B	B
K1024B	36200	90300	N	N	N	20	200	15	N	100	15	N	N	.04
K1028A	34000	90200	N	L	N	5	100	15	15	50	20	N	N	.04
K3190A	31100	86900	N	L	N	15	100	30	10	30	15	N	.30	.04
L1029A	32500	89600	N	N	N	20	500	50	N	100	15	N	.15	L
L1030B	32000	90100	N	L	N	5	150	10	N	50	15	N	.15	.02
M2158A	35300	60300	N	L	N	N	N	10	N	N	10	N	N	0.22
M2535B	34900	58700	N	1.0	N	5	N	15	N	15	30	N	N	.14
N0384A	37300	75100	N	L	N	10	100	15	N	50	100	N	N	.08
P2557A	32600	64500	N	1.5	N	15	30	20	N	15	100	N	L	.04
P2560A	35100	64000	N	L	N	15	30	15	N	20	15	N	.40	.04

P3011A	34200	66300	.5	L	N	10	100	10	N	50	15	N	N	H
P3030A	31700	63700	L	1.0	N	15	100	20	N	20	150	300	N	H
P4012A	30600	60600	N	1.0	N	N	10	N	N	L	20	300	.85	.75
P4012B	30600	60600	N	5.0	N	15	15	N	N	15	150	1500	N	.06
P4013A	31600	60900	N	5.0	N	10	15	N	N	10	70	1500	.10	.26
P4014A	31900	62700	N	L	N	10	N	15	N	10	70	500	N	.14
P4014B	31900	62700	N	2.0	N	15	15	N	N	15	70	700	N	.06
P6031A	33500	60400	N	L	N	N	N	10	N	N	15	N	N	.26
Q3259A	32200	67500	N	1.5	N	15	15	15	N	20	15	N	.20	.02
Q3259B	32200	67500	N	3.0	N	20	20	20	N	20	50	200	L	.04
R072	26600	91600	10.0	L	N	50	500	300	7	70	500	L	.35	B
R073	26300	89500	N	N	N	50	1000	10	N	150	10	N	.25	B
R074	25400	93400	2.0	L	N	30	700	70	N	100	200	300	.15	B
R076	25100	94200	3.0	L	N	20	200	30	5	100	100	L	L	B
R085	31900	78700	N	N	N	30	700	15	N	150	15	N	.10	B
R101	27900	65400	N	1.0	N	10	200	20	N	30	20	200	L	B
R711	26400	92100	L	1.0	N	30	500	300	15	100	700	L	.65	B
R714	26700	91700	20.0	L	N	5	200	100	15	15	2000	L	3.00	B
R719	26700	91600	.5	L	N	20	300	70	5	70	200	L	.45	B
R720	26600	91300	.5	L	N	20	300	300	7	70	200	L	.85	B
R721	26700	90400	.5	L	N	20	700	70	5	70	150	L	.95	B
R722	26700	90400	1.0	L	N	30	700	70	L	100	200	L	.10	B
R726	26500	89600	1.0	N	N	30	1000	70	N	100	100	N	3.00	B
R727	26000	93700	N	L	N	30	500	50	N	100	70	N	.06	B
R728	24900	94200	1.0	L	N	20	300	70	N	100	70	N	L	B
R779	25100	64400	N	L	N	50	500	50	N	100	15	200	L	B
R2427A	35700	74800	N	N	N	15	200	10	N	50	10	N	.15	.04
R2434A	33900	73600	N	N	N	10	150	15	N	30	15	N	L	L
R2436A	32300	73200	N	L	N	15	100	10	N	30	10	N	.15	L
R5002A	31200	72900	N	L	N	N	30	20	N	20	15	N	L	.06

TABLE 2.—*Analyses for selected elements in 144 stream-sediment, panned-concentrate, and soil samples from the North Absaroka study area*—Continued

Sample	Coordinates (meters)		Semiquantitative spectrographic analyses (ppm)										Atomic Absorption(ppm)	
	N.	E.	Ag (0.5)	Be (1)	Bi (10)	Co (5)	Cr (10)	Cu (5)	Mo (5)	Ni (5)	Pb (10)	Zn (200)	Au (0.05)	Hg (0.02)
Stream sediments--continued														
R5093B	31500	71500	N	3.0	N	30	150	15	N	70	20	300	N	.08
S0203B	37200	54300	N	1.0	N	15	70	200	L	20	150	300	.10	.04
S0204A	36500	55000	.5	1.0	N	15	70	200	L	30	150	200	L	.04
S0206A	35900	55200	N	1.0	N	10	70	20	L	30	150	N	N	H
S0207A	35500	55500	1.0	2.0	N	20	70	500	5	50	200	200	1.0	.04
S0208B	34400	55800	.5	1.0	N	15	50	500	7	30	150	1000	L	.02
S0209A	33200	55800	.5	2.0	10	15	50	700	5	30	150	1000	.95	.04
S0210B	32200	55900	.5	2.0	N	20	70	700	10	30	300	1000	.20	.02
S0212A	32100	55800	2.0	20.0	N	50	N	3000	N	5	20	N	N	.02
S0213A	31300	56500	N	1.0	L	5	50	300	5	20	100	300	.05	.06
S0214B	30400	56800	2.0	2.0	L	30	15	1000	50	10	300	500	.15	.18
S0214C	30400	56800	1.0	5.0	N	150	15	5000	300	70	200	2000	L	.04
S0216A	30600	57600	1.0	2.0	N	10	L	700	5	5	150	500	.30	.42
S0235A	27700	59600	N	1.0	N	15	50	5	N	20	100	L	N	.06
S0236A	27600	58600	N	1.0	N	15	70	10	N	20	100	N	N	.06
S0238A	29100	57400	N	1.0	N	10	70	10	N	20	50	200	N	.04
S0239A	29500	57400	7.0	1.0	30	5	30	50	7	L	300	N	1.50	.35
S0302B	34750	51950	N	1.5	N	10	70	15	N	15	15	N	N	.20
S0456B	31000	58000	1.5	1.0	N	20	300	N	20	10	200	300	.60	.30
S0456C	31000	58000	2.0	1.0	L	20	300	N	N	5	100	300	.15	.08

S0463A	31000	58000	1.5	1.0	N	5	30	N	N	7	150	N	L	.06
S0463B	31000	58000	2.0	1.0	N	5	50	N	N	7	200	N	.15	.06
S0464A	30200	58900	.7	3.0	N	5	20	N	N	10	100	500	.15	.14
S2307A	25500	54700	N	1.0	N	15	100	20	5	50	30	N	N	N
S2310A	25500	53500	N	1.0	N	15	100	10	N	70	20	N	.20	.04
S2310B	25500	53500	N	1.0	N	15	100	15	N	60	30	N	.50	.02
S2324A	26700	57400	L	1.0	N	15	70	70	N	50	100	200	L	.10
S4022A	33500	52800	N	L	N	N	N	10	N	N	20	N	N	.35
S4023A	34100	57500	.5	1.5	N	5	N	15	N	15	70	L	B	.06
T2485A	23000	51800	N	2.0	N	N	N	15	N	5	10	N	N	.08
T6000A	19500	53700	N	L	N	10	70	20	N	70	10	N	N	.16
Panned concentrates														
G3056B	57400	91200	N	1.0	N	15	300	20	N	70	15	N	0.5	.02
J0314B	38700	88800	N	N	N	15	200	10	N	30	L	N	.25	L
L2620B	26400	89400	N	L	N	50	1000	30	N	200	15	N	48.0	18.0
L2622B	27500	88800	N	L	N	50	1000	20	N	150	15	N	5.0	.26
L2624B	29300	88600	N	L	N	20	300	15	N	70	10	N	.3	.08
S0203A	37200	54300	.5	1.0	N	15	70	300	5	50	150	200	7.0	L
S0210A	32200	55900	.7	2.0	N	15	70	500	7	20	200	1000	6.0	L
S0214A	30400	56800	.6	2.0	L	10	15	700	30	5	300	500	10.0	.10
S2261A	31600	50700	N	1.0	N	30	150	50	N	70	50	N	L	.02
S2280B	28200	56200	N	1.0	N	50	500	30	N	100	20	L	.62	L
T2442A	14500	47700	N	1.0	N	10	150	15	N	30	15	N	.30	L
U2438A	10100	59500	N	N	N	50	200	15	N	30	15	N	110.0	1.5
Soils														
R3177A	31400	72400	N	1.0	N	N	70	20	N	15	15	N	N	0.08

TABLE 3.—*Analyses for selected elements in 192 rock samples from the North Absaroka study area*

[Coordinates refer to grid shown on plate 3; numbers in parentheses after element symbols are the lower limits of analytical determinations; N, looked for but not detected; L, detected but below limit of determination; G, greater than the value shown; B, not determined; H, interference; M, altered or mineralized sample. Mercury determined by mercury detector method (Vaughn and McCarthy, 1964)]

Sample	Coordinates (meters)		Semiquantitative spectrographic analyses (ppm)													Atomic absorption (ppm)		Sample material
	N.	E.	Ag (0.5)	As (200)	Be (1)	Bi (10)	Co (5)	Cr (10)	Cu (5)	Mo (5)	Ni (5)	Pb (10)	Sn (10)	W (50)	Zn (200)	Au (0.05)	Hg (0.02)	
A0084A	68500	71800	N	N	N	N	100	200	150	N	150	N	N	N	L	N	L	Amphibolite.
A0110A	62700	75400	.5	N	L	N	50	150	300	N	70	10	N	N	N	N	.02	Pegmatite.
A0117A	62800	73400	N	N	N	N	70	70	200	N	50	10	N	N	L	N	.02	Mafic dike.
A0122B	63400	72500	N	N	N	N	70	15	150	N	30	10	N	N	L	N	L	Do.
A0132B	60200	73600	N	N	N	N	50	200	150	N	70	15	N	N	200	N	.04	Schist.
A0133B	59700	73400	1.0	N	L	N	100	70	700	N	150	N	N	N	N	N	.04	M, gossan.
A0133C	59700	73400	N	N	N	N	N	150	200	N	7	100	N	N	L	N	.02	Schist.
A0136B	61000	73800	N	N	L	N	30	100	150	N	30	20	N	N	N	N	L	Amphibolite.
A0137B	61200	71900	N	N	N	N	70	150	150	N	70	L	N	N	N	N	.02	Do.
A0140A	61400	71000	N	N	N	N	70	100	150	N	70	N	N	N	L	N	.04	Mafic dike.
A0141A	61700	70400	N	N	N	N	150	1000	150	N	1000	N	N	N	N	N	L	Amphibolite.
A0182B	57700	72400	N	N	2.0	N	N	10	15	N	10	100	N	N	N	N	L	Gneiss.
A2114A	64900	74000	N	N	10.0	N	N	10	10	7	10	L	N	N	L	N	L	M, limestone.
A2115A	64900	73800	N	N	3.0	N	7	N	10	15	70	N	N	N	L	N	.14	Do.
A2133A	66300	70800	1.0	N	N	N	N	N	20	L	15	30	N	N	N	N	L	Sandstone.
A2141A	69300	71500	N	N	N	N	N	N	5	20	10	L	N	N	N	N	.02	M, limestone.
A2141B	69300	71500	N	N	N	N	N	L	7	20	50	N	N	N	N	N	.06	Do.
A2142A	69500	71100	N	N	L	N	30	L	5	50	50	N	N	N	N	N	.02	Do.
A2158A	61000	72200	N	N	N	N	70	50	150	N	30	10	N	N	N	N	.02	Amphibolite.
A2159A	60500	72400	N	N	N	N	70	150	700	N	50	15	N	N	N	N	.04	M, amphibolite.
A2160A	60700	72500	N	N	N	N	20	150	150	N	70	10	N	N	N	N	.02	Do.
A2166B	5880	73100	.5	N	N	N	70	70	150	N	30	15	N	N	200	N	.04	Amphibolite.
A2239A	47500	71800	N	N	N	N	70	150	150	N	100	L	N	N	L	N	.02	Do.
A2242A	47900	71800	N	N	1.0	N	50	30	150	N	10	L	N	N	N	N	.02	Amphibolite.
A2244A	47900	70800	N	N	N	N	50	150	150	N	70	15	N	N	L	N	L	Quartzite.

B0166A	56400	72100	N	N	N	N	70	N	700	N	20	N	N	N	N	N	.02	M, amphibolite.
B0168B	55400	72400	N	N	1.0	N	20	15	150	N	10	10	N	N	N	N	L	Amphibolite.
B0173B	55700	73000	N	N	N	N	70	150	150	N	100	N	N	N	L	N	L	Do.
B0175A	54500	73000	N	N	2.0	N	10	100	150	N	50	10	N	N	L	N	L	M, schist.
B0175C	54500	73000	N	N	L	N	100	300	150	N	100	20	N	N	300	N	L	Amphibolite.
B0178A	56200	72800	N	N	1.0	N	15	500	200	N	10	L	N	N	L	N	.02	Do.
B0409A	54300	69200	N	N	N	N	300	N	700	N	500	N	N	N	N	N	.02	M, quartz vein.
B0498A	53300	69700	N	N	N	N	15	N	150	N	15	N	N	N	N	N	L	Do.
B0500A	52100	61600	N	N	N	N	50	N	200	N	30	N	N	N	N	N	L	Do.
C0573A	45000	70400	N	N	N	N	30	N	200	N	50	N	N	N	N	N	L	M, mafic dike.
C0573B	45000	70400	1.5	N	N	N	5	N	7000	N	15	N	N	N	N	N	.02	M, quartz vein.
C0576A	44600	69500	N	N	L	N	15	N	150	N	10	N	N	N	N	N	L	Do.
C2546A	43400	72700	N	N	L	N	5	N	10	20	10	L	N	N	N	N	L	M, gneiss.
C2581C	44900	71700	N	N	N	N	N	N	15	500	N	70	N	N	N	L	L	M, pegmatite.
C4092B	44700	66100	N	N	2.0	N	50	150	150	N	100	10	N	N	500	N	.18	Gneiss.
C6035A	43600	71200	N	N	N	N	N	N	N	N	5	100	N	N	N	N	L	Gneiss.
D0064B	64000	78800	N	N	N	N	70	500	150	N	100	300	N	N	N	N	.02	Amphibolite.
D0064C	64000	78800	N	N	N	N	70	150	150	N	70	300	N	N	N	N	L	Mafic dike.
D0065E	64100	78900	.5	N	2.0	N	20	150	50	N	70	100	N	N	N	N	.02	Shale.
D0074B	63900	77600	N	N	N	N	20	200	150	N	100	150	N	N	N	N	L	Gneiss.
D0074D	63900	77600	N	N	N	N	50	200	200	N	100	N	N	N	L	N	L	Iron formation.
D0076A	63900	78500	N	N	N	N	70	200	150	N	100	N	N	N	L	N	.02	Mafic dike.
D0078B	64400	75700	N	N	1.0	N	N	10	7	30	10	N	N	N	N	N	L	M, jasperoid.
D0090A	64800	76700	1.0	N	N	N	15	70	1000	N	50	10	N	N	N	N	L	M, gneiss.
D0092A	65200	76100	N	N	N	N	70	200	150	N	100	L	N	N	N	N	L	Gneiss.
D0098B	65500	75300	N	N	N	N	70	150	150	N	70	10	N	N	N	N	.02	Amphibolite.
D0099A	66000	74800	N	N	N	N	70	500	150	N	150	L	N	N	N	N	.02	Do.
D0100A	66500	74900	N	N	N	N	70	200	150	N	70	L	N	N	N	N	.02	Do.
D0103B	67400	74800	1.0	N	N	N	15	70	1500	N	70	15	N	N	N	L	L	M, pegmatite.
D2085A	63300	76600	N	N	N	N	N	N	20	N	L	15	N	N	500	N	.02	Limestone.
D2109A	64400	77400	N	N	N	N	70	150	150	N	70	10	N	N	200	N	.02	Amphibolite.
D2113A	66400	77000	N	N	N	N	70	150	150	N	70	10	N	N	N	N	.02	Do.
E0150A	61500	75300	N	N	N	N	50	70	300	N	50	N	N	N	N	N	L	Mafic dike.
E0151A	61400	75300	N	N	N	N	10	200	700	N	20	N	N	N	N	N	.02	Amphibolite.
E1057B	61700	77200	N	N	L	N	10	70	150	N	10	N	N	N	L	N	.02	Do.

TABLE 3.—*Analyses for selected elements in 192 rock samples from the North Absaroka study area*—Continued

Sample	Coordinates (meters) N.	E.	Semiquantitative spectrographic analyses (ppm) Ag (0.5)	As (200)	Be (1)	Bi (10)	Co (5)	Cr (10)	Cu (5)	Mo (5)	Ni (5)	Pb (10)	Sn (10)	W (50)	Zn (200)	Atomic absorption(ppm) Au (0.05)	Hg (0.02)	Sample material
E0159A	62600	71800	N	N	N	N	70	150	150	N	100	L	N	N	N	N	L	Mafic dike.
E0159C	62600	71800	N	N	L	N	15	N	100	N	20	100	N	N	N	N	L	Pegmatite.
E1079A	60600	75700	N	N	1.0	N	70	500	1000	N	200	L	N	N	N	N	L	M, amphibolite.
E1079B	60600	75700	N	N	1.0	N	100	700	500	N	300	L	N	N	N	N	.02	Do.
E0192A	58000	74400	N	N	N	N	30	15	500	N	50	L	N	N	N	N	L	Amphibolit.
E0202A	58800	81100	N	N	N	N	100	70	700	N	70	N	N	N	N	N	L	Mafic dike.
E0516A	53700	74500	N	N	N	N	15	N	150	N	30	N	N	N	N	N	L	M, quartz vein.
E2065A	58900	79500	N	N	1.0	N	10	150	150	N	20	150	N	N	N	N	L	M, gneiss.
E2182A	63500	79100	N	N	N	N	20	150	200	N	10	10	N	N	N	N	.02	Mafic dike.
E2251A	57300	77600	N	N	1.0	N	50	150	70	N	70	15	N	N	200	N	L	Amphibolite.
E4025B	52800	84500	7.0	N	L	N	15	N	50	N	15	20000	N	N	N	N	L	M, schist.
F0013C	44800	75700	N	N	N	N	70	70	150	N	20	10	N	N	L	N	.02	Amphibolite.
F0041A	48600	74700	N	N	N	N	N	N	15	N	L	100	N	N	N	N	L	Gneiss.
F0041B	48600	74700	N	N	N	N	70	300	150	N	150	N	N	N	N	N	L	Mafic dike.
F0056A	53700	76900	N	N	L	N	50	200	100	N	100	200	N	N	1000	N	L	Amphibolite.
F0056C	53700	76900	N	N	N	N	70	200	100	N	70	300	N	N	L	N	L	Amphibolite.
F0058A	54100	77400	N	N	N	N	70	50	70	N	100	300	N	N	N	N	.02	Gneiss and amphibolite
F0059A	54400	78600	N	N	N	N	50	300	70	N	100	150	N	N	N	N	L	Do.
F0522A	49800	73200	N	N	1.0	N	20	50	20	N	50	10	N	1000	N	N	.02	M, gneiss.
F2031A	52100	77900	N	N	L	N	N	N	700	N	7	100	N	N	N	N	.02	Gneiss.
F2587B	42800	77500	1.0	N	L	70	N	N	15	N	N	30	N	N	N	N	L	M, fault breccia.
F2587D	42800	77500	1.5	N	L	N	50	200	20000	N	70	N	N	N	N	.10	.12	M. quartz vein.
F2591A	44200	80400	N	N	N	N	20	50	300	N	20	N	N	N	N	L	L	Mafic dike.
F2626A	51600	84200	N	N	L	N	20	300	70	10	100	10	N	N	N	N	L	M, schist.
F2637A	50200	84600	N	N	N	N	70	300	150	N	150	10	N	N	N	N	.04	M, mafic dike.
G0611A	58900	90100	3.0	N	N	N	50	N	10000	N	3000	10	N	N	N	B	B	M, anorthosite.
G2613A	56000	90000	N	N	1.0	N	15	500	300	N	30	15	N	N	N	N	.02	Quartz vein.
G3246B	53100	88600	N	N	N	N	N	N	150	N	15	50	N	1000	N	.40	.02	M, gneiss.
G3246C	53100	88600	N	500	N	N	15	N	700	N	150	70	N	N	N	.85	12.00	Do.
G4047A	49200	86500	N	N	L	300	N	N	L	1500	L	10	N	N	N	H	.04	Quartz vein.

G4048A	49400	87600	N	N	L	N	15	150	15	10	20	15	N	N	N	N	.02	Schist.
G6069A	52100	88000	N	N	L	N	15	50	150	N	70	L	N	N	N	N	.04	Hornfels.
G6070A	52300	88700	N	500	L	N	5	N	50	N	20	L	N	N	N	1.00	L	Quartz.vein.
H0600A	44400	93100	.5	N	3.0	N	L	N	20	N	15	20	N	N	N	B	.04	Granite.
H2608A	43700	82600	N	300	N	N	15	N	1500	N	7	70	N	N	N	.05	1.30	M, quartz vein.
H2608C	43700	82600	N	N	L	N	30	300	700	N	100	N	N	N	N	N	.02	M, mafic dike.
H4054A	53400	92300	N	N	L	N	20	300	50	N	150	200	N	N	N	N	.04	Hornfels.
H4059A	47300	90900	N	N	L	N	15	150	10	10	20	15	N	N	N	N	L	Schist.
H4064A	47900	93800	N	N	L	N	15	700	150	N	100	10	N	N	N	N	.04	Hornfels.
J2605A	43300	81100	7.0	N	L	N	30	N	3000	N	15	15	N	N	N	N	1.30	M, fault breccia.
K0552A	34800	93500	30.0	N	N	N	N	N	50	N	N	500	N	N	N	.30	4.00	Gneiss.
K0563A	35900	88000	10.0	N	5.0	20	10	150	70	15	70	150	N	N	300	13.00	.85	M, fault breccia.
K2635A	32700	86400	N	N	L	N	N	N	15	N	10	500	N	N	700	N	.10	M, limestone.
K3284B	31000	87600	2.0	N	L	N	20	N	2000	N	5	N	N	N	N	13.00	.95	M, fault breccia.
K6083C	31000	88200	N	N	1.0	N	50	70	200	N	70	L	N	N	N	N	L	M, hornfels.
K6087A	31900	87700	N	N	2.0	N	20	50	70	300	15	10	N	N	N	.05	.14	M, dacite porphyry.
L0566A	25700	92400	10.0	1500	3.0	N	N	150	300	N	15	3000	N	N	300	.20	.10	M, monzonite.
L0567B	25800	94200	10.0	N	L	N	N	N	15	20	N	15	N	N	N	.05	.10	M, quartz vein.
L0567D	25800	94200	20.0	N	1.0	L	15	30	20	N	20	200	N	N	N	.20	.18	Do.
L0570B	28800	91700	2.0	N	5.0	N	5	150	200	L	30	15000	N	N	300	N	L	M, agrillite.
L0570C	28800	91700	1.5	N	N	N	N	N	100	N	10	1000	N	N	300	N	.04	M, quartz vein.
L0571A	28600	89800	.5	N	N	N	N	100	15	N	10	20	N	N	N	N	.04	Sandstone.
L4075A	29800	91400	70.0	1500	N	N	N	N	1000	10	N	G	N	N	300	.10	3.10	M, fault breccia.
M2508B	37200	57500	N	N	N	N	N	N	10	N	N	100	N	N	N	N	.04	M, calcite vein.
M2515A	33900	60200	N	N	N	N	10	N	15	N	10	150	N	N	N	N	L	Latite porphyry.
M2534A	35100	59600	N	5000	L	N	N	N	20	7	N	10	N	N	N	N	6.00	Sandstone.
M3005B	40400	62200	.5	N	L	L	100	200	1000	15	150	50	N	N	N	N	.08	M, gneiss.
M3005C	40400	62200	1.0	N	N	N	5	N	2000	N	5	15	N	N	N	N	.06	Gneiss.
M5000B	40400	62200	5.0	N	L	N	50	150	7000	N	50	15	N	N	N	L	.04	M, phyllite.
N2409A	40400	78100	N	N	N	N	N	N	N	N	N	15	N	N	N	.15	.02	Gneiss.
P0487A	31900	61800	.7	N	L	30	5	N	20	N	15	150	N	N	5000	N	L	M, dacite porphyry.
P0488A	31100	60900	500.0	N	1.0	G	N	N	3000	N	15	5000	N	3000	N	10.00	.06	M, gossan.
P0488B	31100	60900	100.0	N	1.0	700	N	N	15000	N	30	2000	N	N	300	.30	L	M, quartz vein.
P2560B	35100	64000	N	N	N	N	15	50	200	N	30	N	N	N	N	N	L	M, schist.
P2561A	32200	62700	700.0	300	L	500	30	N	G	N	20	G	N	N	N	6.50	11.00	M, sulfide vein.

TABLE 3.—*Analyses for selected elements in 192 rock samples from the North Absaroka study area*—Continued

Sample	Coordinates (meters) N.	E.	Semiquantitative spectrographic analyses (ppm) Ag (0.5)	As (200)	Be (1)	Bi (10)	Co (5)	Cr (10)	Cu (5)	Mo (5)	Ni (5)	Pb (10)	Sn (10)	W (50)	Zn (200)	Atomic absorption(ppm) Au (0.05)	Hg (0.02)	Sample material
P2562A	32300	62600	10.0	N	2.0	10	15	50	150	N	15	300	N	N	N	N	.80	M, fault gouge.
Q175	26200	92300	100.0	700	L	200	5	300	300	N	15	500	N	N	L	28.00	B	M, porphyry.
Q5001A	33200	96900	50.0	N	N	N	20	N	N	N	30	N	N	N	N	.20	.02	Dacite porphyry.
R050	21200	64100	N	N	1.0	N	7	30	30	N	5	70	N	N	N	L	B	Tuff.
R051	20100	65300	L	N	L	N	30	150	150	10	30	N	N	100	N	L	B	Do.
R070	26800	91700	1.0	N	N	N	10	200	70	N	50	150	N	N	N	.40	B	M, monzonite.
R071	26700	91800	20.0	N	N	N	100	50	1500	N	100	1000	N	N	L	20.00	B	M, tailings.
R075	25600	93400	10.0	N	L	10	20	100	20	N	30	150	10	N	N	.30	B	M, monzonite.
R332	20800	67400	N	N	L	N	7	20	50	10	10	30	N	100	N	L	B	Tuff.
R335	18700	59300	N	N	1.0	N	10	15	50	5	10	30	N	N	N	L	B	Tuff breccia.
R712	26800	91800	L	N	L	N	7	200	100	N	50	70	N	N	N	L	B	M, monzonite.
R713	26800	91800	7.0	N	L	N	10	300	5	N	50	10	50	N	N	1.00	B	Do.
R715	27300	91500	N	N	L	N	7	200	10	N	50	70	N	N	N	L	B	M, granodiorite.
R716	26900	91800	7.0	N	L	N	7	150	5	7	20	200	10	N	N	.20	B	M, monzonite.
R717	26900	91800	150.0	N	L	150	100	200	70	15	30	700	10	N	N	4.00	B	M, sulfide minerals.
R718	26900	91800	1.0	N	N	N	300	N	L	N	150	N	N	N	N	.10	B	M, pyrite.
R723	21500	90500	2.0	N	N	N	10	100	50	N	30	20	N	N	N	L	B	M, snadstone.
S0204B	36500	55000	N	N	N	N	100	150	500	N	100	10	N	N	N	N	L	Phyllite.
S0210C	32200	55900	70.0	N	2.0	100	N	N	700	N	5	15000	N	N	G	.20	.02	M, fault breccia.
S0210D	32200	55900	100.0	N	2.0	150	N	N	70	N	5	G	N	N	N	.05	.02	Do.
S0213B	31300	56500	.5	N	2.0	N	N	N	100	N	5	200	N	N	N	N	.02	M, dacite porphyry.
S0215A	30500	57000	.5	N	1.0	N	N	N	1000	70	L	70	N	N	N	.05	L	Do.
S0217A	30200	58000	.5	N	1.0	N	10	N	300	50	5	15	N	N	N	L	.02	Do.
S0217B	30200	58000	N	N	2.0	N	N	100	200	N	30	15	N	N	N	N	L	M, granodiorite porphyry.
S0219A	30300	57700	.5	N	L	N	N	N	10	N	L	15	N	N	N	N	L	M, dacite porphyry.
S0242B	29000	60300	.5	N	1.0	N	N	20	10	7	5	10	N	N	N	N	.06	M, sandstone.
S0243A	28700	59400	N	N	1.0	N	N	N	5	5	L	30	N	N	N	N	.04	M, tuff breccia.
S0244B	28800	59100	.5	N	1.0	N	N	30	10	L	5	30	N	N	N	N	.06	M, dacite porphyry.
S0247A	29600	58900	.5	N	1.0	N	N	N	10	N	L	100	N	N	N	N	.02	M, tuff breccia.
S0301A	35550	51500	10.0	1000	L	N	70	150	500	N	150	20	N	N	N	.20	.04	M, schist.

S0304B	32800	49200	3.0	N	N	N	20	N	2000	N	50	L	N	N	N	.05	.02	M, quartz vein.
S0441A	30800	53800	N	N	1.0	N	15	30	15	N	30	15	N	N	200	N	.04	M, dacite porphyry.
S0450B	30600	55200	N	N	1.0	N	N	N	15	N	N	15	N	N	N	.75	L	Do.
S0451A	30700	54700	3.0	N	L	N	N	N	20	5	N	100	N	N	N	.05	L	Do.
S0451B	30700	54700	N	N	1.0	N	5	N	N	N	L	15	N	N	300	N	L	Do.
S0452A	31400	54700	N	N	L	N	N	N	15	100	N	15	N	N	N	L	L	M, dacite porphyry.
S0452B	31400	54700	2.0	N	1.0	N	N	N	700	100	N	20	N	N	N	.10	.04	Do.
S0453A	31500	54700	10.0	N	2.0	N	15	N	5000	10	N	15	N	N	N	.40	L	Do.
S0455A	31100	57200	N	N	1.0	N	5	N	500	N	10	10	N	N	N	L	.02	Do.
S0455B	31100	57200	N	N	1.0	N	N	N	50	10	N	20	N	N	N	N	L	Do.
S0456A	31000	58000	.5	N	2.0	N	10	N	200	70	7	50	N	N	N	L	L	M, granodiorite porphyry.
S0457A	30000	55000	N	N	2.0	N	N	N	N	N	N	15	N	N	300	N	L	M, dacite porphyry.
S0461A	29100	56800	.7	N	2.0	N	N	N	15	5	N	300	N	N	300	N	.02	M, fault breccia.
S0461B	29100	56800	2.0	N	2.0	100	N	N	50	10	N	50	N	N	N	6.00	.10	Do.
S0461C	29100	56800	70.0	500	3.0	G	15	N	50	20	5	500	N	N	N	210.00	.04	Do.
S0462A	29300	57200	N	N	2.0	15	N	N	20	10	N	20	N	N	N	7.00	.02	M, fault breccia.
S0462B	29300	57200	2.0	N	2.0	20	10	N	300	N	5	15	N	N	N	.10	L	Do.
S0465A	30300	58300	N	N	1.0	N	N	N	20	N	N	150	N	N	N	N	.02	M, dacite.
S0470A	30100	59800	N	N	1.0	N	N	N	5	15	N	20	N	N	N	N	.26	M, fault breccia.
S0472A	30900	59400	20.0	1000	1.0	50	N	N	300	N	N	1500	N	N	1500	.45	.06	M, fault gouge.
S0489A	31700	57600	1.5	N	L	20	N	N	20	N	N	20	N	N	N	.05	L	M, dacite porphyry.
S0489B	31700	57600	2.0	N	L	L	N	N	100	N	N	500	N	N	N	L	L	Do.
S0490A	30800	56800	.5	N	N	N	10	N	7	2000	N	N	N	N	N	L	.04	M, fault breccia.
S0491A	29000	53400	3.0	N	N	N	N	N	15	N	N	300	N	N	N	L	L	M, tuff breccia.
S0494A	37200	55300	5.0	1500	N	N	30	N	150	N	150	30	N	N	1000	N	.18	M, gossan.
S2281A	28100	56500	10.0	700	1.0	L	N	N	70	L	L	1000	N	N	2000	.15	.02	M, volcanic breccia.
S2497A	26400	56800	.5	N	L	N	15	100	500	N	30	70	N	N	N	.10	L	M, dacite porphyry.
S4019A	32200	58100	N	N	L	N	N	N	15	N	N	150	N	N	200	L	L	Do.
S4020A	32400	57600	.7	N	1.0	N	N	N	30	N	N	2000	N	N	200	N	.02	Do.
U0427B	16800	54800	.7	N	L	N	20	N	150	N	30	N	N	N	N	N	L	Mafic dike.
U0428A	17200	54900	N	N	N	N	N	N	30	N	10	N	N	N	N	8.00	.02	M, quartz vein.
U0428D	17200	54900	N	N	L	N	N	N	70	N	7	N	N	N	N	.80	.06	Do.
U0429A	18100	55100	N	N	L	N	N	30	5	5	5	15	N	N	N	N	L	M, fault breccia.
1792	31400	91900	.5	N	N	N	10	20	10	N	10	20	N	N	N	B	B	Latite.
1927	37000	93500	N	N	L	N	5	N	10	N	5	100	N	N	N	B	B	Gneiss.
1930	36400	92200	N	N	1.5	N	5	N	10	N	5	100	N	N	N	B	B	Do.
1939	38100	92500	N	N	2.0	N	5	N	15	N	L	70	N	N	N	B	B	Do.

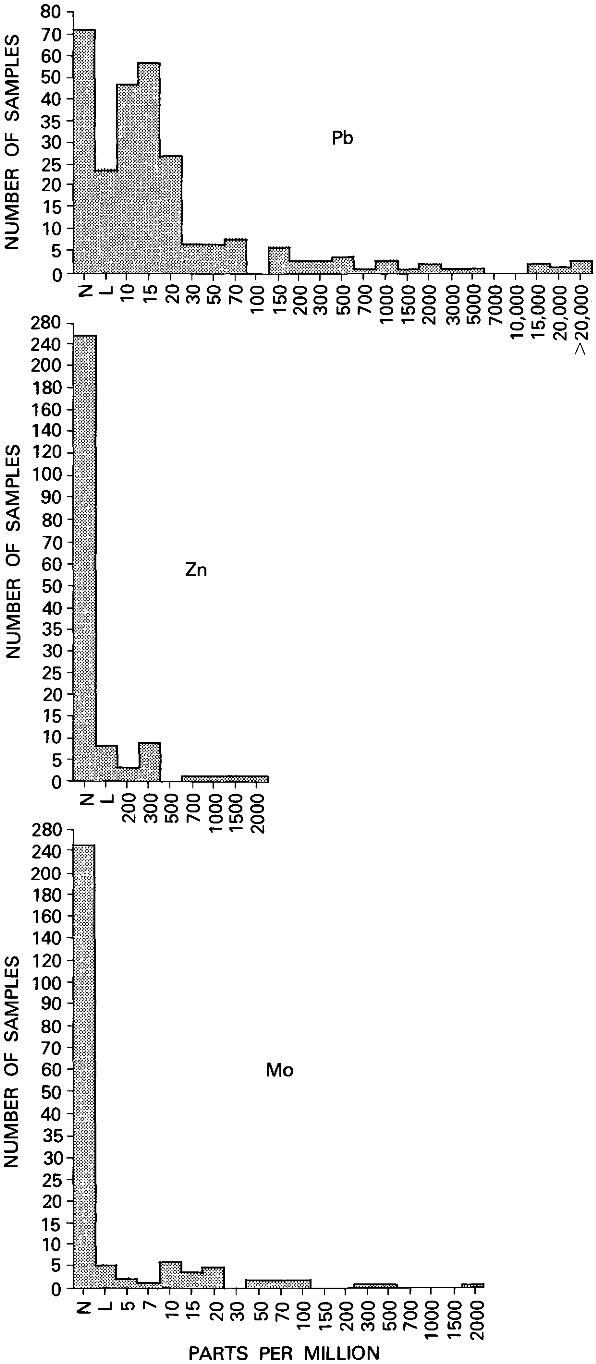


FIGURE 11.—Histograms showing the distribution of copper, gold, lead, molybdenum,
study area. >, greater than value shown; N, looked for but not

silver, and zinc in 279 samples of altered and mineralized rocks, North Absaroka detected; L, detected but below limit of determination.

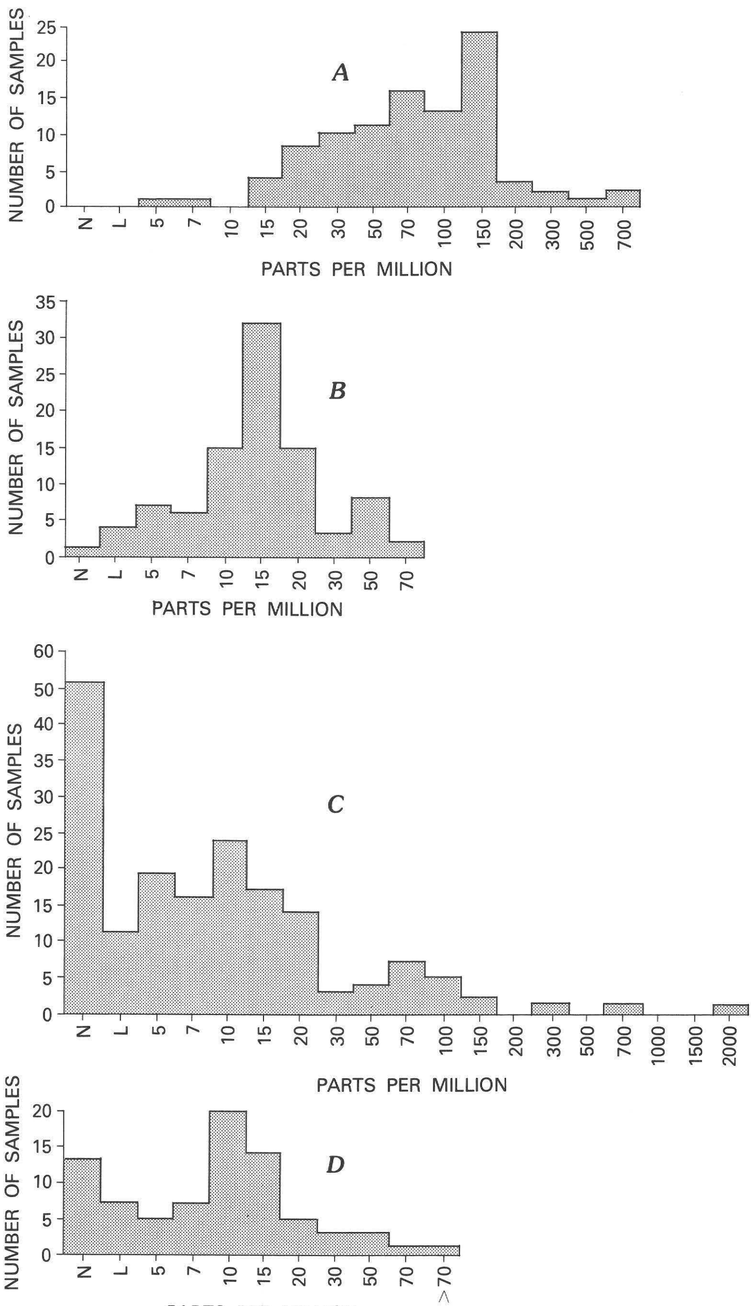


FIGURE 12.—Histograms showing the distribution of copper in various types of unaltered rocks, North Absaroka study area. *A*, Cu in 96 samples of Precambrian mafic rocks; *B*, Cu in 93 samples of Tertiary volcanic rocks; *C*, Cu in 176 samples of Precambrian felsic rocks; *D*, Cu in 79 samples of Tertiary intrusive rocks. >, greater than value shown.

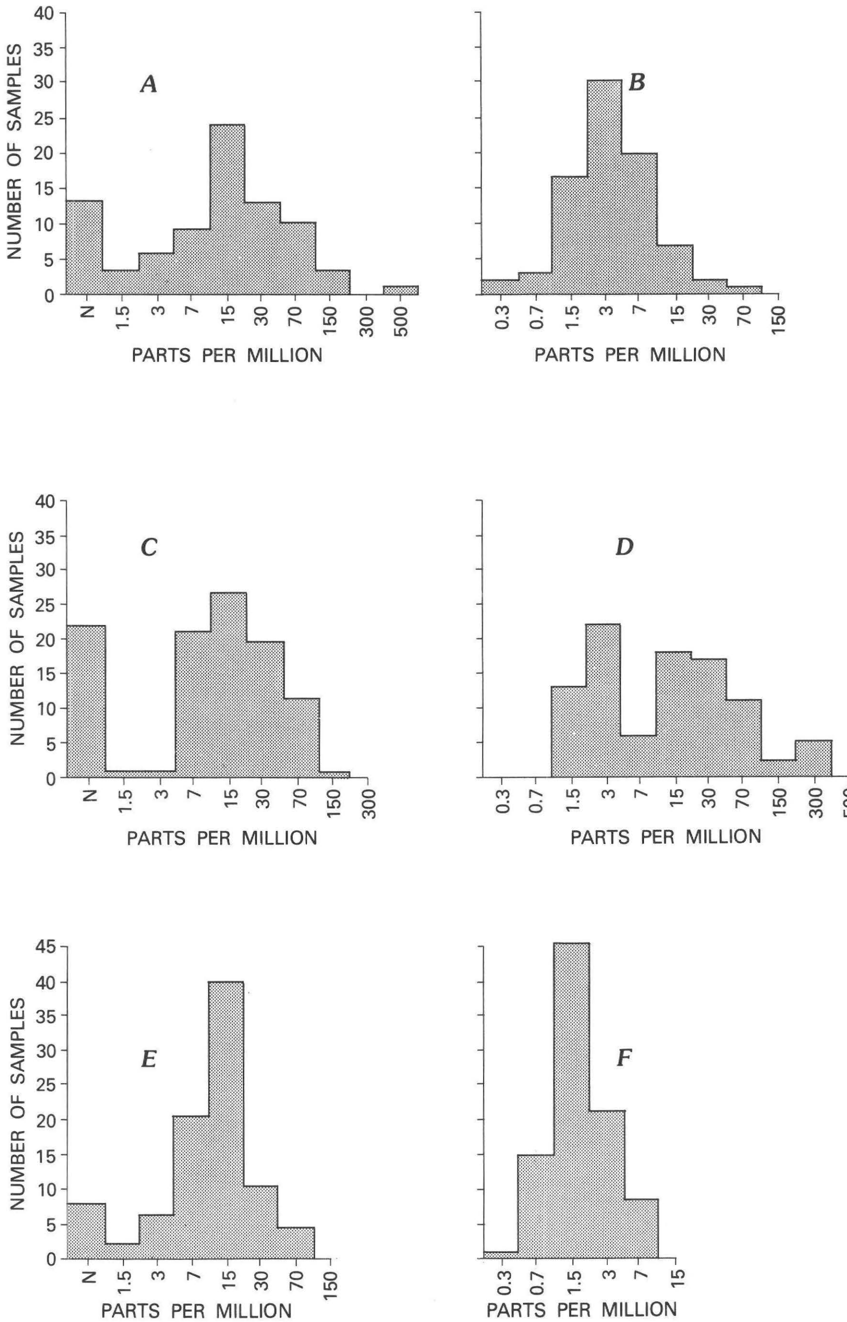
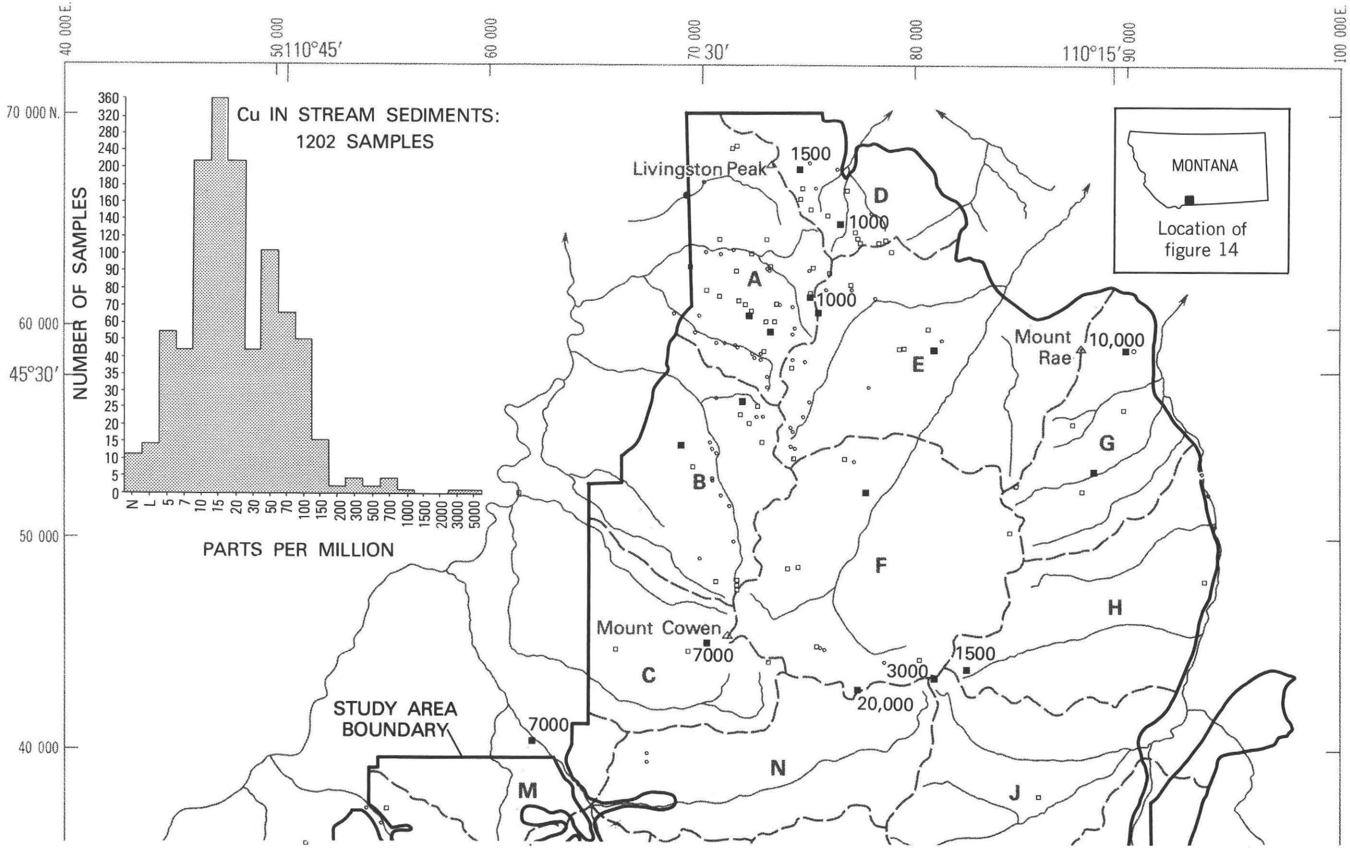


FIGURE 13.—Histograms showing the distribution of uranium and thorium in rock and stream-sediment samples, North Absaroka study area (*A–D*), and of uranium and thorium in rock samples, Beartooth Primitive Area (*E–F*). *A*, thorium in 82 rock samples; *B*, uranium in 82 rock samples; *C* in 94 stream-sediment samples; *D*, uranium in 94 stream-sediment samples; *E*, thorium in 89 rock samples; *F*, uranium in 89 rock samples.


40 000 E.
50 000
110°45′
60 000
70 000
30′
80 000
110°15′
90 000
100 000 E.
70 000 N.
60 000
45°30′
50 000
40 000
Cu IN STREAM SEDIMENTS:
1202 SAMPLES
NUMBER OF SAMPLES
PARTS PER MILLION
N L 5 7 10 15 20 30 50 70 100 150 200 300 500 700 1000 1500 2000 3000 5000
360 320 280 240 200 180 160 140 120 100 90 80 70 60 50 40 35 30 25 20 15 10 5 0
MONTANA
Location of
figure 14
Livingston Peak
Mount Rae
Mount Cowen
STUDY AREA
BOUNDARY
A
B
C
D
E
F
G
H
J
M
N
1500
1000
1000
10,000
7000
7000
3000
1500
20,000

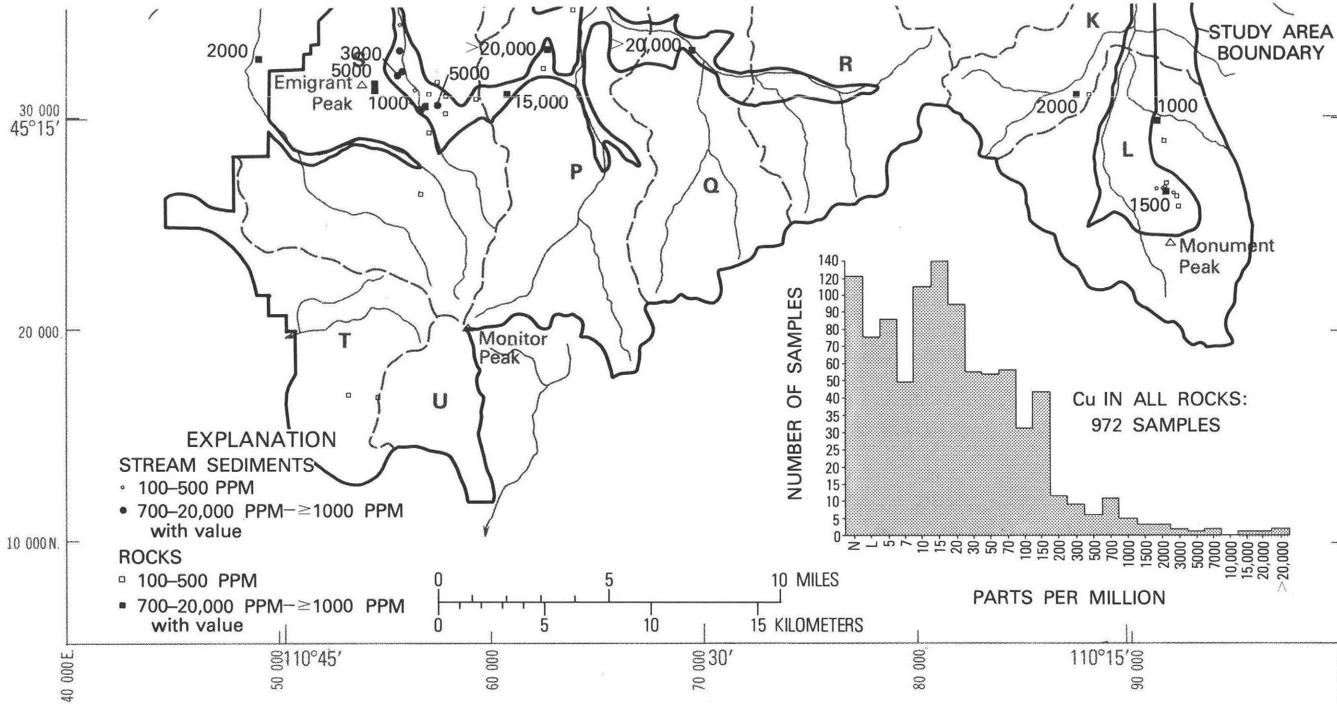
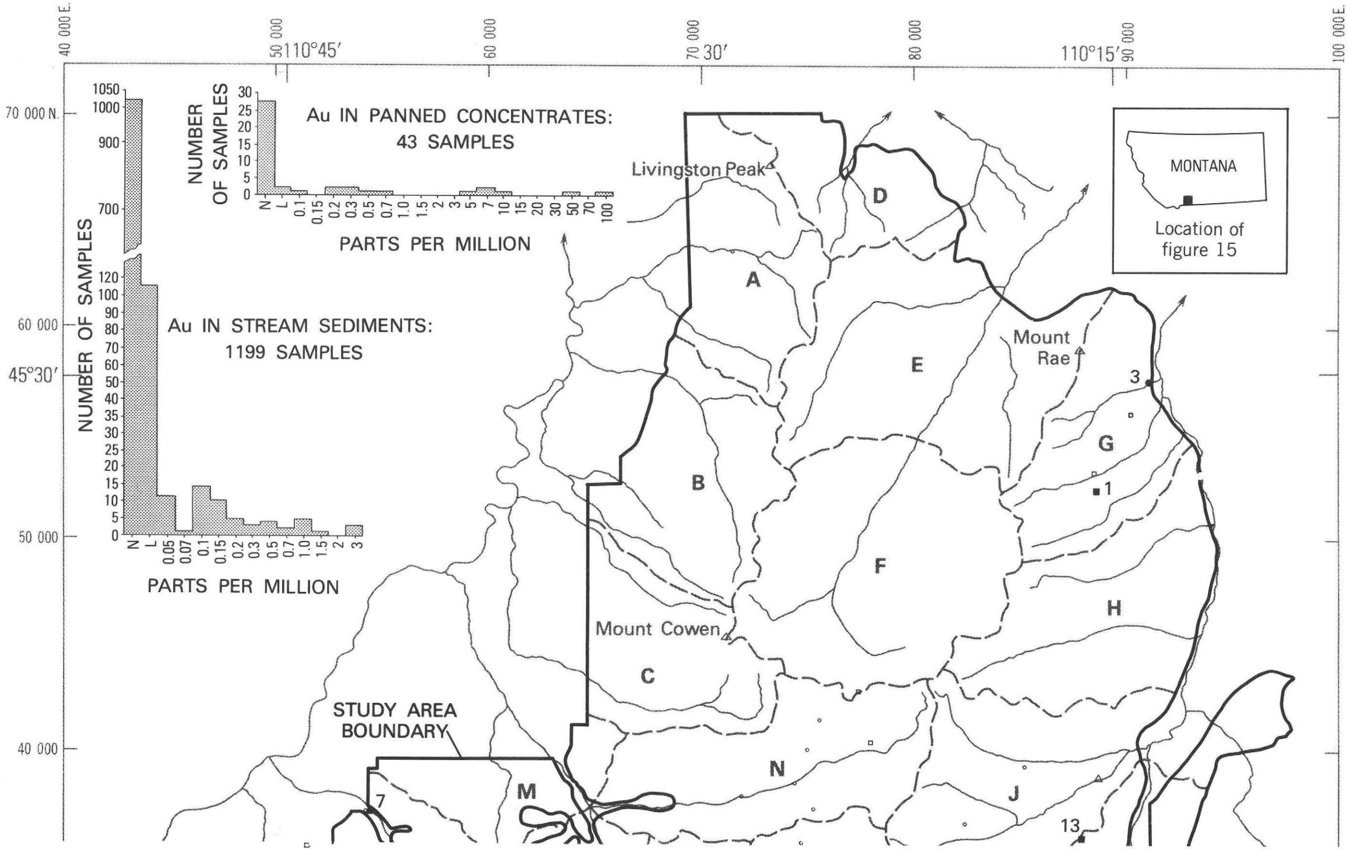


FIGURE 14.—Localities of samples anomalous in copper, and histograms showing distribution of copper in samples, North Absaroka wilderness study area. N, looked for but not detected; L, detected but below limit of determination. Capital letters indicate drainage basins.


Au IN PANNED CONCENTRATES: 43 SAMPLES
NUMBER OF SAMPLES
PARTS PER MILLION
Au IN STREAM SEDIMENTS: 1199 SAMPLES
NUMBER OF SAMPLES
PARTS PER MILLION
N
L
0.05
0.07
0.1
0.15
0.2
0.3
0.5
0.7
1.0
1.5
2
3
5
7
10
15
20
30
50
70
100
40 000 E.
50 000
110°45′
60 000
70 000
30′
80 000
110°15′
90 000
100 000 E.
70 000 N.
60 000
45°30′
50 000
40 000
Livingston Peak
Mount Rae
Mount Cowen
STUDY AREA BOUNDARY
MONTANA
Location of figure 15
A
B
C
D
E
F
G
H
J
M
N
1
3
7
13

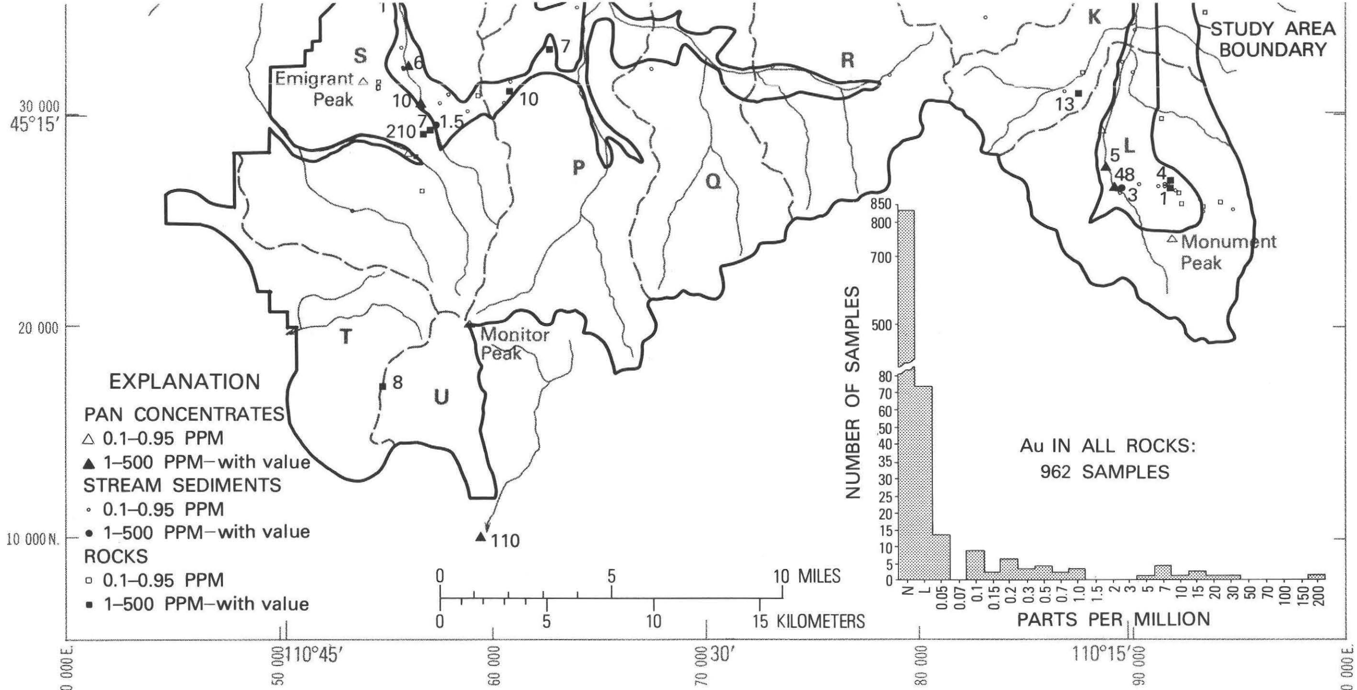
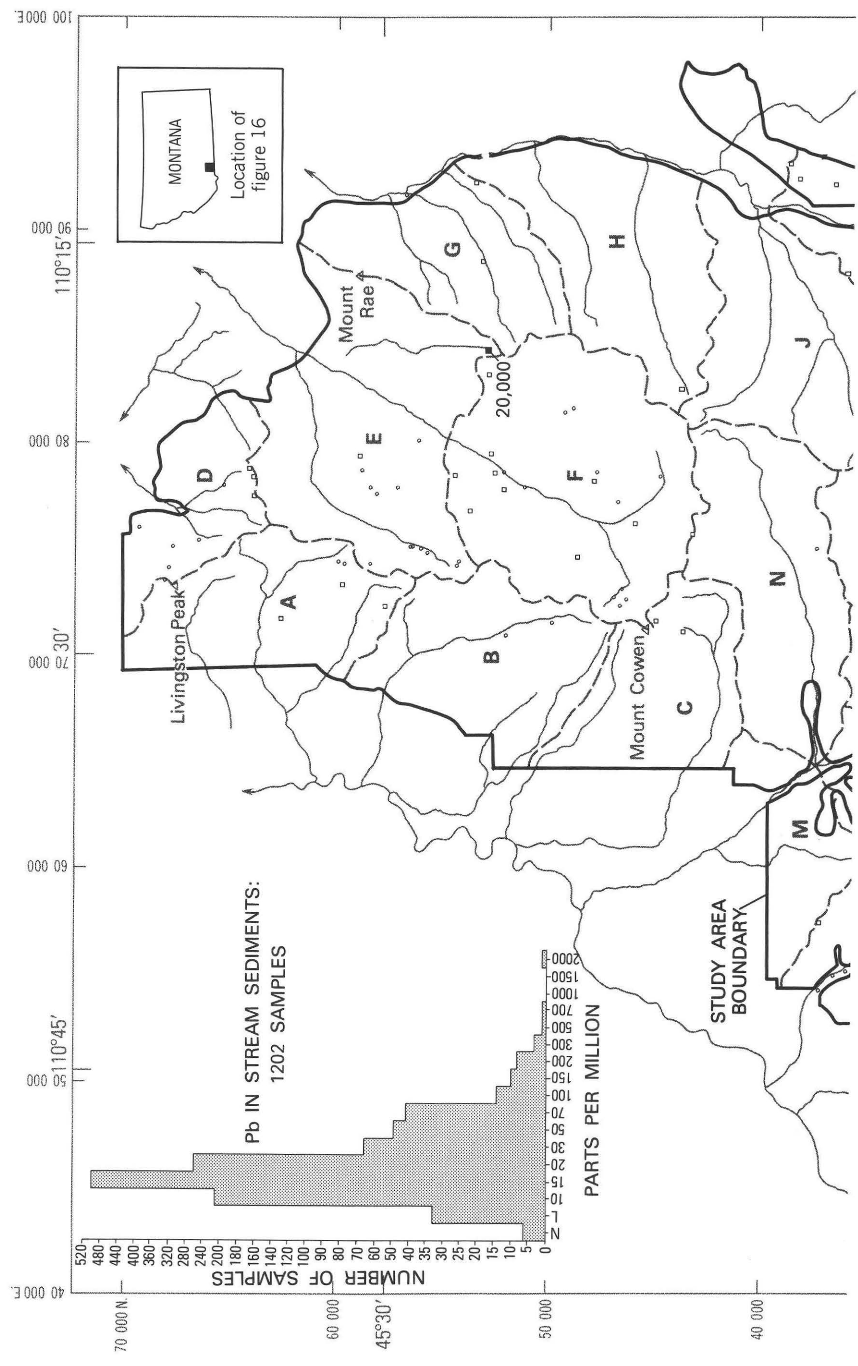


FIGURE 15.—Localities of samples anomalous in gold, and histograms showing distribution of gold in all samples, North Absaroka wilderness study area. N, looked for but not detected; L, detected but below limit of determination.


MONTANA
Location of figure 16
Mount Rae
Livingston Peak
Mount Cowen
20,000
A
B
C
D
E
F
G
H
J
M
N
STUDY AREA BOUNDARY
Pb IN STREAM SEDIMENTS: 1202 SAMPLES
PARTS PER MILLION
NUMBER OF SAMPLES
N L 10 15 20 30 50 70 100 150 200 300 500 700 1000 1500 2000
0 5 10 15 20 25 30 35 40 50 60 70 80 90 100 120 140 160 180 200 240 280 320 360 400 440 480 520
110°15′
30′
110°45′
45°30′
100 000E.
90 000
80 000
70 000
60 000
50 000
40 000 E.
70 000 N.
60 000
50 000
40 000

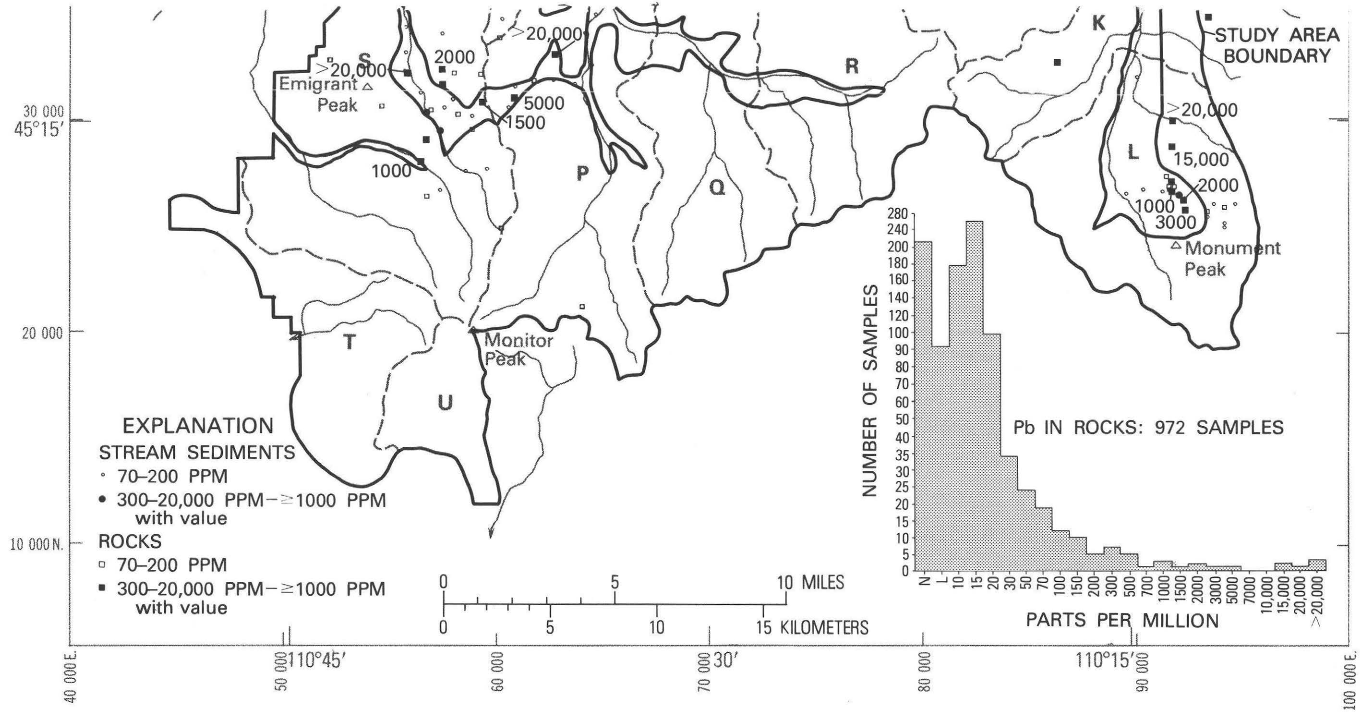
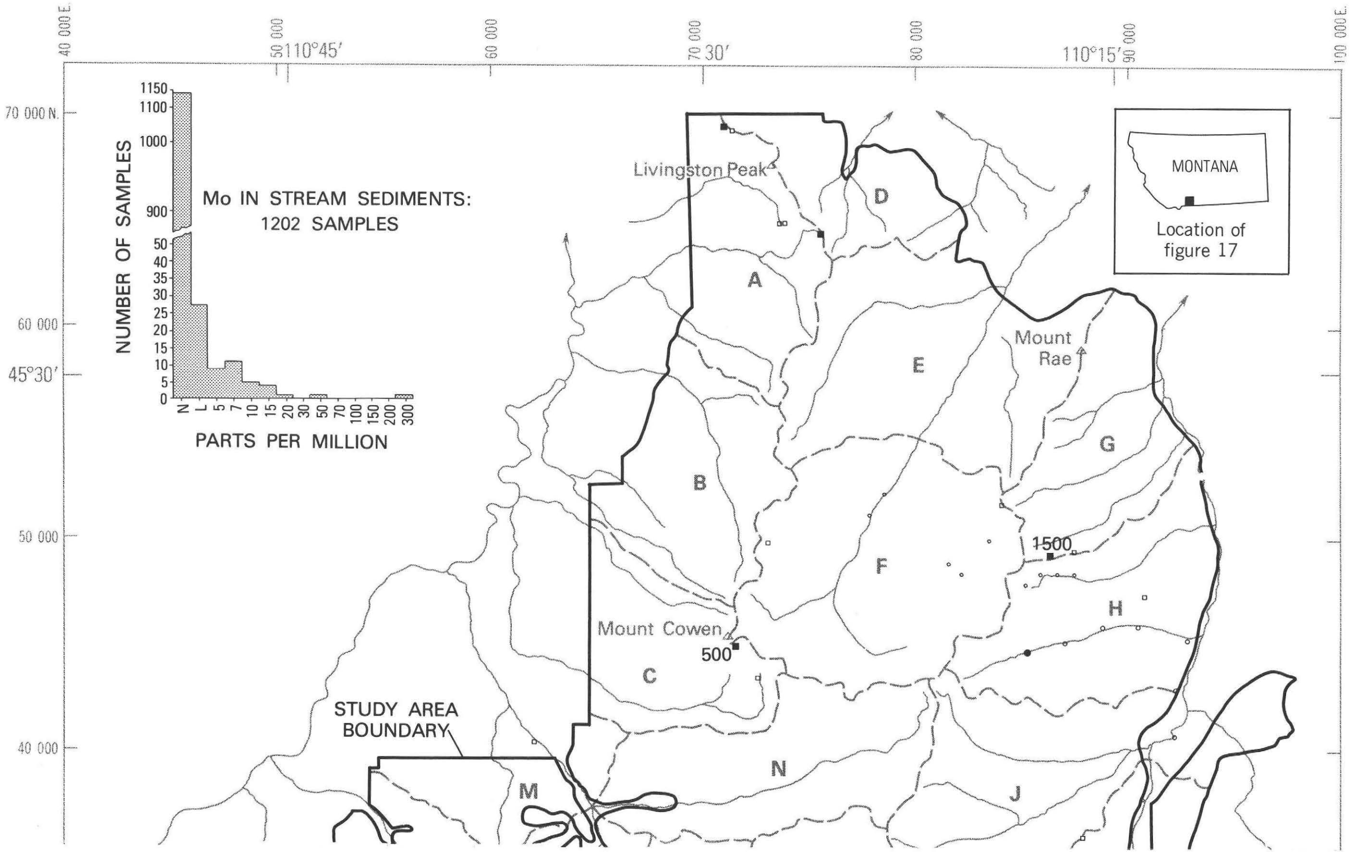


FIGURE 16.—Localities of samples anomalous in lead, and histograms showing distribution of lead in samples, North Absaroka study area. N, looked for but not detected; L, detected but below limit of determination.


40 000 E.
50 000
110°45′
60 000
70 000
30′
80 000
110°15′
90 000
100 000 E.
70 000 N.
60 000
45°30′
50 000
40 000
Mo IN STREAM SEDIMENTS:
1202 SAMPLES
NUMBER OF SAMPLES
PARTS PER MILLION
1150
1100
1000
900
50
40
35
30
25
20
15
10
5
0
N
L
5
7
10
15
20
30
50
70
100
150
200
300
Livingston Peak
Mount Rae
Mount Cowen
500
1500
STUDY AREA BOUNDARY
MONTANA
Location of figure 17
A
B
C
D
E
F
G
H
J
M
N

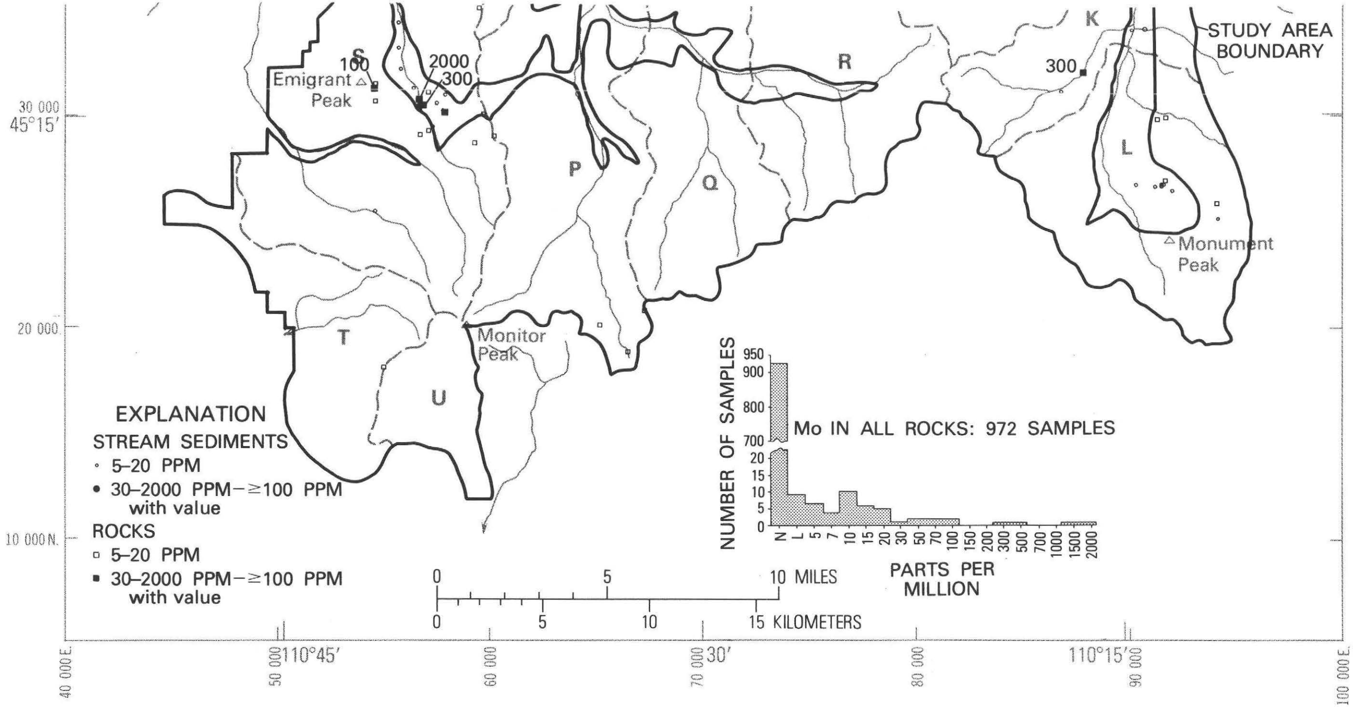
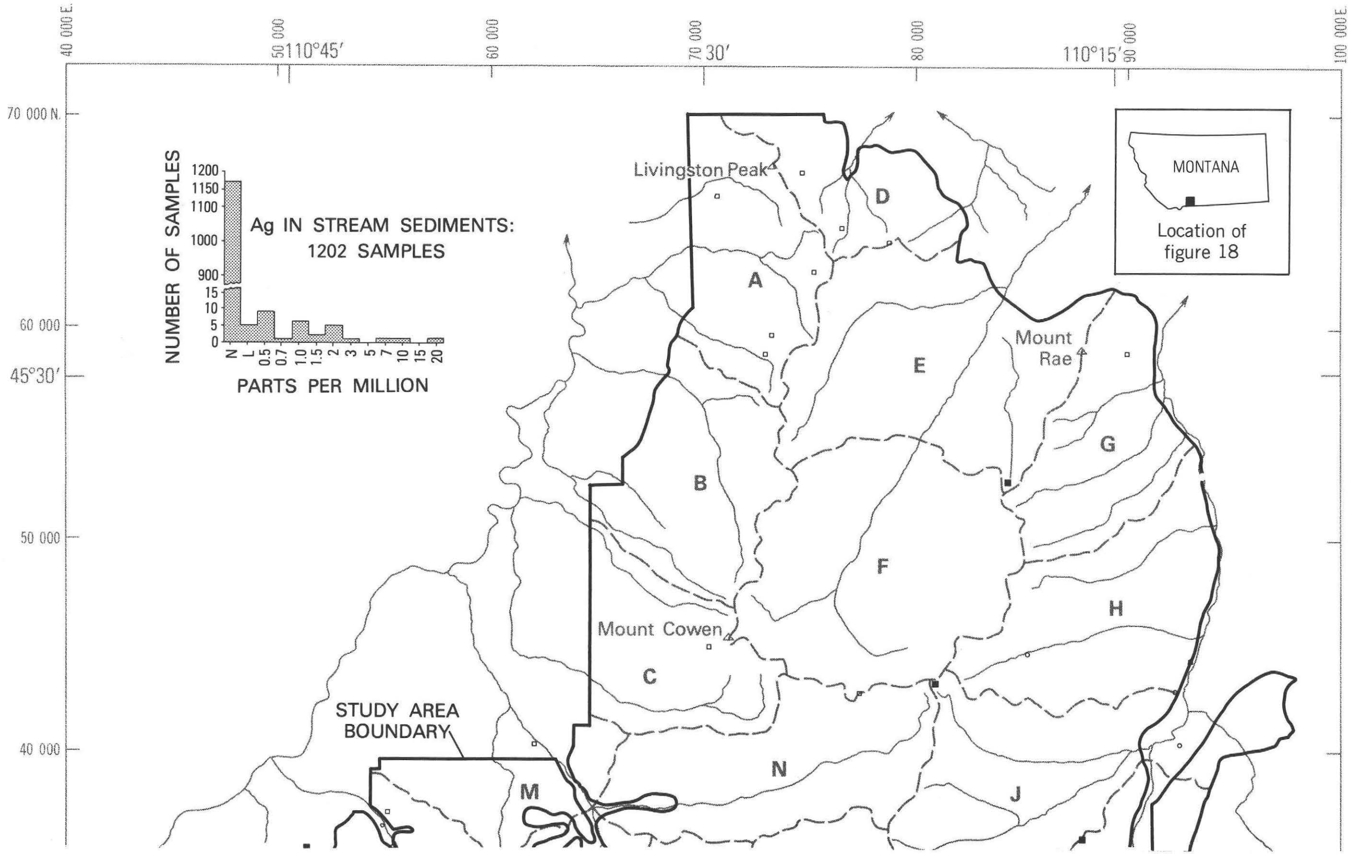


FIGURE 17.—Localities of samples anomalous in molybdenum, and histograms showing the distribution of molybdenum in samples, North Absaroka study area. N, looked for but not detected; L, detected but below limit of determination.


40 000 E.
50 000
110°45′
60 000
70 000
30′
80 000
110°15′
90 000
100 000 E.
70 000 N.
60 000
45°30′
50 000
40 000
NUMBER OF SAMPLES
1200
1150
1100
1000
900
15
10
5
0
N
L
0.5
0.7
1.0
1.5
2
3
5
7
10
15
20
PARTS PER MILLION
Ag IN STREAM SEDIMENTS:
1202 SAMPLES
Livingston Peak
Mount Rae
Mount Cowen
STUDY AREA
BOUNDARY
MONTANA
Location of
figure 18
A
B
C
D
E
F
G
H
J
M
N

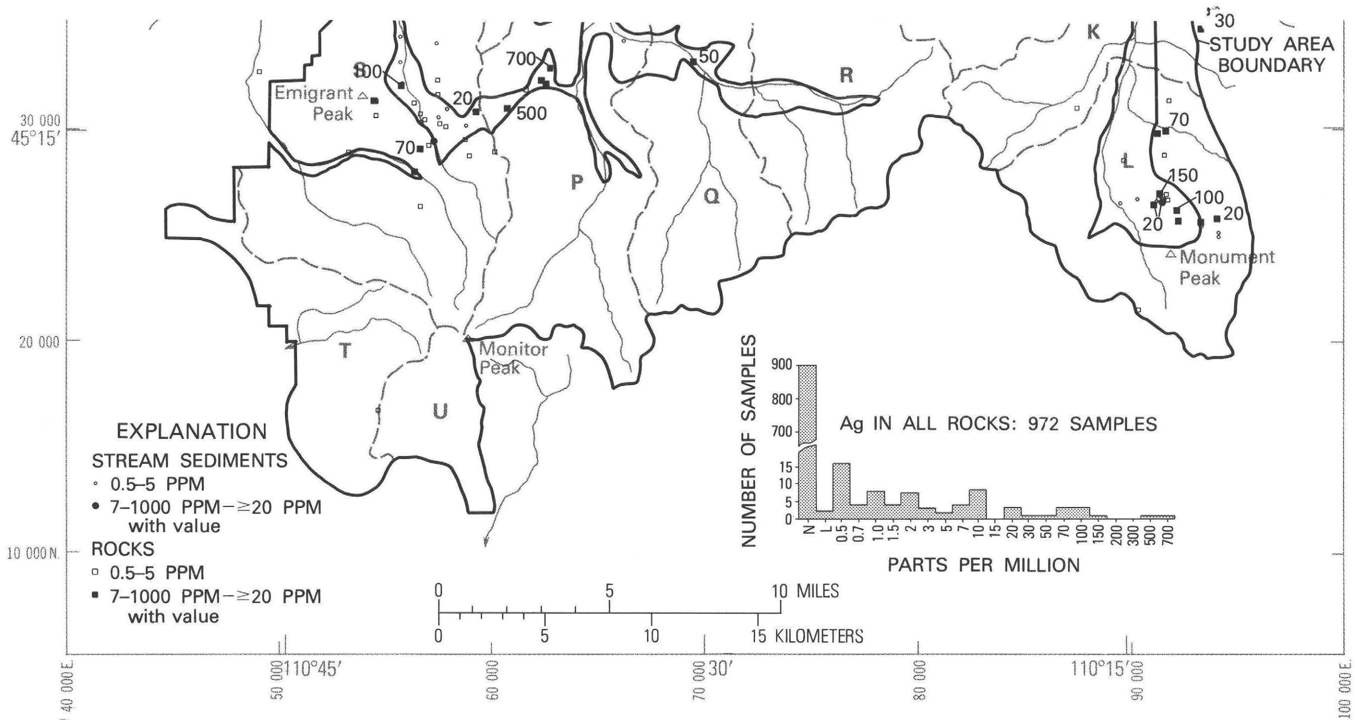
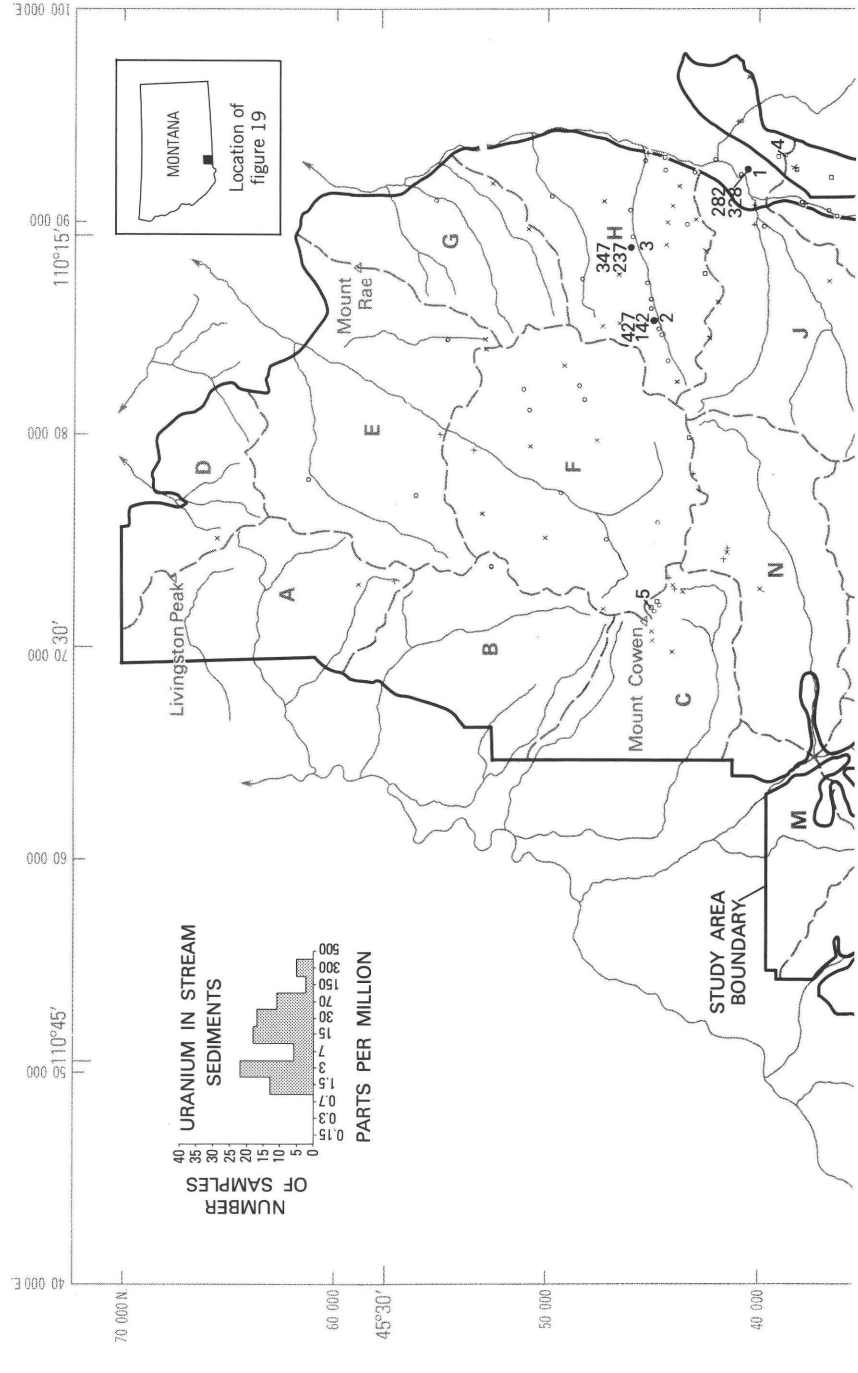


FIGURE 18.—Localities of samples anomalous in silver, and histograms showing distribution of silver in samples, North Absaroka study area. N, looked for but not detected; L, detected but below limit of determination.



MONTANA
Location of figure 19
Mount Rae
Livingston Peak
Mount Cowen
STUDY AREA BOUNDARY
A
B
C
D
E
F
G
H
J
M
N
347
237
3
427
142
2
282
328
1
4
5
URANIUM IN STREAM SEDIMENTS
NUMBER OF SAMPLES
PARTS PER MILLION
0 5 10 15 20 25 30 35 40
0.15 0.3 0.7 1.5 3 7 15 30 70 150 300 500
110°15′
110°30′
110°45′
45°30′
100 000 E.
90 000
80 000
70 000
60 000
50 000
40 000 E.
70 000 N.
60 000
50 000
40 000

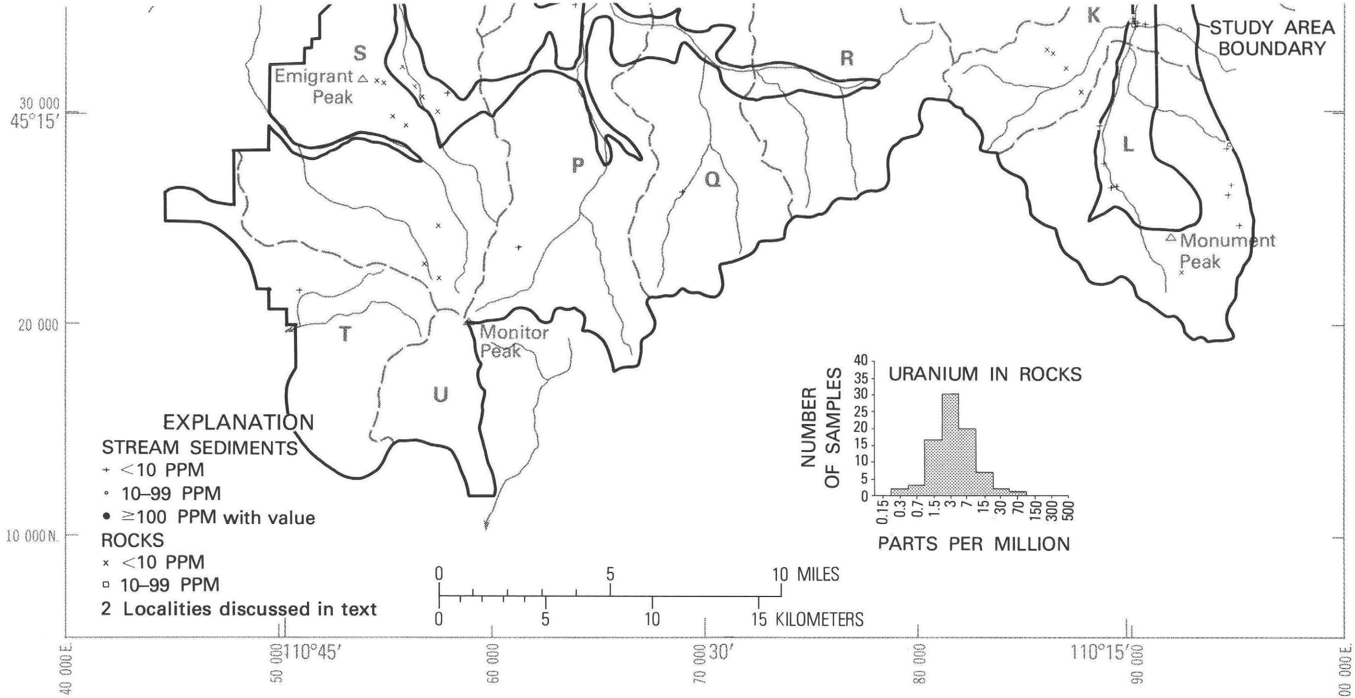
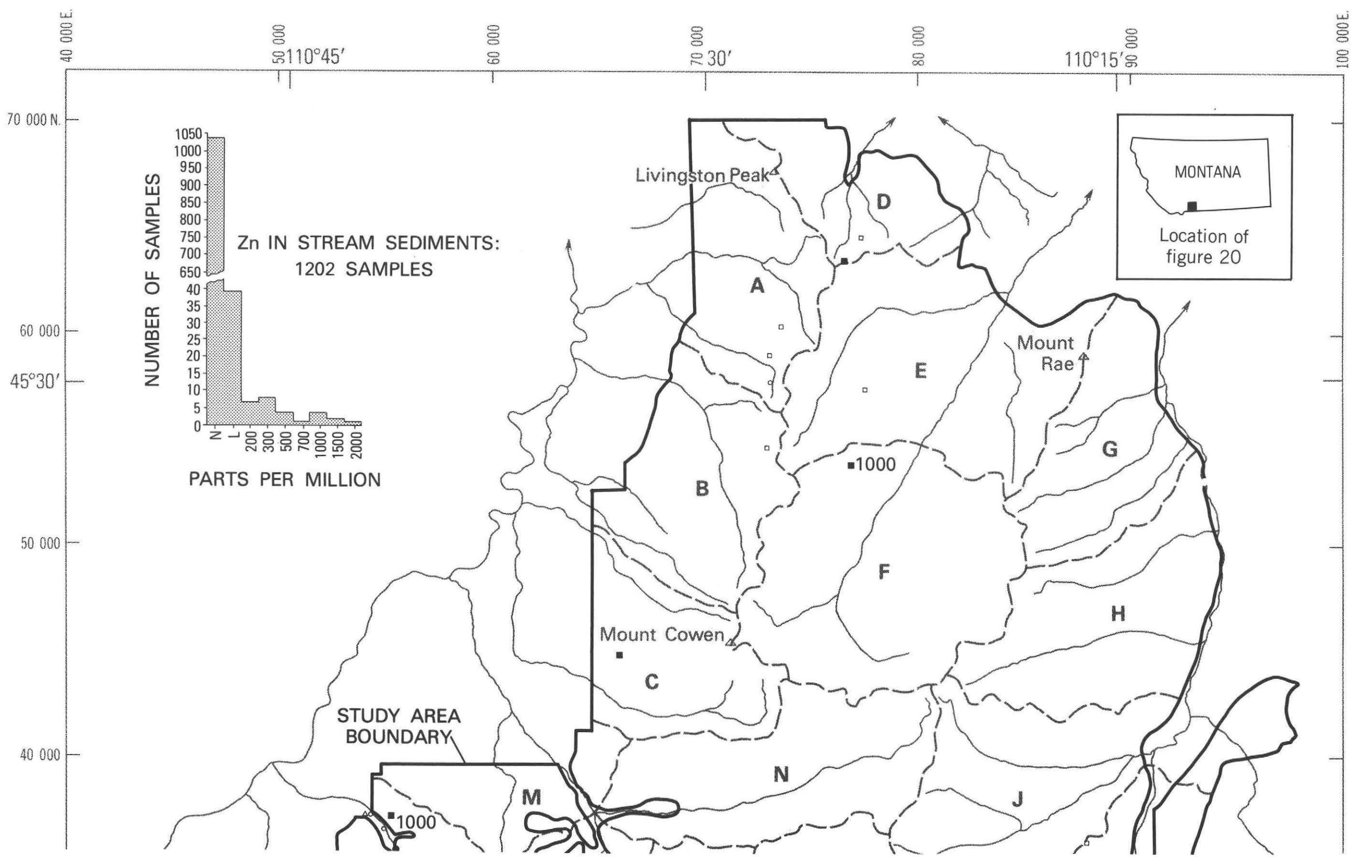


FIGURE 19.—Localities and distribution of anomalous values of uranium, and histograms showing distribution of uranium in samples, North Absaroka study area.


40 000 E.
50 000
110°45′
60 000
70 000
30′
80 000
110°15′
90 000
100 000 E.
70 000 N.
60 000
45°30′
50 000
40 000
NUMBER OF SAMPLES
1050
1000
950
900
850
800
750
700
650
40
35
30
25
20
15
10
5
0
N
L
200
300
500
700
1000
1500
2000
PARTS PER MILLION
Zn IN STREAM SEDIMENTS:
1202 SAMPLES
Livingston Peak
Mount Rae
Mount Cowen
MONTANA
Location of
figure 20
STUDY AREA
BOUNDARY
1000
1000
A
B
C
D
E
F
G
H
J
M
N

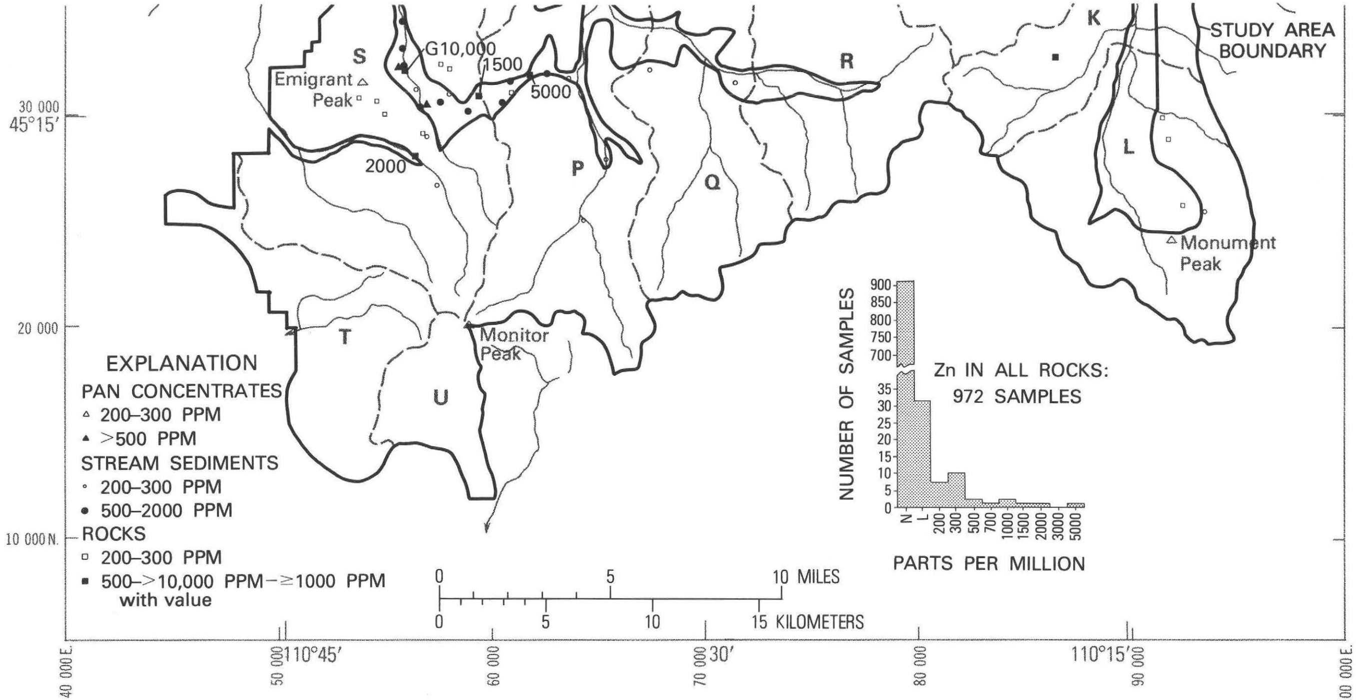


FIGURE 20.—Localities of samples anomalous in zinc, and histograms showing distribution of zinc in samples, North Absaroka study area. N, looked for but not detected; L, detected but below limit of determination.

TABLE 4.—*Median and estimated threshold value for selected elements that occur in anomalous concentrations in rock and stream-sediment samples, North Absaroka study area*

[<, less than value shown]

Element	Medians in ppm: Stream sediments	Medians in ppm: Rocks	Threshold in ppm
Ag-------	<0.5	<0.5	N[1]
As-------	<200	<200	N
Au-------	<0.05	<0.05	.05
Be-------	<1	<1	2
Bi-------	<10	<10	N
Co-------	<15	5	70
Cr-------	100	15	500
Cu-------	15	15	70
Hg-------	.05	<0.02	.4
Mo-------	<5	<5	N
Ni-------	30	10	150
Pb-------	15	15	50
Sn-------	<10	<10	N
Th-------	15	15	40
U--------	15	3	9
W--------	<50	<50	N
Zn-------	<200	<200	N

[1]N, not determined because values were mostly less than lower limits of detectability for these elements.

COMMODITIES

COPPER

Copper mineralization was previously known in the Emigrant–Mill Creek area, the Boulder district, and the Stillwater–Natural Bridge area. Our geochemical sampling program indicates that copper occurs in anomalous amounts at many other places as well (fig. 14).

Copper, as well as several other elements, shows extreme variation in background levels in rocks of different ages and lithologies. Geometric means for copper and for iron, manganese, cobalt, chromium, nickel, and lead, in six groups of rocks are given in table 5. The geometric mean of copper ranges from a low of 3 ppm for sedimentary rocks of Paleozoic and Mesozoic age to a high of 72 ppm for Precambrian mafic rocks, mostly amphibolites. Precambrian felsic rocks, mainly granitic gneiss, have a low geometric mean of 5.5 ppm. Copper shows a positive correlation with iron, manganese, cobalt, chromium, and nickel; the backgrounds of all are high in Precambrian mafic rocks and low in Paleozoic and Mesozoic sedimentary rocks and in Precambrian felsic rocks. Levels of these elements evidently are controlled by the abundance of ferromagnesian minerals such as pyroxene, amphibole, and biotite relative to quartz and feldspar in these rocks.

This variation in background levels of copper in various rock types makes it difficult to estimate threshold values. The choice of 70 ppm as a threshold is based primarily on the histograms for copper shown in figures 11, 12, and 14. This threshold results in the exclusion of some samples containing low but anomalous values of copper in the south half of the study area where the overall background of copper is low and the inclusion of many samples in the north half of the area (fig. 14) that merely reflect the higher background values of copper in metasedimentary and mafic rocks of Precambrian age and thus are not truly anomalous. This distribution of high background values of copper, however, is important in the evaluation of potential copper deposits because these rocks are potential sources of copper for remobilization and concentration in epigenetic deposits.

In general, the anomalous values in copper are clustered around the Emigrant–Mill Creek mineralized area, the Boulder district, and in the north half of the study area.

In the Emigrant–Mill Creek area, nearly all anomalous copper samples are from outside the study area and were collected at or near known deposits. A sample of strongly altered dacite from locality S0453 on the east side of Emigrant Peak in the study area had 5,000 ppm copper; the sample contained quartz veins with pyrite and chalcopyrite. This part of the Emigrant stock exhibits evidence of intensive pyritic alteration. Several samples within the study boundaries in the Emigrant–Mill Creek area contain anomalous concentrations of copper in the range of 100–700 ppm (fig. 14).

In the Boulder district, most of the samples that contain anomalous values of copper are clustered around the previously known mineralized area near Independence Peak. Four anomalous samples were collected north and northwest of this area within the study area. A sample of limonite- and quartz-rich breccia taken from locality L4075, a small dump at the base of a tramway leading down from the Ski Line claim on the north face of Baboon Mountain, contained 1,000 ppm copper. This

TABLE 5.—*Geometric means for iron, manganese, cobalt, chromium, copper, nickel, and lead in 6 groups of unaltered rocks, North Absaroka study area*

[Data for Fe are in percent; all other data are in parts per million]

Rock type	No. of samples	Fe	Mn	Co	Cr	Cu	Ni	Pb
Tertiary intrusive-----	79	1.7	180	4.0	6.2	N[1]	6.8	16
Tertiary volcanic------	93	2.5	250	8.8	35	14	15	16
Mesozoic and Paleozoic sedimentary ---------	107	.38	68	.26	1.8	3.0	1.9	4.3
Precambrian mafic------	96	6.7	1100	34	85	72	52	4.2
Precambrian felsic-----	176	1.4	150	.71	1.9	5.5	3.1	17
Precambrian metasedimentary -----	107	2.9	260	9.1	53	21	27	7.3

[1]N, not determined.

sample also contained 70 ppm silver and more than 20,000 ppm lead. Lower values of these metals were reported for samples taken in place at the Ski Line claim (loc. L0570). At locality K3284, on the north side of War Eagle Mountain and south of Bridge Creek, Cambrian limestone and shale are replaced by pyrite, hematite, feldspar, and chalcedony. A copper content of 2,000 ppm was reported for one sample of mineralized rock.

High values of copper in stream sediments and rocks are most abundant in the north half of the study area, especially in the northwestern part. As mentioned previously, some of the high values shown on figure 14 may not truly be anomalous but instead may reflect the higher background copper content of Precambrian mafic and metasedimentary rocks; nevertheless, values of 700 ppm or greater are undoubtedly anomalous.

Samples that contain copper values of 20,000 ppm (F2587), 3,000 ppm (J2605), and 1,500 ppm (H2608) are shown near the center of figure 14. All three samples are from a strongly altered shear zone that is traceable from the head of Speculator Creek to the vicinity of Mill Creek Pass. Throughout most of its length, the shear zone coincides with a mafic dike that intrudes granitic gneiss. The shear zone, 100–150 ft (30–46 m) wide, weathers bright red; and the rocks within it consist of mafic dike, brecciated mafic dike and gneiss(?), and quartz veins and minor sulfide minerals. The mineralized rock consists of veinlets of pyrite, chalcopyrite, and malachite in quartz. At least some of the copper may have been leached from the mafic dike and precipitated as sulfide minerals with quartz, due to the action of hydrothermal solutions moving along the shear zone.

At locality C0573, a thin quartz vein in a mafic dike contained 7,000 ppm copper. The mafic dike intrudes Mount Cowen Gneiss.

In the northeast corner of the study area, a sample from a sulfide-bearing zone of the Stillwater Complex (locality G0611) contained 10,000 ppm copper. The zone is about 3 ft (1 m) wide, strikes N. 75°W., dips 85° N., and is traceable for approximately 200 ft (61 m) along strike. This sample also contained 3,000 ppm nickel, 0.25 ppm platinum, and 0.4 ppm palladium.

Three samples containing 1,000 ppm or more copper were collected in the northwestern part of the study area. At locality D0090, a lens of mineralized gneiss less than 1 ft (0.3 m) in length contained 1,000 ppm copper. Chalcopyrite, malachite, and azurite, have been identified at this locality. A sample of Precambrian pegmatite at locality D0103 consisted of quartz, feldspar, biotite, and a little chalcopyrite and malachite, and contained 1,500 ppm copper. At locality E0179, veinlets of quartz, calcite, and chalcopyrite and disseminated chalcopyrite in amphibolite contained 1,000 ppm copper; the outcrop is conspicuously stained by malachite.

GOLD

Occurrences of gold are known in all four of the mineralized areas in or adjacent to the study area; therefore, gold was one of the principal metals evaluated in this study. The distribution of samples that contain anomalous vaules of gold in the North Absaroka study area is shown in figure 15.

Gold was detected in about 5 percent of all samples. Maximum values were 210 ppm in rocks, 3 ppm in stream sediments, and 110 ppm in panned concentrates. As with copper and other metals, many highly anomalous gold values were in samples collected from the Emigrant–Mill Creek area and the Boulder district. Values of 1 ppm or greater were also recorded for a sample in the southwest corner of the area and for two samples in the northeastern part of the area. Lower anomalous values in the range of 0.1–0.9 ppm are in samples that occur mainly in a broad band that trends east across the central part of the study area and includes the Emigrant–Mill Creek area and the Boulder district; gold mineralization appears to have been controlled by Laramide faulting, or emplacement of Tertiary intrusive bodies, or both. Only one weakly anomalous sample was detected in the northwestern part of the study area.

In the Emigrant–Mill Creek area most samples that contain gold values of 1 ppm or greater are outside the study area. Within the study area, samples of limonite-rich breccia of highly pyritic andesite and dacite taken at S0461 and S0462 contained 210 and 7 ppm gold, respectively. Both samples are from dumps of adits on a vein-fault system that strikes N. 20° E. and dips vertically. A stream-sediment sample at locality S0239 just east of these localities contained 1.5 ppm gold.

In the Boulder district, gold values of 1 ppm or greater are in samples clustered near Independence Peak and outside of the study area. Two highly anomalous samples, however, are in the study area. A value of 13 ppm was reported for locality K3284, described in the section on copper. Another sample containing 13 ppm was collected farther north at K0563 on Carbonate Mountain. This sample consisted of brecciated and limonite-rich gneiss from a prospect pit on a shear zone that is an extension of the Elbow Creek fault (pl. 1).

Near the southwest corner of the study area, in the Sheepeater district and outside the study area, a panned concentrate from Bear Creek near the Jardine mine contained 110 ppm gold. Northwest of this locality and within the study area, a sample taken at locality U0428 contained 8 ppm gold. The mineralization occurred in a vertical limonite-stained shear zone, about 10 ft (3 m) wide, that strikes N. 45° W. Wall rocks are Precambrian thinly bedded quartzite, iron-formation, and chloritized amphibolite, an assemblage similar to that at the Jardine mine.

In the northeastern part of the study area, four samples anomalous in gold occur in or adjacent to the Stillwater–Natural Bridge area. A stream-sediment sample taken near the mouth of Froze-to-Death Creek (loc. G3046) contained 3 ppm gold. At locality G6070, a 6-in. (15-cm) quartz-limonite vein from a prospect pit contained 1 ppm gold.

LEAD

Lead is a common constituent in known deposits in or adjacent to the North Absaroka study area, principally those in the Emigrant–Mill Creek area and the Boulder district. In these deposits, lead occurs commonly with zinc and silver as sulfide minerals and less commonly with copper and gold.

The distribution of anomalous values of lead in the study area is shown in figure 16. As expected, most of the very high values of lead (1,000 ppm or more) are restricted to known deposits in the Emigrant–Mill Creek area and the Boulder district and are outside of the study area. Samples at four localities in the study area in these two areas contain 1,000 ppm or more lead. As in the case of silver, weakly anomalous values of lead show an irregular pattern of dispersion around the intrusive centers at Emigrant Creek and Independence.

In the Emigrant–Mill Creek area a sample of altered limonite-stained quartz "eye"-bearing dacite porphyry collected from a small prospect pit on the ridge above Fridley Creek (locality S4020) contained 2,000 ppm lead. A composite sample taken from dumps of two small adits exploring a fracture zone in dacite porphyry on Sixmile Creek (locality S2281) contained 1,000 ppm lead.

In the Boulder district, the two samples in the study area that contain >20,000 ppm and 1,500 ppm lead, respectively, are both from the Ski Line claim, which has been discussed previously. The higher grade sample is from a dump at locality L4075, at the bottom of the tramway, and the other is from a stope pillar at the Ski Line claim.

Evidence of lead mineralization was also found at locality E4025, at the head of Lost Creek in the northeastern part of the study area. A sample containing 20,000 ppm Pb consists of galena with pyrite and epidote in quartz. Galena also occurs in an adjacent sheared chloritized mafic dike of Precambrian age. The vertical mineralized zone is about 5 ft (1.5 m) wide, strikes about N. 35° W., and can be traced for about 50 ft (15 m) along strike. Although quartz veins and secondary epidote were observed in Precambrian gneiss over an area of several kilometers (or square miles) near the head of Lost Creek, no other evidence of mineralization or alteration was found.

Many samples containing weakly anomalous values of lead (70 to 200 ppm) appear to define broad lead anomalies in the northwestern part of the study area north and west of the West Boulder River. This region is underlain by rocks of Precambrian age, which have geometric mean contents of lead ranging from a low of 4.2 ppm in mafic rocks to a high of 17 ppm in felsic rocks, mainly gneisses (table 5). The geometric means and the distribution of anomalous values of lead shown in figure 16 suggest that these lead anomalies may be related to the Mount Delano and Mount Cowen Gneisses. However, no significant lead deposits are indicated in this part of the area.

MOLYBDENUM

Occurrences of molybdenum in or adjacent to the North Absaroka study area were previously known in Emigrant Creek, at Mount Cowen, and near Bridge Creek (Reed, 1950; Rubel, 1964). The results of the present study indicate new occurrences and more extensive anomalies of molybdenum than previously suspected. Anomalous values of molybdenum are associated with rocks of Precambrian age as well as with Tertiary intrusive rocks. Molybdenum anomalies in Precambrian rocks show a spatial association with uranium anomalies. The distribution of samples that contain anomalous values of molybdenum in the study area is shown in figure 17. Histograms in figures 11 and 17 show the frequency distribution of molybdenum in altered rocks, all rocks, and stream sediments.

Many samples with anomalous values of molybdenum are from the Emigrant–Mill Creek area, mostly clustered near upper Emigrant Creek. In the central and eastern parts of the study area, a broad belt of anomalies trends north from Independence, then northwest in the vicinity of Speculator Creek, then south to end near Mount Cowen. Anomalous values of molybdenum were detected in five samples from the extreme northern part of the area, and four in the southwestern part. Molybdenite (molybdenum disulfide) was observed in rock samples at several of these localities.

In Emigrant Creek, molybdenite occurs in a breccia pipe in dacite porphyry of the Emigrant stock. A sample of mineralized breccia from the dump at the portal of the Allison Tunnel (locality S0490), just outside of the study area, continued 2,000 ppm molybdenum. Much quartz and pyrite occur with the molybdenite in this sample. Several weakly anomalous and two strongly anomalous (100 ppm) samples were collected within the study area in the Emigrant–Mill Creek area. All are apparently related to the Emigrant stock or bordering dacite porphyry intrusives. Two samples, collected at S0452 on the east side of Emigrant Peak, contained 100 ppm molybdenum; nearby, a sample containing 5,000 ppm copper was collected. Molybdenite at this locality occurs in thin (0.1-in., or 2.5-mm) quartz-pyrite veinlets in altered dacite porphyry.

Samples collected in or near the Boulder district that contain anomalous values of molybdenum include one containing 300 ppm and several with 5–20 ppm. The highest value was in a composite sample of mineralized pyrite-rich float of dacite porphyry and quartzite of the Flathead Sandstone at locality K6087 on Bridge Creek. The bedrock source for this float was not located but is believed to be near K6087.

A molybdenite occurrence was discovered in a quartz vein about 1 in. (2.5 cm) in width in Precambrian schist on the divide between Weasel and Great Falls Creeks in the northeastern part of the study area (locality G4047). A sample of this vein contained 1,500 ppm molybdenum. Molybdenite was not recognized in other samples from this area, but anomalous values of molybdenum in both rock and stream-sediment samples define a zone with a northwest trend (fig. 17).

Molybdenite also occurs on the east side of Mount Cowen in association with quartz and felsic pegmatite at locality C2581 (fig. 21). Crystals of molybdenite as much as several inches (~ 10 cm) in diameter in quartz gangue were collected from a vug in a shear zone that cuts Precambrian pegmatite. A chip sample across 7.9 ft (2.4 m) of the shear zone contained 500 ppm molybdenum.

In the northernmost part of the area, in the vicinity of Livingston Peak, anomalous molybdenum values ranging from 7 to 50 ppm were detected in six samples collected at five localities (fig. 17). All of the samples were of limonite-rich fracture fillings or silicified breccia in Madison Limestone of Mississippian age. No other significant evidence of alteration was noted in the limestone. All these samples occur on the flanks of a prominent magnetic high (pl. 2, No. 1; pl. 3).

A cluster of three samples that contain anomalous values of molybdenum near the south edge of the area of figure 17 may be related

FIGURE 21.—Vug containing large crystals of molybdenite (black, shiny material to right of 15-cm scale) in granitic gneiss, east face of Mount Cowen at locality C2571. This vug is associated with vein quartz emplaced along a thin shear zone.

to welded ash-flow tuffs of the Slough Creek Tuff Member of the Mount Wallace Formation or to intrusive dacite porphyry in the vicinity (pl. 1). Several anomalous values of molybdenum also occur in similar rocks in the adjacent Absaroka study area (Wedow and others, 1975). These anomalous values lie on the flank of a weak magnetic high (pls. 2 and 3).

PLATINUM-GROUP METALS

PGM (platinum-group metals) occur in anomalous amounts in the Stillwater-Natural Bridge area in the northeast corner of the North Absaroka study area. The significant mineralization in PGM was restricted entirely to the Stillwater Complex of Precambrian age. Two zones of PGM occurrences are known, one at the base of the complex in association with nickel and copper and the other several thousand feet (meters) stratigraphically above the base. This upper zone contains major resources of PGM in the vicinity of the West Fork Stillwater River (Engineering and Mining Journal, 1975).

A total of 36 rock and stream-sediment samples were analyzed for PGM; most of these were from the northeastern part of the study area. Platinum-group metals were detected in 26 samples, as shown in table 6; palladium was detected in all of these samples, platinum in 6, rhodium in only 2, and ruthenium and iridium in none. Values believed to be significant were found in only two rock samples and four stream-sediment samples.

Only one rock sample is believed to be significantly mineralized with PGM in the study area. Sample G0611A is of sulfide-bearing anorthosite from the Stillwater Complex, and is from a zone 3 ft (1 m) wide striking N. 75° W. and dipping 85° N. In addition to the PGM content given in table 7, the sample contained 10,000 ppm copper and 3,000 ppm nickel. This zone thus is higher in nickel and copper and lower in PGM than the PGM-bearing upper zone on the West Fork of the Stillwater River but may be the lateral equivalent of that zone or of a parallel zone stratigraphically near the higher PGM zone. A sample of a metadolerite dike near the West Boulder River (locality E020A) contained anomalous platinum and palladium but is not believed to be significantly mineralized with PGM.

Several stream-sediment samples taken near the northeast corner of the study area contain significant values of PGM. However, only one sample, G0612A, taken from a small stream that drains the area of the sulfide zone sampled at locality G0611, is from the study area. This sample contained 1.2 ppm platinum and 0.03 ppm palladium as well as 150 ppm copper, 1,500 ppm chromium, and 100 ppm nickel. Other anomalous samples shown in table 7 include G1001A from a small stream north of Graham Creek on the east side of the Boulder River,

TABLE 6.—*Platinum-group metals (PGM) in rocks and stream sediments, North Absaroka study area*

[Combined fire assay-spectrographic analysis by R. R. Carlson, T. A. Doerge, and E. F. Cooley. Results shown are in ppm. N(0.010), not detected at the stated limit of detection. Limits of detectability for a 15-g sample: platinum, 0.005 ppm; palladium, 0.001 ppm; rhodium, 0.002 ppm]

Field No.	Sample type	Platinum	Palladium	Rhodium
A0141A	Amphibolite------	N(0.005)	0.002	N(0.002)
B0167A	----do-----------	N(0.005)	.002	N(0.002)
E0179A	----do-----------	N(0.005)	.002	N(0.002)
E0179B	----do-----------	N(0.005)	.002	N(0.002)
E0180A	----do-----------	N(0.005)	.002	N(0.002)
E0201A	Gneiss-----------	N(0.005)	.002	N(0.002)
E0202A	Metadolerite-----	.02	.02	N(0.002)
F0044A	Dolerite---------	N(0.005)	.002	N(0.002)
G0611A	Anorthosite------	.25	.4	.06
G6056A	Metadolerite-----	N(0.002)	.007	N(0.002)
G0612A	Stream sediment--	1.2	.03	N(0.004)
G1000A	----do-----------	N(0.005)	.002	N(0.002)
G1001A	----do-----------	.01	.01	N(0.004)
G1002A	----do-----------	.025	.01	N(0.01)
G3040A	----do-----------	N(0.005)	.002	N(0.002)
G3242B	----do-----------	N(0.002)	.003	N(0.002)
G3243A	----do-----------	N(0.002)	.002	N(0.002)
G3247A	----do-----------	N(0.002)	.002	N(0.002)
G3256A	----do-----------	N(0.004)	.005	N(0.004)
G3267A	----do-----------	N(0.004)	.002	N(0.004)
G3268A	----do-----------	N(0.002)	.002	N(0.002)
G6057A	----do-----------	N(0.002)	.002	N(0.002)
G6058A	----do-----------	N(0.002)	.002	N(0.002)
G6058B	----do-----------	N(0.002)	.002	N(0.002)
H1005A	----do-----------	.015	.03	.005
H1006A	----do-----------	N(0.025)	.015	N(0.01)

G1002A from Graham Creek, and H1005A from an unnamed tributary on the east side of the Boulder River.

SILVER

Silver is one of the principal metals known to be present in deposits in both the Emigrant–Mill Creek area and the Boulder district, where it usually occurs with lead, zinc, copper, and gold. Silver is not abundant in either the Sheepeater district or the Stillwater–Natural Bridge area

TABLE 7.—*Uranium and thorium contents, in ppm, of 53 stream-sediment and 18 rock samples from the North Absaroka study area that contain anomalous amounts of uranium (≥50 ppm)*

[Analyses by neutron activation methods by H. T. Millard, A. J. Bartel, and D. A. Bickford. Limits of detection are 0.1 ppm for uranium and 1.0 ppm for thorium for Th:U of approximately 3 or more. The limit of detection for Th increases as the Th:U decreases. N, below limit of detection]

Field No.; Sample type[1]	X-coordinate	Y-coordinate	U (ppm)	Th (ppm)
148; S	33800	92400	24	29
149; S	37700	90800	127	N
152; S	36700	90300	30	22
729; S	40700	94800	76	58
731; S	42000	92900	26	30
B2455; S	52600	73800	16	15
C2571; S	44800	71800	94	56
C2752; S	44600	72100	14	15
E2203; S	61200	78100	21	16
E2249; S	56100	77200	15	49
E4027; S	54700	84500	33	26
F0012; S	44700	75900	15	11
F0018; S	47100	75100	13	14
F0034; S	49600	76600	24	18
F2002; S	44300	77700	24	20
F2010; S	49300	77300	42	35
F3274; S	48300	82300	61	54
F3275; S	48200	81700	83	36
F6090; S	51100	92200	25	N
H0533; S	48300	87400	44	32
H0540; S	49700	91200	12	14
H0601; S	45000	86000	24	66
H0602; S	44700	85000	17	N
H0603; S	45200	87200	27	23
H0604A; S	45400	93100	17	24
H0604B; S	45400	93100	20	25
H0605; S	44300	92500	19	18
H1017A; S	42900	92300	88	52
H1017J; S	42900	92300	56	76
H1017K; S	42900	92300	64	46
H3233A; S	44500	84700	24	32
H3233B; S	44500	84700	39	22
H3233C; S	44500	84700	18	29
H3234A; S	44800	85400	142	61
H3234J; S	44800	85400	427	N

TABLE 7.—*Uranium and thorium contents, in ppm, of 53 stream-sediment and 18 rock samples from the North Absaroka study area that contain anomalous amounts of uranium (≥50 ppm)*—Continued

Field No.; Sample type[1]	X-coordinate	Y-coordinate	U (ppm)	Th (ppm)
H3236A; S	45900	88900	236	N
H3236J; S	45900	88900	347	N
H3237A; S	45900	89400	17	31
H3237J; S	45900	89400	13	44
H3238A; S	45900	90600	35	39
H3238J; S	45900	90600	22	34
H3280; S	43300	89900	66	72
H6052; S	44200	83500	48	N
H6053A; S	45000	86400	19	40
H6053B; S	45000	86400	55	37
J0607A; S	40500	92500	282	84
J0607B; S	40500	92500	324	115
J1019; S	40700	92300	79	52
K1023; S	37700	90800	35	42
K1024; S	36200	90300	17	22
K1028; S	34000	90200	282	84
L4072; S	28400	94700	11	18
S0456; S	31000	58000	24	17
1930; G	36500	92200	12	107
1939; G	38100	92500	24	112
1940; G	38900	93100	14	110
C0495; G	44000	69800	4	58
C2571; P	44800	71800	37	19
C2572; A	44600	72100	14	30
F0521; G	50000	75200	2	52
F2604; B	43200	79900	13	6
H0527; Gr	47300	85200	6	81
H0600; G	44400	93100	10	N
H2616; G	46500	85300	5	53
H3277; G	42400	87600	12	66
H3278; G	42300	88700	3	60
H6067; G	44200	88900	3	71
H6077; G	44200	90000	5	74
J0553; Gr	40400	96900	8	60
J0608; G	38900	93100	13	91
J0609; M	38700	93200	96	748

[1] S, stream sediment; G, gneiss; P, pegmatite; A, amphibolite; B, breccia; Gr, granite; M, dark mineral zone in gneiss.

and therefore seems clearly to be confined to mineral deposits associated with Tertiary intrusive centers. Histograms of silver values in altered rocks, all rocks, and stream sediments are shown in figures 11 and 18. The distribution of samples that contain anomalous values of silver in or adjacent to the study area is shown in figure 18. Silver values are more widely dispersed about the volcanic centers at Emigrant Creek and Independence Peak than are those for copper and gold.

In the Emigrant area, most samples containing silver values of 20 ppm or greater lie outside of the study area and are at or near known deposits. Within the study area, a sample of limonite-rich breccia taken at locality S0461 contained 70 ppm silver. This sample was from the dump of an adit along a vein-fault system described previously in the section on gold.

In the Boulder district, many of the samples containing 20 ppm or more silver are from the principal area of mining near Independence Peak, outside the study area. Within the study area, a sample from the dump of a prospect adit at locality L0567 contained 20 ppm silver. The adit is along a N. 70° W.-trending vertical fracture system in Tertiary monzonite close to the contact with Precambrian gniess to the east. A sample at locality L4075 that contained 70 ppm silver is of the same dump material described previously from the Ski Line claim in the section on copper. A sample taken at locality K0552, near the east edge of the study area, contained 30 ppm silver. This sample is from a fracture zone of limonite-stained Precambrian gneiss trending N. 40° E. and dipping 80° SE.

In the north half of the study area, weak silver anomalies are scattered without much consistent pattern that can be related to geology or geophysics. However, a group of seven samples in the extreme north part, in the vicinity of Livingston Peak, contains weakly anomalous values of silver (0.5–5 ppm) and forms a coherent group that is spatially related to a strong magnetic high (pl. 2, No. 1; pl. 3).

URANIUM

Although a few minor occurrences of uranium were previously known in the study area, the location, extent, and magnitude of uranium anomalies that were found during this study were mostly unsuspected. A total of 82 rock and 94 stream-sediment samples were analyzed for uranium and thorium by neutron activation techniques. Of these, 12 percent of the rock samples and 56 percent of the stream-sediment samples contained 10 ppm or more uranium. Histograms for uranium and thorium in rocks and stream sediments from the North Absaroka study area and in rocks from the Beartooth Primitive Area and vicinity are shown in figure 13. The histograms do not accurately reflect the distribution of uranium and thorium in the study area because a disproportionate number of samples were collected from parts of the area known to contain anomalous amounts. Therefore, threshold values cannot be statistically determined. In the preparation of the uranium anomaly map, a threshold value of 9 ppm was arbitrarily chosen.

Most of the rock samples that were analyzed for uranium and thorium are Precambrian gneiss from the northern and eastern parts of the area and, as would be expected, thorium is generally higher than uranium. Histograms for rock samples from the Beartooth Primitive Area and vicinity (F. S. Simons, unpub. data) show generally lower uranium values and a more restricted range of both uranium and thorium. Histograms showing the distribution of uranium and thorium in stream sediments from the North Absaroka study area indicate a considerable enrichment of uranium relative to thorium, probably because of the greater geochemical mobility of uranium during weathering.

The locations of samples which were analyzed for uranium and thorium are shown in figure 19, and stream-sediment and rock samples that contained anomalous amounts of uranium and thorium are shown in table 7. Stream sediments anomalous in uranium seem to define a broad belt that trends northwesterly from the vicinity of Hawley Mountain to Speculator Creek and towards the West Boulder River. Rocks containing 10 ppm or more uranium occur near the southeast end of this belt.

Very high values of uranium were detected in stream-sediment samples at several locations. Duplicate samples collected at J0607 (fig. 19, No. 1) on an unnamed stream that drains an area on the southwest side of Hawley Mountain contained 282 and 324 ppm uranium, respectively. Samples from two small tributaries on the north side of Speculator Creek at locality K3234 (fig. 19, No. 2) contained 142 and 427 ppm uranium, respectively. Duplicate samples from another south-flowing tributary at K3236 (fig. 19, No. 3) contained 237 and 347 ppm uranium, respectively.

The bedrock source of the uranium anomalies is not clear. Minor or accessory uranium-bearing minerals have been identified in rocks from several localities, but it is questionable that these occurrences can account for the magnitude and extent of the uranium anomalies in stream-sediment samples. Nearly all of the anomalous values in stream sediments occur in areas underlain by Precambrian granitic gneiss, principally Falls Creek Gneiss; and rock samples containing anomalous concentrations of uranium are nearly all of granitic gneiss. At least some of the uranium and thorium may be in the mineral allanite. Thin-section study of a sample of gneiss from locality 1930 indicates a content of 1.1 percent allanite (T. J. Armbrustmacher, written commun., 1975), and a rock sample from this locality contained 12 ppm uranium and 107 ppm thorium. Allanite was also noted in a sample of gneiss containing 11 ppm uranium and 66 ppm thorium from locality H3277.

A rock sample collected at locality J0609 (fig. 19, No. 4) contained 96 ppm uranium and 748 ppm thorium, the highest for both elements of any rock sample in the study area. This sample was taken from a layer of dark minerals about 6 in. (15 cm) thick that is interlayered with and parallel to the foliation in granitic gneiss (fig. 22). The sample contains about 50 percent dark minerals, mainly biotite, together with quartz and minor feldspar, and it is magnetic, indicating the presence of magnetite. Thin-section and X-ray studies indicate the presence of sphene (altered and partially metamict), a black metamict mineral that may be allanite, apatite, zircon, monazite, magnetite, pyrite, and molybdenite. The sphene is highly radioactive and may be the host for much of the uranium and thorium. This and other similar layers of dark minerals in gneiss may be the bedrock source of the anomalous uranium values in samples from locality J0607.

Another radioactive mineral has been identified in a sample from locality C2581 (fig. 19, No. 5). Crystals of a black metallic mineral as much as 2 in. (5 cm) across occur disseminated in felsic pegmatite that is intrusive into Mount Cowen Gneiss. X-ray analysis indicates that

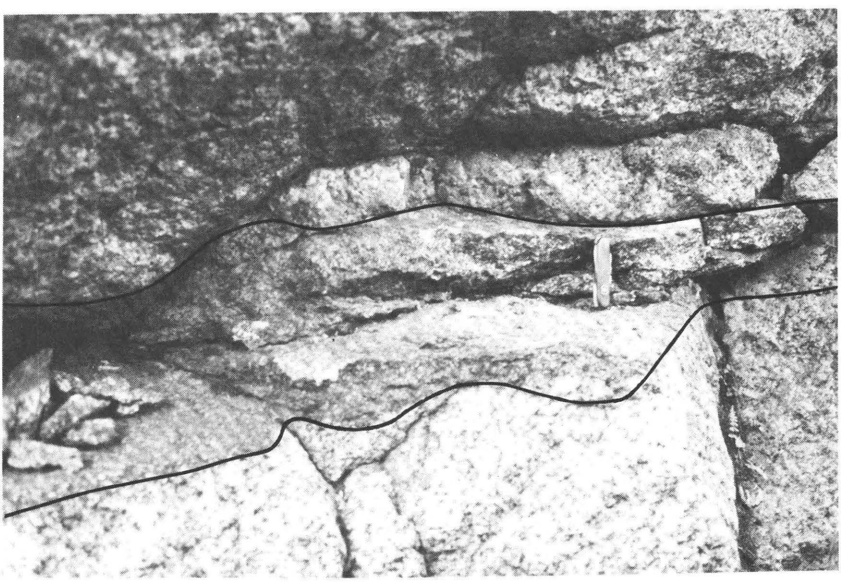


FIGURE 22.—Biotite-rich zone (outlined by dashes) in granitic gneiss that contains anomalous concentrations of uranium and thorium, locality J0609 (approximately 1 mi (1.6 km) west of Hawley Mountain). A sample of this zone contained 96 ppm uranium and 748 ppm thorium.

these crystals consist principally of ilmenorutile that contains minor euxenite, the probable source of the radioactivity and uranium.

Private industry has explored recently for uranium in at least a 60-mi^2 (155-km^2) area in the vicinity of Boulder Plateau, Speculator Creek, and Mount Douglas. County courthouse records show that about 200 mining claims in four groups in this area have been located by Johns-Manville Corp. Anomalies of interest have been found in stream and alluvium samples, but exploration has not identified bedrock deposits. The uranium is presumed to occur either disseminated or as fracture filling in the Precambrian gneiss that underlies the area. Hence, the area of uranium potential shown in figure 1, area No. 5, is probably somewhat larger than shown.

ZINC

In the North Absaroka study area, zinc is commonly present as sphalerite, and it is associated with other metals such as lead and silver in sulfide deposits, particularly those in the Emigrant–Mill Creek area. Zinc was detected in 2.5 percent of rock and 2.2 percent of stream-sediment samples. Background and threshold values could not be determined because of the high detection limit (200 ppm) by the spectrographic method used in the analysis for zinc; however, samples containing 200 or more ppm zinc are considered anomalous.

The localities of samples containing anomalous values of zinc and histograms showing the distribution of zinc in rocks and stream sediments are shown in figures 11 and 20. The distribution of zinc anomalies correspond to those of lead and silver. Most samples containing anomalous zinc are from the Emigrant–Mill Creek area, at or near known mineral deposits; a few anomalous samples are from the Boulder district and several are from the northern part of the study area.

Zinc anomalies that are the result of Tertiary mineralization occur in the Emigrant–Mill Creek area and the Boulder district.

In the Emigrant–Mill Creek area, samples containing 500 or more ppm zinc are mostly outside of the study area. Two strongly anomalous (1,000 or more ppm zinc) and several weakly anomalous (200–300 ppm zinc) samples are from the study area. At locality S0494, a mineralized sample from the dump of an adit developed along quartz veins in Precambrian schist at or near the Precambrian-Cambrian contact contained 1,000 ppm zinc. At locality S2281, a composite sample of altered and mineralized dacite intrusive breccia from the dumps of two adits contained 2,000 ppm zinc. In the Boulder district several mineralized samples containing 200–700 ppm zinc are distributed north and northwest of Independence.

Several samples in the northern part of the study area and one west of Mount Cowen, that contain anomalous zinc, were apparently not produced by Tertiary mineralization or intrusive activity. One sample (locality F0056) of chloritized Precambrian amphibolite with quartz, pyrite, and hematite that is interlayered with gneiss and quartz lenses contained 1,000 ppm zinc. The other anomalous samples have zinc contents of 200–500 ppm; one of these (A0187A) is a stream sediment, another (D2085A) is from Cambrian limestone, and the remainder are from Precambrian rocks. The significance, if any, of these anomalous samples could not be determined; however, the clustering of all but one of these samples in the northern part of the study area suggests a common origin for the zinc.

OTHER METALS

A number of other metals, including arsenic, beryllium, bismuth, cobalt, chromium, iron, mercury, nickel, tin, and tungsten occur locally in anomalous concentrations in the North Absaroka study area, but none of these occurrences are believed to be indicative of potential economic deposits of these metals.

Arsenic is a common constituent in the gold ore of the Sheepeater (Jardine) district and was produced during mining there. In this study, 14 samples were found to contain detectable arsenic in the range 300–5,000 ppm. The majority of these samples are from either the Emigrant–Mill Creek area or the Boulder district and are of sulfide ores that contain lead, silver, gold, bismuth, and in one case, mercury.

Anomalous concentrations of beryllium were determined in 36 samples in amounts ranging from 3 to 20 ppm beryllium. Approximately one-third of these samples are spatially related to the intrusive centers at Emigrant Creek and Independence, and the remaining two-thirds are scattered through the Precambrian terrain in the north half of the study area. None are believed to have economic significance.

Eighteen samples contained anomalous values of bismuth in the range of 10 to greater than 1,000 ppm. These samples are almost totally restricted to either the Emigrant–Mill Creek area or the Boulder district, where the bismuth is in sulfide ores containing gold, silver, copper, arsenic, and (or) tungsten. Twelve of the anomalous samples are from the vicinity of the Emigrant stock. Bismuthinite was observed in veins with scheelite, galena, and chalcopyrite at locality P0488, near Arrastra Creek.

Values of cobalt in the range 100–300 ppm were contained in 17 samples. A few high values are related to sulfide mineralization of Tertiary age, but most of them are from mafic and ultramafic rocks of Precambrian age and are not indicative of economic mineralization. The median value of cobalt is much higher in stream sediments than in rocks (table 4), indicating enrichment in stream sediments; probably in the form of ferromagnesian minerals. Chromium and nickel also show appreciable enrichment in stream sediments.

High values of chromium, mostly in the range 700–1,500 ppm, were determined in 42 samples. One stream-sediment sample containing more than 5,000 ppm chromium was collected at locality G1002 near the Gish mine on the east side of the Boulder River. High chromium values are mostly from samples of Precambrian mafic dikes and sills and of stream sediments derived from Tertiary volcanic rocks, particularly near Independence and the head of Mill Creek.

Several occurrences of iron-formation of Precambrian age are known in the study area, but we believe all to be too low grade or too small to be significant as resources of iron. The thickest sequences of iron-formation are on the west side of the Boulder River between Great Falls and Falls Creeks. The iron-formation is as much as several hundred meters thick and consists of interlayered rocks rich in quartz, magnetite, pyroxene, and olivine (Page and Nokleberg, 1974). Another occurrence of iron-formation is in the north part of the study area in the Mission Creek drainage area. At locality D0093, on the top of a narrow ridge, a 20-ft (6-m) bed of iron-formation is interlayered with marble, schist, and amphibolite of the "nappe core" group of Precambrian age. The entire sequence has a foliation that strikes about N. 70° E. and dips 60° N. Selected grab samples of iron-formation contained 18–48 percent iron (M. S. Erickson, unpub. data). Significant resources of iron are present in a contact metasomatic deposit near Bridge Creek. (See Chapter C.)

Anomalous mercury values of 0.5–12 ppm were determined in 17 samples. Many of these samples came from the Emigrant–Mill Creek area and the Boulder district. In the northeastern part of the study area, a sample of gold-arsenic-tungsten ore from a dump at locality G3246 contained 12 ppm mercury.

Fourteen samples contained from 200 to 3,000 ppm nickel. The only economically significant value (3,000 ppm at locality G0611) was from sulfide-bearing anorthosite that also contained copper and PGM. Most high nickel values occur in mafic and ultramafic rocks of Precambrian age, but a few are from Tertiary volcanic rocks.

Anomalous amounts of tin, in the range 10–20 ppm, occurred in seven samples. These samples are from scattered localities and no significant geochemical or geological associations could be determined.

Anomalous values of tungsten, in the range 50–3,000 ppm, were determined in six samples. A sample at locality P0488 that contained 3,000 ppm tungsten also contained scheelite, bismuthinite, galena, and chalcopyrite. A mineralized sample from a dump at locality G3246 contained 1,000 ppm tungsten as well as some gold, arsenic, and mercury. At locality F0522, a sample of pyritic gneiss with quartz veins contained 1,000 ppm tungsten and 15 ppm molybdenum. Three other samples from the same locality contained no detectable tungsten or molybdenum but one contained 5 ppm beryllium.

PETROLEUM, NATURAL GAS, AND COAL

Oil and gas have not been recovered in commercial quantities anywhere in the study area or adjacent areas. Exploratory holes have been drilled in the Crazy Mountains syncline north of the study area but none were successful (Richards, 1957). The study area contains neither favorable structure nor good reservoir rocks for the accumulation of oil or gas. Potential hosts for oil and gas, the Paleozoic and Mesozoic sedimentary rocks, have been uplifted, tilted, folded, fractured, and locally intruded by Tertiary igneous rocks; therefore, it is unlikely that accumulations of oil and gas occur in the study area.

Coal occurs in beds of Late Cretaceous age, chiefly the Eagle Sandstone, in areas peripheral to the North Absaroka area. Coking coal was mined near Cokedale, 7 mi (11 km) west of Livingston, prior to 1908 (Richards, 1957), and in the Electric coal field 2–6 mi (3–10 km) northwest of Gardiner (Fraser and others, 1969) from coal beds in the Eagle Sandstone. The absence of Eagle Sandstone from the study area precludes the presence of coal deposits in the area.

CONSTRUCTION MATERIALS

The North Absaroka study area contains large deposits of limestone, principally the Madison Limestone, which may be used for the manufacture of cement, and deposits of sand and gravel; but similar deposits are more readily accessible outside of the study area.

Some of the Precambrian rock of the study area, particularly the more massive gneiss and the green variety of quartzite, would make acceptable building stone; but stone of equal or superior quality is available at more accessible locations outside of the study area.

POTENTIAL FOR MINERAL RESOURCES

The results of geochemical sampling combined with geologic observations and mapping and geophysical interpretations indicate several areas of low to high potential for the occurrence of mineral deposits in the North Absaroka study area. Areas of potential for deposits containing copper, molybdenum, gold, silver, lead, zinc, platinum group metals, nickel, uranium, or combinations thereof are indicated in figure 1.

The Emigrant–Mill Creek area (fig. 1, No. 1) has high potential for the occurrence of deposits of copper or of copper-molybdenum, and moderate potential for deposits of gold, silver, lead, and zinc. Although much of this region is outside the study area, our results indicate that mineral deposits may also exist within the study area. The mineralization and alteration in this area were centered on the Emigrant stock, and the stock coincides with a prominent magnetic high and a gravity low (pls. 1, and 2). The magnetic high is much larger than the surface exposures of the stock, suggesting that the stock may enlarge downward. Granodiorite porphyry exposed at the deepest level of erosion contains high-temperature, high-salinity fluid inclusions similar to those in major copper-porphyry deposits. Metal zonation revealed by known deposits and geochemical anomalies suggests that the potential for copper or copper-molybdenum deposits is highest within the Emigrant stock, whereas the potential for deposits of gold, silver, lead, and zinc extends beyond the borders of the stock into the country rocks.

The Boulder (Independence) district (fig. 1, No. 2) has moderate potential for deposits containing gold and copper and low potential for deposits of silver. The two most important types of deposits in this district are pyritic silver-rich gold deposits in granodiorite of the Independence stock and copper-gold replacement deposits in Cambrian sedimentary rocks. The pyrite-gold deposits were the principal type worked in the past and they are outside of the study area, whereas the copper-gold deposits occur in the study area in the vicinity of Bridge Creek. The Independence stock is on the axis of the Cooke City structural zone and coincides with a prominent magnetic high and the nose of a gravity high (pl. 2). Geologic evidence suggests that only a small part of the stock has been removed by erosion. The pyrite-gold deposits have been worked only near the surface, and their possible extension into the subsurface in the intrusive rocks is untested. Comparisons with known copper-porphyry deposits suggests that more copper-rich ores may be found at depth in the Independence stock.

The Precambrian Stillwater Complex is exposed in the northeast corner of the study area (fig. 1, No. 3). This area has high potential for the occurrence of deposits of platinum group metals, copper, and nickel. East of the study area, low-grade copper-nickel deposits are known to occur in the basal zone of the complex, and significant concentrations of PGM occur in a zone in the complex several thousand feet (meters) above its base. Geologic mapping and geochemical sampling indicate the presence of both these zones in the study area.

The Livingston Peak area (fig. 1, No. 4) has been little explored in the past but has a low to moderate potential for deposits of copper and possibly other metals. A conspicuous magnetic high centered just east of Livingston Peak (pl. 2, No. 1) probably indicates a Tertiary pluton in the subsurface, although it may reflect a downfaulted segment of the Stillwater Complex. This anomaly is similar in shape and magnetic relief to anomalies associated with the Emigrant and Independence stocks (pl. 2, Nos. 4 and 8). A partly defined positive gravity anomaly associated with this magnetic high suggests a source material of intermediate to mafic composition possibly more similar to the Independence stock than to the Emigrant stock. Slightly anomalous amounts of copper, silver, and molybdenum were detected in samples, mostly from fracture zones; but surface exposures provide little evidence of mineralization and none of alteration in this area. Anomalies of these metals are common around Tertiary intrusive centers in the study area. If the geophysical and geochemical anomalies are associated with an unexposed Tertiary pluton, then some potential for copper deposits exists, inasmuch as the Precambrian rocks of this area have a very high background copper content and would be excellent source rocks for copper. Copper could have been mobilized by heat and hydrothermal solutions and then incorporated in the intrusive as porphyry-type deposits or concentrated in the country rocks adjacent to such an intrusive.

The Hawley Mountain–West Boulder area (fig. 1, No. 5) is a northwesterly trending zone extending from near Hawley Mountain on the east side of the study area to the vicinity of the West Boulder River in the north-central part of the study area. This area has low potential for the occurrence of molybdenum and uranium resources. Weak geochemical anomalies of molybdenum in rocks and stream sediments and of uranium in rock samples, and a strong uranium anomaly in stream-sediment samples occur along this zone. This area is on the northern flank of a northwesterly trending magnetic high (pl. 2) that is believed to reflect the subsurface extension of the Falls Creek Gneiss, a Precambrian intrusive mass. The molybdenum and uranium anomalies probably reflect a weak mineralization that is genetically related to the gneiss and concentrated in its border zone. The mineralized rock would subsequently have been modified by metamorphism that affected the entire region.

The area adjacent to the Sheepeater (Jardine) district (fig. 1, No. 6) in the southwestern part of the study area has low potential for gold deposits of the Jardine type. Anomalous gold values were determined at one locality (U0428) in this area in rocks lithologically similar to those containing the gold deposits at the Jardine mine. Arsenic and tungsten are potential byproducts of Jardine-type gold deposits.

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Geophysical Interpretations

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By DONALD L. PETERSON, U.S. GEOLOGICAL SURVEY

MAGNETIC AND GRAVITY SURVEYS

The aeromagnetic data are from two surveys; one flown in 1967 and the other in 1972. Both surveys were flown at a barometric elevation of 13,500 ft (4,115 m) above sea level. In the 1967 survey, flight lines were north-south and approximately 1–2 mi (1.6–3.2 km) apart; data were reduced to an arbitrary datum and are compiled as total-intensity contours (pl. 2). The 1972 survey covered only the extreme northern part of the study area, bounded by lat 45°30′ and 45°38′30″N. and by long 110°15′ and 110°30′ W. The survey was flown in an east-west direction with flight lines about 1 mi (1.6 km) apart. Total-intensity magnetic measurements were made with continuously recording fluxgate magnetometers. The 1972 data were referenced to a specific datum of 57,830 gammas; a regional trend of 2.15 gammas per km north and 3.65 gammas per km east was removed using the 1965 International Geomagnetic Reference Field (Fabiano and Peddie, 1969) updated to 1972, and the data were compiled as residual contours (pl. 2).

Most of the gravity data were collected during field work in 1973–1974 by the U.S. Geological Survey. These data were supplemented by data obtained from the Department of Defense Gravity Library in order to compile the Bouguer gravity map at a contour interval of 5 mGal (milligals) (pl. 2). Vertical and horizontal positions for most of the gravity stations are from benchmarks or other elevations shown on U.S. Geological Survey topographic maps at scales of 1:24,000 and 1:62,500. Vertical positions for a few stations were interpolated from map contours. These stations may be in error by 50 ft (15.2 m), which would change the Bouguer anomaly by about 3 mGal. Observed gravity values were referenced to the North American Gravity Control Network at station WA 122, Billings, Mont. (Behrendt and Woollard, 1961). Theoretical gravity was computed from the International Formula. The gravity stations were corrected for terrain out to a distance of 103.6 mi (166.7 km) on a digital computer by a method described by Plouff

(1966). A density of 2.67 g/cm^3 was assumed for the material between sea level and station elevations in reducing the data to the complete Bouguer anomaly.

For a discussion of geophysical anomalies and geologic features outside the boundary of the study area, see Wedow and others (1975), and Simons and others (1973).

Plate 2 shows contours of aeromagnetic and gravity data in relation to geology. The anomalies discussed in the text are identified by numbers on plate 2.

Extreme variations in topographic relief and the generally high magnetic intensity of the Tertiary volcanic rocks, which are widespread in the area, make interpretations somewhat questionable; and only magnetic anomalies believed to have the greatest geologic significance are discussed.

The gravity data are considered to be only of reconnaissance quality because of the wide spacing of stations, extreme topographic relief, and uncertainties of some of the vertical positions. Therefore only a generalized discussion of the gravity data will be presented. The estimated accuracy of the Bouguer anomalies is considered to be about 3 mGal.

DISCUSSION

The geophysical anomalies revealed by the contouring are relatively complex. Some of the anomalies can be correlated with intrusive rock, structural features, and topography; other anomalies suggest concealed intrusive rock, variation in the magnetic mineral content of rock bodies, or other features.

A prominent magnetic high (pl. 2, No. 1) of about 200 gammas amplitude, is located 2 mi (3.2 km) east of Livingston Peak in the northern part of the study area. The anomaly is approximately on trend with a linear anomaly (No. 2) which is probably associated with the Precambrian Stillwater Complex. Only the northwest end of this Stillwater anomaly is present in the study area. Magnetic anomaly 1 is separated from magnetic anomaly 2 by a magnetic gradient zone which continues south-southwesterly, between magnetic anomalies 11 and 12 (pl. 2). The gradient zone coincides with the West Boulder fault, which has been mapped through this area. The causative source of anomaly 1 is uncertain. It may reflect a northwestern downfaulted extension of the Stillwater Complex, or perhaps, more likely, it may reflect a Tertiary pluton in the subsurface. The anomaly has similarities in shape and magnetic relief to anomalies 4 and 8, which are known to be associated with eruptive centers of Tertiary igneous rock. A partly defined gravity anomaly (pl. 2, No. 3), with about 20 mGal of positive relief, coincides with magnetic anomaly 1, which suggests a source material of intermediate to mafic composition. A 22-ft (6.6-m) thick bed of iron-formation, which dips 60° N., is exposed near the peak of anomaly 1 but is not believed to be magnetic enough or massive enough to produce either anomaly.

A belt of magnetic and gravity anomalies crosses the study area in an east–west direction at lat 45°15′ N. A large, east–west-oriented magnetic high (No. 4), with twin peaks, is located at the west end of the belt. This high is interpreted to reflect the Emigrant stock and its subsurface extensions. The steep magnetic gradients bounding most of the anomaly probably delineate the extent of the pluton in the subsurface. A low-amplitude, negative gravity anomaly (pl. 2, No. 5) coincides with the magnetic high. The gravity low suggests that the stock consists of less dense material than the enclosing country rock; measurements of specific gravity indicate that the intrusive rocks have an average specific gravity of about 2.7 g/cm^3, whereas the country rocks, mostly Precambrian in the subsurface, have an average specific gravity of about 2.9 g/cm^3.

A north-northeast-oriented magnetic high (pl. 2, No. 6), with almost 300 gammas of closure, is located 5 mi (8 km) east of anomaly 4. The anomaly may reflect a concealed volcanic plug or other stocklike body. The steepness of the gradients associated with the anomaly suggest a source at or near the surface. A gravity high (pl. 2, No. 7), which is indicated by only two stations, coincides approximately with the magnetic high; however, the peak of the gravity high is displaced about 1 mi (1.6 km) west of the magnetic peak. This suggests either that the inferred body may dip westward with the roots or main mass of the body underlying the gravity peak, or that there is a large variation in the distribution of magnetic minerals within the body. The gravity high also suggests that the inferred body is probably more mafic in composition than the Emigrant stock.

A pronounced magnetic high (pl.2, No. 8) is located at the southeast edge of the study area. It has an amplitude greater than 300 gammas and is located over the Independence volcanic center. The anomaly is probably centered over the roots of a volcano. The strongest part of the anomaly, that enclosed by the 3,000-gamma contour, coincides with the most mafic part of the Independence intrusive complex, which grades from syenogabbro in the south to granodiorite in the north. The east-west-alined upper part of the anomaly may be partly a result of topography. A gravity high (pl. 2, No. 9) is indicated by the westward nosing of the −195-mGal contour over the volcanic center.

A broad northwest-trending magnetic high crosses part of the study area and coincides approximately with a belt of Precambrian gneiss. Magnetic anomalies 10, 11, and 12 are superimposed on the broad high. A two-dimensional model was constructed across the broad anomaly, passing through anomaly 11, in order to determine if the Precambrian gneiss, along with topography, was producing the anomalies. The gneiss was extended downward to sea level and given a magnetic susceptibility of 1.53×10^{-3} emu, as determined by L. A. Anderson (*in* Simons and others, 1973) from an area a few miles to the east. The anomalies could not be matched and the results indicated that a higher magnetic susceptibility would be required. Anomaly 12 coincides with the exposures of the Precambrian Mount Cowen Gneiss of Reid and others (1975). Anomalies 10 and 11 may be related to the Precambrian Falls Creek Gneiss of Reid and others (1975). Anomalies 11 and 12 are located over topographically high areas and are believed to be at least partly due to topography. The peak of anomaly 10 is over a low valley. Along the east edge of anomaly 10, the contour lines are bowed northward over a high ridge. The anomaly is believed to in part reflect high topography, but also may reflect an anomaly-producing body.

It is possible that magnetic anomalies 10, 11, and 12 reflect individual stocklike bodies that are downward continuations of the exposed gneisses. Magnetic anomalies 10 and 11 are associated with a subtle gravity low (pl. 2, No. 13), which is indicated by the gently northwesterly nosing of the contours. If both anomalies do reflect igneous bodies, the gravity low suggests that they may be of similar composition or are parts of the same body. Anomalies 11 and 12 are separated by the magnetic gradient which has been interpreted to reflect the West Boulder fault zone. A low-amplitude gravity high (No. 14) coincides with magnetic anomaly 12, suggesting that the source may consist of more mafic material than that responsible for anomalies 10 and 11. This inference is substantiated by geologic observations that the Mount Cowen Gneiss generally contains a higher percentage of mafic minerals, mainly biotite, than the Falls Creek Gneiss.

The broad magnetic high extends eastward beyond the study area into the Beartooth Primitive Area, where L. A. Anderson (*in* Simons and others, 1973) postulated that the anomaly could not be produced solely by surface rocks and topography but must be caused by a deep-seated magnetic body. Until further evidence becomes available, no firm conclusions can be made regarding the nature of the magnetic source rock of the broad magnetic high and anomalies 10, 11, and 12.

An east-west trending gravity gradient (pl. 2, No. 15) crosses the study area and coincides, in part, to an east-southeast-trending magnetic gradient that lies along the north edges of magnetic anomalies 10, 11, and 12. These two gradient zones may reflect a structural zone that controlled the emplacement of the inferred pluton or plutons, or may reflect the contact of the intrusive rock or block of Precambrian gneiss with different rocks to the north.

About 8 mi (12.9 km) farther south, an east-west-alined gravity gradient (No. 16) coincides with the trace of the Mill Creek fault. This gradient is interpreted to reflect the fault. Higher gravity values north of the gradient are in agreement with geologic evidence that the north side of the fault is upthrown.

A small magnetic high (pl. 2, No. 17) is indicated by the westward nosing of the contours in the southwestern part of the map area, and a Tertiary intrusive body is located on the northern flank of the high, suggesting that the main mass of the body probably lies south from the outcrop.

The magnetic and gravity anomalies discussed in this section, which are interpreted to reflect igneous intrusive bodies, may be related to mineral deposits of economic significance. The most significant of the magnetic anomalies are 1, 4, 6, 8, and 10. The relation between these anomalies and areas known to be mineralized are discussed in Chapter A.

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Economic Appraisal of the North Absaroka Wilderness Study Area, Park and Sweet Grass Counties, Montana

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MINERAL RESOURCES OF THE NORTH ABSAROKA WILDERNESS STUDY AREA, PARK AND SWEET GRASS COUNTIES, MONTANA

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SETTING

The North Absaroka study area includes all or parts of eight organized and unorganized mining districts and subdistricts. Recorded mineral production since 1900 has been mainly gold to the amount of 16,000 oz (497,648 g). Placer operations accounted for 95 percent of all mineral production value and were mainly from the excluded part of the study area on Emigrant Creek; 4 percent was lode gold, and less than 1 percent was silver, copper, lead, and zinc.

Prior to 1900, placer gold production is estimated to have been about 34,000 oz (1,000,000 g) (Western Historical Pub. Co, ca. 1907, p. 187, 216). About 70 percent of this was from the Emigrant district and 30 percent from the Boulder River drainages. No records of lode production exist, but output may have been substantial. Ten mills are known to have operated in the excluded corridors and study area. Ruins of aerial tramways and mining camps (one large enough to require a boarding house) remain. Small stopes in a few of the larger mine workings indicate lode production.

The Sheepeater (Jardine) mining district's production is thought to have come from outside the study area. The Precambrian Stillwater Complex, which extends into the Natural Bridge mining district at the northeast corner of the area, contains the largest resource of chromium and platinum-palladium in the United States. In addition, significant deposits of gold, silver, copper, nickel, and cobalt occur in the complex. No production is recorded from within the study area.

Mining districts and subdistricts are shown on plate 3. The principal lode mines, prospects, or groups of prospects are numbered on plates 3–5 and on figures 44 and 48.

PREVIOUS WORK AND PRESENT INVESTIGATIONS

The Bureau of Mines made a reconnaissance field survey of mineral deposits in Park County and adjacent parts of Sweet Grass County in 1947 and 1948. The summary report by Reed (1950) was one of a series made to provide preliminary information to those concerned with economic development of the Missouri River Basin. Twelve properties in the wilderness study area were briefly described.

Reports on mineral resources of the Absaroka Primitive Area by Wedow and others (1973), and of the Beartooth Primitive Area and vicinity by Simons and others (1973) describe the geology near the southern and southeastern boundaries of the North Absaroka study area.

Reconnaissance sampling of placers for titanium was conducted in western Montana by Holt (1964) of the Bureau of Mines in 1957 and 1958. Several drainages he investigated are in the present study area. Tungsten resources in western Montana, including the Sheepeater (Jardine) district at the southwest corner of the study area, were also studied by the Bureau of Mines (Walker, 1963). Mineral resources of the Sheepeater district are summarized by Seager (1944) of the Montana Bureau of Mines and Geology as well as by Reed (1950) of the U.S. Bureau of Mines. Descriptions of gold placer deposits are included in reports by Dingman (1932) and Lyden (1948) of the Montana Bureau of Mines and Geology. The Great Eastern base-metal mine and the Allison Tunnel molybdenum deposit, on Emigrant Creek, are described by Basler (1965); the Sage Creek lead and Anderson Creek copper occurrences by Fox (1960); and a few of the Boulder (Independence) mining district properties by Rubel (1964).

The Bureau of Mines examined and sampled mines, prospects, and placer deposits during the present study. They compiled mineral production data, estimated mineral resources, and evaluated potential geothermal resources. Claim location data were obtained from courthouse records at Livingston in Park County, and Big Timber in Sweet Grass County. Production data were obtained from unpublished Bureau of Mines statistical files compiled from 1902 to the present, and from other sources for the period prior to 1902. Data on the production prior to 1902 are generalized, and their validity cannot be verified. Patented claim records, survey plats, and geothermal leasing data were obtained from the U.S. Bureau of Land Management, Billings, Mont.

Bureau of Mines field work in 1973 was conducted by Ronald Stotelmeyer assisted by Scott Cranswick and Andrew Leszcykowski. In 1974, the authors were assisted by Stephen Brown, Thomas Hillman, Donald Kennedy, David LaChance, Thomas Mattern, Robin McCulloch, Mary Kate McKerney, Terence Pelton, John Schutt,

Donald Smith, Jeffrey Wilson, and Eric Zahl. Placer concentrates were processed by Steven Schmauch, assisted by Robin McCulloch.

The cooperation of claim holders and property owners is appreciated. The Anaconda Company, Duval Corporation, and Johns-Manville Corporation all contributed valuable information. U.S. Forest Service personnel were exceptionally helpful, especially John Inman and Ralph Meyer, district rangers of the Big Timber and Livingston districts of Gallatin National Forest.

MINING CLAIMS AND GEOTHERMAL LEASES

Park and Sweet Grass County records indicate that more than 3,500 lode and several hundred placer claims have been located within the study area and excluded corridors. These mining claim totals do not include those located in the main part of the Sheepeater district, or east of the Boulder River in the Natural Bridge mining district. Bureau of Land Management records show that applications have been filed for geothermal leases on all or parts of about 25,600 acres (10,360 h).

Gold was reportedly discovered in 1863 on Emigrant Creek and in 1864 on Baboon Mountain; however, the first claims were not recorded until 1882 after the Crow Indian Reservation boundaries were moved eastward. Many mineral occurrences have been claimed more than once over the years, some several times.

Most lode claims fall into seven clusters. The largest is in the west-central part of the study area and includes the Emigrant Creek district and Sixmile and Mill Creek subdistricts. Other clusters are in the north part of the Sheepeater (Jardine) district in the southwest corner of the study area, the Mount Cowen area north of Mill Creek, the Suce Creek area in the northwest corner, the Natural Bridge district in the northeast corner, the Boulder (Independence, Haystack, or Cowles) district in the southeast corner, and the Silver Lake district in the center.

Most placer production came from Emigrant Creek and two tributaries, Huckleberry Gulch and the East Fork Emigrant Creek (pl. 4). Patented placer claims or evidence of placer mining are present on Sixmile Creek, North Fork Sixmile Creek, Placer Basin Creek (Sixmile tributary in sec. 24, T. 7 S., R. 8 E.), Gold Prize Creek, Gold Run Creek, Arrastra Creek, West Fork Mill Creek, Froze-to-Death Creek, Falls Creek, Great Falls Creek, Speculator (Elk Park) Creek, Boulder River, and upper tributaries of Boulder River (principally Basin Creek).

Forty-three lode claims have been patented: of these, 23 are in the Emigrant–Mill Creek districts, 12 in the Boulder (Independence) district, 7 in the Silver Lake district, and 1 in the Natural Bridge district. Patented placer claims extend almost the entire length of Emigrant Creek below the East Fork. The four patented placer claims in the Boulder district are in a corridor excluded from the mineral study. The patented placers in the lower reaches of Sixmile Creek are out of the study area.

Patented mining claims and geothermal lease applications are shown on plate 3. Claim boundaries are plotted approximately.

METHODS OF STUDY

Courthouse records and reports on mineral deposits were used to determine the number and location of claims, and the historical importance of mineralized districts. Owners or previous owners of mineral properties were contacted, and data concerning the history of the property, production records, and unpublished geologic accounts were obtained.

Field examinations were made at all known mines, prospects, and claims. Some examinations of mineral deposits outside the study area were made, when they contributed to understanding of the area's deposits, or when they extended into the study area. Lode properties were sampled and, if warranted, mapped. All placer deposits were examined, and detailed evaluations were undertaken at four localities. Numerous test pits and trenches were dug at the placers, but none reached bedrock, where the highest gold values would be expected.

Bureau of Land Management records were searched to determine the locations of geothermal lease applications in and contiguous to the study area. Geophysical data were obtained from the literature. Water samples were collected from all thermal springs and from selected cold springs. Temperature, pH, chlorine content, discharge, and quantity of mineral precipitates were measured. A brief geologic reconnaissance was made on lease lands.

Several resource category terms are used in the descriptions of individual mineral deposits; definitions of terms are from U.S. Bureau of Mines and U.S. Geological Survey (1976, p. 2–4):

> *Resource*—A concentration of naturally occurring solid, liquid, or gaseous materials in or on the Earth's crust in such form that economic extraction of a commodity is currently or potentially feasible.
>
> *Identified resources*—Specific bodies of mineral-bearing material whose location, quality, and quantity are known from geologic evidence supported by engineering measurements with respect to the demonstrated category.
>
> *Undiscovered resources*—Unspecified bodies of mineral-bearing material surmised to exist, on the basis of broad geologic knowledge and theory.
>
> *Reserve*—That portion of the identified resource from which a

usable mineral and energy commodity can be economically and legally extracted at the time of determination. The term *ore* is used for reserves of some minerals.

The following definitions for *measured, indicated,* and *inferred* are applicable to both the Reserve and Identified-Subeconomic resource components:

Measured—Reserves or resources for which tonnage is computed from dimensions revealed in outcrops, trenches, workings, and drill holes and for which the grade is computed from the results of detailed sampling. The sites for inspection, sampling, and measurement are spaced so closely and the geologic character is so well defined that size, shape, and mineral content are well established. The computed tonnage and grade are judged to be accurate within the limits which are stated, and no such limit is judged to be different from the computed tonnage or grade by more than 20 percent.

Indicated—Reserves or resources for which tonnage and grade are computed partly from specific measurements, samples, or production data and partly from projection for a reasonable distance on geologic evidence. The sites available for inspection, measurement, and sampling are too widely or otherwise inappropriately spaced to permit the mineral bodies to be outlined completely or the grade established throughout.

Demonstrated—A collective term for the sum of measured and indicated reserves or resources.

Inferred—Reserves or resources for which quantitative estimates are based largely on broad knowledge of the geologic character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on an assumed continuity or repetition, of which there is geologic evidence; this evidence may include comparison with deposits of similar type. Bodies that are completely concealed may be included if there is specific geologic evidence of their presence. Estimates of inferred reserves or resources should include a statement of the specific limits within which the inferred material may lie.

Identified-Subeconomic—Resources that are not Reserves, but may become so as a result of changes in economic and legal conditions.

Paramarginal—The portion of Subeconomic Resources that (1) borders on being economically producible or (2) is not commercially available solely because of legal or political circumstances.

Submarginal—The portion of Subeconomic Resources which would require a substantially higher price (more than 1.5 times the price at the time of determination) or a major cost-reducing advance in technology.

Hypothetical resources—Undiscovered resources that may reasonably be expected to exist in a known mining district under known geologic conditions. Exploration that confirms their existence and reveals quantity and quality will permit their reclassification as a Reserve or Indentified-Subeconomic resource.

Speculative resources—Undiscovered resources that may occur either in known types of deposits in a favorable geologic setting where no discoveries have been made, or in as yet unknown types of deposits that remain to be recognized. Exploration that confirms their existence and reveals quantity and quality will permit their reclassification as Reserves or Identified-Subeconomic resources.

SAMPLING AND ANALYTICAL METHODS

A total of 1,214 lode and 99 bulk placer samples were analyzed. Most lode samples ranged from 5 to 10 lb (2 to 5 kg). Representative samples were taken by chipping or cutting channels across veins, mineralized zones, and altered zones, or by digging holes in mine dumps. On occasion, highly mineralized samples or specimens were obtained to indicate the maximum values present in the deposit on the premise that if assays of the richest material were low, then the deposit would have little potential. All samples were checked for the presence of radioactive and fluorescent minerals. All were fire assayed to determine gold and silver content. Metallic values of visible minerals were determined by atomic absorption, colorimetric, or X-ray fluorescence methods. At least one sample from each type of mineralized structure or zone at a property was analyzed by semiquantitative spectrographic methods. If anomalous amounts of elements with economic significance were indicated, the samples were further analyzed for those elements by more accurate methods.

Placers were examined by panning near-surface material or sampling hand-dug pits or trenches. Most of these latter samples consisted of 1 ft^3 (0.03 m^3) of material (bank measurement) per foot (0.3 m) of depth. Samples generally corresponded to lithologic units. Bulk samples were concentrated by using a regular sluice box or a vibrating mechanical sluice box, and further concentrated by processing on a Wilfley table. Concentrates were amalgamated with mercury to determine gold content, and some were examined petrographically.

The chemical composition of thermal springs, when considered in the context of the local geologic and hydrologic setting, can be used to estimate the base temperature of a geothermal reservoir. One-pint (0.47-L) water samples were taken at all thermal springs for standard chemical analysis to determine the amount of common ions. A second 1-pint (0.47-L) sample diluted with distilled water was tested for silica content. One-pint (0.47-L) samples were collected at selected cold springs for standard chemical analysis to determine background values.

MINERAL COMMODITIES

The principal mineral commodities in the North Absaroka study area are gold, silver, copper, lead, zinc, molybdenum, arsenic, iron, manganese, bismuth, and tungsten. Chromium, nickel, and platinum are also present, but in lesser amounts.

GOLD

Some lode and placer deposits in the study area may be economically minable, but additional exploration will be required to verify the average metal content and economic feasibility.

Gold resources occur on 10 lode properties in a mineral belt in the west-central part of the area (Emigrant, Mill Creek, and Sixmile districts). Potential resources also exist on at least 16 other properties in these districts. In addition, in the northeast corner (Natural Bridge district) one property has gold resources and two seem to have potential. Significant gold lode deposits occur at three locations outside the patented claim area at the head of the Boulder River in the southeast corner. There is the possibility of a gold resource in the southwest corner (Sheepeater district), where current exploration is underway on a claim group extending into the study area. Streams draining the various mineralized areas are potential sources of placer gold.

The lode gold is accompanied by silver, or by silver and base metals that might be recovered as coproducts or byproducts. Gold is an accessory mineral in the disseminated copper-molybdenum porphyry deposits being explored in the Emigrant stock (Emigrant–Mill Creek–Sixmile area).

SILVER

Silver with gold or base metals might be economically recoverable at 40 occurrences in the Emigrant–Sixmile–Mill Creek area, 4 or 5 in the Boulder district, 3 or 4 in the Natural Bridge district, 4 outside the patented claim area in the Boulder district, and in the patented claim area in the Silver Lake district.

COPPER

In the study area, copper resources or potential resources are present in at least 24 occurrences in the Emigrant–Sixmile–Mill Creek district; 2 in the Natural Bridge district; 1 in the Silver Lake district; and at least 1 in the Boulder district. The occurrences are with precious and with other base metals. The most important, a copper-molybdenum porphyry in the Emigrant stock, is being drilled and investigated on the surface. Exploratory drill holes in the Stillwater Complex in the northeast corner of the study area have intersected copper-nickel-bearing zones.

LEAD

Resources of lead occurring with other metals are found at eight localities in the study area, all in the Emigrant district and Mill Creek subdistrict. In addition, a potential for resources exists at 18 other properties in those districts, and 2 in the study area section of the Boulder district.

ZINC

Zinc occurs near the mouth of Emigrant Creek. There are at least five other occurrences in the study area. The zinc is found with other metals, and at some smelters would incur a penalty when contained in lead or copper ores.

MOLYBDENUM

Analyses of mineralized rock from exposures, excavation, and drill cores indicate a copper-molybdenum porphyry deposit in the Emigrant stock. Drilling to delineate the deposit has been in progress for several years. Assay results indicate that to be economically minable, a large-volume resource, measured in tens of millions of tons, must be found.

ARSENIC

Arsenic occurs in potentially economic amounts at two locations, one in the West Fork Mill Creek drainage, and at one in the North Fork Sixmile Creek drainage. The deposits are of interest because of their proximity (about 30 mi; 48 km) to the Sheepeater (Jardine) mining district. The district is one of the few locations where arsenic has been sought and produced as usually its presence is undesirable in ores of other metals. Production of 12.6 million lb (5.72 million kg) has been recorded.

Gold and tungsten were also produced in the district. Drilling of gold deposits is underway here, and a reopening of the mines could provide a custom purchasing point for arsenic resources in the wilderness study area.

TUNGSTEN

The only tungsten occurrence of interest in the study area is in Arrastra Creek, a tributary of West Fork Mill Creek, where it occurs in minor amounts with other metals. The property, although only a prospect, is close to the Sheepeater district, where about 750,000 lb (340,000 kg) of tungsten trioxide have been produced.

BISMUTH

Generally, bismuth incurs a smelter penalty when found in ores or concentrates of other metals, and its presence in ores from several deposits in the study area might make them uneconomical to mine. It is, however, present in quantities that possibly could be recovered as byproducts if a custom mill were constructed in the Emigrant–Mill Creek–Sixmile districts. Bismuth was detected in measurable quantities at 12 localities in those districts. Although most assays were less than 0.1 percent bismuth, some high-grade seams contained as much as 15 percent.

IRON

Prospecting is underway in the Sheepeater district extending into the southwest corner of the study area. Claims for iron have been located at various times on Sixmile Creek, in the Natural Bridge district, and in the Boulder district. Bog iron occurs in the Emigrant and Mill Creek districts. Grades and sizes of the deposits appear to be too low and too small to support conventional large-scale iron mining operations. However, they could be sources for specialty uses such as in heavy aggregate and in the manufacture of cement.

MANGANESE

Small deposits in the study area consist of a reprecipitated form called wad, a mixture of minerals composed of hydrated manganese oxides, which is associated with bog iron deposits in Arrastra Creek, a tributary of West Fork Mill Creek, and on Emigrant Creek. These deposits constitute submarginal resources.

NICKEL

A nickel-copper mineralized zone in the Stillwater Complex is being explored both in and beyond the study area. Platinum occurrences several miles east of the study area, associated with the nickel-copper zone, have also been examined. A copper-silver deposit containing minor nickel and platinum is near a tributary of West Fork Mill Creek on the west side of the study area.

ECONOMIC CONSIDERATIONS

Detailed economic analyses of individual mineral deposits were beyond the scope of this report. However, a knowledge of mining costs at operating properties in the Western United States indicates that several mineral deposits in the study area would be potentially minable.

Three methods of processing the ore were considered in the economic appraisal of deposits: milling of ore at company plants, milling at a local custom mill, or direct shipment to smelters.

Lode deposits in the study area or excluded corridors that might support large-volume mining are the Emigrant stock copper-molybdenum porphyry and the gold deposits in the Independence igneous rocks. In 1972, 12 of the copper-molybdenum porphyry deposits operating in the United States had gross ore values ranging from $6.62 to $15.44 per ton ($7.30 to $17.01/t). Ore at the mine having the lowest value averages 0.29 percent copper and 0.048 percent molybdenum disulfide (Mining Engineering, April 1973). Emigrant porphyry drilling results are not available, but company confidential data and sample results indicate a large-volume potential.

The gold is often combined with pyrite and is not cyanide-soluble. The ores would not be treatable by current leaching techniques. The gold, silver, copper, lead, zinc, and other potentially recoverable metals in the deposits generally occur in sulfide minerals. Flotation or other sulfide recovery techniques would be required.

As examples of current practices, two ore-processing mills under construction in the Western United States in 1975—one a 250 ton/day (226.8 t/day) gold mill and the other a 450 ton/day (408 t/day) silver plant—report ore values of $5–$20 per ton ($5.51–$22.04/t) will be required to return capital investment in 3 years or less. Net smelter returns from an underground mine producing 500 tons of silver-lead-zinc ore per day (454 t/day) on a steeply dipping vein combined with a mill capable of processing 400 tons per day (363 t/day) would have to be at least $31.57 per ton ($34.80/t) to pay for operating costs, capital investment, and a return of 14 percent (Gentry and Hrebar, 1976). Three vein-type mineral deposits in the study area or excluded corridor appear to have sufficient tonnage and grade to be paramarginal. These are the St. Julian mine in upper Emigrant Creek, the Barbara Ann–Pilgrim–St. Croix claims in Arrastra Creek, and the Lori Kay deposit on the north slope of War Eagle Mountain in the Boulder district.

A centrally located custom mill processing gold, silver, copper, lead, zinc, or other ores in the Emigrant or Mill Creek area would probably permit development of the 10–50 deposits where sampling indicates mineral potentials or resources. The Natural Bridge and possibly the Boulder district could also contribute ores to a custom mill.

Shipment of ores or concentrates to smelters may not be practical at present. Not only are company ores given priority over custom ore, but energy shortages have reportedly resulted in smelting curtailments. To meet ambient air-quality standards, some smelters have reduced production below plant capacity. However, the major factor preventing custom smelting of ores from the study area may be metallurgical. Bismuth, arsenic, zinc, or other elements unacceptable at some smelters are present in many ores of the district. Smelter charges would have to be negotiated separately for each metallic mineral combination, of which there are about 12 in the study area deposits.

Exploration, development, and operating costs would be low for the manganese and bog-iron deposits. They are at or near the surface and readily accessible.

EMIGRANT MINING DISTRICT AND MILL CREEK AND SIXMILE SUBDISTRICTS

The Emigrant mining district is in the west-central part of the study area. It also includes the Sixmile Creek subdistrict to the south, and Mill Creek subdistrict to the north. Access is by paved roads to near the Wan-I-Gan Lodge in the Sixmile area, Chico Hot Springs Lodge near Emigrant Creek, and the National Forest boundary on Mill Creek. Gravel and dirt roads extend up numerous canyons and gulches. Timber and water are abundant. Winters are severe, with the central parts of the districts usually accessible a maximum of 5 or 6 months a year. Mine exploration roads are sometimes kept open much of the winter in parts of the Mill Creek subdistrict.

Placer gold was discovered at the mouth of Emigrant Gulch in 1863. The Curry mining district was organized in August of the following year (Western Historical Pub. Co., ca. 1907, p. 119). Gold discoveries in the upper part of the gulch led to the organization of the Shorthill district in 1864. Early claim records refer to the area as the Wyoming and Henry Villard districts. After 1881, most claims were recorded as being in the Emigrant, Mill Creek, or Sixmile districts; only the Emigrant district was organized. The area was included in the Crow Indian Reservation in 1868, but in 1882, that section of the reservation was opened to public use. A gold rush followed, resulting in the location of most of the presently known mineral deposits.

Since 1882 approximately 1,900 lode claims have been located in the district, including more than 1,100 in Emigrant Creek. Several hundred placer claims were also located. Seventeen lode claims on Emigrant

Creek and six in the Mill Creek district have been patented. Patented placer claims cover most of Emigrant Creek from the village of Chico to the East Fork of Emigrant Creek. Patented placer claims on lower Sixmile Creek are beyond the study area (pl. 3).

The districts' mineral production has been estimated at about 40,000 oz (1,244,000 g) of placer gold and silver. Gold, silver, copper, lead, and zinc lode production has been minor. Most mining occurred before the Bureau of Mines kept production records. According to Bureau records, the St. Julian mine, which shut down in 1903, was the last producer of lode gold and silver in Emigrant Gulch. Small amounts of gold, silver, copper, lead, and zinc ore were shipped from the Barbara Ann mine in the Mill Creek district between 1946 and 1968. Stopes in accessible workings elsewhere in the study area indicate that the greatest production occurred before records were kept.

Historical accounts and field examinations suggest that difficult access was a major factor in preventing extensive lode deposit exploration. A county road to the St. Julian mine on Emigrant Creek has existed since the 1880's, but it has been open beyond the lower falls at Fridley Creek only intermittently because of almost yearly washouts. As late as 1963, drilling equipment had to be transported to the Great Eastern mine by helicopter, and current travel above the lower falls is limited to four-wheel-drive vehicles. Several mines and prospects in the Mill Creek district can be reached by maintained roads. However, much of the mining activity there has been in Arrastra Creek, a tributary of West Fork Mill Creek, which is served by primitive roads cutthrough in the 1960's.

Another factor probably retarding development has been the refractory properties of the mineralized rock. Until recently gold has been the most sought after metal in the district, but it often occurs as auriferous pyrite. Evidence indicates that lack of roasting equipment plus the high cost of shipping concentrates led to shutdown of the St. Julian mill.

During 1973–1974, several large mining companies were exploring the Emigrant Creek district, or were making reconnaissance surveys of the Mill Creek and Sixmile districts. In early 1973 about 240 current unpatented lode claims existed in the Emigrant, 110 in the Mill Creek, and 130 in the Sixmile districts. Although claim descriptions are vague, about half are in corridors excluded from the study area. Individual owners were performing annual assessment work, and development work was being done on the Barbara Ann mine in 1974. Most claims in the Sixmile and Mill Creek districts are owned by Harvey, Kester, or Garland Counts of Livingston, Mont. Those on Emigrant Creek include a block of about 75, mostly outside the study area, which is owned or leased by Duval Corporation, a division of Pennzoil United, Inc. Another block of approximately 60 claims, partly in the study area, is owned by Golden Nonesuch Mining Co. (address unknown); and a block of about 50, also partly in the study area, is owned by Basic Metals, Inc. of Salt Lake City, Utah. Lead, copper, and molybdenum are the principal metals being sought.

Lode deposits in the Emigrant, Sixmile, and Mill Creek districts are in Tertiary igneous and Precambrian metamorphic rocks. The most important mineral deposits are in the Tertiary igneous rocks, principally dacite, in the central and southern parts of the districts. Both disseminated and vein deposits occur in the Emigrant stock and associated shear and fracture systems in the alteration halo around the stock. The vein and breccia-vein deposits were formed by replacement along the shear and fracture zones. Hydrothermal alteration consisting of argillization, pyritization, and silicification was locally intense. Fragments of rocks rich in mafic minerals were noted on several dumps, but except for the hornblende diorite on Burnt Creek, no mafic rock exposures were seen.

The vein deposits appear to be localized in a cognate pattern. Mineralization is greatest in a system of more or less parallel shear zones trending northeast-southwest. This system is cut by a less highly mineralized shear system trending generally northwest. Mineral deposits occur as lenses, pods, and ore shoots where swelling has occurred in the fractures, or at fracture intersections. At some deposits in the Tertiary igneous rocks mineral deposition was apparently controlled by flow-banding, usually in rhyolite.

In the downstream (north or northwest) parts of the three main drainages, silver, copper, lead, and zinc are found in veinlike deposits in Precambrian rocks, mainly schists. Deposition of minerals occurred as replacement of sheared and brecciated rock, accompanied by minor fissure filling. Mineral deposits occur in areas where the schist has been highly contorted and where stresses have dilated the planes of foliation. The deposits are usually at or near the contact between the Precambrian and Cambrian rocks. Apparent paragenetic zoning between Chico and the Emigrant stock indicates that mineralization was probably related to emplacement of the stock.

Two mining companies are drilling on Emigrant Creek to delineate a porphyry-type disseminated copper-molybdenum deposit associated with the Emigrant stock. Extensions of the stock into Sixmile Creek and Arrastra Creek are also being investigated.

Mineral resources in the Emigrant district and the Mill Creek and Sixmile subdistricts are summarized in table 8, and described in detail on following pages.

Sample results and geology indicate a mineral resource potential at other lode properties in the districts. These are also described in detail.

Most properties with potential are in a mineralized belt about 7 mi (11 km) long and 0.5 mi (0.8 km) wide, that extends from the Magnetic claim group on Sixmile Creek (fig. 23, No. 16) to the Alice C patented

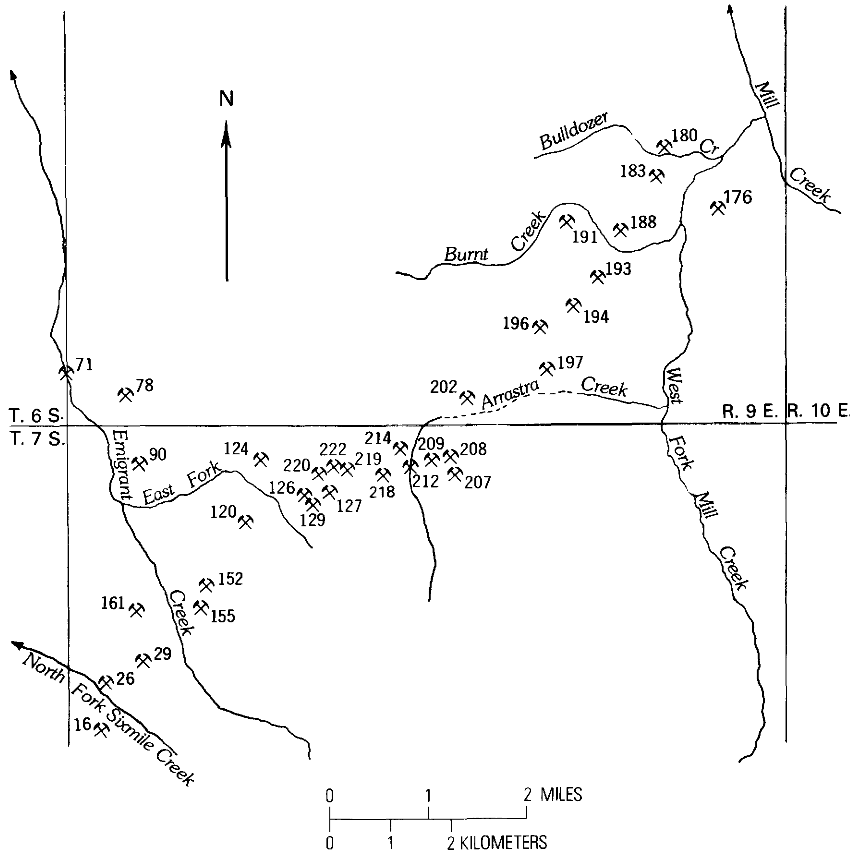
TABLE 8.—*Estimated resources in the Emigrant mining district, Mill Creek, and Sixmile subdistricts*

[Map numbers 55, 58 appear on plate 4A; remainder are on plate 4B. Measurements are in inch-pound units; 1 ft = 0.3048 m; 1 ton = 0.9072 t; 1 oz (troy)/ton = 34.285 g/t]

Map No.	Property[1]	Average vein width (feet)	Tonnage	Resource classification	Product	Grade
Emigrant mining district						
55	Alaska--------	3.1	22,500	Inferred------- paramarginal	Silver-----	0.52 ounce per ton.
					Lead-------	1.44 percent.
					Zinc	2.67 percent.
58	Klu Klux------	1.4	570	Indicated------ submarginal	Silver-----	.96 ounce per ton.
					Lead-------	1.79 percent.
					Zinc-------	3.08 percent.
		2.0	1,860	-----do--------	Silver-----	.26 ounce per ton.
					Lead-------	.24 percent.
					Zinc-------	.15 percent.
90	Allison------	([2])	75,000	Submarginal----	Molybdenum-	.3 percent.
120	St. Julian---	1.0	250,000	Paramarginal--- hypothetical	Gold-------	.5 ounce per ton.
					Silver-----	1.0 ounce per ton.
124	McAdow No. 2-	2.6	([3])	Indicated------ submarginal	Gold-------	.02 ounce per ton.
					Silver-----	1.53 ounces per ton.
					Lead-------	1.54 percent
126	Grand View---	.6	([3])	-----do--------	Gold-------	.75 ounce per ton.
					Silver-----	2.58 ounces per ton.
					Lead-------	7.76 percent.
126 to 127	Grandview- -- Dixie.	1.0	71,000	Inferred------- submarginal	Gold-------	.05 ounce per ton.
					Silver-----	.55 ounces per ton.
					Lead-------	1.48 percent.
146 to 157	Corbett and-- Montana Queen	.8	356,700	Indicated and-- inferred submarginal	Gold-------	.05 ounce per ton.
					Silver-----	.26 ounce per ton.

Mill Creek subdistrict						
180	Alice C------	2.5	2,300	Indicated------ submarginal	Gold------- Silver----- Lead------- Copper----- Zinc-------	0.01 ounce per ton. 1.82 ounces per ton. 2.29 percent. .10 percent. .55 percent.
188	Copper Queen-	2.0	7,000	Inferred------- submarginal	Silver----- Copper----- Nickel-----	.21 ounce per ton. .56 percent. .15 percent.
187 to 188	Copper Queen- to Lost Cabin	2.3	77,600	Inferred------- hypothetical	Silver------ Copper------ Nickel------	.15 ounce per ton .48 percent. .08 percent.
194 to 196	Barbara Ann-- to St. Croix	2.4	673,500	Indicated and-- inferred paramarginal	Gold-------- Silver------ Copper------	.06 ounce per ton. 3.43 ounces per ton. .59 percent.
200 and 201	Spring and--- Virginia	3.6	92,000	Inferred------- submarginal	Silver------ Lead--------	.25 ounce per ton. .66 percent.
118 to 220	McAdow-------	1.7	41,500	Indicated and-- inferred paramarginal	Gold-------- Silver------ Lead-------- Zinc-------- Copper------ Bismuth-----	.27 ounce per ton. 13.97 ounces per ton. 4.10 percent. .18 percent. .03 percent. .05 percent.
214 and 229 to 231	Midnight-----	([4])	230,000	Inferred------- submarginal	Iron-------- Manganese---	10.7 percent. 3.5 percent.
Sixmile Creek subdistrict						
16	Magnetic-----	7.5 and 22.6	175,000	Inferred------- submarginal	Iron--------	27.5 percent.

[1]Underlines denote properties assumed to be in or to extend into the study area.
[2]Not available.
[3]Few hundred.
[4]Bog.



⚒ PROPERTY

16. MAGNETIC
26. OVERLAP
29. CREVIS
71. GREAT EASTERN
78. PETER PEAR
90. ALLISON TUNNEL
120. ST. JULIAN
124. MC ADOW NO. 2
126. GRANDVIEW
127. JEANETTE and DIXIE
129. GARLAND COUNTS
152. CORBETT
155. MONTANA QUEEN
161. SHEILA
176. PEACOCK
180. ALICE C.
183. PLATINUM RIDGE
188. COPPER QUEEN
191. SHARON SUE
193. CONTACT
194. BARBARA ANN
196. PILGRIM and ST. CROIX
197. LIGHTNING NO. 3
202. VIRGINIA
207. MONTANA
208. SHIRLEY
209. FLOYD COUNTS
212. DAVID
214. MIDNIGHT
218. QUEEN ESTHER
219. COMANCHE
220. McADOW
222. VIVIENNE

FIGURE 23.—Distribution of some important mineral deposits in the Sixmile, Emigrant, and Mill Creek mining districts, showing mineralized belt—as outlined by mines, pits, and sample localities—extending from Magnetic (16) to Alice C (180). Arrastra Creek dashed where it flows underground. Numbers correspond to plate 4.

claim on Bulldozer Creek (fig. 23, No. 180). Possibly the mineralized belt is in a fault system that trends N. 45° E. through a lead deposit in the Sage Creek drainage (pl. 3, No. 241) toward the Mill Creek fault mapped by Wilson (1936) and W. J. McMannis (unpub. data, 1973).

The Mill Creek fault is one of two major tectonic structures of the Beartooth uplift. The mineralized belt is at right angles to the other major fault system designated as the Cooke City zone (Basler, 1965). The Cooke City zone is reported to extend from Cooke City through the Horseshoe and Boulder (Independence) mining districts to Mill Creek. It is described as a locus of intrusive activity and the formation of sulfide mineral deposits (Basler, 1965).

Shear zones along the mineral belt may have controlled mineralization during emplacement of the Emigrant stock. Surface expression of the fault system suggests that it is tangent to the south side of the stock. The fault system appears to split on the ridge west of the St. Julian mine (pl. 4B, No. 120); one branch seems to extend south and across the Corbett and Montana Queen patented claims, the other through the Sheila workings and across Sixmile Creek.

EMIGRANT MINING DISTRICT

ALASKA CLAIM

The Alaska was probably one of the first of numerous claims located on the zinc deposit that crops out on a grass-covered slope in the study area less than one-half mile (800 m) southeast of Chico (pl. 4A, No. 55). Workings consist of an 80-ft (24-m) adit, a sloughed trench, one cut, and three caved workings that probably totaled 250-300 ft (75-90 m) in length (fig. 24).

Slickensides along one wall of the open adit are on a vertical shear zone that trends N. 60° W. in schist. The zone is roughly parallel to an outcrop of Middle Cambrian Flathead Sandstone. Sphalerite and galena occur as stringers in fluffy limonite, which fills voids in the highly fractured and contorted schist. Replacement and alteration of the schist were limited to the shear zone. Black, dense rock (sample No. S-337) scattered on one of the dumps suggests the presence of a mafic dike below the surface. Average vein width is 3 ft (0.9 m). Samples representative of the vein yielded weighted averages of 0.52 oz silver per ton (17.8 g/t), 1.44 percent lead, and 2.67 percent zinc. Inferred paramarginal resources are estimated to be more than 17,500 tons (15,900 t) from the face of the open adit to the lowest caved working (S-338 and S-339). Paramarginal resources in the eastward projection of the vein, as inferred from surface exposures, are estimated to be 5,000 tons (4,500 t).

Prospecting was done along the projected strike of the Alaska zone of shearing on the Burlesque and Bank claims (pl. 4A, Nos. 56 and 57), which are situated on the ridge southeast of the Alaska claim. Dump samples contained as much as 0.5 oz silver per ton (17.1 g/t) and 0.26 percent zinc.

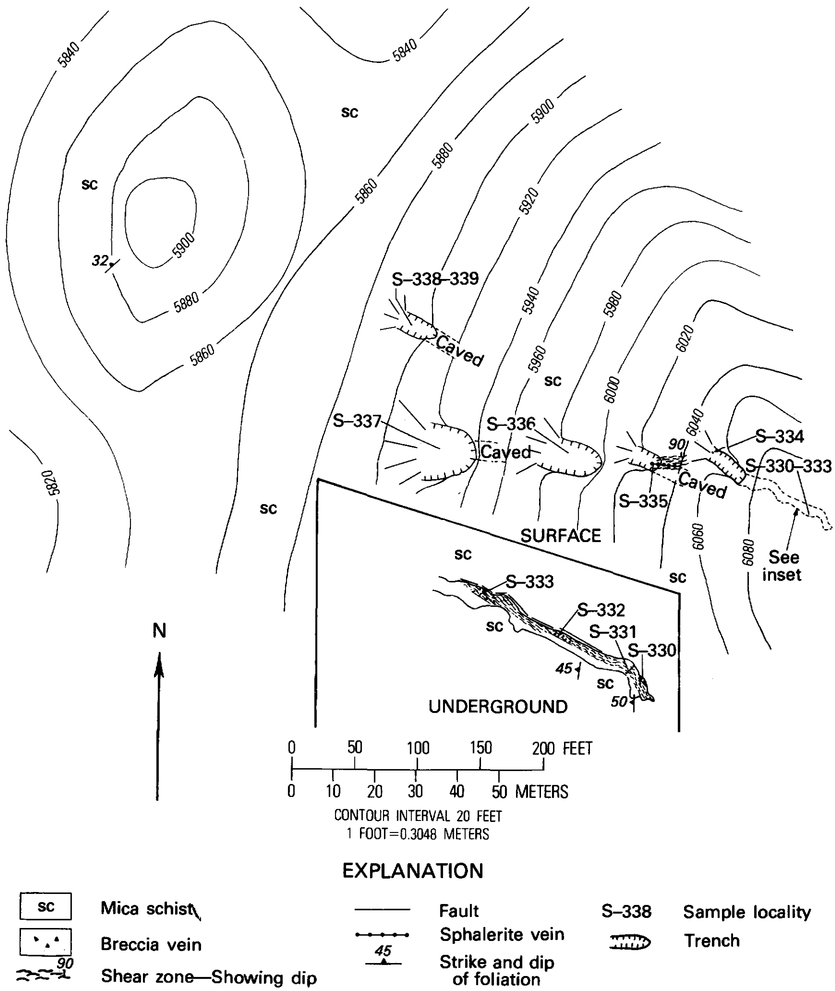


FIGURE 24.—Alaska claim.

KLU KLUX CLAIM

The Alaska zone crops out as a complex shear and fracture system at the Klu Klux claim (pl. 4A, No. 58) in Moze Gulch, about 4,000 ft (1,200 m) southeast of the Alaska workings. The claim, in the study area, has been worked intermittently since 1883, but now has no reported owner. Workings include a lower caved adit, three open adits, a short caved adit, and a shaft (fig. 25).

The mineralized shear zones are in schist near an unconformable, interfingering contact between the schist and sandstone. This contact is not well defined. There appear to be intersecting and parallel fault zones. Mine workings parallel the strikes of various shear planes. As at

Data for samples from localities shown in figure 24

[Tr, trace; N, none detected; - -, not analyzed. Measurements in inch-pound system; 1 ft = 0.3048 m; 1 oz (troy)/ton = 34.285 g/t; 1 in. = 2.54 cm]

Sample				Silver (ounce per ton)	Lead	Zinc
No. S-	Type	Length (feet)	Description		(percent)	
[1]330	Chip---	1.7	Vertical sample down wall of----- adit.	N	--	1.50
331	--do---	4.5	Across shear zone in adit--------	N	0.82	1.14
332	--do---	2.7	----do--------------------------	N	.04	.92
333	--do---	3.3	----do--------------------------	0.5	--	8.44
334	Grab---	--	Small stock pile of gossan con- - taining 2-inch sulfide vein.	2.3	.48	33.60
335	Chip---	3.0	Shear zone with one-half inch---- sulfide stringer. Sloughed trench.	2.0	5.97	.50
336	Select-	--	Iron-oxide-stained schist with--- abundant sulfides.	.9	5.72	10.70
337	Grab---	--	Black rock on dump. Caved adit--	Tr	--	.07
338	--do---	--	Limonite-cemented-breccia and---- gossan block 2 feet thick on dump.	.2	.33	2.24
[1]339	Select-	--	Limonite and silicified-schist--- boulder on dump.	1.3	1.86	23.80

[1]Sample S-339 also contains 0.03 percent cadmium.

the Alaska workings, silver-lead-zinc-bearing minerals have replaced the fragmented schist. Gouge, quartz lenses, cellular vein quartz, box-work limonite, sulfide veinlets, calcite veins, and gossan were noted in the mineralized zones. Wall-rock alteration was intense. Both mineral-bearing vein quartz and barren quartz lenses, believed to be syngenetic, are present.

A 5-ft (1.5-m)-wide shear zone containing a 1.4-ft (0.43-m)-wide sulfide-bearing vein is exposed in the open east adit. The zone strikes N. 60° W., dips vertically, and is exposed for 96 ft (29 m) along the back of the adit. Weighted averages of samples from the sulfide-bearing structure were 0.96 oz silver per ton (32.9 g/t), 1.79 percent lead, and 3.08 percent zinc. The indicated submarginal potential is 570 tons (520 t).

A second sulfide-bearing shear zone exposed in the stoped area of the west adit trends N. 45° W. for 145 ft (44 m) to the adit at sample locality S-104. The zone averages 2 ft (0.6 m) in width. This submarginal resource is estimated to contain 1,900 tons (1,700 t), which average 0.26 oz silver per ton (8.9 g/t), 0.24 percent lead, and 0.15 percent zinc.

If, as inferred, the Alaska shear zone is continuous from the Klu Klux group (pl. 4A, No. 58) through the Bank and Burlesque claims (pl. 4A, Nos. 57 and 56) to the Alaska workings (pl. 4A, No. 55), a distance of about 4,000 ft (1,200 m), further exploration along the zone may disclose additional lead, zinc, and silver resources.

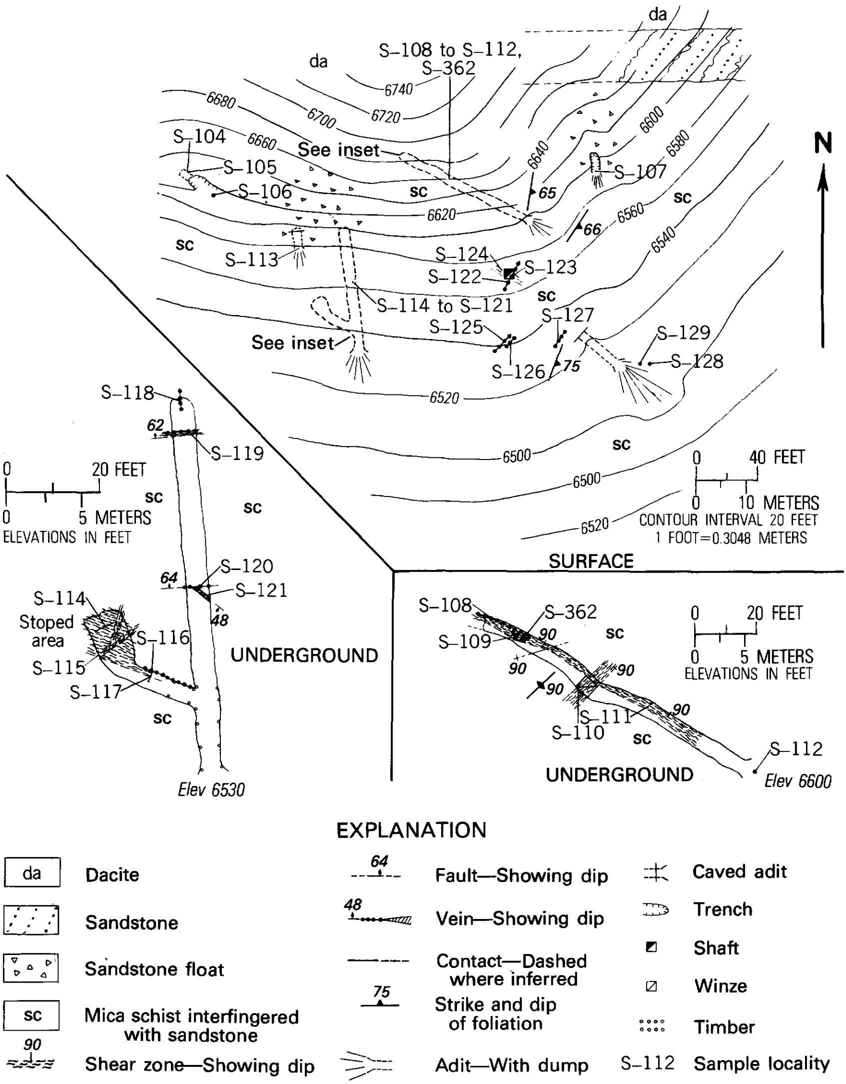


FIGURE 25.—Klu Klux claim.

A fault system southwest of the Klu Klux claim intersects the Alaska–Klu Klux structure. Minor mineral values (table 10) were found in workings of the Mountain Lion claim (pl. 4A, No. 59), which is on the fault system. The projected fault system across Emigrant Gulch was investigated, but no significant mineralized rock was noted. However, in a small area south of the projected structure (pl. 4A, No. 60), several occurrences of galena, chalcopyrite, malachite stain, and azurite stain in quartz lenses were found. The quartz lenses, 4–5 in. (10–13 cm) wide

Data for samples from localities shown in figure 25

[- -, not analyzed. Measurements in inch-pound system; 1 ft = 0.3048 m; 1 oz (troy)/ton = 34.285 g/t; 1 in. = 2.54 cm]

Sample				Silver (ounce) per ton)[1]	Lead	Zinc
No. S-	Type	Length (feet)	Description		(percent)	
104	Chip--	0.3	Spongy limonite 5 ft from adit face.	0.2	--	0.56
105	--do--	1.0	Spongy gossan in east wall of adit.	N	--	1.39
106	Grab--	--	Small stockpile of gossan and cellular vein quartz.	.2	--	--
107	Chip--	.3	Vein quartz	N	--	--
108	--do--	.3	Limonite and quartz vein	1.4	--	12.90
109	--do--	2.8	Shear zone of rock fragments, quartz stringers, limonite.	.3	0.16	.23
110	--do--	2.0	Shear zone	N	--	.03
111	--do--	1.4	Center of shear zone	.3	--	2.71
112	Grab--	--	Five-ton stockpile	.9	2.48	1.56
113	--do--	--	Dump of 25-ft-long caved adit	.1	--	.37
114	Chip--	5.0	Intersection of shears	.2	.07	--
115	--do--	1.6	Shear zone	N	.37	--
116	--do--	.2	Galena vein	.8	33.50	--
117	--do--	2.0	Shear zone at vein	.5	.07	--
118	--do--	.1	Clay and quartz stringer	N	--	--
119	--do--	.5	Quartz vein at water course	N	--	--
120	--do--	.5	Quartz vein	.1	--	--
121	--do--	.5	Calcite vein	.2	--	--
122	--do--	2.7	Quartz vein	.1	--	--
123	--do--	4.0	Shear zone	.1	--	--
124	--do--	.5	Boxwork-limonite vein	.3	--	--
125	--do--	.4	Quartz vein outcrop	N	--	--
126	--do--	1.2	----do----	.1	--	--
127	--do--	2.8	----do----	N	--	--
128	Grab--	--	One-ton stockpile, coarse ore	.6	.70	1.1
129	--do--	--	One-ton stockpile, fine ore	.4	2.38	3.15
362	Chip--	1.0	Highly iron oxide stained segment of S-109.	3.6	9.39	8.64

[1]N, none detected.

and as much as 5 ft (1.5 m) long, were observed in flexures in schist. A 0.4-ft (0.12-m) chip sample across one of the lenses assayed 0.4 oz silver per ton (13.7 g/t), 0.39 percent copper, and 1.51 percent lead. Although scarce, the lenses may indicate a potential resource.

BALM OF GILEAD CREEK

The Precambrian-Cambrian contact has been prospected on the slope north of Balm of Gilead (Mama Gaylord) Creek (pl. 4A, Nos. 62, 63). Workings are in the study area near an excluded corridor. The highest assay for six samples from five badly sloughed and caved workings was 0.03 oz gold per ton (1.03 g/t). This came from a random dump sample taken at a caved adit or trench driven about 25 ft (8 m) in iron-oxide-stained schist. Another adit, about 100 ft (30 m) long originally, had been driven in the Flathead Sandstone about 5 ft (1.5 m) to the east of the shorter working.

Because the Balm of Gilead Creek prospects are in a geologic environment similar to the Alaska and Klu Klux groups, they have a potential for silver, lead, and zinc resources. This favorable environment extends from Balm of Gilead Creek northwest to Moze Gulch, and southeast to Fridley Creek.

FRIDLEY CREEK

The Virginia Dare claim (pl. 4A, No. 64) is on Fridley Creek, possibly at the south end of the geologic environment that extends to Chico. The Precambrian (and Cambrian?) rocks contact the Tertiary volcanic rocks of the Emigrant stock igneous complex in Fridley Creek.

The discovery pit of the Virginia Dare No. 2 claim is on a shear zone striking N. 60° E. and dipping 79° NW. The zone is at the east end of a large, slightly pyritized rhyolite porphyry dike. Small phenocrysts of ferromagnesian minerals and relict pyrite give the rock a unique speckled appearance. The dike can be traced in a westerly direction for at least 1,000 ft (300 m).

Three samples taken across a 5-ft (1.5-m)-thick exposure of a shear zone in the pit face contained copper ranging from 0.37 to 0.76 percent, and averaging 0.41 percent. The copper is in gray, weathered, massive sulfide minerals.The pit was one of the few localities in the study area where beryllium was detected. Analyses of three samples ranged from 60 to 90 parts per million.

Malachite-stained float was found near the bend of the creek (pl. 4A, No. 65). The specimen collected assayed 0.2 percent copper.

Courthouse records and reports by local residents indicate a mine (Old Jim?) was operated in the Fridley Creek cirque. However, except for the ruins of a cabin, no indication of such activity was found despite several traverses of the area.

GREAT EASTERN MINE

The main part of the Emigrant mining district begins at the Great Eastern mine, (pl. 4B, Nos. 70–72) 4 mi (6 km) from Chico. The mine can be reached by a four-wheel-drive vehicle road up Emigrant Gulch. The Great Eastern claim group consists of the patented Great Eastern and Great Western claims and a block of about 54 unpatented claims, all owned by Basic Metals, Inc., Salt Lake City, Utah. Part of the group is in the study area.

The Great Eastern and Great Western claims were located in 1882. The main period of their operation, by National Park Mining Co., was between 1885 and 1901. In 1895, five carloads of ore were shipped for smelter tests (Whithorn and Whithorn, 1968, p. 37).

Patent survey plats drawn in 1900 show underground workings consisting of four adits and a shaft. Total length of the adits is nearly 300 ft (90 m). The shaft was at least 50 ft (15 m) deep; it was measured within the past 2 years (Tom Kardash, oral commun., 1974), but the collar has since been covered. All mine entrances have been obliterated by floods, snowslides, and bulldozing activities.

In 1974, drilling was in progress on the Great Western claim near Emigrant Creek. The upper drill road was being extended south in the study area, near one of two holes that the Climax Molybdenum Co. drilled in 1963 (pl. 4B). The upper hole went to a depth of 1,200 ft (366 m). The lower, in the canyon bottom, went to a depth of 1,505 ft (459 m) (Whithorn and Whithorn, 1968, p. 48). However, courthouse records show the two holes to total 3,087 ft (941 m).

Collars of several drill holes are found along the creek near the ford (pl. 4B, No. 72). Probably these are the holes described in a late 1972 issue of "The Northern Miner," a Canadian mining industry publication. They report drilling results as follows:

[Data quoted in inch-pound system; 1 ft = 0.3048 m; 1 oz (troy)/ton = 34.285 g/t. Leaders (- - -) indicate no data]

Description	Sample interval (feet)	Silver (ounce per ton)	Copper (percent)
Vendor's hole, 840 ft deep	30–320	0.99	0.43
Lessee hole No. 1, vertical, 130 ft northwest of vendor hole, 726 ft deep.	255–455	.58	.55
Lessee hole No. 2, drilled E. 45°, collared 60 ft north of vendor's hole, 335.5 ft deep.	40–118.5	1.20	.50
	171-335.5	1.42	.42
Lessee hole No. 3, vertical, 135 ft northeast of No. 1, 1,143 ft deep.	310–400	.68	.34
	480–535	.79	.43
Lessee hole No. 4, 200 feet west of No. 3, not completed in 1972.	---	---	---

The Great Western adit and shaft dump has been bulldozed, but several tons of mineralized rock are scattered on the drill road (pl. 4B, No. 71). Two select samples taken from the road averaged 1.65 oz silver per ton (56.57 g/t), 0.25 percent copper, 1.61 percent lead, and 0.67 percent zinc.

An exposure of the Great Eastern replacement zone or dike was sampled on the east bank of Emigrant Creek (pl. 4B, No. 72). This zone of hydrothermally altered dacite may be the northernmost limit of the Emigrant stock. (Lessee hole No. 3 is thought to have intersected the chilled margin of the stock.) The silicified and pyritized dacite comprising the exposure has numerous randomly oriented hairline fractures. Scattered galena aggregations as much as 1 in. (2.5 cm) in diameter occur at intervals of about 3 ft (1 m) across the exposure. Because of talus, the limits of the sheared and mineralized dacite are not visible, but the outcrop is at least 100 ft (30 m) wide.

Four samples totaling 68 ft (20 m) in length were taken across two exposed sections of the outcrop. Silver assays ranged from 0.3 to 1.2 oz per ton (10.3 to 41.1 g/t) and lead from 0.08 to 1.53 percent. Weighted averages were 0.86 oz silver per ton (29.49 g/t) and 0.86 percent lead. Copper and zinc assay results were insignificant. The company drill-hole samples averaged 0.95 oz silver per ton (32.57 g/t) and 0.45 percent copper.

The Great Eastern mine could probably not be worked economically as an underground operation at current prices for silver, copper, and lead. However, additional drilling is in progress or planned. In addition, the Emigrant stock copper-molybdenum porphyry deposit currently being drilled on adjacent claims may extend into the property.

PETER PEAR CLAIMS

Several groups of workings are on an avalanche slope, "Fred Schnell Slide," along the east side of Emigrant Gulch, about one-half mile (0.8 km) upstream from the Great Eastern (pl. 4B, Nos. 73-78). The first claim in the area was probably the Ossian, located in 1882 by Peter Peyer, who worked it until about 1918. Most of the workings are now included in the Peter Pear group of three claims owned by David W. Harris. The group is in the block of claims being explored by Duval Corp.

Many adits were driven into the avalanche slope by spiling methods. Over the years, snow slides and creeping talus have closed the entrances. The principal workings (pl. 4B, No. 78) are called the Peter Pear mine.

Lacking exposures, mineralized structures cannot be readily identified, but the general trend is toward the study area. The workings seem to be along a brecciated sheeted zone or breccia pipe, possibly at the contact between a rhyolite porphyry dike and dacite porphyry. The highly fractured and altered aphanitic rock has been partially replaced by silver, lead, and to a lesser extent copper, gold, and molybdenum minerals.

Samples were taken at four open and three caved adits (figs. 26, 27). Evidence of recent sampling by others was seen, and their results are on file at the Park County courthouse, on microfilm roll 6, p. 1159–1161.

The adits were driven into talus where it was stained by iron oxides or where mineralized float indicated buried sulfide deposits. The structure is too poorly defined by the four open adits to allow an estimate of resources. However, high-grade samples indicate that mineral resources are present. The forked adit (south working) may be a few feet short of intersecting the downdip projection of a quartz-sulfide vein exposed in the T-shaped adit higher upslope. The vein strikes N. 2° W. and dips 40° SW.

Underground workings are caved, and pits badly sloughed at five other groups of workings near the Peter Pear group (pl. 4B, Nos. 73–77). The workings are adjacent to the study area. Assays of 27 samples, mostly from dumps, contained a maximum of 0.05 oz gold per ton (1.71

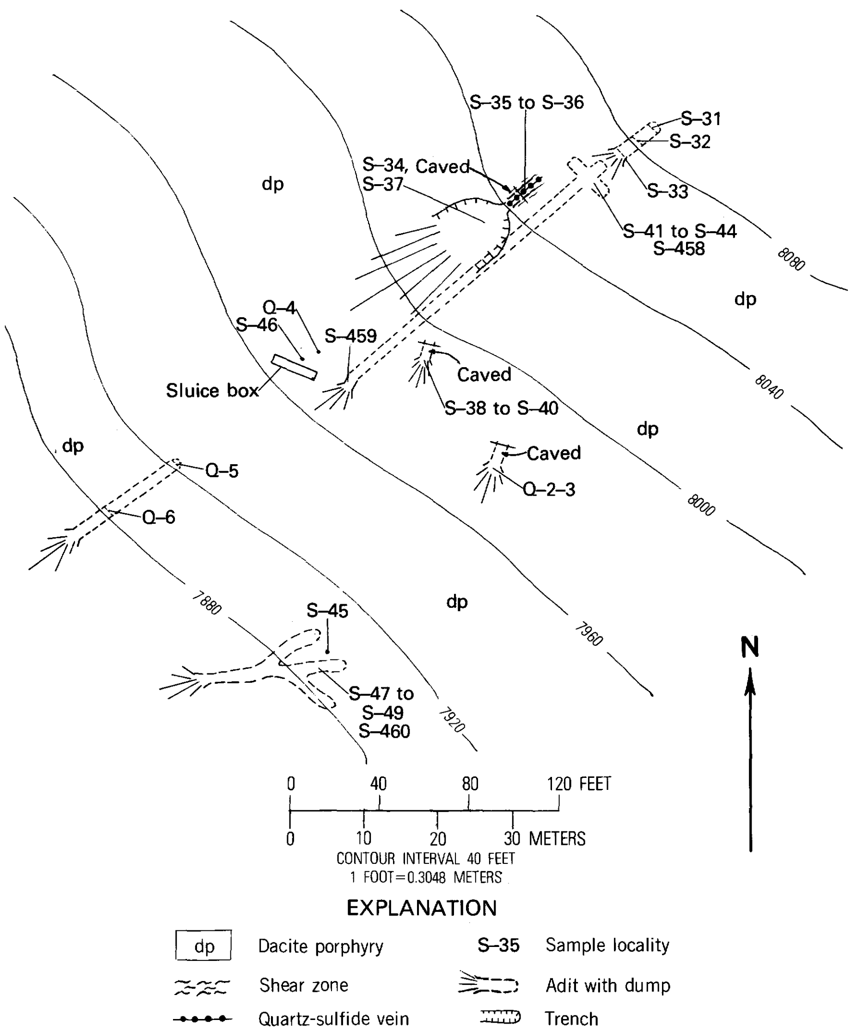


FIGURE 26.—Peter Pear claim, surface map.

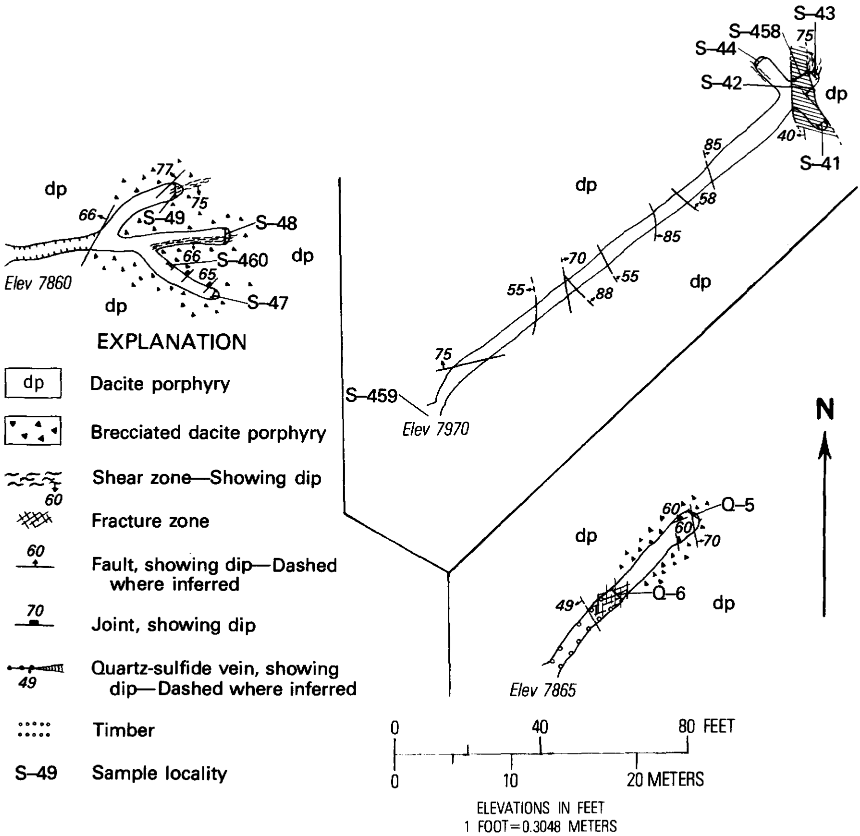


FIGURE 27.—Peter Pear claim, underground workings.

g/t), 32.3 oz silver per ton (1107.4 g/t), 0.40 percent copper, 63.0 percent lead, 1.50 percent zinc, and 0.10 percent molybdenum; average values, however, were much lower. Mineral deposits probably occur beneath the talus, as indicated by assays and the disseminated copper and molybdenum minerals observed in prospect pits at the end of the Basic Metals, Inc. exploration road (pl. 4B, No. 73).

GOLD LEAF NO. 2 CLAIM

Three caved adits totaling about 60 ft (18 m) (p. 4B, No. 79) have been driven into iron-oxide-stained avalanche debris in the "Tom Reynolds Slide." The claim locators were probably exploring for a north extension of the Gold Leaf structure. The property is in the study area.

Dump material indicates an altered zone in dacite or dacite porphyry containing a 3-in. (8-cm)-wide quartz vein.Three samples of quartz and

Data for samples from localities shown in figures 26 and 27

[Tr, trace; N, none detected; - -, not analyzed; <, less than shown. Measurements in inch-pound system; 1 ft = 0.3048 m; 1 oz (troy)/ton = 34.285 g/t; 1 ton = 0.9072 t; 1 in. = 2.54 cm]

Sample				Gold	Silver	Copper	Lead	Zinc	Molybdenum
No. S-	Type	Length (feet)	Description	(ounce per ton)		(percent)			
2	Grab------	--	Dump of 40-ft-long caved-- adit.	N	N	--	--	--	N
3	Select--	0.3	Quartz vein fragments-----	0.01	0.3	0.04	0.35	0.31	0.01
4	Grab----	--	Talus, feed for sluice----	.01	N	--	.07	.04	N
5	Chip----	4.2	Across breccia with minor- copper stain.	N	.1	.03	--	--	<.006
6	--do----	5.0	Across back---------------	N	N	--	--	--	<.006
9	--do----	6.6	Across breccia------------	Tr	.1	--	--	--	<.006
32	--do----	.5	Across fault gouge--------	Tr	.3	--	--	--	<.006
33	--do----	2.4	Across breccia------------	Tr	Tr	--	--	--	<.006
34	Grab----	--	Vein fragments from dump of 100-ft-long caved adit.	Tr	Tr	--	--	--	.10
35	Channel-	6.4	Across bleached shear----- zone outcrop.	.01	.2	--	--	--	<.006
36	Chip----	8.0	Across highly fractured--- wall rock.	N	N	--	--	--	.01
37	Grab----	--	Dump----------------------	.04	1.3	--	.35	--	N
[1]38	Select--	.3	Four-inch galena vein----- fragments, 50-ft-long caved adit.	.02	32.3	.40	63.0	.01	N
39	Grab------	--	Two-inch quartz vein-------	Tr	.4	--	1.13	--	.01
40	--do------	--	Dump----------------------	Tr	N	--	--	--	N
41	Chip----	4.5	Across quartz and sulfide--	.05	1.4	.29	2.55	.57	.01
42	--do----	3.8	Across disseminated-------- sulfides in aplite.	N	.2	.14	.26	.18	<.006
43	--do----	2.2	Across adit face-----------	.04	.1	.14	.19	.14	<.006
44	--do----	3.2	Across left crosscut face--	Tr	.1	.03	.15	.05	<.006
45	Grab----	--	Quartz float---------------	Tr	N	--	--	--	<.006
46	--do------	--	Sluice box stockpile-------	.10	.5	.06	.39	--	<.006
47	Chip----	3.5	Across siliceous breccia--- with disseminated sulfides.	Tr	N	.04	.19	.02	N
48	--do----	4.2	Across porphyry with------- disseminated sulfides.	Tr	N	--	--	--	N
49	--do----	4.5	Across breccia-------------	Tr	N	--	--	--	N
458	--do----	4.5	Across dissminated--------- sulfides in aplite.	.04	.6	.40	.92	1.1	.007
459	Grab------	--	Ten-ton stockpile----------	.02	2.2	.11	3.81	1.5	.03
460	Chip----	3.8	Across siliceous breccia--- with disseminated sulfides.	Tr	N	.04	.19	.02	N

[1]Sample 38 also contained 0.08 percent bismuth and 0.05 percent antimony.

altered rock averaged 0.02 oz gold per ton (0.69 g/t), and 2.2 oz silver per ton (75.4 g/t). These assays indicate a mineral resource potential.

Two pits were explored for the Gold Leaf structure northeast of the adits (pl. 4B, No. 80). A shear zone marks the contact of Emigrant stock dacite porphyry with a xenolith of older dacite. Replacement of dacite by pyrite occurred in a 10-ft (3-m)-wide zone, which strikes N. 40° E. Two samples from this zone assayed 0.2 and 0.4 oz silver per ton (6.9 and 13.7 g/t).

A rhyolite dike, highly argillized, underlies a prominent saddle in the ridge above the Gold Leaf No. 2 workings (pl. 4B, No. 81). A sample from a pit in the dike contained negligible values.

ALLISON TUNNEL AND VICINITY

One of the principal workings on Emigrant Creek is an adit and associated underground development locally called the Allison Tunnel (pl. 4A, No. 90). Leaching of the dump has left an iron-oxide stain that extends several hundred feet down the treeless hillside. The workings are on the east side of the creek, out of the study area. Bad air in the main adit and caving at the upper one make them inaccessible.

Exploration at the Allison Tunnel site began about 1885 when Peter Clausen located claims for gold, silver, and copper in the area. He drove the lower adit 560 ft (170 m) (Whithorn and Whithorn, 1968, p. 41). George B. Allison worked the claim until about 1914. The Metallic group of molybdenum claims were located in 1927. The U.S. Geological Survey investigated the molybdenum occurrence in 1943 (unpub. data, 1943) when the property was owned by W. L. Kearns, who had relocated the Molybdenum Nos. 1–6 claims. Hodges Mining Co. explored the property in 1947 (Reed, 1950, p. 52); Minerals Exploration Co. tested it in 1968. Duval Corp. now controls the claims.

Bad air in the main adit limited the U.S. Geological Survey to a surface examination in 1943. At that time, the district was accessible only by trail. Information on the underground workings was supplied to the U.S. Geological Survey by W. L. Kearns. He reported that the lower adit (figs. 28 and 29) was 700 ft (210 m) long and had a 50 ft (15 m) crosscut or drift in the molybdenite zone 340 ft (100 m) from the portal. Kearns took 10 samples from part of the adit and drift walls. Assays ranged from 0.17 to 1.10 percent molybdenum and had a weighted average of 0.6 percent. Kearns also reported that samples were taken from every fifth car of rock mined as the east drift was extended 30 ft (9 m) in 1937. Assays from the 13 car samples ranged from 0.24 to 0.42 percent molybdenum and averaged 0.30 percent.

A dump sample taken by the U.S. Geological Survey in 1943 assayed 0.30 percent molybdenum. On the basis of Kearn's samples, they estimated 75,000 tons (68,000 t) of mineralized rock near the drift, with a probable grade of 0.3 percent molybdenum. Evidently the last 290 ft (90 m) of the adit had bad air even when Kearns operated the property. A small mill was built but had been removed before the 1943 investigation.

The deposit was explored by Hodges Mining Co. in 1947. The Bureau of Mines reported (Reed, 1950, p. 52) that channel and core samples taken from a breccia zone averaged about 0.07 percent molybdenum, as much as 0.03 oz gold per ton (1.03 g/t), and 0.8 oz silver per ton (27.4 g/t).

In 1969 the main adit and drifts of the Allison Tunnel were sampled in detail by Minerals Exploration Co., a division of Union Oil Corp. Figure 29 is adapted from a map on file at the Park County courthouse (v. 11, p. 327). Their samples, taken from 40 ft (12 m) of the adit

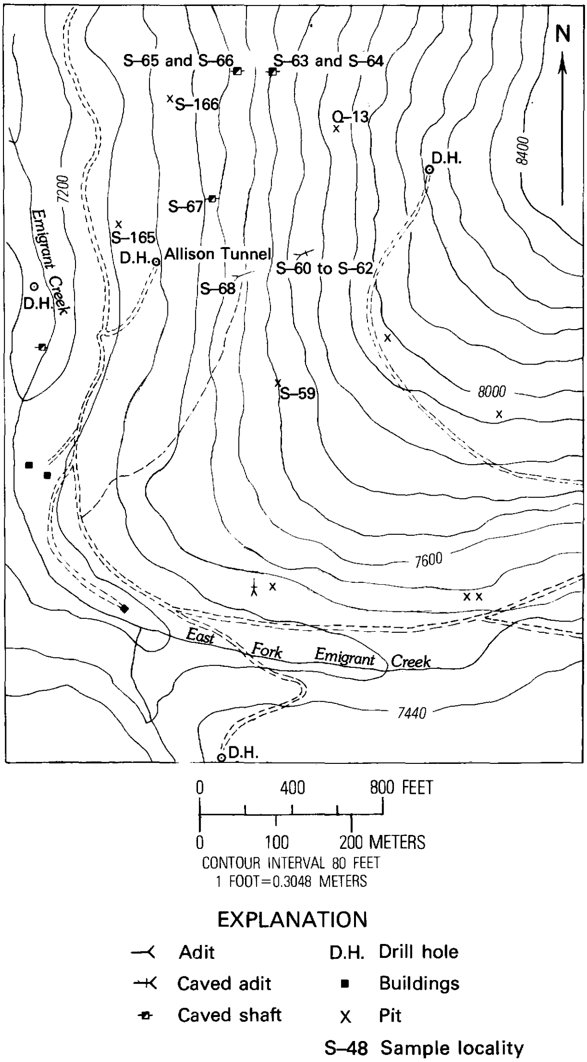


FIGURE 28.—Allison Tunnel and vicinity.

southwest of the drift, and others from the first 50 ft (15 m) of the southeast drift, correspond to the area sampled by W. L. Kearns. These later samples averaged 0.25 percent molybdenum.

The 1969 sampling program showed that molybdenum values were present along much of the adit. The best grade is evidently limited to a pipelike zone of brecciated rock variously described as trachyte porphyry, coarsely porphyritic and dense, flow-banded rhyolite, or dacite porphyry. This feature was thought to have a diameter of about 150 ft (45 m).

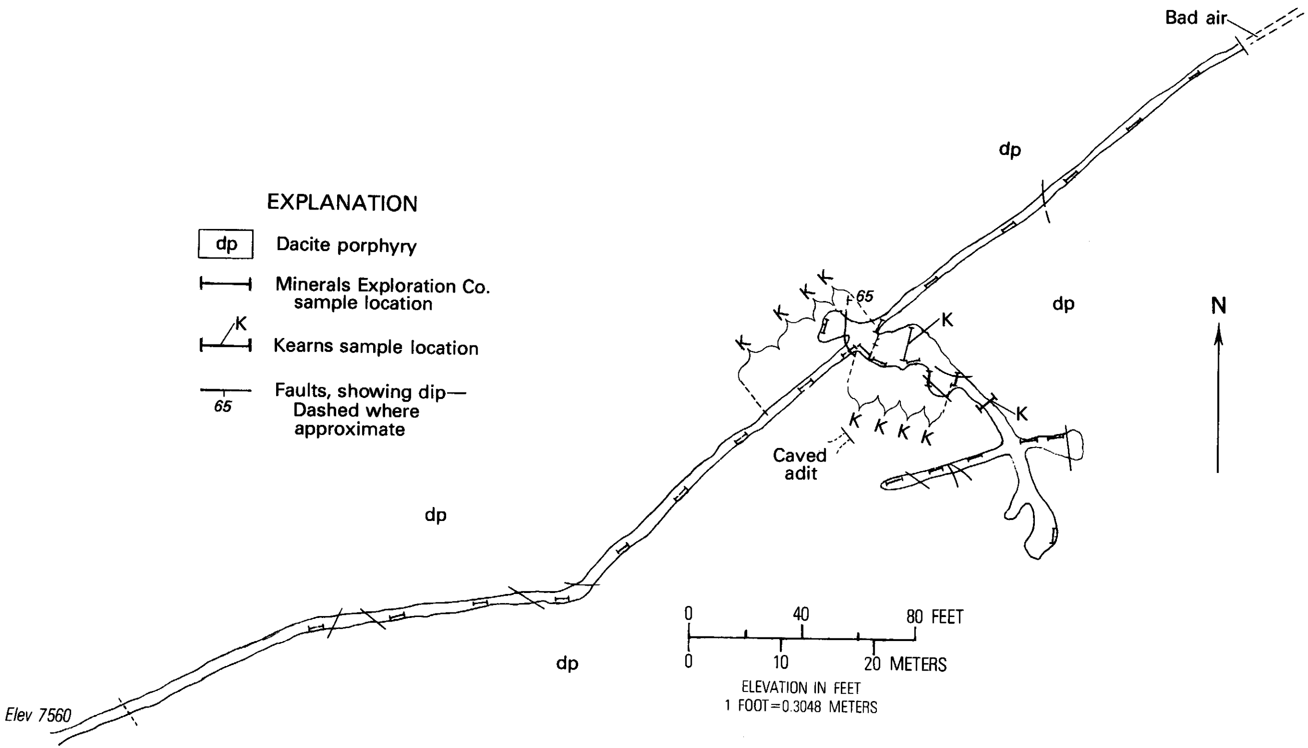


FIGURE 29.—Allison Tunnel (underground map modified from a map in Park County courthouse files).

Data for samples from localities shown in figures 28 and 29

[Tr, trace; N, none detected; - -, not analyzed; <, less than shown. Data measured in inch-pound system; 1 ft = 0.3048 m; 1 oz (troy)/ton = 34.285 g/t]

Sample				Gold	Silver	Copper	Molybdenum
No. S-	Type	Length (feet)	Description	(ounce per ton)		(percent)	
59	Random-chip.	20.0	Altered rhyolite containing MoS_2 "books" up to 6 mm in diameter, malachite, and chalcopyrite.	0.01	0.3	0.35	0.13
60	--do---	12.0	Part of ferrimolybdenite-stained outcrop above upper adit portal.	.01	.6	<.01	.45
61	Grab---	--	Dump	Tr	N	<.01	.13
62	--do---	--	Across caved material, adit portal	N	.2	--	.71
63	--do---	20.0	Massive siliceous zone at 25-ft caved shaft.	.02	1.3	--	.11
64	--do---	--	Dump	.05	1.9	--	.04
65	Select-	--	Siliceous fsragments on dump of 100-ft caved shaft.	.01	N	--	.14
66	Grab---	--	Dump	.02	N	--	.01
67	Random-chip.	20.0	Across malachite-stained blasted area.	Tr	.1	.55	<.006
68	Grab---	--	Highly altered development rock	N	N	.01	.17
165	Chip---	4.0	Molybdenite-bearing rock	Tr	.1	--	.15
166	--do---	1.8	Quartz outcrop with "books" of molybdenite 1 cm in diameter.	N	Tr	--	.10
0-13	--do---	.2	Clay seam in discovery pit	N	Tr	--	--

Sampling by the Bureau of Mines in 1973 indicated that near the Allison Tunnel the areal extent of the higher grade molybdenum-bearing zone was considerably more than indicated by earlier reports. Assays greater than 0.1 percent molybdenum were found in samples from workings in an area about 1,500 ft long by 900 ft wide (460 by 275 m), and through a vertical distance of approximately 600 ft (180 m) (pl. 4B, Nos. 86–91). Similar rock types, along with brecciation and alteration, suggest that the Peter Pear workings (pl. 4B, No. 78) may be on an extension of the Allison Tunnel molybdenum-rich zone.

In addition to the drilling being done by Basic Metals, Inc., at the Great Eastern mine, Duval Corp. is drilling in the vicinity of the Allison Tunnel to delineate a porphyry copper-molybdenum deposit. Late in September 1974, 11 deep holes had been drilled in the target area (pl. 4B). No data have been released. The area being investigated extends southeasterly to the St. Julian group of patented claims and north to the Peter Pear (pl. 4B). Most of the Duval claim group is out of the study area. This target area was selected in part because of thick manganese wad and bog iron deposits in the beds of the East Fork and main Emigrant Creek west of Allison Tunnel (Duval Corp., oral commun., 1973). These occurrences suggest the possibility of secondary enrichment of copper. However, late Pleistocene (Wisconsin) glaciation (Van Voast, 1964) may have kept pace with oxidation of sulfides, reducing chances of extensive supergene enrichment.

Large volume methods, either open pit or underground block caving, would probably be used to mine a copper-molybdenum deposit of the size and grade represented near the Allison Tunnel. At present prices, selective underground methods would not be feasible, except possibly in the area between the drift in the Allison Tunnel and sample localities S-63 to the north and S-59 to the south.

A 20-ft (6-m)-thick section of limonite-cemented gravel is exposed in the creek bank downstream from the Allison Tunnel (pl. 4B, No. 92). Assays of three samples taken across the gravel ranged from 11 to 24 percent iron, trace to 0.01 oz gold per ton (0.34 g/t), and trace to 0.2 oz silver per ton (6.9 g/t).

A short distance upstream, a small bog iron deposit (pl. 4B, No. 93) has been formed by the replacement of organic material with iron oxides. The limonite is composed almost entirely of casts of leaves, insects, and worms. A sample of this material assayed 49 percent iron and 1.07 percent zinc.

Manganese wad and manganese-cemented gravel are exposed along roadcuts near the mouth of the East Fork of Emigrant Creek (pl. 4B, No. 96). A 13-ft (4-m) vertical section was sampled in three intervals. Two 5-ft (1.5-m) intervals of manganese-cemented gravel at the top of the section assayed 0.55 and 0.67 percent manganese and 0.07 and 0.09 percent copper. The bottom 3 ft (0.9 m) was gravel and manganese wad assaying 1.31 percent manganese, 0.33 percent copper, and 0.03 percent molybdenum.

Limonite bogs occur intermittently along the East Fork creek bottom. At the confluence of the North Fork, a partially caved adit has been driven into limonite-cemented gravel. The gravel occurs over an area of several hundred square feet (pl. 4B, No. 109). Assays showed no values of importance. Other similar occurrences were noted along the study area boundary at the confluence of Huckleberry Gulch and Emigrant Creek, and in Arrastra Creek, a tributary of Mill Creek.

LOWER EAST FORK EMIGRANT CREEK PROSPECTS

Numerous small adits and pits on claims of Duval Corp., on both slopes of the lower part of the East Fork, were examined (pl. 4B, Nos. 97–113). No resources are estimated, but based on assays (table 9), potential exists for gold, silver, copper, and molybdenum resources. Mineral showings may be indicators of disseminated sulfide deposits associated with the Emigrant stock, which intrudes into part of the study area.

Nearly all rock types in the main part of the Emigrant mining district are classed as acid extrusive or fine-grained intrusive, mainly dacites (W. J. McMannis, unpub. data, 1973). At a few locations, however, the texture becomes coarser, suggestive of a phaneritic intrusive rock. Quartz monzonite is present in a prospect pit high on the north slope of the East Fork (table 9 and pl. 4B, No. 98). A grab sample of this material assayed 0.4 oz silver per ton (13.7 g/t), and was one of the few from the study area having measurable tungsten (0.01 percent WO_3).

TABLE 9.—*Data for sample Nos. 97–113 from Lower East Fork Emigrant Creek prospects shown on plate 4B.*

[N, not detected; - -, not analyzed. Data measured in inch-pound system; 1 ft = 0.3048 m; 1 oz (troy)/ton 34.285 g/t]

Sample			Gold	Silver	Copper	Molybdenum
Locality No.	Type	Description	(ounce per ton)		(percent)	
97	Grab---	Pit in talus at contact of aphanitic--- phaneritic rock of dacitic composition.	Tr[1]	N	--	--
98	--do---	Fragments of quartz monzonite in------- shallow pit.	N	0.4	--	--
99	--do---	Gossan fragments at pit----------------	Tr	.4	0.15	0.01
100	Select-	Quartz monzonite at pit in talus-------	Tr	.1	.06	.007
101	Grab---	Dump of 25 to 50-ft-long caved adit.---	N	.2	--	.04
102	--do---	Dump of pit in talus-------------------	N	.3	--	--
103	--do---	------do-------------------------------	N	.1	--	--
104	Chip---	Random chip at pit in limonite--------- cemented gravel.	Tr	.3	.16	.01
105	Select	Quartz-stringer fragments and vuggy---- siliceous rock on overlapping dumps of two caved adits.	0.01	.5	--	.08
106	--do---	Disseminated malachite in altered------ quartz monzonite. Loose rock along road bed.	N	N	.11	--
107	--do---	------do-------------------------------	N	N	.37	--
108	Grab---	Dump at discovery site Mint No. 26 claim.	Tr	.1	--	--
109	--do---	Limonite-cemented gravel. Sample of--- muck lying on top of roof timbers at caving portal.	N	.1	--	[3]<.006
110	--do---	Dump of 75- to 100-ft-long caved adit,- Old Bill Gray mine.	N	.3	--	--
111	--do---	Dump of 75- to 100-ft-long caved adit,- pyritized felsic rock.	Tr	.4	--	--
[2]112	Select-	Hematite-stained felsic rock sloughed-- into trench.	.07	1.1	--	--
112	Grab---	Dump of two adjacaent pits, leached---- dacite.	Tr	.1	--	--

[1]Trace.
[2]Sample 112 also contained 0.51 percent lead and 0.03 percent bismuth.
[3]<, less than shown.

The longest accessible working on the north slope of the East Fork of Emigrant Creek is a 178-ft (54-m) adit (pl. 4B, No 115) on the Iron King claim. It was driven along copper-bearing fractures in pyritized, felsic rock (fig. 30). Malachite occurs near the face, and near the portal are colorful hydrous copper sulfate crusts formed by leaching and precipitation.

Although no resources are evident at the adit, a northerly projection of its trend intersects a hematite-stained area on the hillside above, and may indicate a resource. The hematite-stained area is several hundred feet square and is laced by numerous quartz veins averaging 2 in. (5 cm) in width. A sample (fig. 30, Q-23) was taken from one of the wider veins, a 4-in. (10-cm)-thick vuggy-quartz vein striking N. 32° E., at a shallow pit dig in highly bleached dacite or rhyolite. Assays showed 0.17 oz gold per ton (5.8 g/t), 2.2 oz silver per ton (75.4 g/t), and 0.02 percent bismuth. Further projection of the adit trend intersects a shallow pit at the ridge crest, where an assay of a sample (fig. 30, S-228) from limonite-cemented breccia showed no significant values.

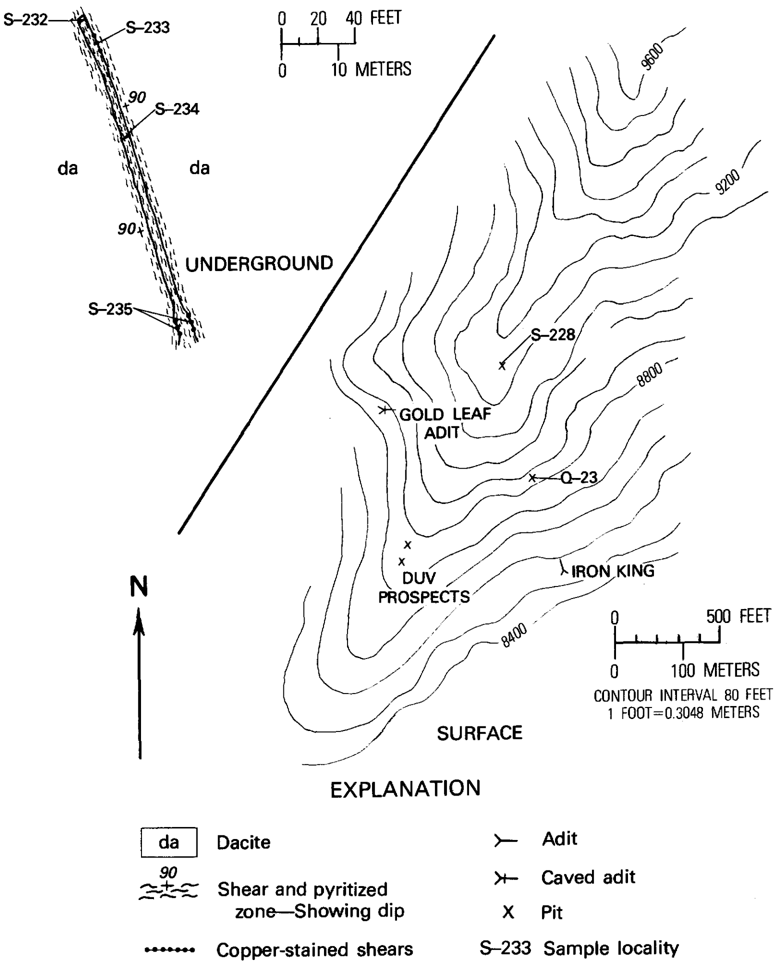


FIGURE 30.—Iron King property.

ST. JULIAN MINE

The major mine workings in the Emigrant mining district are on the upper part of the East Fork of Emigrant Creek outside the study area (pl. 4B, Nos. 119–123). The St. Julian, located in 1885, was the first of nine lode claims to be patented. Others in the group were located between 1889 and 1910. A ten-stamp mill operated from about 1895 to 1906 (Whithorn and Whithorn, 1968, p. 42). The buildings, including mill, offices, and boarding house, are in disrepair.

Patent survey plats drawn in 1910 show eight adits and three shafts. The adits totalled about 1,060 ft (320 m). The last recorded production was a small amount of gold in 1903. Output prior to the mill construc-

Data for samples from localities shown in figure 30

[All samples chip except S-228, grab. Tr, trace. Data measured in inch-pound system; 1 ft = 0.3048 m; 1 in. = 2.54 cm; 1 oz (troy)/ton = 34.285 g/t]

Sample			Gold	Silver	Copper
No.	Length (feet)	Description	(ounce per ton)		(percent)
[1]O-23	0.3	Across 4-in. vein of vuggy--- quartz.	0.17	2.2	--[3]
S-228	--	Fragments from zone of------- limonite- and hematite-cemented breccia	Tr	Tr	--
S-232	2.8	Shear zone-------------------	Tr	.3	0.01
S-233	1.0	Malachite-stained shears-----	.01	Tr	.10
S-234	4.0	Heavily pyritized shear zone-	Tr	N[2]	.04
S-235	2.8	Copper sulfate crust in------ highly fractured and altered felsic rock	Tr	.3	.11

[1]Sample O-23 also assayed 0.02 percent bismuth.
[2]None detected.
[3]Not analyzed.

tion was treated in an arrastra built at the mouth of Huckleberry Gulch.

The refractory nature of the mineralized material may have led to shutdown of operations. No facilities existed for treating the auriferous pyrite, or the bismuth, and there was probably too little free-milling gold to make mining profitable. For treatment, mill concentrates could only have been shipped to Denver at a prohibitive freight cost of $13 per ton ($14.33/t) (Whithorn and Whithorn, 1968, p. 42).

The mineral deposits on or near the patented claims are in shear zones having a general trend of N. 20°–40° E., suggesting a cognate fracture system. Economic minerals have replaced sheared volcanic rock, mainly dacite; hydrothermal fissure-filling is minor. Flow-banded rhyolite was noted in some dumps. This rock type was also seen at important mineral deposits elsewhere in the study area. Hydrothermal alteration, perhaps an indicator of economic mineralization, has introduced secondary pyrite, sericite, and silica over an area of several thousand square feet. Because of the degree of alteration, the original rock composition often could not be determined in the field. Colors vary from white to brown and black in the altered zone. The altered rocks occur in the area being explored by Duval Corp. Production records show the St. Julian mineral deposits to be at the contact of quartzite and granite. No rocks of these types were noted in the immediate vicinity of the St. Julian mine. However, rocks of possible quartz monzonite composition crop out near the bend of the creek (pl. 4B, No. 116). Workings to the south of Huckleberry Gulch (pl. 4B) are on a highly sheared zone that may be a continuation of the St. Julian mineralized zone.

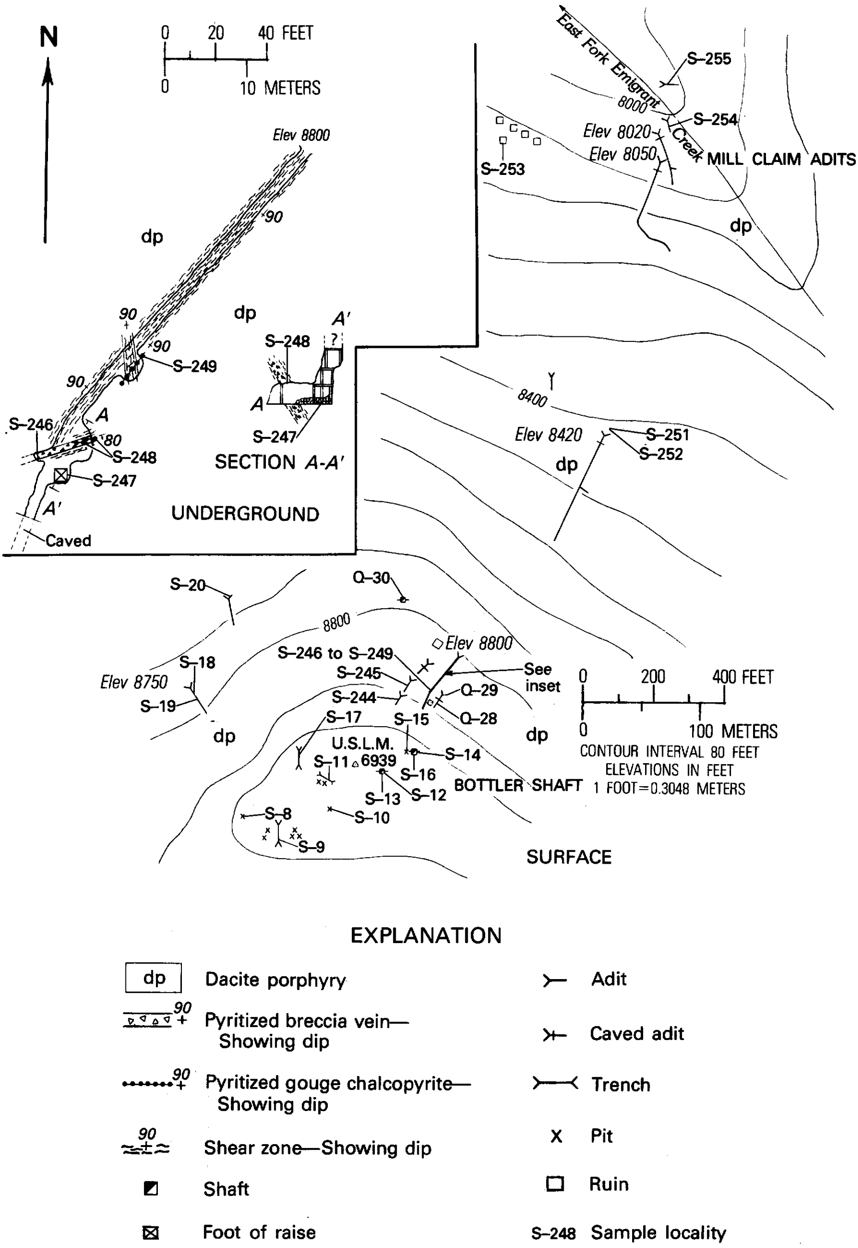


FIGURE 31.—St. Julian mine and vicinity.

A sample of pyrite was taken at the millsite; it is not known if the material was middlings or concentrates from shaking tables. The sample contained 0.82 oz gold per ton (28.11 g/t), 1.4 oz silver per ton (47.99

Data for samples from localities shown in figure 31

[Tr, trace; N, none detected. Data measured in inch-pound system; 1 ft = 0.3048 m; 1 in. = 2.54 cm; 1 oz (troy)/ton = 34.285 g/t]

Sample				Gold	Silver	Bismuth
No.	Type	Length (feet)	Description	(ounce per ton)		(percent)
Q-28	Chip--	2.5	Shears containing pulverized and--- resilicified quartz, partially collapsed 40-ft-long adit.	Tr	N	--
Q-29	--do--	3.0	Adit portal-----------------------	Tr	0.2	--
Q-30	Grab--	--	Dump-----------------------------	Tr	.1	--
S-8	--do--	--	Dump; fractured, silicified and---- bleached volcanic rock.	Tr	.3	--
S-9	Chip--	--	Altered volcanic rock--------------	N	.2	--
S-10	--do--	--	Pyritized rock with pyrite--------- aggregates up to 1 cm diameter.	N	.3	--
S-11	--do--	--	Kaolinized and silicified dacite,-- minor limonite boxwork.	Tr	N	--
S-12	--do--	.5	Six-inch fracture filled with------ equal parts clay, fluffy limonite, and limonite boxwork.	0.20	2.8	--
S-13	Grab--	--	Dump-----------------------------	.02	.6	--
S-14	--do--	--	Dump of caved 100-ft shaft, iron- - oxide-stained altered volcanic rock.	.01	Tr	--
S-15	Chip--	2.0	Fluffy-limonite vein---------------	1.08	2.0	0.18
S-16	Grab--	--	Gossan and cellular vein quartz---- scattered on dump, 4-in. maximum pieces.	1.54	2.0	.35
S-17	--do--	--	Kaolinized and silicified dacite,-- minor limonite boxwork.	Tr	N	--
S-244	Chip--	3.7	Pyritized shear zones in face of--- 25-ft-long adit, silicified rhyolite wallrock.	Tr	N	--
S-245	--do--	7.0	Pyritized shear zones in face of--- 25-ft-long adit.	.01	N	--
S-246	--do--	2.0	Breccia vein-----------------------	.08	.2	[1]<.01
S-247	Grab--	--	Muck pile at bottom of raise-------	.46	.2	.12
S-248	Chip--	.3	Breccia vein-----------------------	.17	.4	<.01
S-249	--do--	.5	Pyritized gouge--------------------	.24	.2	<.01
S-251	Grab--	--	Dump of 350-ft-long St. Julian----- Fraction Tunnel No. 2.	Tr	N	--
S-252	--do--	--	------do---------------------------	Tr	N	--
S-253	--do--	--	Mill concentrates (?)--------------	.82	1.4	.18
S-254	Chip--	.1	Clay seam in 10-ft-long adit,------ basalt country rock.	Tr	N	--
S-255	--do--	3.0	Shear zone at 15-ft-long adit,----- basalt country rock.	Tr	N	--

[1]< Less than shown.

g/t), 0.41 percent copper, 0.95 percent lead, 0.04 percent zinc, 35.0 percent iron, and 0.18 percent bismuth.

Samples were taken at 19 workings (fig. 31), including 7 open adits, that are on or near the patented claims. Assays ranged as high as 1.54 oz gold per ton (52.80 g/t) and 2.8 oz silver per ton (95.99 g/t). A lead assay of 1.25 percent (sample S-12) and copper assays of 0.27 and 0.41 percent (samples S-248 and S-253, respectively) indicate base-metal values may occur at depth. Spongy, fluffy, and boxwork varieties of limonite resulting from oxidation of sulfides are present in considerable quantities.

Only two adits are accessible, and one of these (fig. 31) was probably dug after the patent date. The caved workings account for 94 percent of the more than 800 ft (240 m) of lateral workings shown on patent surveys. The shafts, which may have totaled several hundred feet of depth, are also caved. Metallic minerals occur in at least six approximately parallel shear zones, as shown on survey plats. The minerals also occur in structures intersecting the shear zones. The resulting fracture system is complex and difficult to interpret.

The inaccessibility of workings at the St. Julian group precludes all but hypothetical estimates of resources. Paramarginal hypothetical resources are probably present from the portal of the Mill claim adit on the creek bank to the Bottler shaft atop the hill near U.S. Location Monument 6939. The horizontal distance is about 2,200 ft (670 m) and the vertical about 1,000 ft (300 m). There are estimated to be about 250,000 tons (227,000 t) averaging 0.5 oz gold per ton (17.14 g/t) and 1.0 oz silver per ton (34.28 g/t).

McADOW NO. 2 CLAIM

The projected extension of the St. Julian mineralized zone across the East Fork of Emigrant Creek into the study area intersects an adit driven N. 70° E. for 51 ft (15 m) (pl. 4B, No. 124). The adit is along a shear zone containing a quartz vein dipping 75° NW. The vein terminates against a fault 35 ft (11 m) from the portal.

A sample taken 2.5 ft (0.8 m) across an adit exposure of the zone assayed 0.01 oz gold per ton (0.34 g/t), 0.6 oz silver per ton (20.6 g/t), and 1.71 percent lead. A 2.7-ft (0.8-m) sample from a surface exposure of the zone above the portal assayed 0.03 oz gold per ton (1.03 g/t), 2.4 oz silver per ton (82.3 g/t), and 1.39 percent lead. Only a few hundred tons of submarginal resources are indicated; however, there seems to be a good potential for additional resources.

GRAND VIEW, JEANETTE, AND DIXIE CLAIMS

A small high-grade mineral occurrence (pl. 4B, No. 126) outside the study area, midway up the east slope of the East Fork canyon, was examined. The occurrence is thought to be the old Grand View claim. A caved adit, probably less than 100 ft (30 m) long, has been driven along a fracture system intersecting a shear zone in altered dacite. The fracture system strikes N. 79° W. and dips 50° NE.; the shear zone strikes N. 82° W. and dips 64° NE. Lenses of galena as much as 1.5 in. (3.8 cm) thick occur at some intersections. The galena-bearing outcrop was traced east approximately 100 ft (30 m), where it pinched out. Material in the stockpile, less than 1 ton (0.9 t), indicates a quartz-galena vein at least 12 in. (30 cm) thick in the adit. A random sample of the stockpile assayed 1.22 oz gold per ton (41.83 g/t), 1.7 oz silver per ton (58.3 g/t), and 3.58 percent lead. Another sample taken across 0.8 ft (0.2 m) of the shear zone above the portal assayed 0.26 oz gold per ton (8.91 g/t), 2.1 oz silver per ton (71.99 g/t), and 6.19 percent lead. A sample across the 1-in. (2.5-cm) galena lens east of the portal assayed 0.01 oz gold per ton (0.34 g/t), 15.2 oz silver per ton (521.1 g/t), and 67.4 percent lead. A few hundred tons of mineralized rock are indicated, and the site has a potential for additional resources.

Projection of the general trend of the mineralized structure at the Grand View intersects with workings on the Jeanette and Dixie claims owned by Kester Counts of Livingston, Mont. The Jeanette and Dixie workings (pl. 4B, Nos. 127 and 128), also outside the study area, are high on the mountain slope near the ridge separating the Emigrant and Mill Creek mining districts.

The Jeanette (pl. 4B, No. 127) adit, now partially caved, has been driven about 50 ft (15 m) east along a 2- to 6-in. (5- to 15-cm)-wide vertical breccia vein. A sample taken across the vein outcrop, above the adit, assayed 0.03 oz gold per ton (1.03 g/t) and 0.5 oz silver per ton (17.1 g/t). Vein material scattered on the dump consists of cellular vein quartz, altered and brecciated rhyolite, galena, limonite, and limonite boxwork after galena. This material assayed 0.02 oz gold per ton (0.69 g/t), 2.5 oz silver per ton (85.7 g/t), and 5.21 percent lead.

The rock types in the two sloughed trenches differ from those in the adit. The Jeanette adit was dug in pyritized and highly siliceous rhyolite or bleached dacite, but broken rock in the trenches consists of porphyritic flow-banded dacite and rhyolite having argillized perlite nodules that are a maximum of one-half inch (1.3 cm) in diameter. The vein material exposed in the trenches is limonite gossan and limonite-cemented breccia assaying 0.01 oz gold per ton (0.34 g/t) and 0.6 oz silver per ton (20.6 g/t), 1.17 percent lead, and 0.18 percent zinc.

A 40-ft (12-m) northerly trending adit on the Dixie claim (pl. 4B, No. 128) follows a contact between the perlite-bearing porphyry and pyritized rhyolite. Although pyrite cubes as large as one-fourth inch (0.6 cm) were noted, no values were obtained from a sample across the face. About 25 ft (8 m) from the portal, the adit intersects a shear zone striking due east and dipping 55° S. A 2.8-ft (0.85-m) chip sample across the zone assayed 0.1 oz silver per ton (3.4 g/t), 0.32 percent lead, and 0.86 percent zinc. The Dixie shear zone may be a downdip extension of the Jeanette mineralized structure.

Without measurable vein widths, an accurate estimate of resources is difficult. However, considering the average length of samples from across the mineralized structure and using the distance between the Grand View and Dixie claims as the length, it can be inferred that about 71,000 tons (64,000 t) of submarginal resources occur on the Grand View, Jeanette, and Dixie claims. Samples averaged 0.05 oz gold per ton (1.71 g/t), 0.55 oz silver per ton (18.85 g/t), and 1.48 percent lead. With zinc significant (0.86 and 0.18 percent) in two samples, the mineralized rock at these claims could represent a resource.

GARLAND COUNTS CLAIM

A potential for mineral resources exists at the Garland Counts claim in the excluded corridor southeast of the Grand View (pl. 4B, No. 129). A 38-ft (12-m)-long adit and a short caved adit have been dug along shear zones at or near a narrow basalt dike in altered dacite.

Inside the adit, one sample, 0.4 ft (0.12 m) long, taken across a clay and quartz vein striking N. 86° E., assayed 0.15 oz gold per ton (5.14 g/t) and 1.1 oz silver per ton (37.7 g/t). Maximum values of other samples from inside the adit were 0.03 oz gold per ton (1.03 g/t) and 0.1 oz silver per ton (3.4 g/t). Above the adit, in a hillside cut, a sample of stockpiled dike rock assayed 0.02 oz gold per ton (0.69 g/t) and 0.7 oz silver per ton (24 g/t).

The caved adit to the north, estimated to be about 100 ft (30 m) long, was driven on a limonite- and hematite-filled shear zone striking parallel to the dike at the lower adit. The zone dips 66° N. A sample across 0.2 ft (0.06 m) of the most highly iron oxide stained part of the shear zone assayed 0.41 oz gold per ton (14.06 g/t) and 0.6 oz silver per ton (20.6 g/t).

The Garland Counts, Grand View, Jeanette and Dixie claims appear to be in a secondary mineral belt along a fault or dike system extending across the ridge into the Mill Creek district. The system may reach as far as the Galena Queen mine on the banks of Arrastra Creek (pl. 4B, No. 226). Most of this mineralized zone is outside the study area and has a resource potential.

CORBETT AND MONTANA QUEEN CLAIMS

Two patented claims and nearby workings (pl. 4B, Nos. 145–158) are in Huckleberry Gulch, running through the upper Emigrant mining district in an excluded corridor. Access to the area is by trail.

The patented claims are the Corbett, located in 1894, and the Montana Queen, located in 1890. Although no record of production remains, small stopes indicate that some ore was produced, probably prior to 1904. The survey plat of the Corbett shows three adits with a total length of about 180 ft (55 m). Erosion and revegetation have nearly obliterated the entrance to the main adit, Tunnel No. 4 (pl. 4B, No. 153), which is reported to have been 132 ft (40 m) long. At the south end of the claims are two large caved adits (pl. 4B, Nos. 151 and 156); one is known to have been at least 310 ft (95 m) long.

The workings in the vicinity of the patented claims, which are leased to Duval Corp., are in the Emigrant stock. Alteration and mineral deposition were apparently concentrated near the contact between flow-banded rhyolite, quartz monzonite, and rocks of dacitic composition. Pyritization and argillization are widespread. Field identification of rock types was impossible in most cases.

The mineralized structure at the Corbett and Montana Queen claims is a highly sheared zone, often with open fissures, striking northerly and traceable for nearly 3,000 ft (900 m). It may be an extension of the St. Julian mineralized zone. The Sheila shear zone (pl. 4B, Nos. 159–167) may also be an extension of the St. Julian. Quartz and gougy, brecciated quartz veins, containing sulfides, occur along the shear zone. The oxidized gouge is a bright-red hematitic clay. Hydrothermal vein filling was incomplete, leaving underground fissures, some of which are man-sized.

Mining in the Montana Queen (pl. 4B, No. 155) was accomplished by underhand stoping (fig. 32), and it appears to have been limited to a vein of gritty hematitic mud striking N. 10° E. and dipping vertically. However, some gold values may occur in the wall rock. The south drift could not be examined because loose timbers block the passage. The weighted averages of samples across the mineralized structure exposed in the mine are 0.05 oz gold per ton (1.71 g/t) and 0.26 oz silver per ton (8.91 g/t). Indicated submarginal resources are estimated to be 1,100 tons (1,000 t), assuming vertical continuity both above and below the workings, equal to one-half the 150-ft (46-m) known strike length.

The auriferous, hematitic-gouge vein of the Montana Queen is exposed in a short trench 1,000 ft (300 m) north of the adit. Samples from here and from 15 pits and adits along and near the Corbett and Montana Queen shear zone (pl.4B, Nos. 145–158) assayed as much as 0.3 oz silver per ton (10.3 g/t). Most adits are caved and pits badly sloughed. The shear zone along which most of the workings are dug forms the contact between dacite and quartz monzonite (Nos. 152, 156, and 158). One section of the structure is a pyritized, quartz-monzonite zone covering an area several hundred feet square (No. 154). One working (No. 147) is in limonite-cemented gravel. Two parallel 4-in. (10-cm)-thick open fissures exposed in an 8-ft (2.5-m) drift driven S. 20° E. at the end of a 35-ft (11-m) adit were sampled (No. 149). An adit (No. 151), possibly 500 ft (150 m) long, was driven on a 5-ft (1.5-m)-wide zone of fluffy limonite containing a 4-in. (10-cm)-wide silicified center.

The Corbett and Montana Queen shear zone appears to extend 2,700 ft (820 m) through both patented claims, and inferred submarginal resources are estimated to be 177,800 tons (161,000 t). (A hypothetical resource of about the same amount is estimated to occur northward between the Corbett and the St. Julian claim group.)

An area of hematite-stained volcanic rock that is hundreds of feet square occurs in Huckleberry Gulch, upstream, north of the Corbett claim. A random chip of float at the base of the stained part (pl. 4B, No. 148) assayed 0.5 oz silver per ton (17.1 g/t). The area probably has a potential for resources.

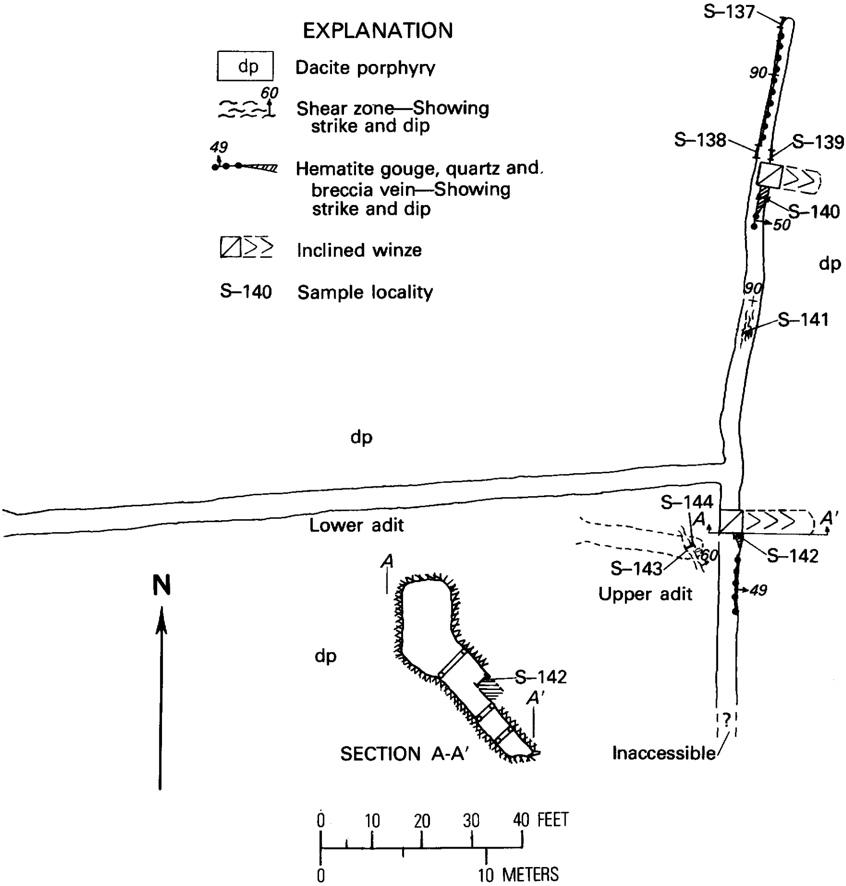


FIGURE 32.—Montana Queen mine.

SHEILA CLAIM

Nine adits exposing a gold and silver occurrence were examined on the west slope of Emigrant Gulch. They are in the study area above the mouth of Huckleberry Gulch (pl. 4B, Nos. 159–167). Access is by trail along the east side of Emigrant Gulch.

The occurrence has been covered by numerous claims since the early 1880's, but no recent mining or exploration is indicated. The Sheila claim was located in 1966 by J. H. Counts. Caving and debris from snowslides have closed portals to all but two short adits. No production has been recorded.

Talus and snowslide debris permits observation of only a few outcrops. As a result, explorations have been centered in areas covered by iron-oxide-stained overburden.

The principal workings are along a shear zone in older volcanic rocks

Data for samples from localities shown in figure 32

[All samples chip. N, none detected. Data measured in inch-pound system; 1 ft = 3.048 m; 1 oz (troy)/ton = 34.285 g/t]

Sample			Gold	Silver
No. S-	Length (feet)	Description	(ounce per ton)	
137	0.2	Hematite-bearing gouge-------------	0.01	0.3
138	.3	Hematite-bearing gouge in roof above 7-ft sloughed winze.-------	.3	.2
139	.3	Hematite-bearing gouge from floor--	.08	.6
140	1.0	Hematite-bearing gouge forming drift wall.---------------------	.04	.3
141	1.0	Shear zone at contorted flow-banded rhyolite.-----------------	.01	.1
142	1.0	Hematite-bearing gouge-------------	.12	.3
143	1.6	Shear zone in upper adit in altered monzonite.--------------	.01	.2
144	.5	Tan-colored gouge in upper adit----	N	N

that lie between dacite of the Emigrant stock and younger dacite flows. Dump material indicates that a basalt dike was intersected that would probably be along the shear zone. The northeasterly projection of the shear zone parallels the St. Julian mineralized zone and intersects the Corbett shear zone. As at the St. Julian, gold occurs in pyrite, and rock types are the same, including the presence of flow-banded rhyolite.

Development rock set aside during adit excavation indicates that the mineralized zone contains cellular and vuggy vein quartz, altered dacite, and coarse pyrite veins. Fragments of vein material on the dumps are as thick as 1 ft (0.3 m). The gold assays from vein material on dumps at three adits were as follows: 0.53 oz per ton (18.17 g/t), 0.43 oz per ton (14.74 g/t), and 0.12 oz per ton (4.11 g/t) (pl. 4B, Nos. 163, 165, and 161), respectively. Corresponding silver assays were 1.3 oz per ton (44.57 g/t), 0.4 oz per ton (13.7 g/t), and 0.2 oz per ton (6.9 g/t).

Six samples were taken from the longest open adit (pl. 4B, No. 162), which trends S. 60°–70° W. for 61 ft (18.6 m), where it crosscuts a N. 20° W.-striking fracture zone. The samples show low gold and silver values, ranging from a trace to 0.03 oz gold per ton (1.03 g/t) and from nil to 0.2 oz silver per ton (6.9 g/t). The adit is probably south of the main mineralized structure.

Assays from 20 samples at the other workings contained a maximum of 0.03 oz gold per ton (1.03 g/t), 0.5 oz silver per ton (17.1 g/t), 0.71 percent arsenic, 1.2 percent barium, and 0.02 percent molybdenum. Arsenic and other elements that are present could make ores from the Sheila area unamenable to treatment.

Most workings are inaccessible, and exposures are lacking. No estimate could be made of the average grade or possible resources, nor could the average vein width be determined. The high-grade samples indicate that a good potential exists for resources.

MACKAY CLAIM GROUP

The Mackay group, consisting of 19 claims, is in the study area, at the head of Emigrant Creek (pl. 4B, No. 173); these claims were located in 1973 by Golden Nonesuch Corp.

The company has done geochemical prospecting and drilling on a fault zone striking N. 30° W. and dipping 81° NE. in dacite (fig. 33). The zone consists mainly of decomposed dacite; it is traceable for 520 ft (160 m) and averages 13.7 ft (4.2 m) in width. Galena in veins and stringers as much as 2 in. (5 cm) wide crops out in and parallel to the zone. Two holes 330 ft (100 m) apart were drilled nearly perpendicular to the fault at −7° incline for 200 ft (60 m). The north hole is reported to be barren. The south hole intersected the fault zone, and its core contained several percent combined galena, sphalerite, and pyrite as fine disseminations and as breccia filling at intervals in the last 109 ft (33 m), which included the zone. Additional drilling is planned to further delineate the mineralized section (Donald Reichmuth, oral commun., 1974).

Nine samples (W-207-208, W-236, W-241-246) taken by the Bureau of Mines across sections in the fault zone averaged 0.23 oz silver per ton (7.88 g/t), 0.07 percent lead, and 0.1 percent zinc. One across a 0.2-ft (0.06-m)-wide galena stringer near the center of the fault zone contained 14.5 oz silver per ton (497.1 g/t) and 6.69 percent lead (sample W-243).

Fourteen chip samples (W-205-206, W-209-216, W-218, W-237-239) totaling 924.4 ft (281.8 m) were taken from altered dacite on each side of the fault zone. Values ranged from nil to 0.5 oz silver per ton (17.1 g/t) and 0.007 to 0.6 percent lead. One sample (W-217), from a 1-ft (0.3-m)-wide calcite-chalcopyrite vein, contained 0.16 percent copper.

Several galena stringers, as much as one-fourth inch (0.6 cm) thick, strike parallel to the fault zone. Composited specimens from these high-grade stringers suggest the grade ranges from very low to 38.8 oz of silver per ton (1,330 g/t).

Assay data were not available for the core samples. Drilling was to resume during the 1974 field season.

CHICO HOT SPRINGS AREA

An isolated deposit of travertine forms a small hill near Chico Hot Springs Lodge (pl. 3, No. 174). Most of the deposit is on private land

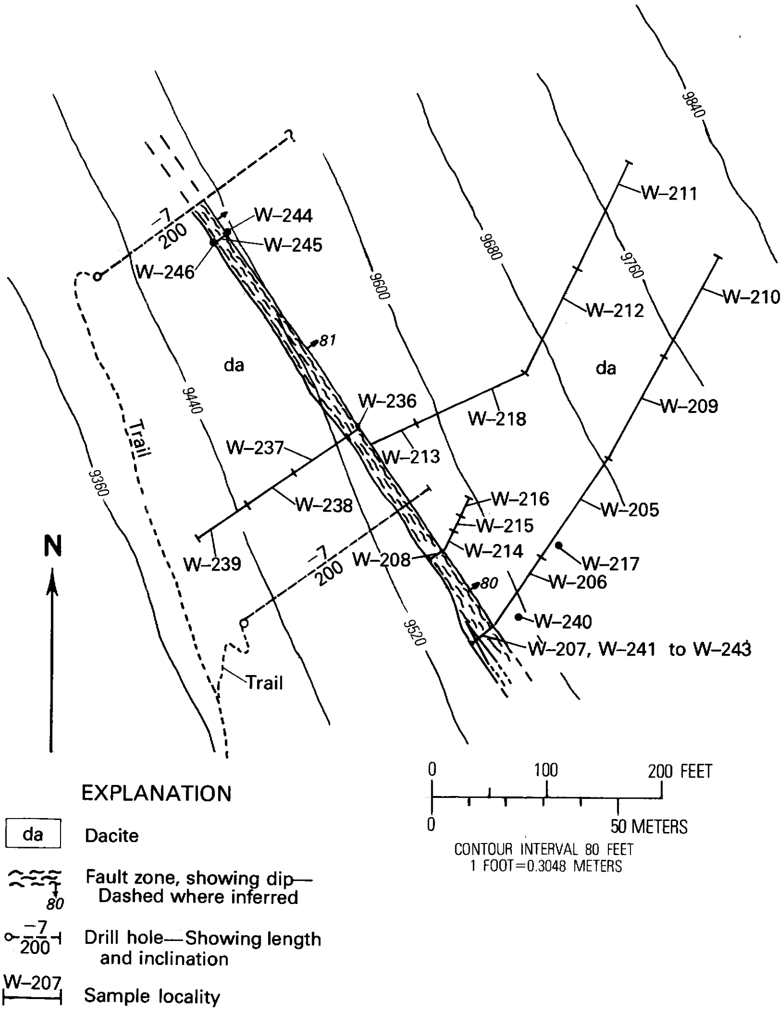


FIGURE 33.—Mackay claim group.

with outcrops mainly confined to a 40-acre (16 h) area with a probable thickness of several hundred feet. The deposit contains 24–35 million tons (23–32 million t). Workings consist of a 22-ft (7-m) trench connected to an 18-ft (5.5-m) adit.

Despite impurities that make its quality poor, the Chico Hot Springs deposit may in the future find local uses as decorative stone. However, with vast deposits of travertine now being quarried at Gardner, Mont., 35 mi (56 km) south, the Chico deposit is not likely to become competitive.

MISCELLANEOUS PROPERTIES, EMIGRANT MINING DISTRICT

Several properties in the district were examined and found to have little or no economic potential or were not well enough exposed to permit evaluation. These properties are listed in table 10.

TABLE 10.—*Miscellaneous properties, Emigrant mining district*

[Data measured in inch-pound system; 1 ft = 0.3048 m; 1 oz (troy)/ton = 34.285 g/t; 1 in. = 2.54 cm; 1 ton = 0.9072 t]

Map[1] No.	Property name[2]	Summary	Number and type of workings	Sample data[3]
43	Little Chief---	Shear zone striking N. 36° E. in limonitic quartz schist.	Inclined shaft, 24--ft long	Three samples; no significant assays.
44	Alpha----------	Limonite-stained shear zones-and schist outcrops at unconformable contacts of graphite schist, amphibolite schist, or quartz gneiss with chlorite schist.	Inclined shaft, 16--ft deep; caved adit, 50 ft long; three pits; and one trench 49 ft long.	Seven samples; as much as 0.2 oz gold and 0.1 oz silver per ton.
45	Alice----------	Fracture zones striking------N. 62° E. in graphite schist schist lens in chlorite schist.	Partially caved adit driven 46 ft along fault, 29-ft and 40-ft drifts at end of adit; one pit.	Six samples; no significant assays.
46	Williamantic---	Lenses of milky quartz and---and gypsum; trace of sulfide minerals, probably bornite and chalcopyrite; chlorite schist country rock.	Pit-----------------	Two samples; no significant assays.
47	Iron Hill------	Contact of limonite-stained--graphite-biotite schist (Precambrian) with quartzite (Cambrian).	Two pits, caved adit 20 to 30 ft long.	Four samples; no significant assays.
48	Fredrick-------	Felspathic quartz gneiss-----stained by limonite.	Pit-----------------	One sample; no significant assays.
49	Charter Oak-----	Limonite-stained quartz vein-or lens striking east-west in schist.	----do---------------	Do.
50	Hunchback-------	Limonite-stained shear zone--striking N. 34° W. and dipping 88° NE. in schist.	----do---------------	Do.
51	Mountain View---	Highly altered mica schist---including 25 percent limonite, 5 percent graphite schist.	Three pits, and a---trench 14 ft long.	Four samples; no significant assays.
52	Lucky Allen-----	Folded and broken quartz-----lens biotite schist. Pyrite stringers.	Pit-----------------	One sample; no significant assays.
53	Wisconsin-------	Graphite schist in chlorite--schist. Adit driven N. 58° E. 22 ft along limonite-stained foliation, then N. 8° W. 9 ft along shear zone.	Adit, 31 ft long----	Two samples; no significant assays.
54	Lookout---------	Limonite-stained graphite----schist fragments on dump of pit dug in biotite schist.	Pit-----------------	One sample; no significant assays.
56	Burlesque-------	Limonite-boxwork gossan in---Precambrian biotite schist, near contact with Cambrian quartzite.	Four pits-----------	One dump sample; 0.26 percent zinc.
57	Bank------------	Quartz stringers striking N.-24° E., dipping 55° SE. in limonite-stained biotite schist.	Caved shaft, 20 to--30 ft deep.	One dump sample; 0.5 oz silver per ton and 0.03 percent zinc.
59	Mountain Lion---	Fault zone. Silicified------schist containing muscovite, biotite, or graphite. Leached sections show abundant limonite boxwork, probably after galena. Zone is silicified.	Adit, 54 ft long;---caved adit, 50 ft long; two pits.	Thirteen samples; as much as 0.3 oz silver per ton and 0.17 percent zinc.
61	Conlin Ridge----	Gray limestone braided by----pinkish-white limestone stringers.	Pit-----------------	One sample; no significant assays.

TABLE 10.—*Miscellaneous properties, Emigrant mining district*—Continued

Map[1] No.	Property name[2]	Summary	Number and type of workings	Sample data[3]
66	Lower Falls No. 1.	Fracture zone. Calcite and quartz bands in lit-per-lit gneiss. Adit driven on 6-in. open fissure.	Adit, 42 ft long	Two samples; no significant assays.
67	Back Pay	Hot spring deposit several hundred feet across and consisting of varicolored travertine. Vents have vugs with calcite and aragonite crystals. Alteration halo is silicified dacite.	None	Three samples; as much as 0.2 oz silver per ton.
68	Montana	Talus-covered summit; silicified and limonite-stained dacite breccia.	Four pits	One sample; no significant assays.
69	Great Eastern group.	Hydrothermally altered dacite in Emigrant stock; pyritization.	Pit	Two samples; no significant assays.
70	do	do	Pit and caved adit 10 ft long.	One sample; no significant assays.
82	Crow Chief	Altered dacite	Three pits	One sample; 0.03 oz gold per ton.
83	Gold Leaf	Patented claim. No outcrops. Lightly silicified dacite on dump.	Caved shaft, 20 ft deep	Two samples; one sample 0.02 oz gold, 0.02 oz silver per ton; One sample 0.3 oz silver per ton.
84	do	Limonite-stained andesite	Caved adit, 110 ft long	One sample; no significant assays.
94	Mint group	Argillized volcanic rocks, principally dacite.	Twelve pits	Eight samples; as much as 0.01 oz gold and 0.2 oz silver per ton.
95	Orschell	Mineralized rock on dump	Unknown. Dump for 500 to 700 ft of workings. Remains of trestle suggest an adit across the creek.	One random dump sample; no significant assays.
116	St. Julian group (?)	Fallen timbers indicate three parallel adits in fine-grained monzonite.	Three caved adits or trenches. Dump indicates 500 to 700 ft of workings.	Four samples; no significant assays.
117	do	Argillized volcanic rock on dump.	Adit, 75 to 80 ft long, in caving condition.	One sample; no significant assays.
118	do	Adit driven S. 34° E. 84 ft on silicified fracture zone (sampled). Two 15-ft caving drifts on 1-in. pyrite vein at end of adit.	114-ft-long adit and drifts.	Two samples; no significant assays.
125	Broken Glasses	Shear zone striking N. 80° W. at gradational contact of dacite and rhyolite. Volcanic rocks altered by argillization and pyritization. Workings were probably an attempt to intersect McAdow structure.	Adit 38 ft long, and two caved adits or trenches.	Four samples; trace to 0.02 oz gold per ton.
130	Margaret	Adit driven into base of low limonite-stained cliff. Cuts 1-ft-thick zone of limonite- and manganese-cemented dacite breccia of rounded fragments 13 ft from portal.	Adit, 25 ft long	Six samples; breccia assayed 0.3 oz silver per ton, adit sample assayed 0.2 oz silver per ton, four 100-ft random samples along cliff returned no significant assays.
131	Winona F	Sheared and fracture porphyritic dacite. Main shear trends N. 85° E. and dips 80° to 84° NW. The dacite contains 1 to 2 percent disseminated pyrite, and is stained by iron and manganese oxides.	Adit, 75 ft long with 15-ft-long drift.	Five samples; as much as 0.01 oz gold per ton, 0.1 oz silver per ton, and 0.02 percent bismuth.

TABLE 10.—*Miscellaneous properties, Emigrant mining district*—Continued

Map[1] No.	Property name[2]	Summary	Number and type of workings	Sample data[3]
132	Huckleberry Ridge.	Highly altered dacite and rhyolite. Argillization, silicification, and pyritization. Entire ridge composed of altered volcanic rocks.	Pit	Two samples; 0.01 oz gold per ton, trace and 0.3 oz silver per ton, and 0.17 and 0.38 percent lead respectively.
133	Little Ax	Highly altered dacite and rhyolite comprising entire ridge.	do	Two samples; as much as 0.01 oz gold per ton.
134	Helen (?)	Stockpile of about 2 tons of gossan. Fragments suggest 12-in.-wide vein of gossan-cemented, brecciated dacite.	Caved shaft, 30 ft deep	One sample; 0.3 oz silver per ton, less than 0.02 percent bismuth.
135	Annie No. 2	Fractured dacite containing less than 1 percent pyrite. Manganese and limonite stain.	Caved adit, 50 ft long	One sample; 0.3 oz silver per ton.
136	Annie	do	Caved adit, 40 ft long.	One sample; no significant assays.
137	Gold Bug	Manganese- and limonite-stained fractured dacite, trending N. 29° W. and dipping 53° SW. Pyrite occurs disseminated in amounts as much as 5 percent.	Pit	Two samples; no significant assays.
138	Hayena	Profusely limonite stained, fractured dacite containing 2-5 percent pyrite.	do	One sample; no significant assays.
139	Mt. Goat	Fine-grained limonite-stained dacite containing 1-2 percent disseminated pyrite.	Caved adit of undeterminable length.	Do.
140	Queen Bee	Fractured, fine-grained, limonite-stained dacite containing approximately 1 percent disseminated pyrite.	Pit	One dump grab sample; 0.03 oz gold per ton and 0.01 oz silver per ton.
141	Hard Cash	Limonite-stained fractured dacite containing 5 to 8 percent pyrite.	do	One sample; no significant assays.
142	Adelle	Fault zone striking N. 13° E. and dipping 75° SE. Zone is profusely limonite-stained, pyritized, and silicified dacite.	do	Three samples; one sample assayed 0.07 percent bismuth.
143	Little Bonanza group.	Altered dacite talus	do	One sample; 0.01 percent bismuth.
144	"A" claim	Atered, leached, flow-banded-rhyolite containing sparse, finely disseminated pyrite.	Two pits	Three samples; no significant assays.
168	Jay	Silicified dacite breccia containing cubes and blebs of pyrite up to one-fourth inch.	Caved adit, 20 ft long.	One sample; no significant assays.
169	Free Silver	Leached, limonite-stained dacite	do	Do.
170	Lee No. 34	Shear zone, silicified and slightly argillized, in porphyritic basalt dike. Near contact of Tertiary volcanic rocks.	Caved adit. Dump removed by creek.	Three samples; no significant assays.
171	Mint #41	Dacite exposed in glacial stream alluvium.	Trench, 15 ft long	One sample; 0.3 oz silver per ton.
172	Mackay #17	Slightly limonite stained biotite-dacite porphyry in glacial rubble.	Trench, 18 ft long	Do.

[1]Map numbers refer to plates 2 and 3.
[2]Underlined names refer to properties assumed to be in, or extend into, the study area.
[3]Assays are considered not significant if the values are less than 0.01 ounce gold per ton, 0.2 ounce silver per ton, 0.1 percent copper, 0.25 percent lead, and 0.25 percent zinc.

MILL CREEK SUBDISTRICT

LOWER MILL CREEK

ROBERT E. LEE OCCURRENCE

The Robert E. Lee copper occurrence is on private land near the mouth of Mill Creek Canyon (pl. 3, No. 175). The strikes of the copper-bearing schist and shear zones lie toward the wilderness study area, one-half mile (0.8 km) south. No indication was found, however, that the mineralized structures cross Mill Creek and extend into the study area.

Malachite, azurite, and chalcopyrite occur as filling in dilated foliation planes and along a shear zone in schist. Silicified graphite and chlorite schist crop out beside the road and are exposed in two adits (fig. 34). Small lenses of calcium carbonate occur in the schist, usually a few feet from copper mineral fillings. Samples contained from nil to 0.8 oz silver per ton (27.4 g/t) and 0.02 to 1.41 percent copper. Only here were significant amounts of antimony encountered; two samples contained 0.17 percent (S-352) and 0.51 percent (J-5).

The Precambrian-Cambrian contact is on the hillside above the adits. In the Emigrant mining district and subdistricts, mineral deposits in schist are nearly always at or near the contact.

BULLDOZER CREEK

ALICE C, BIG PINE, AND PLATINUM RIDGE CLAIMS

The Alice C claim (pl. 4B, No. 180) in the study area was patented in 1915, but has no recorded production. Apparently the property has been idle since 1904.

Two workings, the lower one caved (figs. 35 and 36), have exposed two altered shear zones in biotite schist. The upper workings reveal the zones for a strike length of 93 ft (28 m). The north zone ranges from 4.2 to 7.7 ft (1.3 to 2.3 m) in width but is only partly mineralized. It conforms to the foliation of the schist; strikes range from N. 58° E. to N. 77° W. The dip ranges from 26° to 47° W.

Quartz, along with galena, pyrite, sphalerite, and a trace of chalcopyrite, has locally replaced the schist, and also occurs as fracture filling. Malachite stain is found near the hanging wall. The mineralized zone's thickness varies from 1 to 5 ft (0.3 to 1.5 m), averaging 2.5 ft (0.8 m).

Six samples (fig. 36) taken across the zone, weighted by length, averaged 0.01 oz gold per ton (0.34 g/t), 1.82 oz silver per ton (62.40 g/t), 0.10 percent copper, 2.29 percent lead, and 0.55 percent zinc.

The Bureau of Mines investigated the property in 1948 (Reed, 1950,

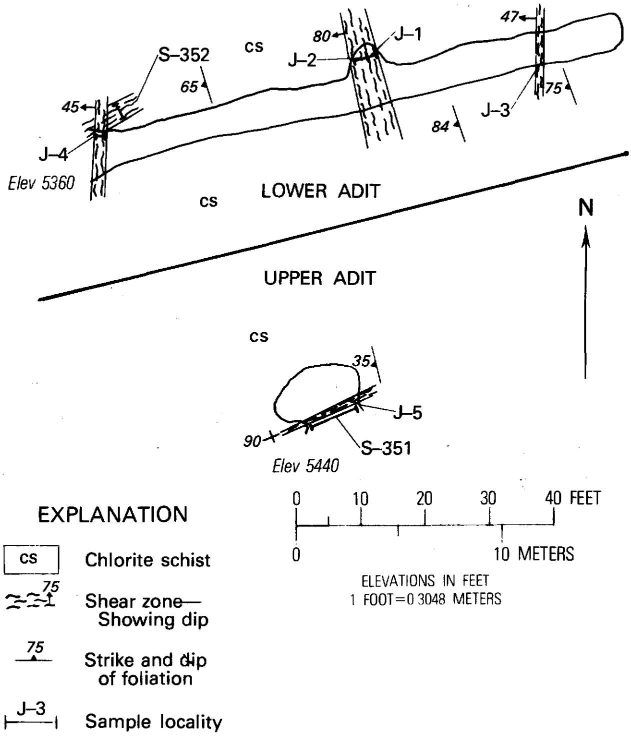


FIGURE 34.—Robert E. Lee occurrence.

Data for samples from localities shown in figure 34

[All samples chip. Data measured in inch-pound system; 1 ft = 0.3048 m; 1 oz (troy)/ton = 34.285 g/t]

Sample			Silver	Copper
No.	Length (feet)	Description	(ounce per ton)	(percent)
J-1	1.7	Across east segment--- of shear zone.	N[1]	0.18
J-2	2.3	Across west segment--- of shear zone.	N	.05
J-3	.7	Across shear zone-----	N	.02
J-4	1.6	-----do---------------	0.2	.53
J-5	2.0	-----do---------------	.3	1.15
S-351	8.0	Along shear zone------	.4	.59
S-352	3.5	Across shear zone, possibly a siliceous lens.-----	.8	1.41

[1]N, none detected.

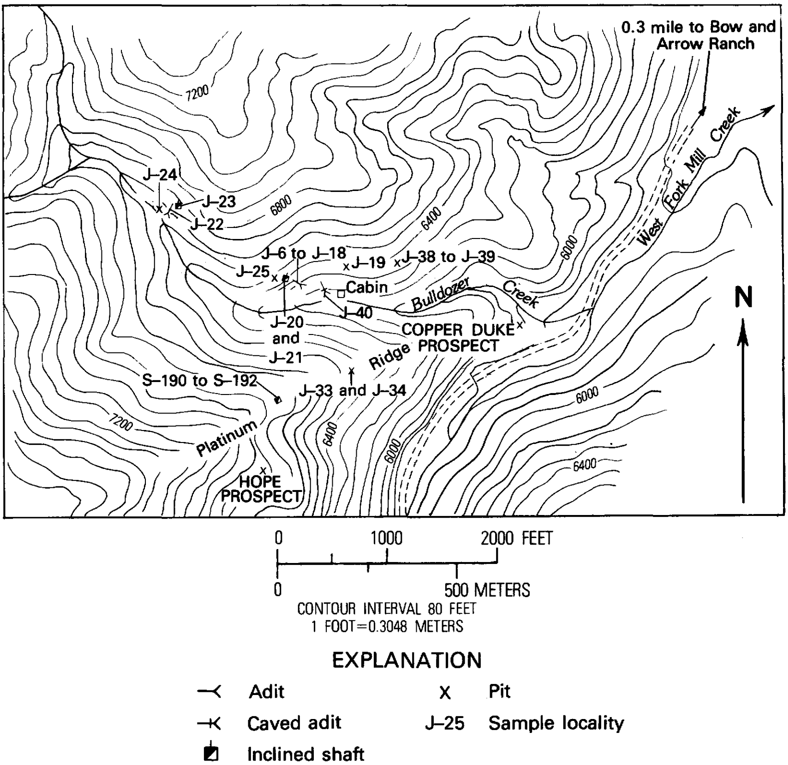


FIGURE 35.—Alice C patented claim area. Base from U.S. Geological Survey 1:62,500 Emigrant, 1955.

p. 50). A large composite sample taken at intervals along the vein assayed 0.12 oz gold per ton (4.11 g/t), 12.0 oz silver per ton (411.4 g/t), 27.0 percent lead, and 3.5 percent zinc; no vein width was given. Samples may have represented the most highly mineralized material.

Resources at the Alice C upper workings are estimated to be 2,300 tons (2,100 t) of indicated submarginal material. This assumes a dip length of half the exposed strike length below the adit, with the grade averaging the same as the six samples taken during the current study.

Approximately 1,200 ft (370 m) to the northwest, an inclined shaft on the Big Pine claim (pl. 4B, No. 181), exposes a shear zone trending N. 88° E. and dipping 47° NW. in biotite schist. The zone is more than 5 ft (1.5 m) wide and contains a mineralized section 1.1 ft (0.3 m) thick. In similarity with the Alice C, quartz with pyrite and galena occurs as hydrothermal replacement products in the schist, and as fracture fillings. One sample, J-23, taken across the mineralized section, assayed 0.01 oz gold per ton (0.34 g/t), 0.4 oz silver per ton (13.7 g/t), and 1.23 percent lead.

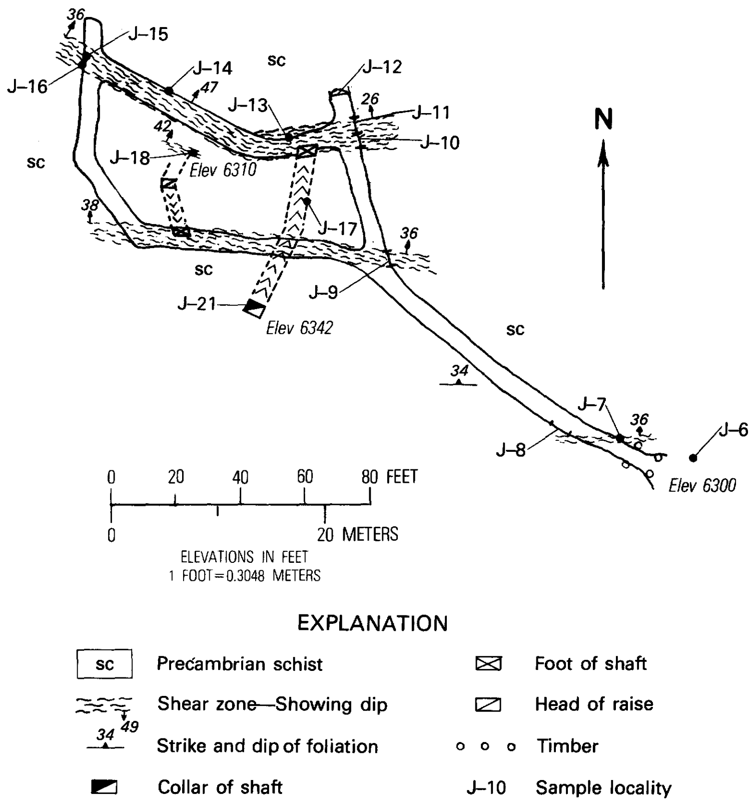


FIGURE 36.—Alice C claim, upper workings.

The Platinum Ridge claim (pl. 4B, No. 183), owned by Kester Counts, is in the study area on the ridge south of the Alice C. In this area, arsenic is the principal metal, occurring in amounts of as much as 9.64 percent, contained in arsenopyrite, over a vein width of 1.7 ft (0.5 m). A shear zone, containing relatively high amounts of arsenic, strikes N. 60° E. in mafic rock. A 20-ft (6-m) inclined shaft was sunk downdip, northwest 40° to 50°. Projection of the strike down the ridge intersects a 2-ft (0.6-m)-wide quartz vein striking N. 40° E. Two samples (J-33 and J-34) from a pit (pl. 4B, No. 182) on the vein returned negligible assays. Despite the name, the Platinum Ridge claim samples contained no platinum.

Arsenic has been produced commercially from deposits in the Jardine district about 30 mi (50 km) south. If current explorations result in the re-opening of these properties, arsenic would probably be recovered as a byproduct. This might provide a market for mineralized material from the Platinum Ridge deposit.

Data for samples from localities shown in figures 35 and 36

[Tr, trace; N, none detected; leaders (- -), not analyzed. Data measured in inch-pound system; 1 ft = 0.3048 m; 1 oz (troy)/ton = 34.285 g/t; 1 in. = 2.54 cm]

Sample				Gold	Silver	Copper	Lead	Zinc	Arsenic
No.	Type	Length (feet)	Description	(ounce per ton)		(percent)			
J-6	Select-grab.	--	From stockpile-------------	0.02	0.6	0.08	0.58	0.21	0.5
J-7	Chip---	2.8	Shear zone-----------------	N	N	.01	--	--	--
J-8	--do---	6.0	Wall rock------------------	N	N	.01	--	--	--
J-9	--do---	5.1	Shear zone-----------------	N	N	.01	--	--	--
J-10	-do----	5.0	----do---------------------	N	.1	.02	.03	.04	--
J-11	--do---	2.7	Mineralized part of shear-- zone	.01	1.2	.11	1.49	.50	--
J-12	--do---	5.2	Across face of adit--------	--	Tr	.01	.01	.01	--
J-13	--do---	3.7	Mineralized part of shear-- zone	.01	2.1	.04	3.34	.84	--
J-14	--do---	1.1	----do---------------------	.03	4.3	.66	1.79	.15	.32
J-15	--do---	1.8	----do---------------------	.01	1.3	.08	1.38	.30	--
J-16	--do---	2.4	Shear zone-----------------	N	.1	.01	.02	.01	--
J-17	--do---	4.9	Mineralized zone-----------	.01	.8	.03	1.18	.38	--
J-18	Chip---	0.6	Mineralized part of shear-- zone	N	8.2	.10	12.1	1.95	--
J-19	Select-grab.	--	Dump material from trench--	N	N	--	--	--	--
J-20	Random-grab.	--	Surface rock---------------	N	.2	.01	.08	.17	--
J-21	Chip---	3.0	Shear zone-----------------	Tr	.5	.02	.69	.07	--
J-22	--do---	2.5	----do---------------------	N	N	--	--	--	--
J-23	--do---	1.1	Collar of shaft, section--- of shear zone.	.01	.4	--	1.23	--	--
J-24	Random-grab.	--	Country rock---------------	N	N	--	--	--	--
J-25	--do---	--	Rock fragments from small-- pit.	Tr	.2	--	--	--	.2
J-33	Chip---	7.0	Across shear zone in------- quartz-rich dacite.	Tr	N	--	--	--	--
J-34	--do---	2.0	Across quartz vein con- --- tained in shear.	Tr	.1	--	--	--	--
J-38	Select-grab.	--	Select grab from dump of--- trench.	N	N	--	.01	.01	--
J-39	Chip---	1.0	Shear zone near trench-----	N	Tr	--	.01	.01	--
J-40	Random-grab.	--	Dump-----------------------	N	N	--	--	--	--
S-190	Chip---	1.7	Across shear zone 10 feet-- below collar of shaft.	.03	.3	.05	.37	--	9.64
S-191	--do---	.3	Across 2-inch sulfide vein- and 1 inch of wall rock on each side, hanging wall at shaft collar.	.01	.3	.02	.29	--	3.7
S-192	--do---	1.2	Across gossan on footwall--	.01	.1	.10	.25	--	1.5

BURNT CREEK

COPPER QUEEN AND LOST CABIN CLAIMS

The Copper Queen claim on Burnt Creek (pl. 4B, No. 188) is on a copper-bearing occurrence containing gold, silver, platinum, and nickel. Graphite and asbestos are also present, but not in recoverable quantities.

Several pits and trenches expose the mineralized structure (fig. 37), which is in the study area near the boundary. Hydrothermal alteration, mineral replacement, and deposition of quartz and metallic minerals have occurred in the hornblende diorite and schist country rocks. The

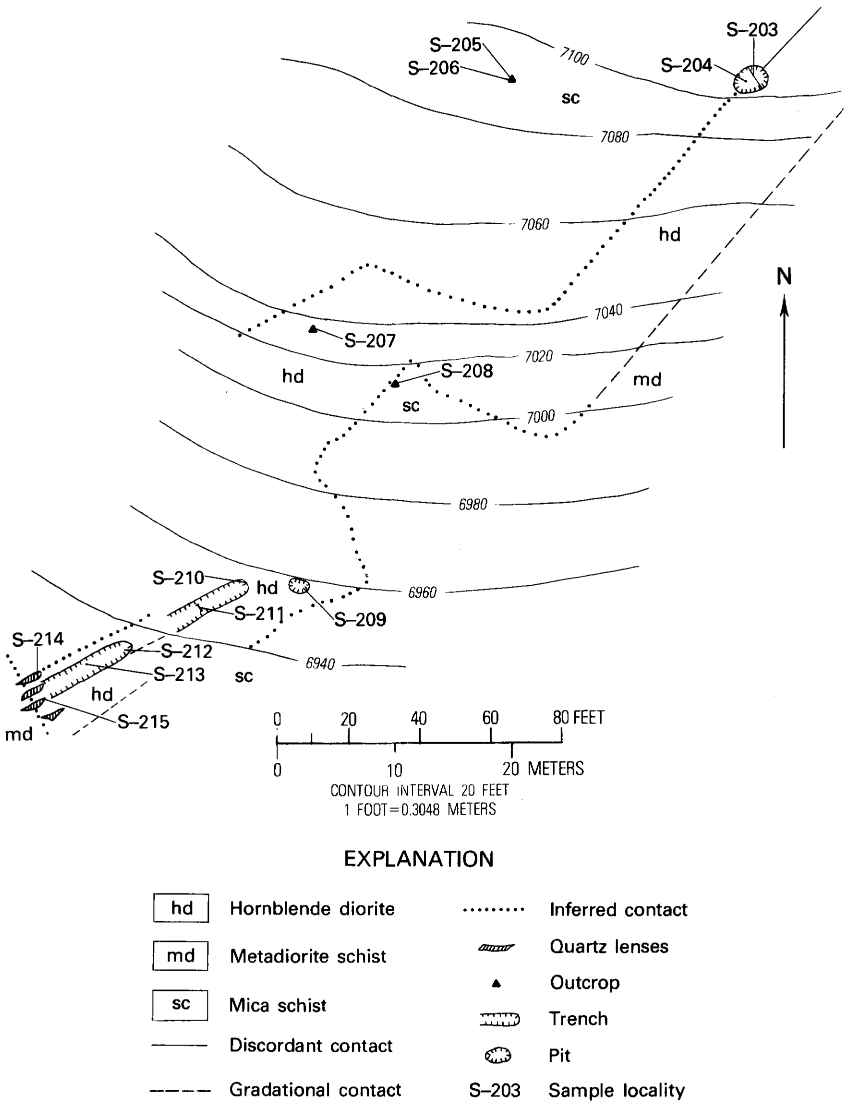


FIGURE 37.—Copper Queen claim.

hornblende diorite is between mica schist on the north and highly foliated metadiorite on the south. The dike-like hornblende diorite trends northeasterly and may be an unmetamorphosed equivalent of the metadiorite. The contact between the metadiorite and hornblende diorite is gradational, but the contact between these two rocks and the mica schist is abrupt. The hornblende diorite is as much as 100 ft (30 m) wide and crops out intermittently for about 300 ft (90 m).

Data for samples from localities shown in figure 37

[N, none detected; leaders (- -), not assayed. Data measured in inch-pound system; 1 ft = 0.3048 m; 1 in. = 2.54 cm; 1 oz (troy)/ton = 34.285 g/t)]

Sample				Silver	Copper	Nickel	Platinum
No. S-	Type	Length (feet)	Description	(ounce per ton)	(percent)		(ounce per ton)
203	Chip---	7.0	Schist-hornblende diorite---- contact.	0.4	0.27	0.008	N
204	Random-chip.	--	Schist and hornblende-------- diorite in pit.	.2	.33	.09	0.001
205	--do---	--	Malachite- and calcanthite- - stained schist outcrop.	.3	.20	.11	--
206	Chip---	1.0	Across 4 in. of quartz------- vein and 8 in. of stained schist.	.1	.49	.38	--
207	Select-chip.	--	Limonite-stained siliceous--- zone 10 ft in diameter; near the contact of schist and hornblende diorite.	N	.23	.11	N
208	Chip---	.5	Across platy schist stained-- with copper minerals.	Tr[3]	.11	.09	.001
209	--do---	3.4	Across schist stained with--- copper minerals.	N	.35	.11	--
[1]210	--do---	.3	Across copper-bearing vein--- striking N. 61° E. and dipping 50° NW.	.8	5.41	.29	.002
[1]211	--do---	1.8	Across copper-bearing vein---	.3	1.66	.40	--
212	Chip---	.4	Graphitic pod---------------	N	.17	.24	--
[2]213	Grab---	--	Highly altered vein fragments sloughed into trench.	N	1.35	.60	.001
214	Chip---	2.0	Across two 12-in. quartz----- veins or lenses.	N	.03	--	--
215	Select-chip.	--	Hornblende diorite stained--- with copper minerals.	N	.12	.14	--

[1]Sample S-210 and S-211 also assayed 0.02 and 0.09 oz gold per ton, respectively.
[2]Sample S-213 also assayed 1.2 percent arsenic.
[3]Tr, trace.

Crushed or sheared zones along probable contacts have an average width, where sampled, of 2 ft (0.6 m). These zones contain an inferred 7,000 tons (6,400 t) of submarginal resources with a weighted average grade of 0.56 percent copper, 0.21 oz per ton (6.8 g/t) silver, and 0.15 percent nickel.

About 900 ft (270 m) along a northeasterly projection, the vein-bearing contact coincides with a mineralized outcrop on the Lost Cabin claim (pl. 4B, No. 187). On the Lost Cabin, also in the study area, the schist is severely contorted, and the general strike and dip of the structure could not be determined.

Two 1-ft (0.3-m) chip samples taken 30 ft (9 m) apart on the outcrop at the Lost Cabin claim assayed 2.00 and 0.71 percent copper. The sample with the higher copper content showed 0.9 ounce silver per ton (30.9 g/t), 0.51 percent nickel, and 0.59 percent arsenic. In the other sample silver, nickel, and arsenic were negligible.

A shallow pit in malachite-stained schist is southwest of the Lost Cabin outcrop. A 6-ft (1.8-m) chip sample from the pit assayed 0.11 percent copper.

Inferred subeconomic resources between the Lost Cabin and Copper Queen workings, assuming a vertical depth equal to one-half the strike distance and a 2.3-ft (0.7-m) average width, are 77,600 tons (70,400 t). The weighted average of samples indicates a grade of 0.48 percent copper, 0.15 oz silver per ton (5.1 g/t), and 0.08 percent nickel.

SHARON SUE AND CONTACT CLAIMS

A silver-bearing lead occurrence was sampled on the Sharon Sue claim, which is just inside the study area along a spur ridge on the southwest side of Burnt Creek Canyon (pl. 4B, No. 191).

According to the Bureau of Land Management Master Township Plat (T. 6 S., R. 9 E.), the Sharon Sue and the Barbara Ann are the only unpatented claims in the Park County portion of the study area where surface rights belong to the claimant.

The Sharon Sue workings consist of two caved adits, each about 100 ft (30 m) long. No samples were taken at the lower working, which was extensively sloughed. The upper adit trends approximately S. 50° W. in faulted Cambrian sandstone along or near its contact with Tertiary volcanic rock. The local dip of the contact is 75° NE.

A 1.6-ft (0.5-m) channel sample taken across fault zone gouge in the south wall of the upper caved portal assayed 5.24 percent lead, 0.5 oz silver per ton (17.1 g/t), and 1.3 percent barium. Development rock scattered about the dump consists of vuggy sandstone containing galena-, cerussite-, and barite-filled fractures as much as 2 in. (5 cm) thick. Specimens of this material assayed 23.9 percent lead, 2.6 oz silver per ton (89.1 g/t), and 13.3 percent barium.

Two samples from pits on the hill above the adit assayed 0.29 percent lead and 0.2 oz silver per ton (6.9 g/t) (pl. 4B, No. 192).

A copper-bearing shear zone occurs on the Contact No. 2 claim at the study area boundary, southeast of the Sharon Sue (pl. 4B, No. 193). The shear zone, which strikes N. 6° W. and dips 74° NE., is in fine-grained hornblende diorite similar to that at the Copper Queen. A 5-ft (1.5-m) chip sample taken across the zone assayed 0.4 oz silver per ton (13.7 g/t) and 0.14 percent copper. A grab sample from a pit stockpile assayed 0.01 oz gold per ton (0.34 g/t), 0.2 oz silver per ton (6.9 g/t), and 0.96 percent copper.

The Sharon Sue and Contact claims have potentials for mineral resources.

PEACOCK CLAIM

The Peacock copper occurrence on the slope east of the mouth of Burnt Creek traverses the study area boundary. It is in the Mill Creek–Sixmile Creek mineral belt. The claim's copper showings (pl.

4B, No. 176) are in an altered Precambrian schist near its contact with Precambrian metadiorite, Cambrian sandstone, and Tertiary dacitic volcanic rock.

Soil and talus cover much of the area and pits are sloughed. However, samples from four of five pits indicate that a copper resource may exist under the talus, between three pits on the ridge and a pit 150 ft (46 m) to the southwest. Sample results are as follows:

Location	Type of sample	Copper (percent)
Northwest pit on ridge.	Chip 9.0 ft (2.7 m) long across east face.	0.23
Center pit	Select grab from dump	.89
Southeast pit	Random grab of dump	.52
South pit	Select grab from dump	.75

ARRASTRA CREEK

BARBARA ANN MINE, AND PILGRIM, ST. CROIX, AND LIGHTNING NO. 3 CLAIMS

The Mill Creek mining district's only recorded mineral production has been from the Barbara Ann mine (pl. 4B, No. 194), which is on the ridge between Burnt Creek and Arrastra Creek just outside the study area. Between 1947 and 1968 ore shipments totalled 98 tons (83 t). Average smelter returns (Reed, 1950) on 53 tons (48 t) were as follows: 0.8 oz gold per ton (27.43 g/t), 12.1 oz silver per ton (414.85 g/t), 0.9 percent lead, 0.3 percent copper, 0.3 percent zinc, and 0.26 percent bismuth. The bismuth was determined on one lot only.

Workings include a shaft and adit (fig. 38). Loose timbers prevented access to the shaft, which is reported to be 25 ft (8 m) deep with a 20-ft (6-m) drift at the bottom. The adit was an unsuccessful attempt to undercut mineralized rock cropping out on the hill above (Kester Counts, oral commun., 1973). Quartz and sulfides of copper, lead, silver, zinc, and iron occur as replacement along a brecciated shear zone in basalt.

About 10 tons (9 t) of development rock was stockpiled during mining operations in September 1974. Plans to ship the ore to a lead smelter were deferred when it was learned that no payment would be made for the copper. Samples S-177 and S-178 were taken before the material was mined.

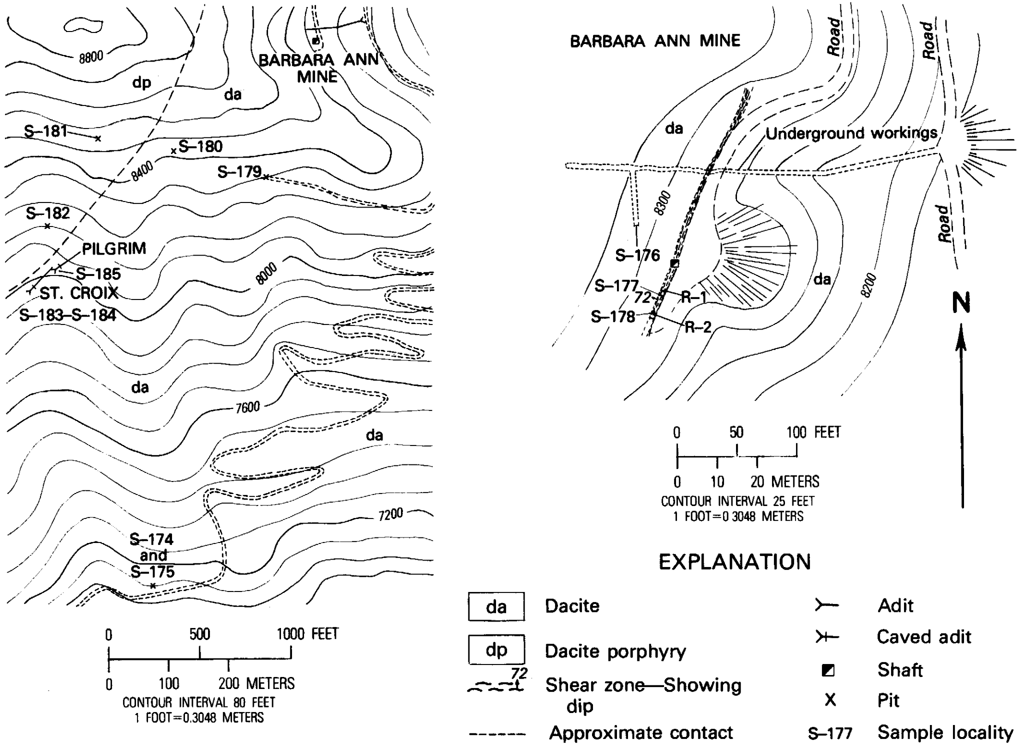


FIGURE 38.—Barbara Ann mine, and Pilgrim and St. Croix patented claims.

Data for samples from localities shown in figure 38

[Tr, trace; N, none detected; leaders (- -), not analyzed. Data measured in inch-pound system; 1 ft = 0.3048 m; 1 oz (troy)/ton = 34.285 g/t]

Sample				Gold	Silver	Copper	Lead
No.	Type	Length (feet)	Description	(ounce per ton)		(percent)	
-1	Chip	4.3	Reported in Reed (1950); across outcrop. Waste inclusion.	0.05	2.25	0.7	0.6
-2	do	2.5	Reported in Reed (1950); foot-wall vein split.	.13	11.13	1.8	1.3
-174	do	6.0	East sample segment across intersection of shear zones. Sampled normal to 36° dipping zone.	N	.7	.85	--
-175	do	4.6	West segment across exposed part of zone.	Tr	.6	.17	--
-176	do	1.0	Across breccia vein in crosscut	N	Tr	--	--
-177	do	2.5	Across shear zone	Tr	N	.20	.03
-178	do	2.3	do	.04	5.8	.26	.91
-179	Select-grab.	--	Limonite-stained shear zone in roadcut.	N	.1	.03	--
-180	Chip	2.1	Across malachite- and limonite-stained shear zone in porphyritic andesite.	.02	.9	.30	--
-181	do	1.5	Across silicified shear zone in porphyritic basalt or dacite. Minor malachite stain.	.05	2.4	.11	2.74
-182	do	.9	Across silicified and limonite-stained shear zone.	.28	2.7	.25	--
-183	Grab	--	Dump	Tr	Tr	--	--
-184	do	--	Two-foot-thick vein material on dump. Malachite stain.	.05	.9	.18	--
-185	do	--	Leached stockpile	N	.2	[2]<.01	--

[1] Sample S-178 also assayed 0.07 percent bismuth.

[2] <, less than shown.

An excavation was dug in October 1974 to explore the intersection of the shear zone with erosional remnants of Paleozoic limestone. A mineralized replacement shoot containing high-grade copper ore and native silver was encountered in the limestone. A nugget of silver reportedly measured more than an inch (2.5 cm) across (Kester Counts, oral commun., 1974).

Metallic minerals occur intermittently on the surface southwest of the shaft. The Barbara Ann shear zone may split a few hundred feet from the mined area; one branch can be traced intermittently on the surface to the Pilgrim–St. Croix patented claims (pl.4B, No. 196) and the other possibly extends toward an exposure in a roadcut south of the mine (pl. 4B, No. 195).

The St. Croix and Pilgrim (Mike Walsh claims) were located in 1889. They are just outside the study area. Patent survey plats of 1906 show a 180-ft (55-m) adit, 52-ft (16-m) crosscut, and 37-ft (11-m) drift on the St. Croix claim, and a 185-ft (56-m) adit on the Pilgrim. These workings are inaccessible.

The dumps and a 2-ton (1.8-t) stockpile composed of limonite-cemented breccia stained by hematite are highly leached. Country rock at the Pilgrim claim is a porphyritic dacite or bleached andesite. The claims are near a contact, as mapped by W. J. McMannis (unpub. mapping, 1973), between Precambrian metadiorite, Cretaceous(?) volcanic rock, and Tertiary dacite of the Emigrant stock. Intense hydrothermal alteration prevented field identification of rock types.

Several shear zones are exposed in roadcuts. The effects of hydrothermal alteration were noted along several hundred feet of road. A section 10 ft (3 m) wide resembled a decomposed granite.

An excavation was started on the Lightning No. 3 claim where a mineralized body occurs at the intersection of two shear zones (pl. 4B, No. 197). The zones are intensely weathered, containing oxidized minerals, clay, and interlaced and fractured quartz stringers. Copper minerals occur in a zone dipping 36° NW. at the intersection of a vertical zone; both strike northerly. Wall rock is porphyritic basalt.

The strike distance between the Barbara Ann shaft and the St. Croix adit is 2,050 ft (625 m). Assuming a depth equal to one-half the strike length, and an average vein width of 2.4 ft (0.7 m), the indicated mineral resources are 480,300 tons (435,700 t). An additional 193,200 tons (175,300 t) are inferred along the projection of the mineralized zone to the southwest of the St. Croix adit. Samples from the indicated and inferred paramarginal resources have a weighted average grade of 0.06 oz gold per ton (2.06 g/t), 3.43 oz silver per ton (117.60 g/t), and 0.59 percent copper. Material sampled at the Barbara Ann mine also contained 0.69 percent lead.

Additional gold, silver, copper, and lead resources may occur in a shear zone that roughly parallels the Barbara Ann–St. Croix zone. The parallel zone exposed in the pit S-181 (fig. 38) is malachite stained; it strikes N. 60° E. and dips vertically in an altered, coarse-grained or porphyritic volcanic rock.

SPRING AND VIRGINIA CLAIMS

The southwest projection of the Barbara Ann–Pilgrim–St. Croix shear system trends into the study area through the Cathy and Spring claims (pl. 4B, Nos. 200 and 201). Limonite-stained shears in slightly siliceous andesite are revealed in eight pits on the Spring claim. Generally, the sheeted zone trends northeasterly, but individual shears have strikes ranging from N. 48° E. to N. 88° W. in what is probably a cognate pattern. Nine samples were taken across the shears. Assay results were inconsequential except for two containing 0.96 percent and 0.81 percent lead. One of these also assayed 0.3 oz silver per ton (10.3 g/t). Sample lengths were 1.6 ft (0.5 m) and 4.7 ft (1.4 m), respectively. Calcite lenses as much as 3 in. (7.6 cm) thick occur locally along with a few stringers of specular hematite. Quartz lenses a maximum of 1 in. (2.5 cm) thick were noted at a few pits.

Lead and copper occurrences were examined on the Virginia claim (pl. 4B, Nos. 202–205), which is just inside the study area. At the east showing (No. 202), a pit has been dug on a shear zone striking N. 70° E. The zone, with an average width of about 5 ft (1.5 m), can be traced for at least 75 ft (23 m) in volcanic rock grading from dacite to basalt. Galena occurs at intersections of fractures lacing the zone. Two samples from across the structure assayed 0.84 percent and 0.43 percent lead, 0.2 oz and 0.3 oz silver per ton (6.9 and 10.3 g/t), 0.04 and 0.03 percent copper, and 0.17 and 0.15 percent zinc, respectively.

A sample from a 1-ft (0.3-m)-wide parallel shear zone (pl. 4B, No. 203) contained tungsten (<0.01 percent WO_3), as did a piece of float (0.01 percent WO_3). The latter (No. 204) also assayed 0.02 oz gold (0.69 g/t) and 0.3 oz silver per ton (10.3 g/t).

Copper minerals occur with quartz in a vein striking northwest and dipping 65° SW. in a cliff face (pl. 4B, No. 205) about 1,000 ft (300 m) west of the Virginia pit. A sample from across the 1-5-in. (2.5-13-cm)-thick vein assayed 0.4 oz silver per ton (13.7 g/t), 0.53 percent copper, and less than 0.01 percent bismuth.

A resource of 92,000 tons (83,500 t) is inferred in a 3.6-ft (1-m)-wide zone between the Virginia and Spring workings, a distance of about 750 ft (230 m). Although submarginal with average grades of 0.66 percent lead and 0.25 oz silver per ton (8.6 g/t), the Virginia-Spring structure resembles nearby higher grade deposits.

MONTANA, SHIRLEY, AND FLOYD COUNTS CLAIMS

Samples containing gold, silver, copper, lead, bismuth, and tungsten were obtained from workings on the ridge east of upper Arrastra Creek (pl. 4B, Nos. 207–209, and fig. 39). The study area boundary passes through the properties, which are owned by Kester Counts.

Metallic minerals have partly replaced igneous rock along shear zones in the claimed area. Usually the zones are at contacts between intermediate to mafic extrusive and intrusive igneous rocks. Some of the narrower flows may be sills. Talus and overburden make it difficult, if not impossible, to trace most structures.

On the Montana claim (pl. 4B, No. 207), the mineralized material is localized at the intersection of shear zones striking N. 28° W. and N. 42° E. The intersection is composed predominantly of limonite boxwork, which might indicate a zone of secondary enrichment at depth. Two sample intervals (S-226 and S-227) totaling 5.6 ft (1.7 m) across the intersection had a weighted average of 0.01 oz gold per ton (0.34 g/t), 2.18 oz silver per ton (74.7 g/t), 3.62 percent copper, and 0.54 percent bismuth. In one sample 0.06 percent tungsten trioxide was present.

A pit was sampled on the Shirley claim (pl. 4B, No. 208) where copper minerals occur in a shear zone striking N. 55° E. A sample (S-225) across 6 in. (15 cm) of the zone assayed 2.86 percent copper, 4.0 oz silver per ton (137.1 g/t), 0.22 percent bismuth, 0.01 oz gold per ton (0.34 g/t), 0.04 percent antimony, 0.49 percent lead, and 0.06 percent tungsten trioxide. The rugged topography precluded examination of possible extensions of the zone, particularly at its inferred intersection with the northwest-trending shear zone on the Montana claim.

The principal mineralized shear zone in the immediate vicinity is on the Floyd Counts claim across the steep ridge west of the Shirley claim (pl. 4B, No. 209). A high-grade mineral occurrence has been exposed in a 60-ft (18-m) adit and 17-ft (5-m) trench (fig. 17).

Highest assays were obtained from a 0.3-ft (0.1-m)-wide shear zone near the face of the adit (sample J-74), a 1-in. (2.5-cm)-wide vein at the face of the cut (sample S-222), and from material probably blasted from the vein and walls of the cut (sample S-221). Upward projection of the shear zone dip in the adit, and downward projection of the dip of the vein in the cut indicate the two exposures are not on the same structure.

Only a few tons of high-grade material are in sight, including about 1 ton (0.9 t) of broken material in the floor of the cut. Even with a penalty for the first 3 percent bismuth and no smelter payment for tungsten, the Floyd Counts deposit has the potential to become a small, high-grade mineral producer. A detailed study of the joint, shear, and fault systems on the Montana, Shirley, and Floyd Counts claims might lead to the discovery of additional resources.

DAVID AND PYRITE CLAIMS

Gold, silver, bismuth, and copper minerals occur on two claims located on both sides of Arrastra Creek southwest of the Floyd Counts (pl. 4B, Nos. 210–213). The claims are in the excluded corridor. Workings consist of a 15-ft (4.6-m) adit (No. 212), a 28-ft (8.5-m) trench (No. 211), and a shallow pit (No. 213).

On the David claim is a highly brecciated shear zone that is faulted at the face of an adit (No. 212) that has been driven S. 58° E. A sample across 5 in. (13 cm) of the zone's more highly limonite stained material assayed 0.35 oz gold per ton (12.00 g/t), 1.3 oz silver per ton (44.6 g/t), and 0.85 percent bismuth. The face of the adit was barren.

Talus covers most of the mountain slope east of the David workings. Southeast of the adit, however, a trench (No. 211) has been dug on a bearing of N. 80° E. along an outcrop of silicified and argillized rhyolite breccia, possibly a dike, in basalt talus. A 1-ft (0.3-cm) chip sample across the altered rhyolite breccia contained 0.56 oz gold per ton (19.2 g/t), 1.8 oz silver per ton (61.7 g/t), and 0.21 percent bismuth. A dump sample assayed 0.03 oz gold per ton (1.03 g/t) and 0.05 percent bismuth. The structure exposed by the trench may be the faulted segment of the shear zone noted in the adit. Predominant fractures in the area trend N. 80° W. and dip 79° NE. Rhyolite brecciation was evidently in two stages, each followed by the introduction of silica.

A malachite-stained basalt dike was sampled (No. 210). The dike occurs on the south side of a fault striking N. 45° E. and dipping vertically. The fault may be an extension of the Montana shear zone. The presence of copper minerals and the trend of the fault suggest a closer relationship with the Montana shear zone than with the David. Two samples taken across 6 in. (15 cm) of the fault and 15 in. (38 cm) of the dike assayed 0.01 oz and 0.02 oz gold per ton (0.34 g/t and 0.69 g/t), 0.2 oz silver per ton (6.9 g/t), and 0.21 percent and 0.20 percent copper, respectively.

A shallow pit (No. 213) exposes an area of altered rock on the Pyrite claim, which is on the west side of Arrastra Creek, opposite the David trench. A random chip sample taken over several square feet assayed 0.4 oz silver per ton (13.7 g/t) and 0.03 percent bismuth.

Because of the talus cover, exposures of structures on the David and Pyrite claims are insufficient to permit an estimate of resources. However, potential mineral resources may exist.

McADOW CLAIM GROUP

The McAdow group consists of three patented claims in an excluded corridor on the west side of Arrastra Creek, and extends across Mineral Mountain into the Emigrant mining district (pl. 4B, Nos. 218–220).

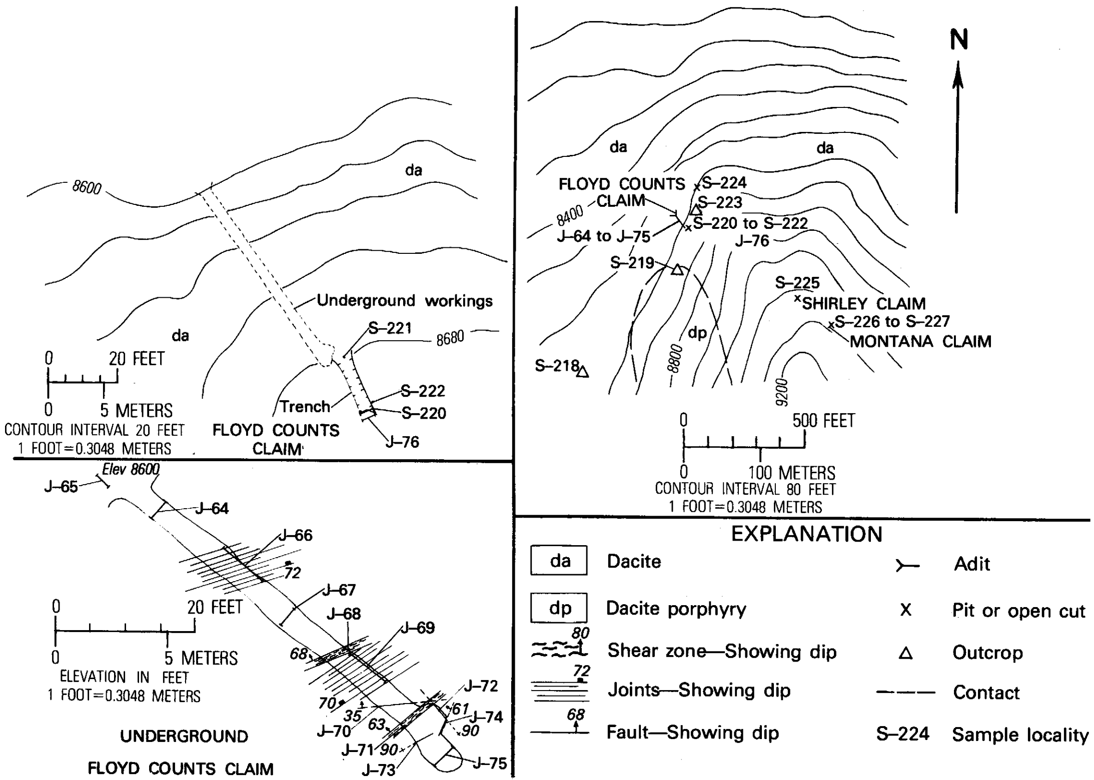


FIGURE 39.—Montana, Shirley, and Floyd Counts claims.

Data for samples from localities shown in figure 39

[Tr, trace; N, none detected; leaders (- -), not analyzed. Data measured in inch-pound system; 1 ft = 0.3048 m: 1 oz (troy)/ton = 34.285 g/t]

Sample			Gold	Silver	Copper	Bismuth	Lead	Tungsten (percent	Antimony
No.	Length (feet)	Description	(ounce per ton)		(percent)			WO_3)	(percent
J-64	3.8	Across back-------------------	N	Tr	[1]<0.01	--	--	--	--
J-65	2.5	Outcrop of altered volcanic-- rock.	N	0.1	.01	--	--	--	--
J-66	7.4	Across jointed area----------	N	N	--	--	--	--	--
J-67	3.0	Across back-------------------	N	N	--	--	--	--	--
J-68	1.0	Across shear zone------------	N	N	[1]<.01	--	--	--	--
J-69	6.4	Across highly pyritized------ jointed area.	Tr	N	--	--	--	--	--
J-70	.1	Across highly pyritized------ fault. As much as 5 percent sulfides.	N	Tr	--	--	--	--	--
J-71	.8	Across shear zone. Contains 1/8 in. chalcopyrite stringer.	0.01	.8	.22	--	--	--	--
J-72	.2	Across fault zone------------	Tr	.6	--	--	--	--	--
J-73	1.0	-----do-----------------------	N	N	--	--	--	--	--
J-74	.3	Veinlets of chalcopyrite as-- much as 1/4 in. wide in quartz vein or silicified. dacite.	.03	15.1	.74	1.06	1.04	--	--
J-75	4.4	Across back-------------------	N	N	--	--	--	--	--
J-76	4.0	Across face of cut. Copper-- stain after chalcopyrite.	N	.8	.22	.05	--	<0.03	--
S-218	.2	Across quartz-lined fissure-- in cliff.	N	N	--	--	--	.05	--
S-219	--	Select sample of copper- ---- stained spall from cliff. Stain on cliff face covers several hundred square feet.	Tr	1.1	.42	.12	.15	<.01	0.04
S-220	4.7	Across face. May represent-- wall of 1-in.-thick vein.	Tr	.9	.38	.25	.25	.04	.04
S-221	--	Muck pile containing copper-- carbonates on floor of cut.	.07	15.0	4.16	2.03	1.13	.06	.03
S-222	.1	Veinlet containing bismuthi-- nite, scheelite galena, and copper and silver minerals.	.49	68.4	1.53	15.7	3.03	.81	.02
S-223	.1	Seam of black rock or min- -- eral in cliff face. May be north extension of a shear zone in adit.	.06	.6	--	.14	.11	.59	--
S-224	2.0	Across shear zone------------	Tr	N	--	--	--	.01	--
S-225	.5	Across shear zone including-- 3-in.-thick copper-bearing vein.	.01	4.0	2.86	.22	.49	.06	.04
S-226	4.3	Across south segment of------ shear zone.	N	.9	3.21	.01	--	--	.03
S-227	1.3	Across north segment of------ shear zone.	.04	6.4	4.97	2.29	--	.06	.02

1< less than shown.

Another peak, also named Mineral Mountain, is a few miles south. The three claims, owned by Kester and Garland Counts, consist of the Queen Esther, located in 1900; the Comanche, originally located as the Bertie M in 1886; and the McAdow, located in 1888. No production has been recorded, but small stopes in the workings indicate that some ore was probably mined.

Mineral alteration made field identification of most rock types impossible. However, the composition appears to vary from rhyolite to dacite, and basalt. Flow-banded rhyolite was noted, which was also present at important mineral deposits across the ridge in Emigrant Gulch.

A sheared or fractured dike may be the controlling geologic structure. Metallic minerals have replaced volcanic rock in shear zones with nearly complete replacements in some areas. Pyritization, silicification, and argillization were locally intense over widths of several hundred feet (over 100 m). The general trend of the mineralized zone is N. 87° W. on the Queen Esther, N. 84° E. on the Comanche, and N. 60°–80° E. on the McAdow. Local variations reflect extensive faulting. Principal workings consist of four open adits, one caved adit, and a shallow shaft (figs. 40 and 41).

Sloughing has almost obliterated the portal of the Queen Esther discovery adit (S-3116); the length is shown as 127 ft (39 m) on the survey plat. Another adit (S-311 through S-315) evidently missed the mineralized structure until driven north, indicating the structure was faulted between the upper and lower workings.

The country rock of the Comanche claim is cut by several mineralized shear zones and joints. At the south adit (fig. 41), galena-bearing veins trend N. 86° E. In the north adit, breccia veins trend N. 83° E., but galena and silver values are more concentrated along a joint system trending from N. 65° W. to due W. One grab sample (S-302) across a 4-ft (1.2-m)-wide stope muck pile of altered dacite contained relatively high values (fig. 41).

The shear zone extends from the north adit westward for a distance of about 300 ft (90 m) to the 25-ft (8-m) McAdow discovery shaft. The zone is as much as 200 ft (61 m) wide and stained black with iron and manganese oxides. Galena is localized as lenses at fracture intersections on approximately 2 ft (0.6 m) random centers. The lenses are a maximum of 6 in. (15 cm) in diameter and 1 in. thick. The long axes follow a fracture system striking N. 30° E. and dipping 65° NW. Apparently galena deposition was structurally controlled by flow banding.

The McAdow mine, about 350 ft (100 m) west of the discovery shaft, was sampled to the winze, which was too hazardous to cross. Breccia veins as much as 1.4 ft (0.4 m) wide and containing galena are exposed along most of the 160 ft (50 m) from the portal to the winze. According to the owner, the drift continues for about 100 ft (30 m) beyond the winze and then trends south.

A road to the McAdow mine was extended over the ridge from Arrastra Creek into the East Fork of Emigrant Creek drainage (pl. 4B) late in the summer of 1974. It was built to facilitate shipment of ore scattered on the McAdow dump.

Several east-west-trending, highly fractured, silicified, and weathered shear zones were uncovered by roadcuts. A 2.2-ft (0.7-m)-long sample (S-416, fig. 40) across one of these zones, on the border of the McAdow claim, assayed 0.58 oz gold per ton (19.89 g/t), 2.4 oz silver per ton (82.3 g/t), and 0.50 percent lead. Minerals occur in unique

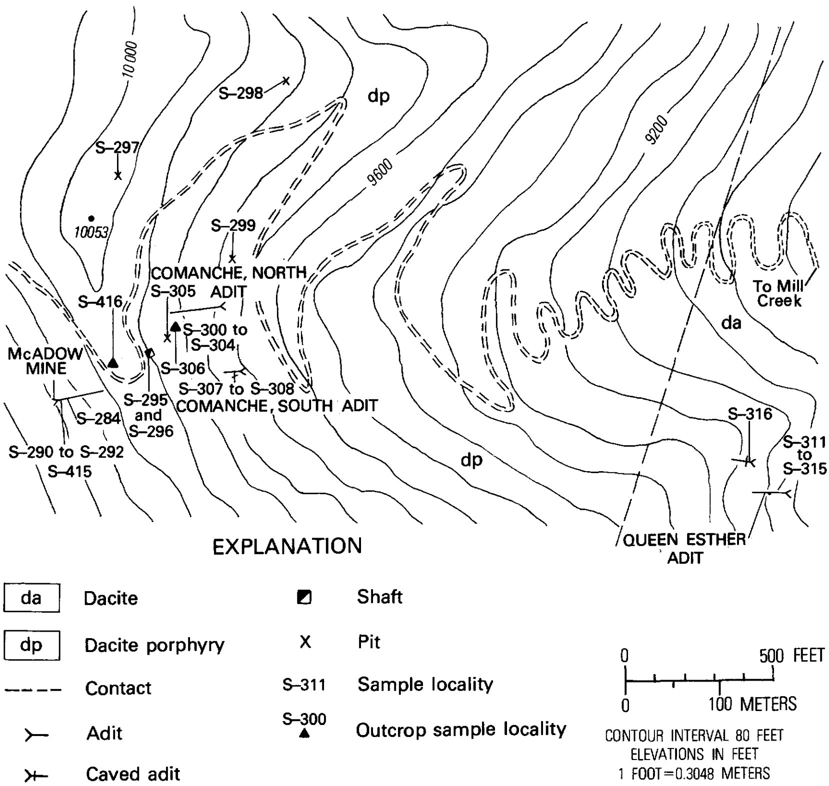


FIGURE 40.—McAdow claim group.

peacock-colored veinlets braiding a silicified fracture zone which crosses the road 100 ft (30 m) from its crest. The strike is N. 75° W. and dip is 78° NW.

The principal mineralized zone extends 650 ft (200 m) from the Comanche north adit to the McAdow mines, and perhaps farther. The vein system within the zone is severely faulted, but based on an average sample length of 1.7 ft (0.5 m), the system is estimated to contain 8,500 tons (7,700 t) of indicated paramarginal resources from the surface to the adit levels and 33,000 tons (30,000 t) of inferred paramarginal resources from the adit levels to a depth of 295 ft (90 m). The weighted average of eleven samples across the veins was 0.27 oz gold per ton (9.3 g/t), 13.97 oz silver per ton (478.9 g/t), 4.1 percent lead, 0.18 percent zinc, 0.03 percent copper, and 0.05 percent bismuth. The vein averaged 1.7 ft (0.5 m) wide where sampled. A small tonnage of relatively high grade material is also present at the Queen Esther adit and the Comanche south adit.

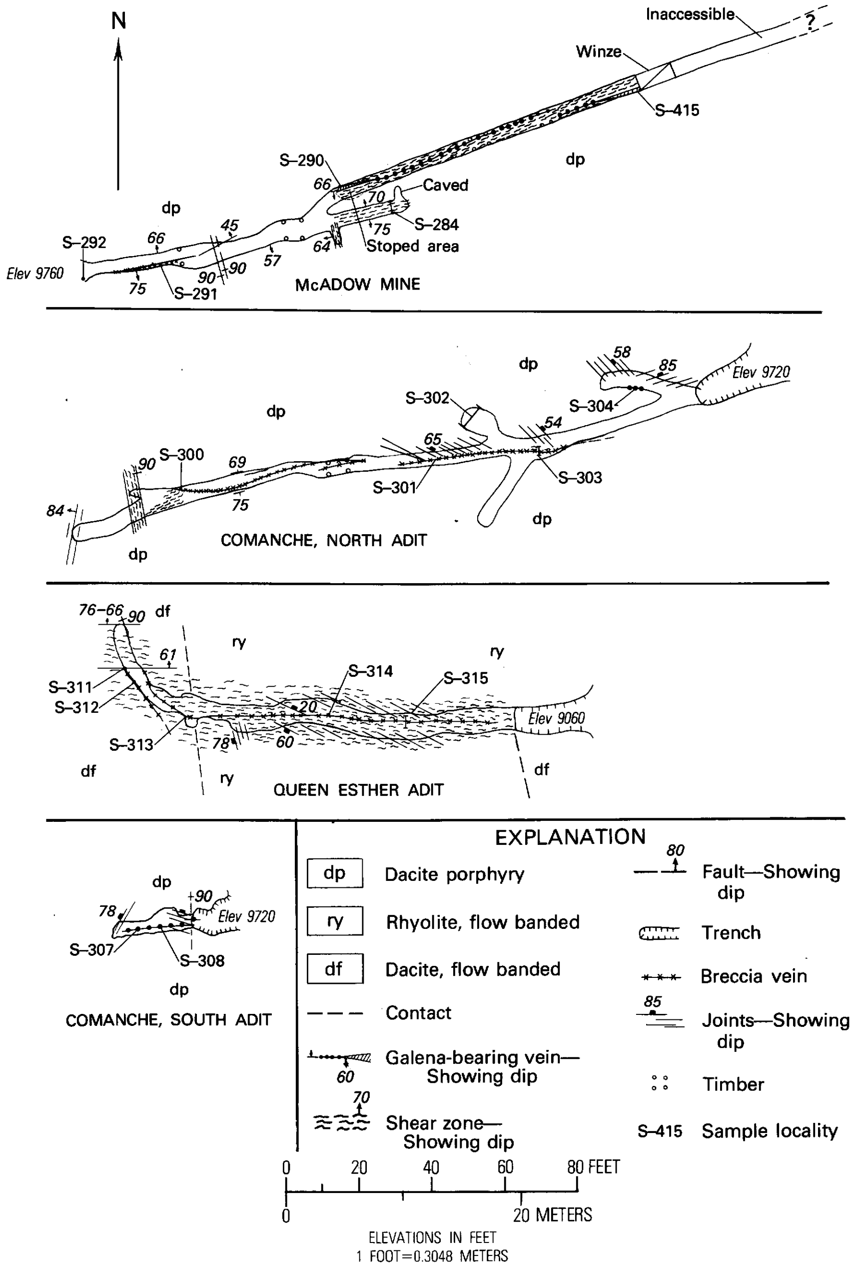


FIGURE 41.—Underground workings on the McAdow claim group.

Data for samples from localities shown in figures 40 and 41

[N, none detected; leaders (- -), not analyzed. Data measured in inch-pound system; 1 ft = 0.3048 m; 1 oz (troy)/ton = 34.285 g/t]

Sample No. S-	Sample Length (feet)	Sample Description	Gold (ounce per ton)	Silver (ounce per ton)	Copper (percent)	Lead (percent)	Zinc (percent)	Bismuth (percent)
284	4.0	Across south drift floor.-- Slightly porphyritic dacite.	0.02	2.0	--	--	--	--
290	1.4	Across galena and breccia-- vein in front brow of 20-ft-high stope.	.66	11.6	0.07	5.36	0.08	0.06
291	.2	Across breccia vein of----- dacite, quartz, limonite, galena and argentite.	.09	20.6	.01	2.93	.11	.18
292	--	Stockpile------------------	.12	95.0	.01	12.10	.05	1.30
295	.6	Vein in east collar of----- McAdow shaft, caved to 8 ft. Limonite and Fe-Mn oxides (60 percent), hematite (30 percent), and quartz (10 percent) localized blebs of galena.	.26	1.7	.06	.55	.26	--
296	6.0	Across shaft development---	.07	1.2	.05	.55	.19	--
300	.5	Across breccia vein;------- quartz (50 percent), dacite (45 percent), argentite (5 percent).	2.10	76.2	--	8.19	.09	--
301	.4	Across breccia vein. Fe- - Mn oxides with galena and argentite (?) (50 percent), and halotrichite or melanterite (5 percent).	.24	46.2	.28	29.2	.34	.32
302	4.0	Across muck pile of-------- altered dacite.	.62	16.2	--	--	--	--
303	2.	Across shear zone;--------- clay (50 percent) dacite (?) (50 percent).	.03	.6	--	.16	--	--
304	.2	Across vein; quartz (50---- percent gouge (30 percent), galena (10 percent), limonite (10 percent).	.40	16.6	--	15.3	.31	.10
305	4.4	Across face of cut---------	.04	10.7	--	7.10	.32	.07
306	88.0	Random chip across center-- of outcrop.	Tr[1]	.6	--	.19	.19	.01
307	.2	Galena vein----------------	.02	12.0	.24	28.5	.10	.02
308	.1	-----do--------------------	Tr[1]	8.3	.05	16.3	.16	.02
311	.2	Across breccia vein;------- limonite clay (60 percent), manganese dioxide (20 percent), hematite (10 percent), kaolinite (10 percent).	.17	5.9	.53	--	--	.23
312	.3	Breccia vein---------------	N	N	--	--	--	--
313	.2	-----do--------------------	Tr[1]	N	--	--	--	--
314	.2	Breccia vein---------------	N	N	--	--	--	--
315	3.8	Sheeted zone of limonite- - stained, flow-banded rhyolite.	N	N	--	--	--	--
316	1.0	Across highly-weathered---- shear zone; clay (60 percent), limonite (30 percent), jarosite or bismite (10 percent).	.17	3.7	.17	.43	--	.26
415	1.0	Across galena vein at------ collar of 15-ft winze, McAdow mine.	.05	123.4	.03	14.8	.38	--
416	2.2	Across shear zone in------- roadcut containing veinlets in silicified zone.	.58	2.4	--	.50	--	--

[1]Tr, Trace

VIVIENNE CLAIM

A mineral resource potential might exist in a shear zone on the ridge north of the McAdow claim. A sample of highly siliceous material 0.8 ft (0.2 m) thick was obtained from the west face of a pit (pl. 4B, No. 221) on this zone. The assay was 0.02 oz gold per ton (0.69 g/t), 0.2 oz silver per ton (6.9 g/t), and 0.58 percent lead. Projection of the zone's N. 72° W. trend intersects with a pit near the ridge crest (No. 222), a distance of 500 ft (150 m). A grab sample from that badly sloughed pit assayed 0.45 percent lead and 0.01 percent molybdenum. The property is just outside the study area.

GALENA QUEEN CLAIM

The Galena Queen claim (pl. 4B, No. 226), owned by Kester Counts, is at the study area boundary. It is near the east end of a mineral zone that appears to extend westward 1 mi (1.6 km) through the Dixie, Jeanette, Grand View, Garland Counts, and Broken Glasses claims in the Emigrant mining district.

Principal workings consist of an adit at least 200 ft (60 m) long, and flooded 55-ft (17-m) shaft which is 5 ft (1.5 m) from the adit. The adit was driven on a bearing of S. 65° W. to N. 80° W. in a sheeted zone in highly pyritized volcanic rock. The rock has been described as rhyolite (Reed, 1950, p. 52) but is mainly dacitic in composition.

Reed (1950) indicated that within the sheeted zone, metallic minerals are in gash structures that strike N. 75° W., dip 79° S., and range from 2 in. (5 cm) to 1 ft (0.3 m) in width. The sheeted zone strikes N. 65° E. into the study area, dips vertically, and exceeds 400 ft (120 m) in width. It is probably the same zone exposed on the ridge to the west (pl. 4B, No. 224). The gash structures contain pyrite and coarse galena with minor amounts of sphalerite and chalcopyrite in a quartz gangue (Reed, 1950). Finely disseminated galena occurs where the sheeted zone is silicified.

Thick deposits of iron oxides coat the Galena Queen adit. Water-saturated limonite terraces become progressively higher as they approach the excavation's face. Beyond the last sample site, which is 144 ft (44 m) from the portal, the terraces are at least 4 ft (1.2 m) high. There are several limonite stalagmites as much as 3 ft (0.9 m) high with diameters of more than 1 ft (0.3 m). Because of this thick limonite crust, sampling results were inconclusive. Two water-saturated breccia veins, one 30 ft (9 m), and the other 144 ft (44 m) from the portal were sampled and contained insignificant values. Probably most metallic minerals have been leached out.

A sample across an exposure of the sheeted zone on the east creek bank also showed negligible values. A small stockpile on the dump, however, assayed 0.12 oz gold per ton (4.11 g/t), 0.15 oz silver per ton (5.1 g/t), and 0.46 percent lead. No resources are estimated for the property.

A caved adit (pl. 4B, No. 224) beyond the study area, near the ridge crest dividing the Mill Creek and Emigrant mining districts, is believed to be on the westward extension of the Galena Queen structure. The sheeted zone strikes N. 80° E., dips 45° NW., and is about 200 ft (60 m) wide near the adit. Iron and manganese oxides, pyrite, and limonite boxwork are found in a highly altered gangue of basalt and dacite. The occurrence is similar to the McAdow mineralized zone about 1,500 ft (460 m) north.

A select sample of mineralized rock was taken from the badly weathered dump of the caved adit, which is estimated to be 20–30 ft (6–9 m) long. Assay results were 0.7 oz silver per ton (24.0 g/t), 2.03 percent lead, and 0.14 percent zinc. A grab sample from this dump returned assays of 0.3 oz silver per ton (10.3 g/t), and 0.36 percent lead, and 0.14 percent zinc.

A shear zone on the trend of the Galena Queen structure crops out in the study area on the Arrastra Quartz claim about 1,500 ft (460 m) east of the main Galena Queen adit (pl. 4B, No. 227). A chip sample taken across 3 ft (0.9 m) of the more highly iron oxide stained portion assayed 0.04 oz gold per ton (1.38 g/t) and 0.3 oz silver per ton (10.3 g/t).

MIDNIGHT DEPOSIT

A low-grade manganese-wad and bog iron deposit containing zinc is in the bottom of Arrastra Creek. The general area is indicated on plate 4B (Nos. 214 and 229 to 231). Deposition is currently taking place at several springs in the deposit.

Reed (1950, p. 52) indicated that the deposits consist of lenses, each with a plan area of less than 5,000 ft^2 (465 m^2), and ranging in thickness from 3 to 6 ft (0.9 to 1.8 m). In places, manganese and iron oxides have cemented sand, gravel, and cobbles into dense, conglomeratic masses. These oxides also occur as high-grade spongy lenses. One test shipment reportedly assayed battery grade (68-75 percent MnO) (Kester Counts, oral commun., 1973).

Iron ore with a manganese content of from 2 to 35 percent is classified as manganiferous ore. The required iron content is variable but is usually about 35 percent. Such material is added to blast furnace feed. Any zinc present would not be recoverable if the material were shipped for its iron and manganese content. This may make the material less than economical.

The deposits were sampled at four locations (pl. 4B, Nos. 214 and 229–231). At the northern site (No. 214), two samples (J-77 and J-78) were taken from the top 1.7 ft (0.5 m) and bottom 2.1 ft (0.6 m), respectively, of a pit wall. Another (S-30) came from a 6-ft (1.8-m)-thick manganese-cemented conglomerate exposed for 30 ft (9 m) along the hillslope above the Galena Queen adit (pl. 4B, No. 229). Site 230 is a bog iron deposit from which a grab sample (S-29) was taken. Site 231 provided a grab sample (S-25) of the spongy bog material. Near site 231, a pit was dug and sampled in three intervals. The first interval was 1 ft (0.3 m) of topsoil (sample D-99). The second was 1 ft (0.3 m) of subsoil (D-100). The third (D-101) was from the lower 10 ft (3 m) of the trench and pit face, which consisted of a mixture of iron-and-manganese oxides loosely cementing coarse rock fragments. Sample results follow:

Map No.	Sample No.	Iron (percent)	Manganese (percent)	Zinc (percent)[2]
214	J-77	0.53	18.5	2.78
214	J-78	2.51	4.85	.52
[1]229	S-30	2.3	2.67	---
230	S-29	41.7	.01	---
231	S-25	33.3	.10	---
231	D-99	4.6	.81	.04
231	D-100	23.4	3.29	.42
231	D-101	18.5	1.53	.16

[1]Sample S-229 also assayed 0.03 oz gold per ton (1.03 g/t).

[2]Leaders (---), not analyzed.

The assays averaged 10.7 percent iron and 3.5 percent manganese. Approximately 230,000 tons (209,000 t) of resources are inferred, assuming a 7-ft (2-m) average depth. The grade may be quite different in the center of the deposit, which could not be sampled because of a soil mantle.

Bulk samples from sites 214 and 231 were wet screened to determine if the cementing oxides could be recovered by trommeling, and thereby could provide a higher grade product. Assay of the minus 60 mesh fraction, which comprises most of the cementing material, indicate no appreciable upgrading, as shown in the following table:

Sample No.	Iron (percent)	Manganese (percent)	Zinc (percent)	−60 mesh as percent of total sample weight
J-77	1.01	13.9	2.30	37.3
J-78	2.53	10.4	1.25	20.4
D-99	29.8	1.90	.15	8.5
D-100	38.5	4.27	.55	14.3
D-101	34.3	1.97	.30	9.5

The manganese-to-iron ratio increases from upstream to downstream sites. Iron and manganese deposits may also exist on the east side of Arrastra Creek, but coarse talus covers the surface.

CARMEL CLAIM

A mineral resource potential exists at the Carmel claim (pl. 4B, No. 232), which is on the study area boundary. A heavily pyritized area several hundred feet in diameter is penetrated by two adits. These pyrite zones, found at several locations in the Emigrant district and Mill Creek and Sixmile subdistricts, may be indicative of porphyry-type disseminated copper-molybdenum deposits at depth.

Four samples from across various fractures and breccia veins in the lower adit had inconsequential values. A select sample from the dump assayed 0.07 oz gold per ton (2.4 g/t) and 0.1 oz silver per ton (3.4 g/t). The lower adit is driven S. 52° W. for 155 ft (47 m) along a weak fracture in argillized, pyritized, and irregularly silicified rhyolite. A 14-ft (4-m) crosscut bears S. 15° E. along a 5-ft (1.5-m)-wide breccia 70 ft (21 m) from the portal.

The upper adit is 35 ft (11 m) long on a bearing of S. 73° W., and is 200 ft (60 m) upslope from the lower adit. About 15 ft (5 m) inside the upper adit portal is a crosscutting watercourse. It is 2 ft (0.6 m) wide and filled by hematite gouge veins that are as much as 1 in. (2.5 cm) thick on each wall. Between the two hematite occurrences is a 10-in. (25-cm) vein of manganese oxide, and as much as as foot (0.3 m) of highly fractured and argillized rhyolite. The lower adit may have been driven to test the downdip projection of a vein in the upper adit.

Although a sample from across the watercourse assayed insignificant values, a 0.1-ft (0.03-m) stringer of pyrite on the south wall assayed 0.12 oz gold per ton (4.1 g/t) and 0.7 oz silver per ton (24 g/t).

An iron-oxide-stained breccia zone on the ridge to the southeast and extending along the study area boundary is on the projection of the trend of the Carmel adits. It is similar in appearance to the Galena Queen and McAdow mineral zones.

ANDERSON CREEK

COPPER QUEEN CLAIM

The Copper Queen claim is on a tributary of Anderson Creek (pl. 3, No. 240), within the study area. The workings consist of two caved adits, a pit, and a trench, all of which are badly sloughed. Overburden covers the mineralized structures. However, the claim seems to be a potential copper resource.

The workings follow a contact between shale and limestone on the west and a porphyritic andesite intrusive on the east. Limestone has been replaced by silica, cuprite, and chalcocite. Locally the volcanic rock is weathered and has the appearance of decomposed granite. Accurate measurements of dips and strikes were not possible because of the irregularity of the contact.

Vein material 4 in. (10 cm) wide taken from the dump at the lowest working, assayed 0.13 percent copper. The caved adit was reportedly driven 50–100 ft (15–30 m) N. 40° W. through Park Shale to the andesite intrusive (Fox, 1960, p. 73).

Another sample was taken from a 20-ft (6-m) trench bearing N. 35° W. approximately 120 ft (37 m) northwest of the adit. In the exposed replacement zone, the copper-bearing portion is about 3 in. (8 cm) wide. A sample from across the zone assayed 3.27 percent copper and 0.8 oz silver per ton (27.4 g/t).

The zone is also exposed in a pit N. 25° E. 90 ft (27 m) from the trench. Although the outcrop is only 6 in. (15 cm) wide, material in two 1-ton (0.9-t) stockpiles shows that vein fragments as much as 12 in. (30 cm) thick came from the pit. The deposit consists of chalcocite in a gangue of siderite, with minor calcite coating some fractures. Values were negligible in a sample taken across the contact zone. Stockpile materials contain specular hematite. Limestone is present under the slough at the pit.

SAGE CREEK

ARROW PEAK CLAIM

The Arrow Peak claim is in the study area on a tributary of Sage Creek (pl. 3, No. 241). This lead occurrence is on the projection of the mineral belt extending 10 mi (16 km) to the southwest through the Emigrant district and the Mill Creek and Sixmile subdistricts.

An adit was driven N. 70° E. for 40 ft (12 m) in Precambrian gneiss at a concordant contact (Fox, 1960, p. 71) with schist. It turns northward 30 ft (9 m), crosses the contact, and terminates at another contact between schist, gneiss, and sandstone. A 1-in. (2.5-cm)-wide galena vein is crosscut at the adit portal, and another is crosscut 18 ft (5.5 m) inside the adit. The veins strike N. 46° W. and N. 63° W. with dips of 67° SW. and 36° SW., respectively. A sample taken across fault gouge stringers in the face showed no significant assay values.

Compared to other deposits in the mineral belt, the lead to silver ratio was high. Two samples from across the veins assayed 29.3 percent lead with no silver or gold and 52.0 percent lead with 0.4 oz silver (13.7 g/t) and 0.02 oz gold per ton (0.69 g/t).

The claim has a mineral resource potential, particularly at the dip intersection of the two galena veins.

MISCELLANEOUS PROPERTIES MILL CREEK SUBDISTRICT

Several properties in the Mill Creek subdistrict either have little or no economic potential, or are insufficiently exposed to indicate a potential. These properties are listed in table 11.

SIXMILE SUBDISTRICT

SI CLAIM

The Si claim (pl. 3, No. 17) is in the study area, near the head of Placer Basin Creek, a tributary of Sixmile Creek. It was located in 1967 by T. H. Counts. Two pits and five shallow trenches expose iron- and manganese-oxide-stained dacite and dacite porphyry. The workings appear to be on localized oxide concentrations, for no major extensions could be found.

Four chip samples from the workings assayed from a trace to 2.7 oz silver per ton (92.6 g/t); the weighted average was 0.3 oz per ton (10.3 g/t) representing a 5.1-ft (1.5-m) width. Three dump grab samples contained as much as 0.2 oz silver per ton (6.9 g/t). A select sample of vuggy breccia also assayed 0.2 oz silver per ton (6.9 g/t). Samples and mineralized dacite from the Si claim comprise a geologic environment similar to that of the Emigrant Creek district. This environment indicates the possibility of resources on the Si claim.

MAGNETIC CLAIM GROUP

The Magnetic group consists of eight claims located for iron. They are on the south side of North Fork Sixmile Creek (pl. 4B, No. 16), with principal workings in the study area near an excluded corridor.

The property was probably first located as the Giant Lode in 1895. Three relocations were filed within the next ten years, and the excavation of two adits was recorded in 1905. The Magnetic group was located in 1963.

Workings consist of one pit, and two adits that are driven southerly along mineralized shear zones in Precambrian schist (fig. 42). The zones strike N. 22° W. and dip 60° to 87° SW. parallel to foliation. One averages 7.5 ft (2.3 m) in width and is traceable for 390 ft (120 m). Samples from the lower adit, weighted by length, averaged 39.3 percent iron (samples W-21 and W-22). An outcrop sample (W-20) from between the adits assayed 23.4 percent iron. The zones are composed of vuggy quartz veinlets as much as 1 in. (2.5 cm) wide, with limonite, and siliceous schist that has fine disseminations and streaks of magnetite as much as 3 in. (8 cm) wide. Magnetic concentrations seem discontinuous, and boundaries are gradational within the siliceous schist. The upper adit seems to be on a relatively barren shear zone.

TABLE 11.—*Miscellaneous properties, Mill Creek subdistrict*

[Assays are considered not significant if the values are less than 0.01 oz gold per ton, 0.2 oz silver per ton, 0.1 percent copper, 0.25 percent lead, and 0.25 percent zinc. Data measured in inch-pound system; 1 oz (troy)/ton = 34.285 g/t; 1 ft = 0.3048 m. Map numbers from plates 3 or 4B]

Map No.	Property name[1]	Summary	Number and type of workings	Sample data
177	C & H	Limonite, fault gouge and silicified schist as much as 0.7-ft-wide striking N. 40° W. and dipping 55° NE. in shear zone several feet wide.	Pit	Four samples; no significant assays.
178	Copper Duke	Mineralized shears in schist. Malachite stains cliff face over an area 10 x 12 ft. Schist is interfingered with quartzite. Shear zone traced 50 ft south.	----do----	One select sample; 0.60 percent copper.
184	Hope	Flat-lying quartz vein or lens in biotite-muscovite schist.	----do----	Two samples, no significant assays.
185	Burnt Creek	Three aplite dikes as much as 6 ft wide striking north. Twenty-five-foot horizontal, and 30-ft vertical exposure.	Adit, 25 ft long, bearing due west.	Do.
186	Chips	0.8-ft-wide shear zone in schist. Foliation trends N. 15° E. and dips 48° NW.	None	Two samples no significant assays.
189	Bornite	Area 400 ft wide of talus containing veinlets and blebs of copper and lead sulfides and their oxides in quartz.	----do----	One select sample; 0.01 oz gold per ton, 1.52 percent lead, and 0.98 percent copper.
190	----do----	Hornblendite (diabase dike?) and schist containing minor white-quartz vein material and disseminated pyrite.	Pit	One select sample; no significant assays.
198	Fountain	Limonite- and manganese-oxide-stained-altered dacite porphyry.	Two pits	Two samples; no significant assays.
199	Alice	Replacement and minor vein-filling in shear zone in contorted basalt dike at newly opened pit on south creek bank. Bleached and brecciated rock cemented by calcite in old pit on north bank. Limonite boxwork mainly after pyrite. Vein quartz. Most of country rock covered by talus.	----do----	Three samples, as much as 0.02 oz gold and 0.3 oz silver per ton, 0.06 percent copper, 0.24 percent lead, 0.30 percent zinc, less than 0.006 percent molybdenum.
200	Cathy	Pipe-like breccia zone. Volcanic breccia replaced and cemented by silica and limonite. Breccia cut by shear zone having fault gouge. Zone strikes N. 15° E. at south adit, due north at north adit.	Fifteen-ft-long adit with 28-ft drift. Caved adit, 30-50 ft long.	Five samples; from 0.1 to 0.5 oz silver per ton.
206	Falls	Outcrop of rhyolite in talus or angular moraine rocks.	Two pits	Two samples; no significant assays.
215	Jewell	Ten-foot-wide shear zone striking northerly in argillized rhyolite. About 20 percent limonite with minor manganese oxide.	Pit	One sample; no significant assays.
216	Crystal	Thirty-foot-long exposure of shear zone averaging 5 ft wide. Contains 30 percent coarsely-crystalline calcite, and 70 percent leached and argillized dacite. Zone strikes N. 6° W. and dips 75° W.	None	Do.

TABLE 11.—*Miscellaneous properties, Mill Creek subdistrict*—Continued

Map No.	Property name[1]	Summary	Number and type of workings	Sample data
217	Julie Ellen	Bleached aphanitic rock showing minor flow-banding. Siliceous zone striking north across the arete.	Pit	Do.
223	Dodge	Alteration zone on arete between McAdow and Galena Queen shear zones. Possibly a wide crosscutting fault zone. North-south trending zone is altered dacite, about 15 percent hematite and 2 percent MnO_2. Hematite is specular and massive varieties. Localized breccia cemented by calcium carbonate. Zone is at least 7 ft wide.	do	Two samples; as much as 0.33 percent lead, 0.04 percent molybdenum, and less than 0.01 percent bismuth.
225	Midnight	Altered dump rock	Two 50-ft-long caved adits.	Two samples; no significant assays.
228	Arrastra Quartz.	Fractured and pyritized dacite breccia. Fractures trend N. 5° W. and due east and dip 75° NE. and 70° N. respectively.	Two cuts	Three samples; as much as 0.03 oz oz gold and 0.1 oz silver per ton
233	High Point	Five barite veins from 0.1 to 0.5 ft wide striking N. 28° to 31° W. in fractured porphyritic dacite. The veins tend to be parallel to the direction of fracturing. Mineralization appeared to have been localized on the ridge.	Three pits	Five samples; two barite veins assayed 45.9 percent and 84.0 percent $BaSO_4$ and as much as 0.01 oz gold and 0.4 oz silver per ton. Dacite is barren.
234	Virginia 1	Limonite-stained quartz dacite containing disseminated pyrite cubes.	Pit	Two samples; no significant assays.
235	Iron Hat	Highly altered limonite-stained dacite containing disseminated pyrite cubes.	Two pits	One sample; no significant assays.
236	Silver Reef	Pyrite disseminated in fine-grained to coarse-grained porphyritic dacite. Moderate limonite stain.	Pit	Five samples; no significant assays.
237	Silver Queen	Limestone outcrop in dacite. One pit in each rock type.	Two pits	Two samples; no significant assays.
238	Bull Moose	Chlorite-bearing area in schist.	Adit, 7 ft long	One sample; no significant assays.
239	Hot Shot	Travertine deposit at Montanapolis Springs. Claims located for uranium reported at the soda springs (personal commun.). Travertine deposit fills gulch bottom from springs to Mill Creek. Widths up to 400 ft and thickness of probably less than 50 ft. Active deposition of flowstone on adit walls. Travertine is impure in Mill Creek roadcut; no economic potential is estimated.	Adit, 31 ft long in gulch bottom.	Do.

[1]Properties underlined are in the study area.

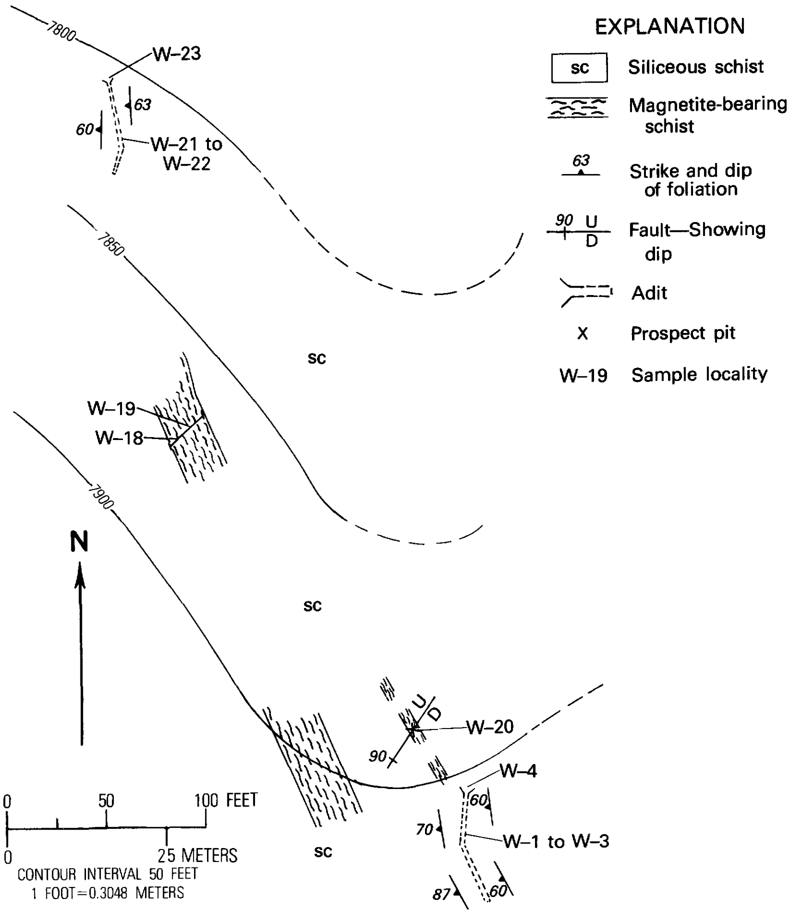


FIGURE 42.—Magnetic claim group.

A parallel mineralized zone (fig. 42) is traceable for 250 ft (76 m). Two samples (W-18 and W-19), taken across 23.2 ft (7.1 m) of width, averaged 22.6 percent iron.

Assuming that both zones persist to a depth one-half the indicated strike length, 175,000 tons (159,000 t) containing an average of 27.5 percent iron is inferred. Size and grade are not sufficient to constitute an iron resource. Gold and silver resources may exist. Assays were as much as 0.04 oz gold per ton (1.37 g/t) and 0.4 oz silver per ton (13.7 g/t).

OVERLAP CLAIM

The Overlap claim is at the study area boundary on the north side of North Fork Sixmile Creek, 5 mi (8 km) upstream from its junction with Sixmile Creek (pl. 4B, No. 26).

Data for samples from localities shown in figure 42

[All samples chip, except W-4, W-23, select. Tr, trace; N, none detected; leaders (- -), not analyzed. Data measured in inch-pound system; 1 oz (troy)/ton = 34.285 g/t; 1 ft = 0.3048 m]

Sample			Gold	Silver	Iron
No. W-	Length (feet)	Description	(ounce per ton)		(percent)
1	8.8	Across shear zone-	N	0.1	1.0
2	1.0	-----do-----------	N	N	.94
3	.9	-----do-----------	N	N	1.1
4	--	Stockpile---------	N	N	--
18	9.8	Across shear zone-	0.02	.3	15.3
19	13.4	-----do-----------	Tr	.3	28.1
20	13.0	-----do-----------	.04	.1	23.4
21	2.1	-----do-----------	Tr	.1	44.0
22	2.0	-----do-----------	N	.4	34.4
23	--	Stockpile---------	Tr	Tr	28.8

Workings consist of three caved adits estimated to total approximately 500 ft (150 m) in length (fig. 43). Small stockpiles are atop two dumps. The first location was probably the Spring Tunnel claim located in 1895. The prospect was relocated as the Overlap in 1967. Development plans call for the reopening of the two major adits, and the shipment of the stockpiles to a smelter (J. H. Counts, oral commun., 1974).

All three adits are caved, and talus covers most bedrock. A small ridge-like outcrop above and between the two larger workings was examined. A vein containing gouge and masses of vuggy pyrite and galena intergrowths is traceable for 65 ft (20 m) in dacite porphyry. The maximum width is 2.0 ft (0.6 m). Projected along strike and dip (N. 65° E. and 52° NW., respectively), the vein would intersect adit No. 1. Adits 2 and 3 have a northeast orientation and seem to follow a different geologic structure.

Dump material indicates that adits 1 and 2 encountered veins as much as 8 in. (20 cm) wide. Dump materials include pyrite, galena, and sphalerite occurring in a calcite-quartz gangue of silicified dacite porphyry. Assays ranged from nil to 0.15 oz gold per ton (5.1 g/t), nil to 1.5 oz silver per ton (51.4 g/t), nil to 3.0 percent lead, and nil to 2.0 percent zinc. Stockpiled material is less than 100 tons (90 t); the dumps contain about 900 tons (820 t).

The Overlap property has a mineral resource potential. It is near the apparent southern terminus of a mineral belt extending 6.5 mi (10.5 km) to Bulldozer Creek in the Mill Creek area (fig. 23).

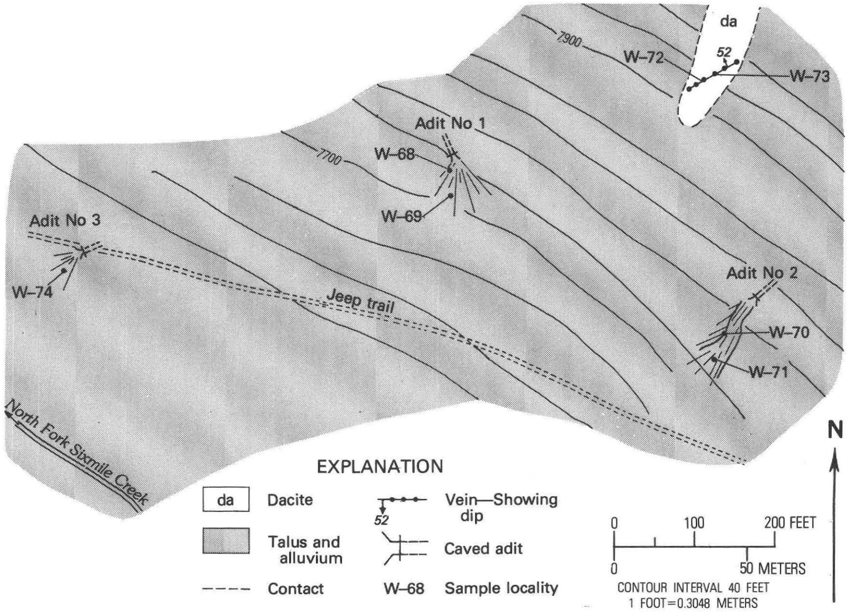


FIGURE 43.—Overlap claim.

CREVIS CLAIM

The Crevis claim (pl. 4B, No. 29, and fig. 23) is about one-half mile (0.8 km) north of the Overlap. J. H. Counts is the claimant.

An 18-ft (5.5-m) trench on a shear zone in dacite exposes 5 ft (1.5 m) of a galena vein, which is as much as 5 in. (13 cm) wide. It strikes N. 10° E. and dips 85° W. A 0.7-ft (0.2-m) chip sample taken across the vein and part of the wallrock assayed 0.03 oz gold per ton (1.0 g/t), 4.9 oz silver per ton (168.0 g/t), and 8.8 percent lead. A 12-ft (3.7-m) chip sample across the shear zone contained no significant values. The Crevis claim has a mineral resource potential.

GOLDBUG CLAIM

The Goldbug claim (pl. 3, No. 37) was relocated by J. H. Counts in 1966. The claim lies in the study area 1 mi (1.6 km) up North Fork Sixmile Creek, on the north side. A 20-ft (6-m) adit exposes a 3.1–3.4-ft (0.9–1.0-m)-wide fault zone in siliceous dacite. The zone strikes N. 50° W. and dips from 85° SW. to vertical. Three samples across it assayed a maximum of 0.1 oz gold per ton (3.43 g/t), 1.0 oz silver per ton (34.3 g/t), and 0.07 percent bismuth. These assays indicate the possibility of resources.

Data for samples from localities shown in figure 43

[All samples grab, except W-72, W-73, chip. Tr, trace; N, none detected. Data measured in inch-pound system; 1 oz (troy)/ton = 34.285 g/t; 1 ft = 0.3048 m]

Sample			Gold	Silver	Lead	Zinc	Arsenic
No. W-	Length (feet)[2]	Description	(ounce per ton)		(percent)		
[1]68	---	Stockpile of galena and pyrite in leached dacite.	0.15	0.5	3.0	2.0	1.0
69	---	Leached dacite porphyry on dump.	.05	.6	.6	.5	1.0
70	---	Limonite-stained dacite containing pyrite disseminations.	.02	.5	.6	.1	N
71	---	Leached dacite containing calcite and quartz.	Tr	Tr	N	N	N
72	2.0	Limonite-stained vein---	.01	.8	.6	.2	N
73	1.6	-----do----------------	Tr	.2	N	N	N
74	---	Dacite porphyry on dump-	N	N	N	N	N

[1]Sample W-68 also contained 0.04 percent cadmium.

[2]Leaders (---), not measured.

HARVE NO. 1 CLAIM

The Harve No. 1 claim (pl. 3, No. 42), which is on private land just outside the study area, may have silver and copper resources. The prospect, claimed by J. H. Counts, was originally located by F. Carr and others, in 1892, as the Mable Claire. A pit in schist exposes a quartz lens and a limonite-stained, gouge-filled shear zone. The zone is 4.5 ft (1.4 m) wide, strikes N. 5° E., dips 48° to 55° E., and is traceable for 50 ft (15 m). The lens is a maximum of 2 ft (0.6 m) wide, strikes N. 70° E., dips 40° N., and is conformable with foliation. The lens, terminated on the east by the shear zone, is traceable 7 ft (2 m) westward. It is shattered and contains about 15 percent calcite, 5 percent limonite, and less than 1 percent chalcopyrite and malachite, in addition to the quartz.

Three samples from across the quartz lens assayed from 0.1 to 0.3 oz silver per ton (3.4 to 10.3 g/t), and from 0.03 to 0.52 percent copper. One of two samples across the gouge-filled shear zone assayed 0.4 oz silver per ton (13.7 g/t).

MISCELLANEOUS PROPERTIES, SIXMILE SUBDISTRICT

Numerous prospects were found along the north side of North Fork Sixmile Creek, where they occur in pyritized and silicified dacite and dacite porphyry, heavily stained by manganese and iron oxides. Claims have been located from the junction of the main fork of Sixmile Creek to 1 mi (1.6 km) beyond the low pass separating North Fork Sixmile and Emigrant Creeks. A few claims were also located on the south side of

TABLE 12.—*Miscellaneous properties, Sixmile subdistrict*

[Assays are considered not significant if the values are less than 0.01 oz gold per ton, 0.2 oz silver per ton, 0.1 percent copper, 0.25 percent lead, and 0.25 percent zinc. Data measured in inch-pound system; 1 oz (troy)/ton = 34.285 g/t; 1 in. = 2.54 cm; 1 ft = 0.3048 m. Map numbers from plate 3 or 4B]

Map No.	Property name[1]	Summary	Number and type of workings	Sample data
10	Iron group----	Dacite at contact with iron-bearing schist striking N. 10° to 15° W., dipping 35° to 40° NE. The iron-bearing schist averages 30 ft in width along a strike of 487 ft	None-----------	Six samples from dacite; no significant assays. Four samples from iron-bearing schist; as much as 29.1 percent iron. Two samples from quartzites and richer zones of iron-bearing schists; as much as 0.4 oz silver per ton and 26.0 percent iron.
11	Alta----------	Limonite- and malachite-stained-fractured quartz.	Adit, 6 ft long; two pits	Three samples; maximum 0.035 percent copper.
12	Emma----------	Two minor joints in schist------	Adit, 21 ft long	One sample; no significant assays.
13	Lyon No. 13---	Precambrian interbedded quartzites and schists, and altered Tertiary dacite intrusives. No mineralized rock observed. Owner reported iron present.	None------------	One hundred-foot continuous chip sample; no significant assays.
14	Lyon No. 1----	----do------------------------	----do----------	One sample no significant assays.
15	Magnetic------	Altered dacite and schist outcrop on ridge.	Trench, 16 ft long	Sixteen samples; maximum of 0.2 oz silver per ton.
18	Mortar No. 4--	Blocky, siliceous, jointed dacite containing finely disseminated pyrite.	Pit-------------	One sample; no significant assays.
19	Mortar No. 2--	Fractured, leached dacite containing finely disseminated pyrite cubes.	----do----------	Do.
20	Pedestal------	Five-ft-thick fault zone in siliceous dacite. Zone strikes N. 25° E. and dips 65° to 70° NW.	----do----------	Four samples; as much as 0.2 oz silver per ton.
21	Mortar--------	Minor disseminated sulfide minerals in leached dacite.	Adit, 10 ft long.	Two samples; no significant assays.
22	Mortar No. 3--	Fractured, leached, limonite-stained dacite containing very sparse pyrite disseminations.	Pit-------------	One sample; no significant assays.
23	Pot-----------	Iron- and manganese-oxide-stained, fractured dacite containing sparsely disseminated pyrite.	Two pits--------	Two samples; as much as 0.2 oz silver per ton.
24	Pan-----------	Limonite-stained dacite. No apparent geologic structure.	Pit-------------	One sample; no significant assays.
25	Allen---------	Leached, gray dacite from dump contains disseminated pyrite cubes and pyritized hair-line fractures. Calcite vein material as much as 4 in. wide.	Two caved adits, 50 ft long	Do.
27	Barb No. 1----	Massive, fractured, limonite-stained, siliceous dacite. Pyrite occurs as fine disseminations.	Pit-------------	Do.

North Fork along Tertiary dacite intrusive contacts with Precambrian schists and quartzites.

The properties along North Fork Sixmile Creek lie within the alteration halo of the Emigrant stock. Although no known economic mineral potential exists, the North Fork area would be a likely exploration target if a porphyry deposit were to be discovered on Emigrant Creek.

Properties with no potential or those not well enough exposed to determine potential are listed in table 12.

TABLE 12.—*Miscellaneous properties, Sixmile subdistrict*—Continued

Map No.	Property name[1]	Summary	Number and type of workings	Sample data
28	Barb No. 2----	Siliceous dacite containing------ disseminated pyrite cubes as much as one-fourth inch across.	----do----------	One sample; 0.6 percent lead, and and 0.2 percent zinc.
30	Bar No. 4-----	Manganese- and iron-oxide- ------ dacite. Pyrite occurs as fine disseminations.	Trench, 12 ft -- long.	One sample; no significant assays.
31	Bar No. 5-----	Profusely limonite-stained------- dacite containing finely disseminated pyrite.	Pit------------	Do.
32	Bar No. 6-----	Adit N. 58° E. along a 7.0-ft- -- wide shear zone in fractured, silicified dacite containing disseminated galena and pyrite near hanging wall.	Adit, 22 ft ---- long.	Two samples; as much as 0.6 ounce silver per ton and 0.22 percent lead.
33	Bar No. 6-----	An 0.8-ft-wide profusely iron- -- oxide-stained, shear zone striking N. 70° to 80° E. and dipping 80° NW. in dacite. The shear zone consists of silicified dacite with disseminated pyrite and minor hematite-limonite-bearing gouge.	Adit, 33 ft ---- long.	Four samples; as much as 0.3 oz gold per ton, 0.1 oz silver per ton, and 0.3 percent lead.
34	Bar No. 7-----	Sparsely disseminated pyrite----- in limonite-stained, fractured siliceous dacite.	Trench, 17 ft -- long	One sample; 0.4 oz silver per ton.
35	Dianna--------	Highly fractured, moderately----- limonite-stained siliceous dacite.	Pit------------	Two samples; no significant assays.
36	Goldenrod-----	Manganese- and iron-oxide- ------ stained dacite and dacite porphyry with as much as one-fourth-inch-wide disseminated pyrite cubes.	----do----------	Four samples; as much as 0.2 oz silver per ton.
38	The John------	Precambrian siliceous schist-----	Trench, 10 ft -- long	One sample; no significant assays.
39	Gold Prize----	Gray, porphyritic rhyolite- ----- dacite float.	Pit------------	Do.
40	Marve---------	Small (100 x 300 ft) intrusive-- of brecciated dacite porphyry. Moderate iron- and manganese-oxide stain near contact with schist.	----do----------	One 4-ft-long chip sample from near contact 1.1 oz silver per ton.
41	Madgliere------	Stockpile of siliceous schist----	Caved adit, 20-- ft long	One sample; 0.9 oz silver per ton.
43-48	Alpha and------ Eastern Montana claim group.	Workings are generally in ------- graphite schist lenses between walls of chlorite-biotite schist. Quartzite (Flathead Sandstone ?) exposed at one site (pl. 5A, No. 47).	Thirteen adits, shafts, and pits: longest open adit is 115 ft long (pl. 5B, No. 45); two inclined shafts 24 and 16 ft deep (Nos. 43 and 44, respectively). Workings are on private land.	Twenty-two samples; as much as 0.02 oz gold per ton and 0.1 oz silver per ton.

[1]Properties underlined are in the study area.

NATURAL BRIDGE MINING DISTRICT

Part of the unorganized Natural Bridge mining district is in the northeast corner of the study area. A road from Big Timber crosses the district, but a trail up Great Falls Creek is the only maintained access route into this portion of the study area.

Precambrian granitic and metamorphic rocks, the main types in the district, have been intruded by the Stillwater Complex. Paleozoic sedimentary rocks occur along the north edge of the district, but have no economic significance. Regionally, the rocks strike northwesterly and dip steeply to the northeast. Intense folding and fracturing have caused local variations of the regional structure pattern. In the study area, the Lost Creek–Graham Creek fault strikes northwesterly across the lower part of Froze-to-Death Creek, and is the dominant local structure. Smaller, more localized displacements were observed in the metamorphosed rocks underlying the Stillwater Complex. These structures strike both northeasterly and northwesterly and dip moderately to steeply.

Prospecting concentrated on numerous quartz-filled fissures in the metamorphic rocks. The fissures range from a few inches to several feet thick and contain auriferous pyrite. The lower ultramafic zone of the Stillwater is known to contain chromite, platinum-group metals, nickel, and copper. A zone containing low to moderate amounts of iron minerals is basal to the complex. Recently, attention has been drawn to the possibility of a platinum-palladium-bearing horizon, perhaps analogous to the horizon being explored in the complex by Johns-Manville Co., Inc., near Iron Mountain, several miles to the southeast. The company's claims cover rock units similar to those in the study area.

The first claims were located in 1882 when the area was excluded from the Crow Indian Reservation. Most prospecting took place during the following 18 years. Approximately 340 lode and about 14 placer claims have been located in the study area section. One lode claim, the Oregon, is patented. U.S. Bureau of Mines records show mines in this section of the district produced 1,401 tons (1,271 t) of ore, which contained 213 oz gold (6,624 g), 895 oz silver (27,834 g), and 1,154 lb copper (523.5 kg). Production was intermittent from three mines between 1901 and 1937. A more productive period could have occurred in the 1800's, before records were kept.

Stamp mills were erected at sites on Froze-to-Death, Falls, and Great Falls Creeks. Ore was processed at each locality, but apparently most production came from deposits on Froze-to-Death Creek.

Exploration in the Natural Bridge district has been hampered by dense stands of timber, thick underbrush, lack of access into the interior, steep slopes, talus slides, and a relatively short prospecting season. Evidently some ores were not free-milling, and their refractory nature may have discouraged development. Many workings are badly sloughed or caved. In most instances a thick soil mantle and lack of outcrops prevented structure tracing.

Prospects and properties sampled in the district are shown on figure 44.

Resources of copper and nickel are inferred in the Stillwater Complex, which includes the Nicon claim group. The grade could be as

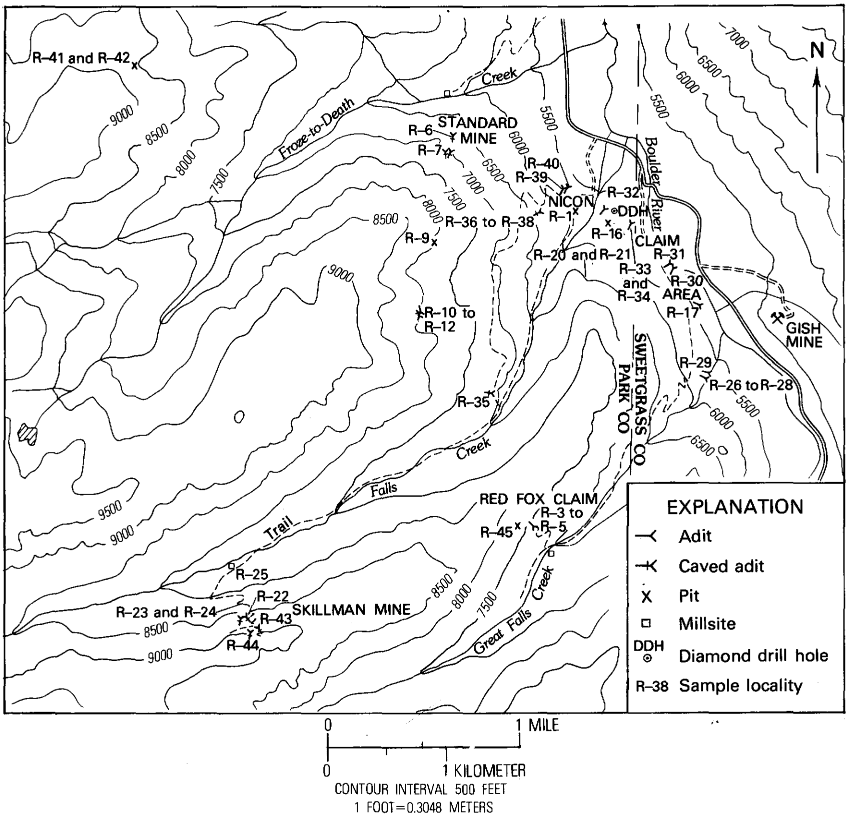


FIGURE 44.—Sample localities in the Natural Bridge district.

much as 0.25 percent copper and 0.25 percent nickel if comparable to mineralization found several miles to the east. Detailed mapping of the occurrence by the mining company is not yet complete. Elsewhere, the Red Fox property on Great Falls Creek is estimated to have 21,000 tons (19,000 t) of material containing 0.1 oz gold per ton (3.4 g/t). A few other prospects, including the Standard mine on Froze-to-Death Creek and the Skillman claim on Falls Creek, may have gold, silver, copper, or nickel resources.

NICON GROUP

The Nicon group of 12 claims is part of a larger group of 117 claims currently being evaluated by the Anaconda Company. Their area extends from north of the mouth of Great Falls Creek to Froze-to-Death Creek. The basal zone of the Stillwater Complex comprises the main exploration target.

The iron-formation, associated with the basal zone, can be traced intermittently for 1.8 mi (3 km) in the study area. Recently, the Anaconda Company completed a phase of a program that included geologic mapping, geochemical soil sampling, and geophysical surveys in the Boulder River area. Both ground magnetic and aeromagnetic surveys show a strong positive anomaly over the iron-formation immediately below the basal zone of the Stillwater Complex. The anomaly can be traced northwestward from the Boulder River into Froze-to-Death Creek, a distance of 2.6 mi (4 km), and possibly into the Lost Creek drainage, a total distance of about 5 mi (8.0 km) (J. Adler, written commun., 1975). The magnetic anomaly can be used to locate the base of the Stillwater Complex along most of its length. The company completed a 690-ft (210-m) diamond drill hole, which penetrated the base of the complex and bottomed in the hornfels footwall (fig. 45). An interval of 128.5 ft (39.2 m) at the base of the complex contained weighted averages of 0.12 percent copper and 0.12 percent nickel with a range of 0.06–0.20 percent copper and 0.03–0.22 percent nickel.

Assuming a length of 1.8 mi (3 km), a depth along the dip equal to one-half the length, a thickness equal to the mineralized interval of the drill hole, and mineralized material existing throughout one-half this block, inferred submarginal resources would be about 300 million tons (270 million t). If the copper-nickel zone extends to Froze-to-Death Creek as inferred, resources could be twice this amount. Speculative resources may occur further west, extending into the Lost Creek drainage, if the known magnetic anomaly is indicative of continuing mineralization.

Samples from various sites (fig. 44) within the block of claims held by the Anaconda Company in the study area are summarized in table 13. At the east end of the complex, several miles away, the basal zone is known to contain as much as 0.25 percent copper and 0.25 percent nickel. Based on these values, company data, and scattered sample results from the present investigation, the area is thought to have potential for future mineral resource development.

STANDARD MINE

The Standard mine is in the study area about 1 mi (1.6 km) up Froze-to-Death Creek at approximately 7,000 ft (2,100 m) elevation (fig. 44, Nos. R-6 and R-7). The workings are accessible by steep trail from the former millsite.

The deposit was first located in 1894 as the Standard claim and operated under that name until 1903, at which time the mine shut down. Bureau of Mines records show that during 1902, 1,000 tons (900 t) of ore was produced, containing 161 oz of gold (5,007 g) and 112 oz of silver (3,483 g). The mine was closed when higher grade portions of the

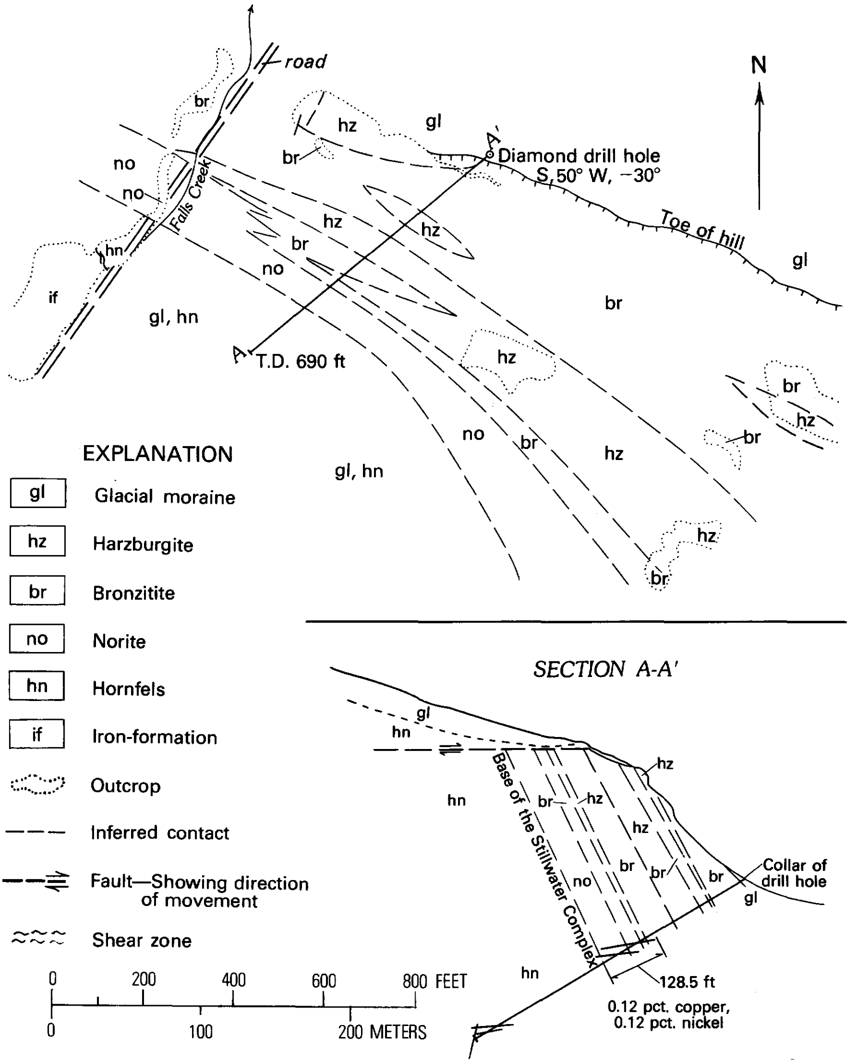


FIGURE 45.—Geology of diamond drill hole site BR-1 (modified from map by The Anaconda Company).

vein were depleted, and remaining values were found to be widely scattered (Standard Mining Co., unpub. data, 1903). It reopened as the Drago mine 9 years later. Between 1912 and 1917 a total of 102 tons (92.5 t) of ore were produced, containing 11 oz of gold (342.1 g), 20 oz of silver (622.0 g), and 1,154 lb (523.5 kg) of copper. Apparently activity ceased after 1917. In the meantime, the mill was dismantled and moved. The mine was later relocated as the Standard. Value of production prior to 1902 is not known.

TABLE 13.—*Summary of sample localities and analyses, Nicon group and associated claims (see fig. 22), Natural Bridge district*

[Assays are considered not significant if the values are less than 0.01 oz gold per ton, 0.2 oz silver per ton, 0.1 percent copper, 0.25 percent lead, and 0.25 percent zinc. Data measured in inch-pound system; 1 oz (troy)/ton = 34.285 g/t; 1 ft = 0.3048 m; 1 in. = 2.54 cm. See fig. 44 for localities]

Map No. R-	Summary	Number and type of workings	Sample data
1	Shear zone striking N. 85° E. and dipping 80° NW. In quartz-rich schistose hornfels. The structure has a maximum observed thickness of 1.5 ft and contains concentrations of sulfide minerals as much as 2 in. thick. Some of the structure contains about 50 percent sulfide minerals consisting mostly of pyrrhotite, with small amounts of chalcopyrite, pyrite, and arsenopyrite.	Pit	One chip sample across structure; 0.1 oz silver per ton, 0.061 percent copper, and 0.047 percent nickel.
16	Heavily iron oxide stained rock containing about 5 percent finely disseminated chromite in laminae, and surficial malachite stains. Extent of iron-oxide-stained area could not be determined because of overburden.	Possible caved adit, less than 10 ft in length.	One grab sample; trace gold 0.4 oz silver per ton, 0.19 percent copper, 4.2 percent percent chromium, and 0.25 percent nickel.
30	Adit along two sub-parallel shear zones in basal Stillwater Complex rocks. Structures strike N. 40° E. and dip 60° SE. and are a maximum of 6 in. thick. Zones contain cubic pyrite to one-eighth inch in size, and pyrrhotite. Total sulfide mineral content is 5-10 percent.	Adit, 20 ft long.	Chip sample across portal; 0.2 oz silver per ton, 0.10 percent copper, 0.09 percent chromium, and 0.06 percent nickel.
31	Adit trends S. 70° W. along shear zone in basal Stillwater Complex rocks. Structure strikes N. 70° E. and dips 70° SE. Hanging wall is visibly mineralized for 4 ft beyond shear and contains pods of finely crystalline sulfide minerals.	Adit, 25 ft long.	Chip sample across hanging wall; trace of gold and 0.3 oz silver per ton, 0.07 percent copper, 0.18 percent percent chromium, 0.20 percent nickel.
32	Heavily iron oxide stained shear zone strikes N. 30° E. and dips 50° NW., and is a maximum of 1.2 ft thick. Country rock is granular harzburgite.	Adit 20 ft long.	Chip sample across shear zone; 0.09 percent copper, 0.89 percent chromium, and 0.10 percent nickel.
33, 34	Adit crosscuts a 2-ft-thick shear zone striking N. 70° W. and dipping 65° SW. in granular to poikilitic harzburgite. Poikilitic harzburgite contains very fine grained, disseminated chromium with malachite stains present along small fractures in the rock. Shear zone was stoped for 10 ft in adit.	Pit, and adit, 40 ft. long.	Two chip samples, 4.0 and 4.3 ft long from face of workings; 0.009 and 0.13 percent copper, 2.05 and 2.51 percent chromium, and 0.14 and 0.15 percent percent nickel.
39	Mineralized shear zone, striking N. 40° W. and dipping 40° NE., contains about 5 percent pyrite and arsenopyrite. Country rock is a schistose hornfels.	Adit, 25 ft long.	One sample; no significant assays.
40	A small bedding plane shear was crosscut at face of adit but contained no visible mineralized rock. Schistose hornfels country rock.	Adit, 20 ft long.	Do.

The deposit was apparently a quartz-filled fissure in hornfels country rock. Workings are caved, and the structure was not observed on the surface. Evidently, the mine was worked from two levels, with two adits on the upper and one on the lower. The distance between levels is about 250 ft (76 m). The aggregate length of the three adits could not be determined, as a snowslide has removed much of the dump material. However, one was reported to have been more than 500 ft (150 m) long.

Grab samples were taken from the dumps at both levels. The material was composed of about 5 percent pyrite with limonite stain and traces of malachite in a quartz gangue. One sample (R-6) contained 0.4 oz silver per ton (13.7 g/t) and 0.04 percent copper. The other (R-7) contained 0.22 oz gold per ton (7.5 g/t) and 0.01 percent copper. Workings would have to be rehabilitated to determine whether resources remain.

SKILLMAN CLAIM

The Skillman claim is in the study area on the south side of upper Falls Creek (fig. 44, R-22 through R-25; R-43 and R-44). A poor trail follows the creek to the property. Workings range in elevation from 8,600 to 9,000 ft (2,600 to 2,750 m). Remains of a five-stamp mill are adjacent to the creek, and a cable tramway leads to the lower levels.

The claim was probably first located in the 1890's. It was relocated as the Skillman in 1973 but was known earlier as the Milwaukie and Montana. Bureau of Mines statistical files report 200 tons (180 t) of ore were produced from the "Milwaukie and Montana" in 1901. The ore contained 20 oz of gold (622 g) and 8 oz of silver (248.8 g).

Country rock is muscovite schist. A large quartz-filled fissure as much as 30 ft (9 m) thick, and averaging 15 ft (4.6 m), crops out at about the 8,350-ft (2,550-m) level. The structure strikes N. 30° W. and dips from 75° SW. to vertical. It can be traced southeast intermittently to the top of the ridge, a distance of about 1,300 ft (400 m). Here it horsetails into veins 6 in. to 2 ft (0.15–0.6 m) in thickness, across an area of 50–100 ft (15–30 m) in width. The quartz is limonite stained and contains octahedral pyrite crystals as much as one-eighth inch (0.3 cm) in diameter. Some of the rock contains about 10 percent pyrite.

At 8,600 ft (2,600 m) are the remains of two and possibly three caved adits. Their total length may have been as much as 500 ft (150 m). Further upslope, along the switchback trail leading to the ridge, are several small surface pits and two small caved adits. Each adit is probably less than 15 ft (4.6 m) long.

Two chip samples from outcrops of the structure contained no gold or silver. Four grab samples from dumps and the mill contained from nil to 0.04 oz gold per ton (1.37 g/t) and nil to 0.1 oz silver per ton (3.4 g/t).

Rehabilitation of the workings would be required before the mineral potential could be evaluated.

RED FOX GROUP

The Red Fox group of six claims is in the Great Falls Creek drainage (fig. 44, Nos. R-3 to R-5 and R-45). Access is by trail from Boulder River.

The group was located in 1908, and some ore was mined around the turn of the century, but the amount is unknown. The property has been idle for many years. The country rock is hornfels. Auriferous pyrite, pyrrhotite, and arsenopyrite occur in a siliceous gangue comprising a shear zone striking N. 60° W. and dipping 50° to 80° NE. The zone has a maximum observed thickness of 3 ft (0.9 m) and a traceable length of about 500 ft (150 m). Iron sulfide and iron oxide content of the zone is as much as 15 percent.

A 60-ft (18-m) adit and two small pits constitute the workings. The adit was driven on the shear zone for 40 ft (12 m), and the zone stoped 20 ft (6 m) to the surface. The remains of a five-stamp amalgamation mill, a rail tramway, and two collapsed cabins are below the workings.

Two chip samples were cut from the shear zone in the adit. These contained an average of 0.20 oz gold per ton (6.9 g/t), 0.05 oz silver per ton (1.7 g/t), and 0.035 percent copper. A grab sample from the dump contained no gold and a trace of silver. A chip sample taken across the shear zone in a small pit 500 ft (150 m) northwest of the adit also contained no gold and only a trace of silver.

Assuming an average thickness of 2 ft (0.6 m), a length of 500 ft (150 m), and a depth of 250 ft (76 m), approximately 21,000 tons (19,000 t) of inferred submarginal resources containing 0.1 oz gold per ton (3.4 g/t) is present. Possibly, the refractory nature of the gold-bearing material prevented successful development of the property.

MISCELLANEOUS PROPERTIES, NATURAL BRIDGE DISTRICT

Prospects in the district with little or no mineral potential, and those not sufficiently exposed to indicate their potential, are summarized in table 14.

BOULDER (INDEPENDENCE) MINING DISTRICT

The Boulder mining district, partly in the study area, is at the headwaters of the Boulder River (pl. 3). An excluded corridor containing the Boulder River road and patented claims was not studied except where geologic evidence indicated a possible continuation of mineralized structures into the proposed wilderness.

Access to the area is by gravel road to the Box Canyon ranger station, after which travel is limited to trails and rough roads. One road extends to the patented claim area from the old mining camp of Independence, and is open to vehicular traffic only from July 10 to September 10. The entire district is inaccessible during most winters.

Gold was discovered on Baboon Mountain by John Allen and Barney Hughes (Western Historical Publishing Co., 1907?, p. 217) in 1864. At that time, the area was part of the Crow Indian Reservation. Location of mining claims began after the reservation boundaries were moved east in 1882.

TABLE 14.—*Miscellaneous properties, Natural Bridge mining district*

[Assays are considered not significant if the values are less than 0.01 oz gold per ton, 0.2 oz silver per ton, 0.1 percent copper, 0.25 percent lead, and 0.25 percent zinc. Data measured in inch-pound system; 1 lb = 2.2 kg; 1 oz (troy)/ton = 34.285 g/t; 1 ft = 0.3048 m]

Sample No.[1]	Property name	Summary	Number and type of workings	Sample data
R-9	Prospect------	Limonite-stained quartz on--- dumps in hornfels country rock.	Four pits----------	Ore sample 0.02 oz gold per ton.
R-10 to R-12	Oregon-------- (patented).	Quartz-filled fissure in----- schistose hornfels country rock. Zone contains about 5 percent pyrite with some arsenopyrite. Structure pinches and swells from 1 to 3 ft in 75-ft-long adit.	Two adits, 75 and-- 150 ft in length; one ahaft with 60 ft of drifts. The 75-ft-long adit is open, other workings caved.	Three samples; 0.01 to 0.3 oz gold per ton.
R-17	Eve group-----	Heavily limonite-stained---- hornfels with weak to moderate magnetic response, and occasional thin veinlets and laminae of pyrite, Strong arsenic odor and sulfide bloom in adit.	Adit, 10 ft long---	One sample; 0.012 percent copper and 0.014 percent nickel.
R-20, R-21	Prospect------	Heavily limonite-stained----- siliceous hornfels contains areas of leached boxwork structures. Some areas contain thin laminae of magnetite.	Outcrop-----------	Two samples; as much as 37.6 percent iron.
R-26 to R-29	Eve group----- (Moonlight group).	Limonite-stained quartz in--- profusely fractured hornfels. Very fine grained pyrite as much as 1 percent of the rock.	Two adits, 20 ft--- long and 10 ft long.	Four samples; one sample assayed 0.2 oz silver per ton.
R-35	Rattler-------	Quartz material on dump.----- Country rock is schist.	Caved adit, 50 ft-- long.	One sample; no significant assays.
R-36 to R-38	Empire No. 2-- (Minnie Mund No. 2, Mineral Survey 10460).	Magnetite-bearing quartz----- and gneissic country rock. Strong local deflections of compass.	Caved adit, 50 ft-- long; open adit, 20 ft long; and two pits.	Three samples, no significant assays.
R-41, R-42	Lake View-----	Massive quartz zone in------- schist. Material is limonite-stained but contains no visible sulfide minerals.	Two pits----------	One chip sample; no significant assays. One grab sample; 0.1 oz gold per ton.
257	None----------	A 20-lb fragment of molybdenite-bearing pegmatitic float on top of mica schist country rock. No apparent source.	None--------------	Spectrographic analysis also showed anomalous bismuth.

[1]Shown on figure 22 or plate 1.

Nearly all claim records, as well as official survey plats, refer to the area as the Boulder mining district. It is also called the Cowles or Haystack district. However, popular usage refers to it as the Independence district, for the Independence was one of the principal mines.

Because the Park and Sweet Grass County line passes through the district, the number of claims is difficult to ascertain. Not only were claim records filed at both courthouses, but the area was also part of Gallatin County at one time. However, it is estimated that approximately 1,200 lode and 200 placer claims have been located in the Boulder River drainage south of Fourmile Creek. Twelve lode and four placer claims have been patented. Approximately 35 unpatented lode claims, on which assessment work is being recorded, are in the district.

Although location descriptions are vague, some of these claims are thought to be in the wilderness study area.

Production records are scant. Most activity was before the Bureau of Mines kept statistics. One source (Western Historical Pub. Co., 1907?, p. 216) reports gold production value (mainly placer) at $200,000, representing about 10,000 ounces (311,000 g) prior to about 1907. However, some of this output may have come from the Silver Lake or Natural Bridge mining districts. Other output included silver and lead ore reportedly shipped in carload lots.

Six mills operated in the district until the financial panic of 1893 (Western Historical Pub. Co., 1907?, p. 217). Records show a minor output of gold and silver from the Hidden Treasure mine in 1901 and 1904.

The district was reactivated in the 1930's. According to Rubel (1964, p. 177), a ball mill with two shaker tables was constructed at the Daisy (Yager)[1] mine. Concentrates sent to the East Helena smelter reportedly had gold values of $16.50 per ton ($18.18/t) at the price of about $20.00 per ounce ($0.64/g). The 1939 production was valued at several thousand dollars. The last recorded production at the Independence mine was in 1933. Output was 29 tons (26 t) from which 12 oz gold (373.2 g), 20 oz silver (622 g), and 23 lb of copper (10.4 kg) was recovered. The Tramway or Mountain View mine (Ski Line claim) reported minor gold output in 1941. In 1942 it produced 19 oz of silver (591 g) and 924 lb of lead (419.1 kg). The last reported output was in 1950, when the Daisy produced 18 oz (559.9 g) of gold, 118 oz (3,670 g) of silver, 536 lb (243.1 kg) of copper, and 893 lb (405.1 kg) of zinc.

The area's deposits are varied and not restricted to a particular type. In the central part of the district (pl. 5), auriferous sulfide and quartz veins occur in fine-grained rocks, mainly of intermediate composition, that intrude coarse-grained rocks of the geologic structure described as the Independence volcano (Rubel, 1964). Sulfide minerals occur as fissure filling, as replacement of sedimentary rocks, and as replacement in fault or shear zones. They are also disseminated in the hydrothermally altered granodiorite or monzonite at the center of the volcano. Beyond the area shown on plate 5, contact metamorphic iron and molybdenum minerals and gold occur on War Eagle Mountain (pl. 3) in a strongly mineralized zone between metamorphosed limestone and a granitic intrusive.

Placer gold can be found in most streams in the Boulder district, but output was probably never significant. The steep gradient and active downcutting of canyons have precluded deposition of large volumes of auriferous gravel. However, a potential for high-grade pockets below the lode deposits exists on East Fork of the Boulder River, Sheep Creek, and Bridge Creek. Placer gold resources probably occur outside the

[1]The Daisy is erroneously shown as the Independence on most maps.

study area in the patented claim areas on Basin Creek and the Boulder River.

Several factors combined to prevent an earlier and successful development of the Boulder mining district's mineral deposits. The area is both remote and rugged. Freight rates have always been prohibitively high; the rates from Independence to Big Timber were $0.04/lb ($0.088/kg) as late as 1894 (Western Historical Pub. Co., 1907?, p. 217). The ores are refractory; no facilities existed to recover auriferous sulfides, nor to roast the sulfide minerals to free the gold.

Mineral resources recoverable by open-pit or block-caving mining methods may exist in the central part of the district. In that area with its many workings (pl. 5) assays indicate the average gold tenor to be a few hundreths of an ounce, and silver a few tenths of an ounce per ton. Assays and production records also indicate base metals may occur at depth.

Four lode properties in the Boulder district, but outside the patented claim area, may have potential for mineral resources. The Lori Kay, in the study area on the north side of War Eagle Mountain, has about 11 million tons (10 million t) of copper-iron-gold-silver-bearing resources. The 7777 property, just outside the study area on Sheep Creek, has a potential as replacement lead-zinc-silver deposit. Amit No. 5 on Baboon Mountain outside the study area has high-grade assays suggesting gold-silver resources. Assays indicate Ski Line, also on Baboon Mountain, has lead-silver-gold resources. These latter two deposits may merge on the same stratigraphic unit.

BASIN CREEK

The patented claim area is the central part of the Boulder mining district, at the headwaters of Basin Creek (pl. 5). A detailed examination of the 584 workings which were found was beyond the scope of this report. Therefore, mineral evaluations were restricted to properties in the study area. Land bounded by the Hidden Treasure mine on the north, the Springfield claim on the east, the Emma claim on the south, and the Crown claim on the west was not evaluated. This contains 505 workings, nine buildings, five mills, several aerial tramways, tailings ponds, diversion dams, roads, and hydraulicked placer gravel.

Workings were, however, examined in detail at 79 locations on three sides of the excluded land (pl. 5, Nos. 281–359). In addition, 28 samples (D series) were taken at 16 locations in the excluded land to aid in the interpretation of the geology and mineralogy of those areas studied in detail. A summary of these samples is given in table 15.

The 28 reconnaissance samples contained as much as 0.44 oz gold per ton (15.1 g/t), 3.0 oz silver per ton (102.9 g/t), 6.2 percent lead, 0.36 percent copper, 0.5 percent bismuth, 0.5 percent zinc, and 0.5 percent

TABLE 15.—*Data for reconnaisance samples from patented claim area, Boulder (Independence) mining district*

[Sample localities shown on plate 5. Tr, trace; N, none detected; - -, not analyzed. Data measured in inch-pound system; 1 oz (troy)/ton = 34.285 g/t; 1 ft = 0.3048 m; 1 in. = 2.54 cm]

Sample				Gold	Silver	Copper	Lead	Zinc
No. D-	Type	Length (feet)	Description	(ounce per ton)		(percent)		
45	Select-	---	Caved 150-ft-long adit, driven in fissure------ zone in monzonite. Quartz vein containing crystals of quartz, pyrite, and marcasite. Sample from dump.	Tr	0.1	--	0.41	0.25
46	Random-grab.	---	-------do------------------------------------	0.01	Tr	--	.14	--
47	Chip---	2.0	Caved 60-125-ft-long adit along slightly------- pyritized shear zone in monzonite.	.01	Tr	--	.39	.21
64	Select-	---	Pit in monzonite[1] percent pyrite.--------------- 1 percent pyrite. Stockpile material contains 5 percent pyrite. Stockpile sample.	Tr	N	--	--	--
65	Chip---	1.5	Pyritized shear zone at pit-------------------	N	.1	--	--	--
66	Select-	---	Caved 20-ft-deep shaft. Minor sulfide--------- minerals in dacite and andesite porphyroy. Sample from dump.	N	N	0.01	--	--
67	Chip---	2.0	Caved 300-ft-long adit. Driven on 4- and------- 6-in.-thick shear zones in dacite. Zones contain as much as 42 percent gouge and minor malachite stain.	.05	.1	.05	--	--
[1]68	Select-	---	Caved 40-ft-long adit. Galena-bearing dacite-- and monzonite. Minor limonite boxwork. Sample from dump.	.39	2.2	--	6.2	--
69	Random-grab.	---	--------do-----------------------------------	.22	1.9	--	1.2	--
70	Select-	---	Caved 100-ft-long adit. Driven on sulfide- --- bearing fault gouge vein in sheared monaonite. Sample from dump.	.44	3.0	--	1.3	--
71	Chip---	1.5	Chip across shear zone------------------------	.18	.8	--	.15	--
72	Random grab.	---	Dumps below Independence tramway house.-------- Chalcopyrite and galena in dacite.	.03	N	.04	.02	--
73	Select	---	---------do----------------------------------	.40	1.8	.36	.06	--
74	--do---	---	Caved 450-ft-long adit. Pyritized monzonite--- in shear zone. Sample from dump.	.09	.7	--	.10	.19
75	Random-grab.	---	----------do---------------------------------	.02	N	--	--	.28
76	--do---	---	Daisy mill. Ore bin sample-------------------	.03	.1	--	--	--
77	--do---	---	Daisy mill. Fine concentrates bin sample------	.02	N	--	--	--
78	--do---	---	Daisy mill. Material from ball mill----------	.02	N	--	--	--
79	--do---	---	Daisy mill. Wilfley table concentrates--------	.07	.8	.13	--	--
80	--do---	---	Hidden Treasure lower mill. Concentrate------- bin sample.	.25	.1	--	--	--
81	-do----	---	Hidden Treasure ore bin. Ore bin sample-------	.03	N	--	--	--
82	Select-	---	Caved 250-ft-long adit. Sulfide-bearing ------ dacite, slightly stained with copper. Sample from dump.	.05	N	.17	.24	.50
83	Random-grab.	---	-----------do--------------------------------	Tr	.3	--	--	--
84	Chip---	2.5	Pit on shear zone striking N. 22° E.------------ Monzonite intruded into dacite. Fault gouge and minor malachite.	N	N	.13	.6	.10
85	Select-	---	Caved adit, 300 ft long. Pyritized------------ monzonite with abundant pyrite. Boxwork and cellular vein, quartz. Sample from dump.	Tr	.2	--	--	--
86	Random-grab.	---	------------do-------------------------------	Tr	.2	--	--	--
87	Select-	---	Ore bin---------------------------------------	.35	N	--	--	--
88	Random-grab.	---	-------------do------------------------------	.06	N	--	--	--

[1]Sample D-68 had 0.35 percent antimony.

arsenic. Average gold and silver values were 0.10 oz and 0.44 oz per ton (3.43 and 15.1 g/t), respectively. Measurable gold was found in 70 percent of all samples. This fact, combined with the density of workings as shown on plate 5, indicates the possibility for a large-volume open-pit or block-caving operation in the basin. This assumes fractures to be closely spaced or values disseminated.

BRIDGE CREEK

LORI KAY GROUP

Access to the Lori Kay copper-iron deposit (pl. 3, No. 261) is by trail up Bridge Creek to War Eagle Mountain. Workings range in elevation from 8,000 to about 8,500 feet (2,400 to 2,600 m). The area is densely forested and outcrops are few.

The original claim dates back to the War Eagle located in 1882. For the past 20 years, the property has been known as the Black Diamond. The present owner relocated the Black Diamond claims as the Lori Kay group. The property has no known production. Information gathered during earlier U.S. Bureau of Mines investigations (unpub. data, 1946 and 1960) is used freely in the following text. In addition, the area was briefly mentioned by Rubel (1964).

Country rocks include Precambrian gneiss, Paleozoic sedimentary rocks, and Tertiary extrusives and intrusives. They appear to strike northeasterly and dip moderately to the south. The few exposures indicate that the rocks are moderately fractured.

The mineralized zone, composed predominantly of magnetite, is between a tactite footwall and a diabase hanging wall. Magnetic compass deflection makes attitude of the deposit difficult to determine, but it seems to strike east-northeast and dip between 65° and 73° N., as indicated in adit Nos. 1 and 2. The zone measured in the lower adit is more than 90 ft (27 m) thick. Explored length of the deposit between the main workings (adit Nos. 1, 2 and 3) is about 400 ft (120 m), but it may extend more than one-half mile (0.8 km) westward through several small excavations (figs. 46 and 47).

The zone's sulfide mineral content increased from east to west, and with depth. In the western portion, sulfide minerals constitute 20 percent of the material. A small amount of molybdenite is present in the vicinity of the main workings, and minor quantities of specular hematite and pyrrhotite were also observed.

The west workings (fig. 46, Nos. R-53 through R-57) consist of two adits estimated to total 300 ft (90 m) in length, two caved shafts estimated to total 80 ft (24 m) in depth, and numerous small exploration pits. The main, or east, workings include two open adits, a caved adit estimated to be 100 ft (30 m) in length, and several small sloughed pits. Adit No. 1 was open, but accumulated water prevented access. The vertical distance between the highest and lowest levels is 245 ft (75 m).

Seven samples taken by U.S. Bureau of Mines engineers in 1943 assayed from 40 to 53 percent iron, 0.02 to 0.21 percent molybdenum, and less than 0.02 percent copper. These samples were probably from adit Nos. 1, 2 and 3 (east workings). Sample NR-439 (fig. 47), taken by a Bureau of Mines engineer in 1947, assayed a trace gold, 0.05 oz silver per ton (1.7 g/t), 0.1 percent copper, and nil molybdenum. During the

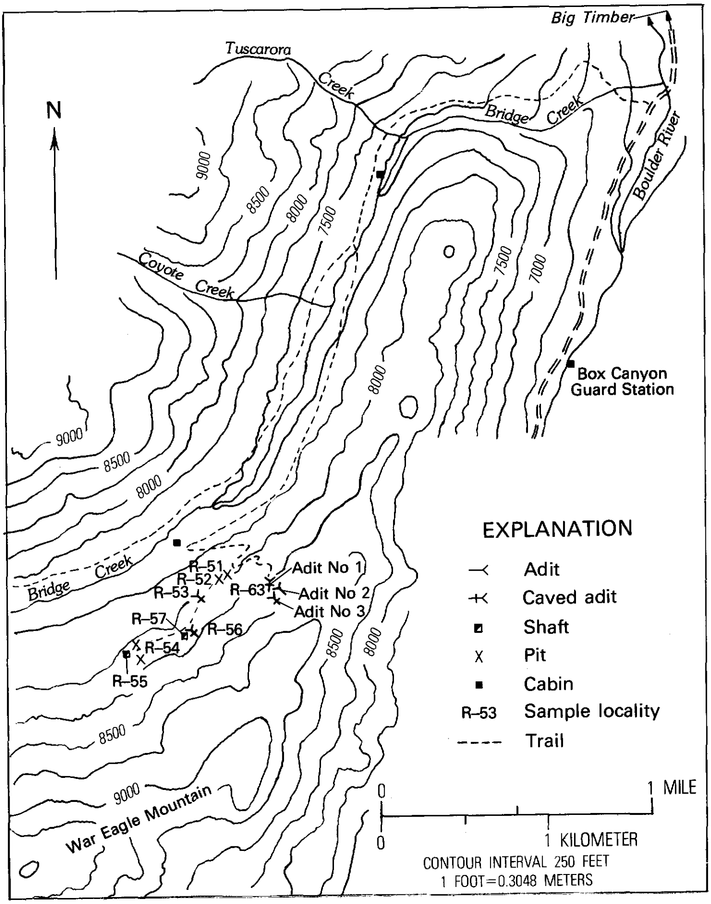


FIGURE 46.—Lori Kay group.

present study, five samples were taken of the iron-bearing zone exposed in adit Nos. 1 and 2 (east workings). They ranged from a trace to 0.02 oz gold per ton (0.69 g/t), a trace to 0.05 oz silver per ton (1.7 g/t), 0.03 to 1.86 percent copper, and 13.0 to 58.5 percent iron. One sample contained 0.08 percent molybdenum. Seven samples of iron-bearing material from the west workings ranged from nil to 0.03 oz gold per ton (1.03 g/t), nil to 1.3 oz silver per ton (44.6 g/t), and 0.10 to 2.38 percent copper. Three contained 39.3 to 50.6 percent iron. The others had low values. Two samples contained 0.003 percent molybdenum.

Combined samples taken by Bureau of Mines engineers from this zone averaged 45.9 percent iron, 0.87 percent copper, 0.05 percent molybdenum, 0.001 oz gold per ton (0.034 g/t), and 0.29 oz silver per ton

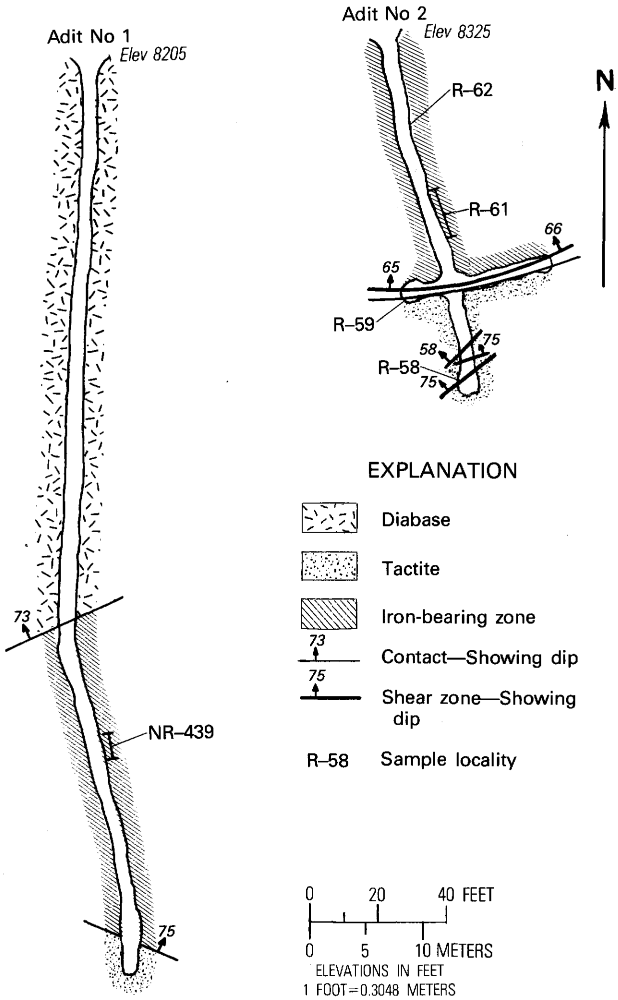


FIGURE 47.—Underground workings on Lori Kay group.

(9.9 g/t). A sample of the tactite assayed 10.3 percent iron; gold, silver, and copper assays were insignificant.

Inferred resources at the main workings, using a 90-ft (27-m) thickness and a depth equal to one-half the length, are estimated to be 866,000 tons (786,000 t). If the zone persists for one-half mile (0.8 km) between the two groups of workings, the inferred resources would be approximately 11 million tons (10 million t). Two factors, the remoteness of the area and the apparent increase of sulfide mineral content with depth, combine to keep this deposit from being now economically minable for iron. However, the deposit is probably paramarginal for the other metals.

SHEEP CREEK

7777 CLAIM

The 7777 claim, just outside the study area, covers a lead-zinc-silver deposit that crops out on the west bank of Sheep Creek about three-fourths of a mile (1.2 km) south of the Boulder River (pl. 3, No. 277). A corduroy road on the creek bank originally provided access, but now there are bulldozed roads in the vicinity.

A recently dug 6-ft (2-m)-deep trench has been excavated for 25 ft (8 m) on a bearing of S. 79° W. along the creek bank and into an old mine dump. The excavation was then driven N. 55° W. for 25 ft (8 m) directly under an old adit that is estimated to have been 150 ft (46 m) long. The excavation extends along a low-angle (18° NE.) fault contact between metasedimentary and granitic rocks. The metasedimentary rock is on the hanging wall and is light-gray, porous, silicified and pyritized, sheared gneiss (Rubel, 1964, p. 179). The granitic rock is near complete decomposition.

At the contact, the metasedimentary rock has been replaced by silica, pyrite, galena, and sphalerite. Pyrite-rich breccia veins, a maximum of 6 in. (15 cm) thick, lace the metasedimentary rock in the excavation face. A fault-gouge stringer is also present in the face. A 1.8-ft (0.5-m) sample taken down the face from the back to the gouge assayed 1.7 oz silver per ton (58.3 g/t), 1.95 percent lead, and 1.4 percent zinc. Samples taken for 2.4 ft (0.7 m) below the gouge returned negligible assays. The granite, though silicified and pyritized, was also barren. A small stockpile near the mouth of the trench provided a sample that assayed 0.90 percent lead, 0.7 oz silver per ton (24.0 g/t), and 0.57 percent zinc.

The mineralized metasedimentary rock crops out along the creek bank for at least 50 ft (15 m) to a caved adit downstream from the open adit. A 10-ft (3-m) sample taken across the outcrop assayed 0.50 percent lead, 0.6 oz silver per ton (20.6 g/t), and 0.08 percent zinc. A sample from a stockpile at the caved adit assayed 0.36 percent lead, 0.2 oz silver per ton (6.9 g/t), and 0.06 percent zinc.

A potential for silver, lead, and zinc resources exists at the 7777 claim.

BABOON MOUNTAIN

AMIT NO. 5 CLAIM

The Amit No. 5 claim main workings consist of two adits. They are on the east side of the Boulder River canyon, 0.7 mi (1 km) downstream from the mouth of Elk Creek (pl. 3, No. 270). They are in an excluded corridor. The workings expose fracture zones containing gold values.

Assays of eight samples taken across fractures averaged 0.03 oz per ton (1.03 g/t). Chips from boulders of siderite or dense carbonate-bearing gossan on the lower dump assayed 0.22 oz gold per ton (7.5 g/t). Silver assays were much as 0.4 per ton (13.7 g/t).

The upper adit was driven S. 4° E. for 18 ft (5.5 m) then S. 26° E. for 10 ft (3 m) along a shale-like zone in silicified and pyritized, porphyritic igneous rock. The lower adit was driven S. 37° E. for 16 ft (5 m) into a highly fractured and altered contact zone between schist and granitic rock. A short drift or stope suggests minor production in the past. The contact probably extends to the upper adit, which is about 30 ft (9 m) above.

Assays indicate that the Amit property has a mineral resource potential. The stratigraphic sequence is the same as the Ski Line mine to the east. Possibly the Tertiary-Precambrian contacts are topographically lower than mapped by Rubel (1964), or the Amit is in a down-faulted block.

SKI LINE MINE

The Ski Line mine, also known as the Tramway or Mountain View (pl. 3, No. 271), is in the study area on the north face of Baboon Mountain. The site's elevation is approximately 9,450 ft (2,880 m). Access is by trail along the East Fork Boulder River for approximately 3 mi (5 km) and then cross-country up the flank of the mountain.

The first known claims in this locality were located in 1892. The last location is dated October 1965. U.S. Bureau of Mines production files show that a total of 3 tons (2.7 t) of ore was produced in 1941 and 1942. The yield was 1 oz gold (31.1 g), 19 oz silver (591 g), and 887 pounds lead (402.3 kg). A tramway, now collapsed, was used to haul ore to the foot of the mountain. An automobile engine provided the power.

Host rocks are quartzite, limestone, and shale, which are underlain by granitic gneiss and capped by volcanic breccia (Rubel, 1964). The strata, approximately 200 ft (60 m) thick, can be traced for several thousand feet on the mountain's north and west flanks. A mineralized flat-lying shear zone is at the contact between quartzite and shale. It consists of fractured, brecciated country rock and gouge in a matrix of quartz. The zone is about 2 ft (0.6 m) thick and strikes westerly in the precipitous headwall of a north-facing cirque. It is visible, intermittently, for about one-fourth mile (0.4 km). No sulfide minerals were observed, but iron-oxide stains may indicate their presence.

The only working found on the claim was a 75-ft (23-m) adit, which is partially sloughed and unsafe to enter. A 2-ft (0.6-m) chip sample across the shear zone at the adit portal assayed 1.5 percent lead. A sample of this same zone taken by the Bureau of Mines in 1947 assayed 10 percent lead, 6.84 oz silver per ton (234.5 g/t) and 0.02 oz gold per ton (0.69 g/t). During the current study two grab samples taken from the dump and small stockpile at the foot of the tramway assayed 3.0 and 5.4 oz silver per ton (102.9 and 185.1 g/t), and 15.0 and 17.8 pecent lead, respectively.

If these values persist throughout the outcrop, resources would be a few hundred thousand tons of gold, silver, and lead-bearing material.

MISCELLANEOUS PROPERTIES, BOULDER (INDEPENDENCE) MINING DISTRICT

Many prospects examined in the Boulder mining district have little or no potential, or they are not sufficiently exposed to permit their evaluation. These prospects are included in table 16.

SILVER LAKE MINING DISTRICT

The Silver Lake district, 22 mi (35 km) southeast of Livingston, and 37 mi (60 km) southwest of Big Timber, is in the central part of the study area (pl. 3, fig. 48). The district is unorganized and includes the headwaters of East Fork Mill, Fourmile, Speculator (Elk Park), and Falls Creeks and East Fork of the West Boulder River. There are no roads to the district.

Gneiss, schist, and granitic rock with dikes are predominant in the district. Metallic minerals occur in a fault zone approximately 4 mi (6 km) long and as much as 300 ft (90 m) wide. The zone strikes N. 80° E.; dip is variable and approaches vertical. A generalized sequence of outcrops across the zone, from northwest to southeast, is gneiss, fault breccia, quartz lenses and pods, gabbro, and granitic gneiss. Copper and silver minerals are usually associated with the quartz lenses and pods. The western third of the zone is offset to the north by a right lateral fault striking N. 21° W. The offset section is concave along strike to the northwest. The offset's dip is variable, and strikes N. 62° E. at the east end. The zone is intersected near the east end by a mafic dike, 42 ft (13 m) thick, striking N. 45° W. and dipping approximately 70° NE.

Four claims were recorded in the Silver Lake district in 1884. Since then 37 lode and 2 placer claims have been located. Seven lode claims are patented (fig. 48). One unpatented claim was located in 1973. The placer claims (Mineral Survey 6686 and 6687) were located along Speculator (Elk Park) Creek. There is no record of production, either lode or placer.

Ten workings lie along the major fault zone: an open adit 18 ft (5.5 m) long, a partially caved adit about 2,000 ft (610 m) long, a caved adit at least 103 ft (31 m) long, a trench 20 ft (6 m) long, a shaft 15 ft (4.6 m) deep, and five pits. Total length of workings is estimated to be 2,150 ft (655 m).

A shear zone in granitic gneiss and quartzite is to be seen on the Montana claim (fig. 48, claim No. 2). An adit estimated to be 2,000 ft (610

TABLE 16.—*Miscellaneous properties, Boulder (Independence) mining district*

[Map number on plate 5. Assays are considered not significant if the values are less than 0.01 oz gold per ton, 0.2 oz silver per ton, 0.1 percent copper, 0.25 percent lead, and 0.25 percent zinc. Data measured in inch-pound system; 1 oz (troy)/ton = 34.285 g/t; 1 ft = 0.3048 m; 1 in. = 2.54 cm; 1 mi = 1.6 km; 1 ton = 0.9072 t]

Map No.	Property name[1]	Summary	Number and type of workings	Sample data
258	Gold King------	Apparent quartz fissure-filling in biotite schist country rock. Shaft was sunk on structure which was not crosscut in adit below. Quartz contains approximately 5 percent pyrite and about 10 percent limonite. A faint arsenic odor was also detected. No known extension of the zone.	Adit, 50-ft-long;-caved shaft, estimated 25 ft deep.	One sample; no significant assays.
259	Shawn Marie----	Quartz-filled fissure between---metasedimentary rock and a mafic dike. Structure strikes N. 10° W., dips 60° SW., and can be traced for about 50 ft. Maximum thickness is 1 ft. Quartz contains about 5 percent iron oxides and about 5 percent sulfide, including galena, pyrite, and chalcopyrite.	Caved shaft, 10---ft deep.	One select sample; 0.03 oz gold and 0.6 oz silver per ton 0.013 percent copper, 0.45 percent lead, and 0.17 percent molybdenum.
260	Cabin----------	Quartz-cemented shear zones-----containing less than 1 percent pyrite and calcite veinlets, in altered gneissic country rock. Major structures strike northeasterly and dip southeast and northwest. Maximum observed thickness of the zones was 3.1 ft Calcite veinlets as much as 1 in. thick are randomly oriented in small fractures, and are barren of sulfide minerals.	Two small cuts----	Three samples; from a trace to 0.8 oz silver per ton.
262	Charity--------	Major strike-fault system-------traceable for 1 mi. Fault marks general contact between sedimentary rocks on the south and igneous on the north. Sedimentary rocks are mainly limestone underlain by shale. Igneous rock is highly argillized granite. Contact locally pyritized and showing slickensides.	Pit---------------	Four samples; as much as 0.4 oz silver per ton.
263	Baldy----------	Erosion exposes red, clayey-----shale.	----do------------	One sample; no significant assays.
264	Raymond Rudd---No. 2.	Contact, striking N. 10° W.,----of black, siliceous iron-oxide-stained schist (said by former claimant to be uranium-bearing) and silicified granite. Schist is on west side.	----do------------	Two samples; 0.002 percent U_3O_8 in schist outcrop.
265	Lawyer group---	Quartzite containing as much as 5 percent pyrite, striking N. 35° E. and dipping 1° NW.	----do------------	Three samples; no significant assays.
266	Falcon---------	Apparent contact of limestone---overlying columnar basalt. Limonite-stained zone about 6 ft thick. Select chip of fluffy variety of limonite.	None--------------	One sample; 0.01 oz gold and 0.2 oz silver per ton.
267	Holy Terror----	Creek bank outcrop. Four-------heavily pyritized shears in in 50-ft section of outcrop. Fluffy limonite and pyrite stringers as much as 1 in. wide.	----do------------	One select sample; 0.3 oz silver per ton.

TABLE 16.—*Miscellaneous properties, Boulder (Independence) mining district* —Continued

Map No.	Property name[1]	Summary	Number and type of workings	Sample data
268	Mountain Sheep.	Quartz-filled fissure in gneissic country rock. Hanging wall is small shear zone trending N. 40° W. and dipping 80° to 85° SW. Footwall contact is indistinct, but zone may be as thick as 15 ft. Material on dump shows pyrite boxwork with some cubic voids as large as 3/8-inch. Quartz in place is iron oxide stained and contains as much as 5 percent very fine grained pyrite.	Pit	One sample; no significant assays.
269	Minnesota	Weathered granitic rock containing zone of quartz stringers, fluffy limonite, and sulfide stringers.	Cut, 20 ft long.	Three samples; no significant assays.
272	Gent No. 59	Argillaceous dacite near contact with granitic gneiss.	Pit	One sample; 0.2 oz silver per ton.
273	Carter No. 50	Porphyritic dacite containing a trace of pyrite.	Two pits	Two samples; no significant assays.
274	Robert	Probably narrow quartz-filled fissure in tuff. Quartz material is lightly iron oxide stained.	Three pits	Three samples; no significant assays.
275	Way Bell	Massive quartz lens striking N. 30° W. and dipping 25° SW. in granitic rock. Quartz is lightly iron oxide stained but contains no visible sulfide minerals. Lens is about 6 ft wide and 10 ft long.	Two pits	One sample; no significant assays.
276	Corina	Small shear zone, striking east-west and dipping 75° N., in gneiss. Zone is 0.8 ft maximum thickness and can be traced for 30 ft. Material is iron oxide stained.	Pit	Do.
278	Buffalo No. 3	Morainal debris composed of till, boulders and cobbles of slightly iron oxide stained granite.	do	Do.
279	South Fork No. 1	Granite-latite contact. Pyrite disseminated in granite, and occurring as random 1 in. aggregations of spheroidal pyrite in granite and latite. Spheres are as much as 5 cm in diameter.	Trench, 3 ft long, and bull dozed bedrock area of several thousand square feet.	Three samples; as much as 0.2 oz silver per ton.
280	Blakely	Intensely argillized rock in isolated outcrop.	Pit	One sample; 0.4 oz silver per ton.
(Plate 3)				
281-289	Bench	Iron-oxide-stained quartz monzonite.	Nine pits	Nine samples; one sample (284) assayed 0.4 oz silver per ton.
290	Sunny Side	Shear zone striking N. 30° E., dipping 80° SE., in altered quartz monzonite. Zone is exposed for 4 ft with a maximum thickness of 1.4 ft, and can be traced about 100 ft by gossans exposed in two pits. Zone contains very fine grained pyrite, as much as 2 percent, in a matrix of country rock, gouge and quartz.	Caved adit, 30 ft long, and two small cuts.	One sample; no significant assays.
291	Sunny side	Silicified argillite with thin laminae of sulfide minerals, along fractures and bedding. Sulfide minerals comprise less than 1 percent of sample.	Caved adit, 50 ft long; one small trench.	Do.
292	Tam and Zana	Altered quartz monzonite and quartz vein material containing a trace of very fine grained pyrite. No visible structure. Iron-oxide gossan extends 125 ft eastward from trench.	Trench, 25 ft long.	One sample; 0.5 oz silver per ton.

TABLE 16.—*Miscellaneous properties, Boulder (Independence) mining district* —Continued

Map No.	Property name[1]	Summary	Number and type of workings	Sample data
293	Columbus	Altered quartz monzonite dike in volcanic rock. Dike has a maximum thickness of 32 ft and a minimum exposed thickness of 20 ft, strikes N. 30° E. and dips 75° SE.	Two pits	One sample; no significant assays.
294	Queen Victory	Shear zone striking N. 50° E., and dipping 75° NW., in volcanic porphyry. Zone is moderately iron oxide stained and has a maximum thickness of 3 in.	Adit, 15 ft long.	Do.
295-296	Annie	Diabase dike and fractured quartz-vein in monzonite. The vein is 15 ft wide, strikes N. 63° W. and dips vertically.	Two trenches, 21 and 23 ft long.	Two samples; no significant assays.
297	Gold Leaf	Diabase (?) dike in quartz monzonite.	Caved shaft, 20 ft deep.	One sample; no significant assays.
298	Cumberland	Altered monzonite containing minor disseminated sulfide minerals.	Caved adit, 25 ft long.	One sample; 0.5 oz silver per ton.
299	Cumberland	Fault zone 0.8 ft wide strikes N. 75° W., dips 79° NE. in monzonite. Zone contains weakly iron oxide stained, decomposed monzonite.	Pit	One sample; no significant assays.
300	Ida B	Adit driven along a 0.5- to 0.9-ft-wide fault zone of decomposed monzonite.	Adit, 35 ft long.	Two samples; as much as 0.2 oz silver per ton.
301	Dixie	Adit driven along strike of vertical fault zone of slightly iron oxide stained decomposed monzonite.	Caved adit, 20 ft long.	Two samples; 0.2 oz silver per ton.
302-303	Wheelon	A northwest-trending fault zone traceable for 300 ft in monzonite. Fault zone consists of limonite-stained decomposed monzonite containing discontinuous quartz veins as much as 6 in. wide and blebs, stringers, and disseminated grains of pyrite.	Two adits, 58 and 115 ft long.	Ten samples; nine samples across fault zone contained as much as 0.01 oz gold and 0.4 oz silver per ton. One dump sample contained 0.01 oz gold and 0.3 oz silver per ton.
304	Clara	Iron-oxide-stained monzonite from dump.	Trench, 48 ft long.	One sample; 0.3 oz silver per ton.
305	Clara	Altered monzonite contains minor disseminated sulfide minerals.	Pit	One sample; no significant assays.
306	Clara	Iron-oxide-stained monzonite from dump.	Trench, 42 ft long.	One sample; 0.2 oz silver per ton.
307	Clara	Iron-oxide-stained monzonite	Trench, 27 ft long.	One sample; no significant assays.
308	Clara	Iron-oxide-stained, altered monzonite with some druzy quartz inclusions. Minor disseminated sulfide minerals.	Three pits	Do.
309	Clara	Float on dumps indicate a fault zone at least 4 in. wide consisting of siliceous, heavily iron-oxide-stained monzonite. The workings trend N. 63° W.	One pit, one trench 38 ft long, one shaft 20 ft deep.	Do.
310	Cora	Iron-oxide-stained monzonite	Caved shaft, 20 ft deep.	Do.
311	King William	Iron-oxide-stained monzonite with druzy quartz crystal vugs containing intergrown pyritohedrons up to one-half inch in diameter.	Pit	Do.
312	King Solomon	Iron-oxide-stained monzonite	do	Do.
313	King Solomon	Druzy quartz in monzonite. Some iron-oxide stain.	do	Do.
314	Elkhorn	Iron-oxide-stained monzonite	do	Do.
315	Elkorn	Shear zone strikes N. 73° W. in monzonite. Zone is 6 in. wide at maximum and contains very finely disseminated pyrite.	Two pits	Do.

TABLE 16.—*Miscellaneous properties, Boulder (Independence) mining district* —Continued

Map No.	Property name[1]	Summary	Number and type of workings	Sample data
316	Gillead	Iron-oxide-stained shear zones maximum of 1 in. wide in quartz monzonite.	Pit	Do.
317	Gillead	do	Trench, 30 ft long.	Do.
318	Diadem	Shear zones maximum of 0.3 ft wide in quartz monzonite.	Pit	Do.
319	Diadem	Monzonite containing limonite and hematite.	do	One select sample; 0.01 oz gold per ton.
320	Diadem	Adit driven along shear zone striking N. 10° E. and dipping 58° NW. in monzonite. Shear zone transected by siliceous mafic dike.	Adit, 12 ft long	Three samples; no significant assays.
321	Diadem	Iron-oxide-stained quartz monzonite.	Trench, 20 ft long.	One sample; no significant assays.
322	G.S.	Disseminated pyrite in iron-oxide-stained quartz monzonite.	Trench, 15 ft long.	Do.
323	G.S.	Magnetite fracture fillings maximum of one-half inch wide in brecciated, quartz monzonite. No geologic structure observed.	Pit	One sample; 0.02 oz gold per ton.
324	Harvey	Iron-oxide-stained shear zones as much as 1 in. wide in quartz monzonite.	do	One sample; 0.9 oz silver per ton.
325	Harvey	Iron-oxide-stained fault gouge in quartz monzonite. Shear zone 1.3 ft wide. Structure not traceable through overburden.	do	One sample; no significant assays.
326	Harvey	Silicified and hydrothermally altered monzonite specimens from dump.	Caved adit, 20 ft long.	Do.
327	Harvey	Shear zone consisting of heavily iron oxide stained gouge and quartz veinlets maximum of one-half inch wide in quartz monzonite. Zone strikes N. 36° and dips 25° NE.	do	One sample; 0.05 oz gold per ton and 0.4 oz silver per ton.
328-329.	King William	Leached, altered quartz monzonite float. Minor disseminated sulfide minerals observed in one sample.	Two pits	Two samples; as much as 0.01 oz gold per ton and 0.2 oz silver per ton.
330	King William	Specimens of iron-oxide-stained monzonite from dump.	Caved shaft, 15 ft deep.	One sample; no significant assays.
331	King William	Fault zone consisting of altered, silicified heavily iron oxide stained quartz monzonite. Specimens from 3 ton stockpile contain as much as 5 percent pyrite occurring as blebs and fine dissemination.	Pit	Do.
332	G.S.	Iron-oxide-stained gouge filling joints in quartz monzonite. Minor disseminated pyrite.	Trench, 15 ft long.	One sample; 0.03 oz gold per ton.
333	G.S.	Sparsely disseminated pyrite in quartz monzonite float.	Pit	One sample; 0.6 oz silver per ton.
334	G.S.	Iron-oxide-stained quartz monzonite float from dump.	do	One sample; no significant assays.
335	Lilliput	Altered, iron-oxide-stained quartz monzonite.	Caved adit, 50 ft long.	One sample; 0.6 percent lead and 0.1 percent zinc.
336-342.	Cody	Series of northeast and northwest-trending shear zones from 1 in. to 4 ft wide. Zones are in limonite-stained, decomposed monzonite, and contain disseminated pyrite or limonite-bearing quartz veins as much as 3 in. wide. Quartz contains arsenopyrite, galena, and pyrite.	Adit, 100 ft long; six pits.	Sixteen chip and grab samples; nil to 0.02 oz gold per ton, nil to 0.5 oz silver per ton. One sample contained 1.0 percent arsenic. One stockpile sample; 0.03 oz gold per ton, 7.9 oz silver per ton, 4.9 percent lead, and 0.6 percent arsenic.

TABLE 16.—*Miscellaneous properties, Boulder (Independence) mining district* —Continued

Map No.	Property name[1]	Summary	Number and type of workings	Sample data
343	Major Pease----	Magnetite blebs as much as-------- one-fourth inch in diameter, and finely disseminated iron sulfides in latite dike intruding quartz monzonite.	Pit-------------	One sample; no significant assays.
344	Major Pease----	Decomposed, slightly iron -------- stained monzonite.	Trench, 36------ ft long.	One sample; 0.03 oz gold per ton and 0.2 oz silver per ton.
345	Major Pease----	Decomposed monzonite-------------	Shallow trench-- 40 ft long.	One sample; no significant assays.
346	Pauzy----------	Intersecting shear zones in------- limonite-stained fault gouge maximum of 2.2 ft wide.	Partly caved---- adit, 23 ft long.	Two samples; no significant assays.
347	Mastadon-------	Decomposed monzonite-------------	Trench, 22 ft--- long.	One sample; no significant assays.
348	Mastodon-------	Monzonite and iron-oxide-stained-- latite on dump.	Caved adit, 30-- ft long.	Do.
349	O.K.-----------	Adit driven southerly along------- latite intrusive containing minor disseminated pyrite.	----do----------	One sample; no significant assays.
350	O.K.-----------	Iron-oxide-stained monzonite and-- latite porphyry from dump.	Pit, 15 ft deep-	Do.
351	O.K.----------	Dump specimens indicate a latite-- porphyry dike in quartz monzonite. Latite contained very finely disseminated pyrite.	Caved adit,----- 150 ft long.	Two samples; no significant assays.
352	Toledo---------	Latite dike in quartz monzonite---	Trench, 23 ft--- long.	One sample; no significant assays.
353	Lake View------	Iron-oxide-stained latite---------	Pit-------------	Do.
354	Golden--------- Slipper	Seven-foot-wide fracture zone----- in volcanic breccia, traceable for 250 ft.	----do----------	Do.
355	Seneca---------	Specimens of quartz monzonite----- from dump.	----do----------	Do.
356	Pony-----------	Fractured monzonite---------------	----do----------	Do.
357	Pony-----------	Iron-oxide-stained quartz veins--- as much as 1-1/2 in. wide in 3-ft-wide fault zone in fractured monzonite.	----do----------	Do.
358	Pony-----------	Iron-oxide-stained fault gouge---- in silicified quartz monzonite.	----do----------	Do.
359	B Nye----------	Fractured shear zone in quartz---- monzonite.	----do----------	Do.

[1]Properties underlined are in the study area.

m) long, but caved 223 ft (68 m) from the portal, was driven due west along the zone. Three samples (fig. 48, Nos. J-182 through J-184) from between timber in the adit assayed as much as 0.2 oz silver per ton (6.9 g/t) and 0.09 percent copper.

A select sample from a sloughed prospect pit, possibly on the Granite Mountain claim, assayed a trace gold, 0.7 oz silver per ton (24 g/t), and 2.03 percent copper (fig. 48, No. D-48). It consisted of quartz float containing malachite, azurite, and chalcopyrite. A random grab sample from the same pit (No. D-49) assayed 0.01 oz gold per ton (0.34 g/t), 0.1 oz silver per ton (3.4 g/t), and 0.31 percent copper. Fault breccia and quartz float composed the sample.

The Silver Lake district's mineral potential could not be estimated because of limited exposures. The metal-bearing samples, however, indicate a resource potential.

A description of the workings is summarized in table 17.

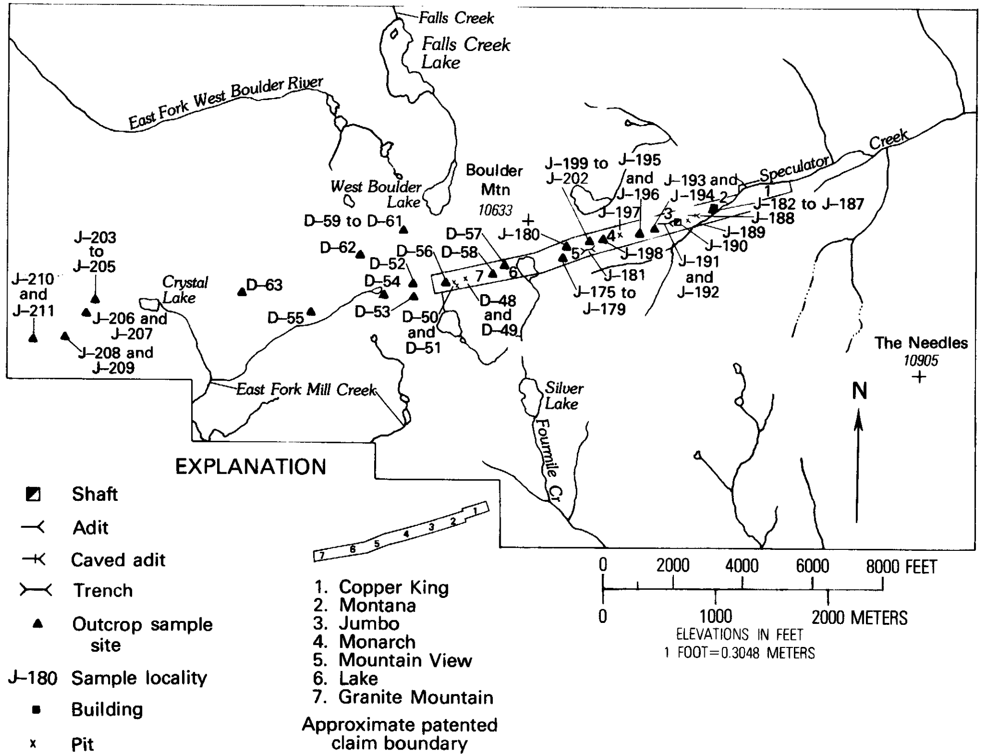


FIGURE 48.—Silver Lake mining district.

SHEEPEATER (JARDINE) MINING DISTRICT

The Sheepeater mining district extends into the southwest corner of the study area and is accessible by trails from Jardine, Cedar Creek, and Sixmile Creek.

According to county records, 52 claims were located in or near the study-area portion of the mining district between 1889 and 1973. No record of production from the study-area portion exists. Claims and workings are clustered in two locales (pl. 3, Nos. 1-9)—the first, a ridge between North Fork Bear Creek and Bear Creek, and the second, the Sheep Mountain area, including a ridge extending north. The study-area boundary passes through both clusters.

Production from the Sheepeater district through 1974 was 180,433 oz (5,612,008 g) gold, 35,256 oz (1,096,567 g) silver, 9,124 lb (4,139 kg) of copper, 1,292 lb (586 kg) of lead, 12,615,131 lb (5,722,223 kg) of arsenic trioxide, and 778,420 lb (353,092 kg) of tungsten trioxide. Production data are from Bureau of Mines production files, Reed (1950), and Seager (1944).

The Anaconda Company is drilling on Mineral Hill, less than 1 mi (1.6 km) from the study area boundary. The claim group under investigation extends into the study area.

Gold and tungsten minerals are often found in quartz veins in the Sheepeater district. The veins are in quartz-biotite schist and biotite quartzite. The metals are also found in arsenopyrite veins in quartz cummingtonite schist (Seager, 1944). The quartz veins usually contain some sulfide minerals.

The veins in quartz cummingtonite schist are of two types: (1) well-defined arsenopyrite-bearing veins along the borders and within the schist layers, and (2) sulfide minerals and quartz more or less uniformly distributed throughout the schist (Seager, 1944, p. 48).

A very important point that Seager (1944, p. 44) made is that "* * * the most striking and significant feature of the veins of the district is their irregular and generally unpredictable habit as regards thickness, continuity, and grade."

Samples from 47 workings in or adjacent to the study area indicate no economic mineral resources. However, rocks not unlike host rocks in the productive portion of the Sheepeater district occur in the study area. Arsenopyrite veins in quartz cummingtonite schist are found at the Iron King property approximately one-fourth mile (0.4 km) south of the study boundary. The Standard group of claims and the Horseshoe claim, both located partly in the study area between North Fork Bear Creek and Bear Creek, are on quartz veins in quartz-biotite schist and biotite quartzite.

During the summer of 1974, geochemical investigations were being conducted on a banded iron-formation in the Pole Creek drainage, just

TABLE 17.—*Miscellaneous workings, Silver Lake mining district*

[Map numbers on figure 48. Assays are considered not significant if the values are less than 0.01 oz gold per ton, 0.2 oz silver per ton, 0.1 percent copper, 0.25 percent lead, and 0.25 percent zinc. Data measured in inch-pound system; 1 oz (troy)/ton = 34.285 g/t; 1 ft = 0.3048 m; 1 in. = 2.54 cm]

Map No.	Property name	Summary	Number and type of workings	Sample data
D-48, D-49.	Granite Mountain	Float indicates laminated quartzite, containing malachite, azurite, chalcopyrite, and carbonaceous fault.	Pit	Two samples; select sample contained a trace of gold, 0.7 oz silver per ton, and 2.03 percent copper; random grab sample contained 0.01 oz gold per ton, 0.1 oz silver per ton, and 0.31 percent copper.
D-50	----do-------	Float indicates calcareous fault breccia and milky quartz.	Trench, 20 ft long.	One random grab sample; as much as 0.08 percent copper.
D-51	----do-------	Calcareous fault breccia and milky quartz on dump.	Pit	One sample, no significant assays.
D-52	Mayflower	Quartz pod enclosed in fault breccia, 1 ft wide.	Outcrop	Do.
D-53	----do-------	Granitic dike striking north-south and dipping 67° W., 3 ft wide.	----do---------	Do.
D-54	----do-------	Limonitic breccia, striking N. 46° E. and dipping 64° NW., 2 ft wide.	----do---------	Do.
D-55	Comstock	Limonite-stained quartz breccia.	----do---------	Do.
D-56	Granite Mountain	Pod of granite adjacent to gabbro, 7 ft wide.	----do---------	Do.
D-57	Lake	Contact zone between granitic gneiss and fault breccia, 3 ft wide.	----do---------	Do.
D-58	----do-------	Contact zone between granitic gneiss and gabbro, 1.5 ft wide.	----do---------	Do.
D-59 to D-61.	Bell	Fault zone composed of limonitic, granitic fault fault breccia, granitic fault breccia with quartz lenses, and granitic gneiss. Country rock is gneissic schist.	----do---------	Three samples; no significant assays.
D-62	Comstock	Granitic quartz fault breccia.	----do---------	One sample; no significant assays.
D-63	Noble	Massive milky quartz vein	----do---------	Do.
J-175 to J-179.	Mountain View	Granitic gneiss; limonite-stained, calcite-encrusted granitic gneiss and quartzite; and limonite-stained mafic dike material. Limonite-stained quartzite containing a 2-3 percent pyrite, 25 ft wide.	Two outcrops	Five samples; no significant assays.
J-180	----do-------	Mafic dike striking N. 72° W. and dipping 60° SW.	Outcrop	One sample; no significant assays.
J-181	Monarch	Quartz vein, 2.4 ft wide stained with limonite, striking N. 85° E. and dipping 72° SE.	Trench, 8 ft long.	One sample; 0.5 oz silver per ton.
J-182 to J-184.	Montana	Shear zone in granitic gneiss and quartzite. Adit driven west. Chlorite-schist and argillic granitic gneiss stained with copper minerals are exposed underground.	Adit, 2,000 ft long, caved 223 ft from portal.	Three samples; as much 0.2 oz silver per ton and 0.09 percent copper.
J-185 to J-187.	----do-------	Limonite-stained quartz-rich dump material including some mafic dike rock.	Adit	Three samples; as much as 0.3 oz silver per ton.
J-188	Jumbo	Brecciated, limonite-stained quartzite with silica cement and pyrite.	Caved adit, 103 ft long.	One sample; no significant assays.
J-189	----do-------	Brecciated quartzite encrusted with calcite.	Pit	Do.

TABLE 17.—*Miscellaneous workings, Silver Lake mining district—Continued*

Map No.	Property name	Summary	Number and type of workings	Sample data
J-190	----do-------	Brecciated quartzite cemented with limonite. Zone strikes N. 77° E. and dips 80° SE.	Shaft, 15 ft---deep.	Do.
J-191, J-192.	----do-------	Brecciated quartzite with----- malachite and limonite stain. Adit driven N. 83° W. and open cut dug N. 58° W.	Adit, 18 ft---- long, with open cut 28 ft long.	Two samples; as much as 0.4 oz silver per ton and 0.06 percent copper.
J-193, J-194.	----do-------	Limonite-stained granitic----- gneiss and quartzite. Brecciated quartzite, granitic gneiss, and chlorite amphibolite schist, 28 ft wide.	Outcrop--------	Two samples; no significant assays.
J-195 to J-196.	----do-------	Limonite-stained, fractured--- quartzite 26 ft wide. Limonite-stained mafic dike material.	----do---------	Two samples; as much as 0.01 oz gold per ton and 0.2 oz silver per ton.
J-197	Monarch------	Brecciated quartzite with----- silica cement, a trace of malachite, and encrusted with calcite.	Pit------------	One sample; 0.2 percent copper.
J-198	----do-------	Brecciated, limonite-stained,- calcite-encrusted with calcite.	Outcrop--------	One sample; no significant assays.
J-199 to J-202.	----do-------	Alternating mafic dike material and brecciated, silica-cemented, calcium-carbonate encrusted, limonite-stained quartzite.	----do---------	Four samples; as much as 0.2 oz silver per ton.
J-203 to J-205.	Stanley------	Limonite-stained quartzite---- and amhibolite schist.	Outcrop, 54-ft-exposure.	Three samples; as much as 0.3 oz silver per ton.
J-206, J-207.	----do-------	Mafic dike containing quartz-- stringers as much as one- of pyrite. Limonite stained quartzite and amphibolite schist.	Outcrop--------	Two samples; as much as 0.2 oz silver per ton chromium.
J-208 to J-209.	Chester------	Limonite-stained quartzite---- and quartz-amphibolite schist. Mafic dike material containing limonite veinlets maximum one-eighth inch thick.	Outcrop, 50-ft-exposure.	Two samples; as much as 0.2 oz gold per ton.
J-210, J-211.	----do-------	Limonite-stained granitic----- gneiss containing a trace of pyrite. Mafic dike containing a trace of chalcopyrite and malachite.	Two outcrops---	Two samples; 0.01 percent copper.

south of the study area. A banded iron-formation is within the study area on what may have been the old Hazel claim on North Fork Bear Creek, approximately 1.5 mi (2.4 km) from its confluence with Bear Creek. A 96-ft (29-m)-thick section of metasedimentary layers rich in quartz, magnetite, and amphibole minerals intercalated with quartz-biotite schist and quartzite. Assays showed as much as 24.1 percent iron.

No minable mineral deposits were observed in that part of the Sheepeater mining district within the study area. However, close proximity to the old producing part of the district, and the presence of favorable rocks, suggests that a potential exists for mineral deposits in the area near the old workings. A description of workings in the study area is given in table 18.

TABLE 18.—*Miscellaneous properties, north part of Sheepeater (Jardine) mining district*

[Map numbers on plate 3. Assays are considered not significant if the values are less than 0.1 oz gold per ton, 0.2 oz silver per ton, 0.1 percent copper, 0.25 percent lead, and 0.25 percent zinc. Data measured in inch-pound system; 1 oz (troy)/ton = 34.285 g/t; 1 ft = 0.3048 m; 1 in. = 2.54 cm]

Map No.	Property name[1]	Summary	Number and type of workings	Sample data
1	Iron King-----	Highly folded and sheared quartz-cummingtonite schist containing quartz and arsenopyrite veins as much as 0.2 ft wide. Limonite stain is present throughout entire adit.	Adit, 153 ft long--including drifts.	Fifteen samples; as much as 0.6 oz silver per ton.
2	Standard group-	Quartz veins in schist, quartzite,-quartz amphibole and gneissic granite.	Ten pits; seven----trenches as much as 45 ft long; three open adits, 17, 20, and 30 ft long; and five caved adits ranging between 30 and 300 ft long.	Twenty-six samples; as much as 0.01 oz gold per ton, 0.1 oz silver per ton, and less than 0.02 percent tungsten trioxide.
3	Hazel---------	The open adit exposes metasedi- ---mentary layers rich in quartz and amphibole minerals which are intercalated with quartz biotite schist and quartzite. Garnetiferous schist is exposed near the face.	Five caved adits,--the longest about 650 ft long. One open adit 96 ft long.	Ten samples; as much as 0.2 oz silver per ton; 24.7 percent iron, and less than 0.02 percent tungsten trioxide.
4	Horseshoe------	Quartz veins in schist, quartzite,-quartz amphibolite and gneissic granite.	Two 8-ft-deep------shafts and five pits.	Nine samples; no significant assays.
5	Clipper--------	Limonite- and manganese-oxide- ----stained quartzite.	Three pits---------	Two samples; no significant assays.
6	Moon-----------	Shear zones and quartz veins in----schist, metagabbro, and quartzite. Limonite- and manganese-oxide stain.	Nine pits----------	Six samples; no significant assays.
7	Top All--------	Float indicates a quartz vein 1.5--in. wide in phyllite.	Pit----------------	One sample; no significant assays.
8	Tip Top--------	Phyllite and mica schist. Quartz--float in one pit. Limonite stain.	Two pits-----------	Two samples; no significant assays.
9	Boston---------	Limonite-stained quartz vein 4.5---ft wide striking east and dipping 30° N.	Pit----------------	Do.

[1]Names underlined are properties in the study area.

MOUNT COWEN AREA

Between 15 and 20 claims have been located on the south side of the Mount Cowen massif, which is in the study area. The claims are in the vicinity of Elbow and Fire Lakes and the one above Elbow Lake, which is called "Frozen Lake" by the claimant. They are glacial tarns at the headwaters of Elbow Creek (pl. 3). Claim elevations range from about 9,000 ft (2700 m) to more than 10,500 ft (3,200 m). Most of them were located after 1942 by Kester Counts of Livingston. Access is by trail from the Snowy Range Ranch on East Fork Mill Creek.

The claims were located for molybdenum and uranium, and many are in the swarms of quartz-feldspar pegmatite dikes that cut Precambrian gneisses. Apparently other claims lie along the area's very prominent mafic dikes. The mafic dikes, one of which is about 200 ft (60 m) wide, often persist for miles.

An examination of the Mount Cowen mineral occurrences was conducted by the Bureau of Mines in 1948. It was reported (Reed, 1950, p. 53) that the maximum molybdenum assay was 0.012 percent from several samples of the mafic dikes, pegmatite masses, and adjoining gneisses.

During 1974, the Bureau of Mines took an additional 28 samples from the various geologic structures (pl. 3, No. 242); no workings were found. All samples were checked for radioactivity. No anomalous readings were obtained.

Pods of molybdenite as much as one-half inch (1.3 cm) in diameter were found in pegmatitic float south of Mount Cowen. The site is 500 ft (150 m) north of a small lake. The molybdenum source was not found. Magnetite pods as much as 6 in. (15.2 cm) in diameter give a speckled appearance to much of the gneissic rocks near Elbow Lake. Combined specimens of magnetite assayed 0.02 oz gold per ton (0.69 g/t), 1.6 oz silver per ton (54.9 g/t), and 1.45 percent titanium. Of the other 27 samples from various rock types, 1 had an assay of 0.01 oz gold per ton (0.34 g/t), 8 ranged from 0.1 to 0.3 oz silver per ton (3.4 to 10.3 g/t), and 1 had an assay of 1.15 percent titanium. Seventeen samples, mainly from the mafic dikes, were assayed for platinum; no measurable amounts were detected. No mineral resources were found in the Mount Cowen area.

SUCE CREEK MINING DISTRICT AND VICINITY

The Suce Creek district and vicinity includes the Suce Creek mining district (unorganized) and the Pine, Pool, Deep, Dry, Beaver, and Mission Creek drainages. Access is by gravel, dirt, and unimproved roads along the creeks, with some of the unimproved roads extending into the study area.

The vicinity's first recorded mineral exploration occurred in 1883, at which time three claims were located. Since then, 70 lode and 24 placer claims have been recorded. Most of the placer claims were located for stone or clay. Activity on both lode and placer claims has been limited to exploration and assessment work. There is no history of production other than stone, and no active claims remain.

The main rock types are Precambrian metamorphic and Paleozoic sedimentary. The metamorphic rocks contain pegmatite dikes. Principal metallic mineral occurrences are in gneiss, schist, and pegmatite dikes, and are controlled by shear zones striking northwest or joints and foliation planes striking northwest or northeast.

Nonmetallic mineral deposits of interest include limestone in the S ½ sec. 4, T. 3 S., R. 10 E. Sixteen placer claims were once located on this deposit. Because large amounts of limestone elsewhere are closer to potential markets, this occurrence is considered submarginal. Another nonmetallic deposit, called the "Smitty Mine," is in the SW¼ SE¼ sec. 8, T. 4 S., R. 10 E. This deposit is a series of talus slopes, composed of cobbles and boulders of greenish micaceous schist. The rock is used locally as ornamental building stone, but has little economic potential.

Descriptions of metallic mineral deposits are summarized in table 19. They have no potential or are not well enough exposed to ascertain their potential.

PLACER DEPOSITS

Most of the area's placer deposits are in the Emigrant Creek, Sixmile Creek, and Boulder River drainages. Depending upon the gradient, stream sections are either low-lying flood-plain gravel accumulations, or rapids and falls that are generally devoid of gravel. The accumulation is often a mixture of stream gravel, glacial debris, and talus. Generally, alluvium in the Emigrant and Sixmile drainages is composed of schist and dacite detritus. Alluvium in the Boulder River drainage consists of detrital monzonite, granite, or volcanic breccia, depending upon the source. Material is generally subrounded and ranges in size from silt to large boulders.

Most placer production came from Emigrant Creek or two of its tributaries, Huckleberry Gulch and east fork of Emigrant Creek (pl. 4). Patented placer claims, or evidence of placering, are also present on Sixmile Creek, North Fork Sixmile Creek, a tributary basin of Sixmile Creek locally called "Placer basin" (pl. 3, No. 17), Gold Prize Creek, Gold Run Creek, Arrastra Creek, West Fork Mill Creek, Froze-to-Death Creek, Falls Creek, Great Falls Creek, Speculator (Elk Park) Creek, Boulder River, and upper tributaries of Boulder River (principally Basin Creek).

Placer samples contained as much as 78 mg (milligrams) of gold per cubic meter ($0.2875/yd^3, based on $150/oz ($4.82/g)). Maximum black sand content is 11.5 lb/yd^3 (6.8 kg/m^3). Major constituents of the black sand were magnetite and magnetite intergrowth, garnet, and zircon. Traces of barite and tungsten were detected in some samples. Radioactivity was not above background, and most samples contained no fluorescent minerals. Samples from an area of less than 2 acres (0.8 h) near the forks of Sixmile Creek contained as much as 2 lb of garnet per cubic yard (1.2 kg/m^3). This mineral is not of economic grade.

EMIGRANT CREEK

Placer mining activity began in Emigrant Gulch in the 1860's. By 1889, an estimated 250,000 yd^3 (190,000 m^3) had been treated yielding an average of $1/yd^3 ($1.97 g/m^3) at a gold price of $20.67/oz ($0.66/g) (Western Historical Pub. Co., 1907?, p. 124). By 1900, gold valued at $500,000—about 24,000 oz (746,000 g)—had been recovered from

TABLE 19.—*Miscellaneous properties, Suce Creek mining district and vicinity*

[Map numbers on plate 3. Assays are considered not significant if the values are less than 0.01 oz gold per ton, 0.2 oz silver per ton, 0.1 percent copper, 0.25 percent lead, and 0.25 percent zinc. Data measured in inch-pound system; 1 oz (troy)/ton = 34.285 g/t; 1 ft = 0.3048 m; 1 in. = 2.54 cm]

Map No.	Property name[1]	Summary	Number and type of workings	Sample data
243	Silver Mountain	Gradational contact between gneiss and schist.	Pit	One sample; no significant assays.
244	First Out	Orthoclase-gneissic schist, striking north and dipping 50°.	Caved adit, 50 ft long, driven south.	One sample; 0.2 oz silver per ton.
245	Crosby's Adventure.	Chlorite schist, foliation striking N. 25° E. and dipping 55° NW.	Pit	One sample; no significant assays.
246	Sixty-five	Biotite-amphibolite schist striking N. 7° W. and dipping 40° NE.	Caved adit, 200 ft long, driven N. 35° W.	Do.
247	King Philip	Float indicates a quartz lens in biotite-amphibolite schist.	Two pits	One grab sample; 0.27 percent copper (north pit). One sample; no significant assays (south pit).
248	Honolulu	Shear zone, 18 in. thick, filled with quartz mica schist, limonite, quartz vugs and a small amount of chalcopyrite. Strikes N. 66° E. and dips 32° SE.	Caved adit, 50 ft long.	Two samples; as much as 0.2 oz silver per ton and 0.045 percent copper.
249	First Chance	Massive Madison Limestone.	Two pits	Two samples; 0.2 to 0.3 oz silver per ton.
250	Oro-y-Plate	Micaceous quartzite striking N. 9° W. and dipping 76° SW. on the northeast side of caved portal. Hematite schist on the southwest side of portal.	Caved adit, 100 ft long.	One sample; no significant assays.
251	Blue Manganese	Shear zone, 1-18 in. thick, filled with hematite gouge striking N. 15° W. and dipping 85° SW, Several crosscutting shear zones also contain gouge. Country rock is chlorite schist.	Adit 127 ft long in the shape of a partial horseshoe.	Eleven samples; as much as 0.4 oz silver per ton, trace of gold, and 0.13 percent copper.
252	Ruby	Micaceous schist with foliation striking N. 51° E. and dipping 62° NW; amphibolite schist and micaceous quartz schist float.	Three pits	Three samples; 0.10 percent chromium (south pit).
253	Big Chief	Milky quartzite with joints striking N. 62° E. and dipping 50° NW.	Two pits	Two samples; 0.01 oz gold per ton (west pit).
254	Northern Pacific.	Granite pegmatite lens striking N. 74° E. and dipping 54° NW. In conformable contact with amphibolite schist.	Pit, and trench, 41 ft long.	Two samples at pit; as much as 0.10 percent copper. One sample at trench; no significant assays.
255	Tip Top	Madison Limestone striking N. 61° E. and dipping 60° NW.	Two pits	Two samples; no significant assays.
256	Oliver	Madison Limestone with some iron oxides.	Caved shaft, 30 ft deep.	Do.

[1]Properties underlined are in the study area.

Emigrant Gulch gravel deposits (Western Historical Pub. Co., 1907?, p. 187). From 1904 to 1946, placer production in Park County, mostly from Emigrant Gulch, amounted to 15,592 oz (484,900 g).

Placer tailings, old equipment, hydraulicked slopes, and drift mines (pl. 3) in various states of caving and disrepair were noted along most of Emigrant Creek below the upper falls, along the east fork of Emigrant Creek and in Huckleberry Gulch. Prior to 1906, mining operations included ground sluicing, hydraulicking, and drift mining. Spiling methods were sometimes used to reach the auriferous gravel beneath the barren talus which covered much of the gulch bottom lands and walls. Miners also worked gravel accumulations not covered by talus, as well as gravel in perched placers, some of which were several hundred feet above Emigrant Creek. The perched deposits, on private land about 1 mi (1.6 km) upstream from the mouth of Emigrant Gulch, may have been deposited, in a lake that formed behind a barrier of piedmont ice and (or) moraine (Van Voast, 1964, p. 47–49).

About 1904, a 70-ton (64-t) rail-mounted steam shovel served by 3 dinkey engines, 40 ore cars, and a track-mounted washer worked gravel below the mouth of Emigrant Gulch (Whithorn and Whithorn, 1968). In 1939, a dry-land dredge was employed. The volume mined during these operations is not known. A 10-ft^3 (0.3-m^3), 110-bucketline dredge called Mosier II operated from August 1941 to October 1942. Gold recovery from 1.6 million yd^3 (1 million m^3) averaged slightly less than 163 mg/m^3 (\$0.14/yd^3 at a gold price of \$35.00 per troy ounce) (Lyden, 1948, p. 110). The dredge was reactivated in 1946 and 947,000 yd^3 (724,000 m^3) was mined with an average recovery of about 123 mg of gold per cubic meter (\$0.106/yd^3). Increased maintenance and labor costs, combined with lower average gold values, made operations unprofitable. They ceased in 1947, and the dredge was sold and sent to Colombia, South America (Whithorn and Whithorn, 1968).

During 1973 and 1974, a placer mining operation, in which a front-end loader dug and fed gravel to a trailer-mounted trommel screen and washing plant, was observed near Chico. The operation resulted in the recovery of several ounces of gold (T. Kardash, oral commun., 1974).

Lower Emigrant Gulch and its tributaries were sampled by reconnaissance panning. Gold was found in nearly every sample taken from the main gulch. The placer deposits above the junction of the east fork of Emigrant Creek (deposits from which some gold has probably been recovered) were sampled by trenching (pl. 4B) and panning. Eleven samples contained traces of gold. For safety reasons no test sites could be dug to bedrock where highest values would be expected. Seismic tests at the lower end of the upper Emigrant placer indicate the deposits are shallow, not exceeding 20 ft (6 m). Over 1 million yd^3 (765,000 m^3) of auriferous gravel is estimated to occur in the upper Emigrant placer.

Van Voast (1965, p. 47) suggested that placer gold may have been deposited in an ice-marginal channel between Emigrant Creek and Chico Hot Springs, or in an old Emigrant Creek channel located between the dredge pond (pl. 4A) and the fish hatchery near the Yellowstone River. The ice-marginal channel borders the wilderness study area.

Emigrant Creek's severe spring floods continually rework the gravel. Therefore, many of the earlier mined areas might be again minable. Floods, snowslides, rock avalanches, and deep snows will continue to be a serious hindrance to placer mining.

SIXMILE CREEK AND TRIBUTARIES

Placer mining in the gulch of Sixmile Creek began in the 1880's, probably by miners from Emigrant Gulch searching for new deposits. Numerous pits, trenches and several drift mines, as much as 650 ft (200 m) long, indicate that activity was centered in Gold Prize Creek, "Placer Basin Creek" (claimant's name for drainage in sec. 24, T. 7 S., R. 8 E.), and near the forks of Sixmile Creek. Nearly 4 mi (6.4 km) of the creek below the forks is covered by patented placer claims (pl. 3). No production records exist; output figures may have been included with those of the Emigrant district.

Placer examination in the study area included digging pits and trenches along streams. Accessible drift mines were also sampled.

Placer samples from Sixmile Creek contained no measurable gold, but bedrock was never reached. Intensive sampling in Gold Prize Creek indicated no gold in the upper gravel, although numerous old workings and tailings piles are present. The best gold values were found in Placer Basin Creek near the center of sec. 24, T. 7 S., R. 8 E. The deposit is reported to be 8 ft (2.4 m) deep (J. H. Counts, oral commun., 1974) and to contain an estimated 150,000 yd^3 (115,000 m^3). Samples indicate that near-surface gold values range from \$0.01 to \$0.03/yd^3 at a price of \$150.00/oz (2.7 to 8.0 mg/m^3) and increase with depth. Bedrock samples were not obtained. The Sixmile Creek drainage system has a potential placer gold resource.

BOULDER RIVER AND TRIBUTARIES

Production from Boulder River placers prior to 1907 was valued at \$200,000 (10,000 oz (311,000 g) of gold) (Western Historical Pub. Co., 1907?, p. 216). This was at a time when gold sold for \$20.67/oz (\$0.66/g). Production probably came from the Natural Bridge, Silver Lake (Speculator Creek), and Boulder mining districts, as well as from the main Boulder River. Since 1970, output is valued at several hundred dollars, but many former placer locations have long been homesteaded.

All tributaries on which lode gold claims were located were sampled. No significant amounts of placer gold were indicated. A block of placer claims covering a glacial cirque that drains into East Fork on the main Boulder River was sampled. No measurable gold values were found, and no increase in values with depth is indicated. Depositional features indicate that the material is reworked glacial debris. Most of the main Boulder River is beyond the study area and was not examined.

In the placer areas examined, stream gradients were steep, gravel deposits small and narrow, and amounts of recoverable gold insignificant. However, small high-grade pockets may occur in the streams that drain areas covered by lode claims.

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Geothermal Resource

By N. T. ZILKA, U.S. BUREAU of MINES

MINERAL RESOURCES OF THE NORTH ABSAROKA WILDERNESS STUDY AREA, PARK AND SWEET GRASS COUNTIES, MONTANA

GEOLOGICAL SURVEY BULLETIN 1505-D

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GEOTHERMAL RESOURCE

By N. T. ZILKA, U.S. BUREAU of MINES

DISCUSSION

The presence of the Yellowstone Known Geothermal Resource Area on the southwest side of the study area has stimulated interest in the geothermal potential of the region. Geothermal lease applications have been filed to cover land in and close to the study area near Chico Hot Springs and La Duke (La Duc) Spring (pl. 3 and fig. 49). Burlington Northern, Inc., has applied for a lease on the northern block. Application for the southern block is divided among Burlington Northern, Inc., LVO Corp., C. J. Heringer, Thermal Resources, Inc., and Earth Power Corp. Based on geologic interpretation and private industry's competitive interest, the area surrounding the southern block will be classified as a Known Geothermal Resource Area by the U.S. Geological Survey (J. H. Hinds, oral commun., 1975).

The area occupied by the lease applications is within the Northern Rocky Mountain physiographic province on the edge of the Beartooth uplift. Rocks of all eras are represented and have been highly deformed by periods of tectonic activity, especially the Laramide orogeny.

The northern block of land under application lies along the Emigrant fault zone. Chico Hot Springs is also along this zone, which extends from Tom Miner Basin N. 45° E. for at least 20 mi (32 km) (fig. 49). The fault is of normal displacement with the downthrown side on the northwest. Country rock is composed mainly of Precambrian metamorphic and Tertiary volcanic rock. Sedimentary rocks occur locally around the Chico spring vents and are predominantly light to medium gray limestone with black chert nodules.

The southern block of land under lease application centers on the northern portion of the Sepulcher Mountain graben. La Duke Spring is within the Sepulcher Mountain graben on the cross-cutting Gardner reverse fault. The graben extends south into Yellowstone National Park. It is bounded by the East Gallatin and Mammoth normal faults, which are related to thermal activity within the park. Country rock is

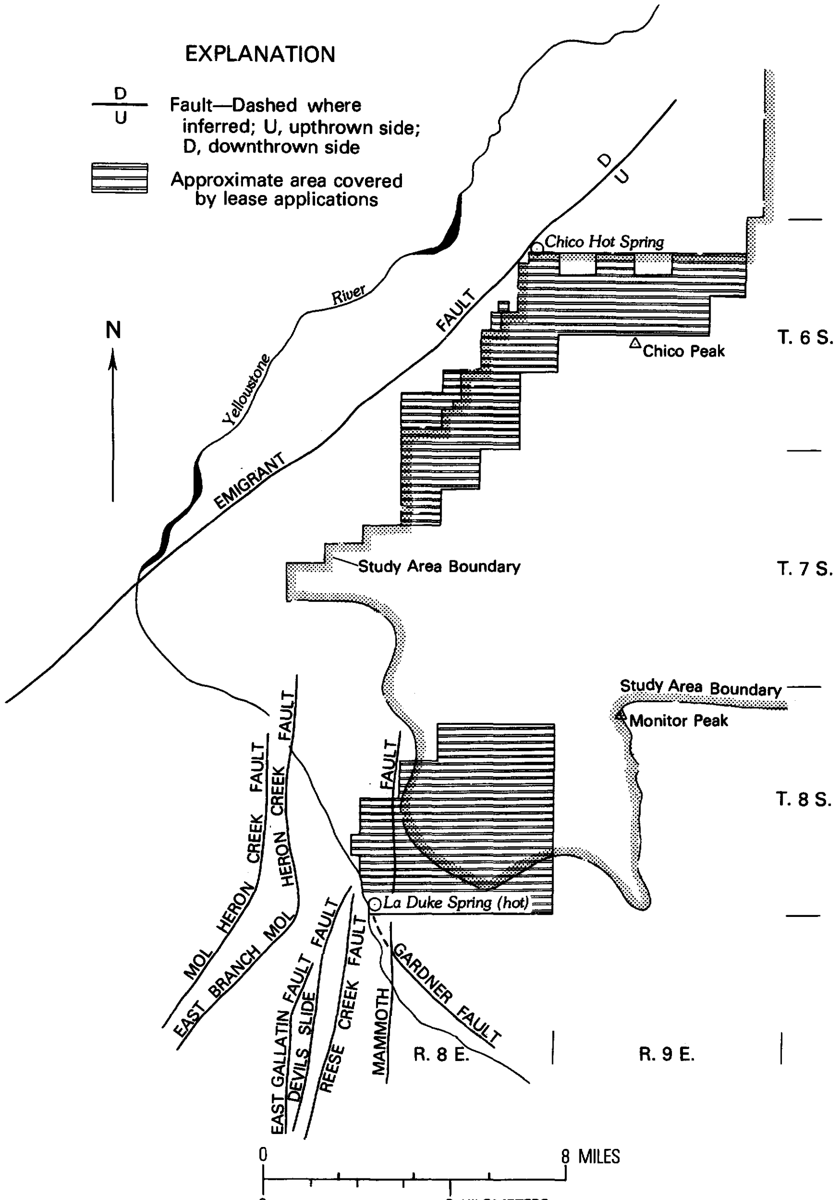

FIGURE 49.—Map showing area covered by geothermal lease applications in the North Absaroka study area.

primarily Tertiary and Quaternary volcanic and Precambrian metamorphic rock. Sedimentary rocks crop out locally, with gray, chert-bearing limestone around the La Duke spring vents.

Thermal ground water is under artesian conditions and is heated by deep circulation in a zone of high geothermal gradient. Sedimentary-rock aquifers at depth, and the numerous large faults, provide the conduits. Based on a geothermal gradient of 1.5°C/100 ft (30 m), temperatures above 100°C may exist below a depth of 6,100 ft (1,900 m).

Both Chico and La Duke hot springs supplied water for swimming pools at resorts near the springs. The La Duke facilities were destroyed by an earthquake. The Chico spring has two vents inside the study area. The La Duke spring has four, all outside the study area. Both springs are slightly alkaline and the vents are surrounded by travertine and orange algae. Vent water temperature was higher at La Duke, 63°C versus 47°C, but discharge was greater at Chico, 240 g/m versus 170 g/m (908 to 644 L/m).

The chemical composition of the sampled waters is shown in table 20. Thermal waters generally have a higher percentage of dissolved solids than waters from cold springs. The use of various geochemical thermometers is based on the assumption that no dilution or enrichment has taken place as the water travels to the surface and the constituents are in a valid equilibrium (Fournier and Truesdall, 1974). Estimated aquifer temperatures calculated by using the silica thermometer were 47°C for Chico spring and 59.3°C for La Duke spring. Molar concentrations of Na, K, and Ca used in the Na-K-Ca thermometer give results of 67.0°C and 82.8°C for the two springs, but are too high owing to deposition of $CaCO_3$, before analysis. Whereas the proximity of the Yellowstone River suggests the possibility of water-mixing, such a possibility is discounted because of the narrow difference between estimated and measured temperature (Fournier and Truesdall, 1974). High Cl/F ratios usually indicate high temperatures; they are low for these springs. Minor amounts of lithium and magnesium were detected in all samples. The La Duke spring water is high in sulfate.

TABLE 20.—*Chemical analysis of selected spring waters*

[Samples collected Oct. 15, 1974. Chemical constituents in milligrams per liter]

Spring	Location			SiO_2	Ca	Mg	Na	K	Li	HCO_3	SO_4	Cl	F	B	pH
	Sec.	T.S.	R.E.												
Chico--------	SW 1/4 1	6	8	30.5	33	7.5	70	6.0	0.20	190	43	9.8	0.4	0.1	8.1
La Duke------	SW 1/4 32	8	8	40	270	62	272	25	.27	277	1143	45	1.7	.4	7.9
Cold spring--	SW 1/4 29	8	8	51.8	24.7	10.7	11	1.4	.02	137	5.1	.4	.1	.1	7.7
Do-----------	NE 1/4 12	7	10	12.2	33	37.5	16	2.9	.01	315	72	2.6	.1	.1	8.4

Results of gravity and aeromagnetic surveys by the U.S. Geological Survey indicate coincident gravity lows and magnetic highs in the vicinities of Monitor Peak and Chico Peak. These two anomalous areas may be eruptive centers with thick accumulations of volcanic rocks.

This assumption is further substantiated by the local abundance of intrusive rocks. If the assumption is true, the areas may be locales of anomalous geothermal heat flow.

The region lies within the intermountain seismic belt, a zone of earthquake activity extending from Arizona to Montana. A seismic survey conducted in 1972 (Trimble and Smith, 1973) in the vicinity of La Duke spring revealed activity similar to that in the belt as a whole, but not nearly as high as around the Yellowstone Park geothermal center.

Recent studies of the Yellowstone geothermal area suggest that the thermal activity is related to a mantle plume (Smith and Sbar, 1974). The hypothetical Yellowstone plume would be confined to a small area within the park and cannot be related directly to thermal activity in the study area. Geophysical data suggest the possibility of similar crustal hot spots occurring in the study area, but the geochemical results indicate that reservoir temperatures are not sufficient to be a source of thermal fluids for significant power production. The study area's geothermal potential does not seem to warrant extensive development.

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