STUDIES RELATED TO WILDERNESS

PRIMITIVE AREAS

BEARTOOTH AREA, MONTANA AND WYOMING

GEOLOGICAL SURVEY BULLETIN 1391–F

Mineral Resources of the Beartooth Primitive Area and vicinity, Carbon, Park, Stillwater, and Sweet Grass Counties, Montana, and Park County, Wyoming.

By FRANK S. SIMONS *and* THEODORE J. ARMBRUSTMACHER,
U.S. GEOLOGICAL SURVEY *and by* RONALD M. VAN NOY,
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U.S. BUREAU OF MINES

With a section on INTERPRETATION OF AEROMAGNETIC DATA
By LENNART A. ANDERSON, U.S. GEOLOGICAL SURVEY

STUDIES RELATED TO WILDERNESS—PRIMITIVE AREAS

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An evaluation of the mineral potential of the area

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STUDIES RELATED TO WILDERNESS

PRIMITIVE AREAS

In accordance with the provisions of the Wilderness Act (Public Law 88-577, September 3, 1964) and the Conference Report on Senate bill 4, 88th Congress, the U.S. Geological Survey and the U.S. Bureau of Mines are making mineral surveys of wilderness and primitive areas. Areas officially designated as "wilderness," "wild," or "canoe" when the act was passed were incorporated into the National Wilderness Preservation System. Areas classed as "primitive" were not included in the Wilderness System, but the act provides that each primitive area be studied for its 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 the Beartooth Primitive Area and vicinity, Carbon, Park, Stillwater, and Sweet Grass Counties, Mont., and Park County, Wyo., that may come under discussion when the area is considered for wilderness designation.

CONTENTS

ILLUSTRATIONS

TABLES

CONVERSION TABLE

English to metric	*Metric to English*
1 acre = 0.004047 km^2	1 km^2 = 247.1 acres
1 in. = 2.54 cm	1 cm = 0.3937 in.
1 mi = 1.609 km	1 km = 0.6214 mi
1 mi^2 = 2.590 km^2	1 km^2 = 0.3861 mi^2
1 ft = 0.3048 m	1 m = 3.281 ft
1 in. = 25.4 mm	1 mm = 0.03937 in.
1 short ton = 0.9078 t	1 t = 1.101 short tons
1 oz (avdp) = 28.349 g	1 g = 0.03527 oz (avdp)
1 oz (troy = 31.103 g	1 g = 0.003215 oz (troy)
1 oz(troy)/ton = 34.2857 g/t	1 g/t = 2.291667 oz (troy)/ton

1 percent of a metric tonne = 10,000 g/t
1 percent of a metric tonne = 291,667 oz(troy)/ton
1 sample/mi^2 = 1 sample/2.59 km^2
1 sample/km^2 = 1 sample/0.386 mi^2

STUDIES RELATED TO WILDERNESS—PRIMITIVE AREAS

MINERAL RESOURCES OF THE BEARTOOTH PRIMITIVE AREA AND VICINITY, CARBON, PARK, STILLWATER, AND SWEET GRASS COUNTIES, MONTANA, AND PARK COUNTY, WYOMING

By FRANK S. SIMONS and THEODORE J. ARMBRUSTMACHER
U.S. Geological Survey, and by RONALD M. VAN NOY,
NICHOLAS T. ZILKA, FRANK E. FEDERSPIEL, and JAMES RIDENOUR,
U.S. Bureau of Mines

SUMMARY

Mineral resources of the Beartooth Primitive Area and vicinity were studied in 1969-72 as part of a program to evaluate the resource potential of primitive and wilderness areas in the United States. Geologic study was made by the U.S. Geological Survey, and appraisal of known mines, prospects, and mining claims was made by the U.S. Bureau of Mines. The area studied comprises the Beartooth Primitive Area of 950 square kilometers (365 square miles) in south-central Montana and contiguous areas in Montana and Wyoming aggregating 610 square kilometers (235 square miles), or a total area of 1,560 square kilometers (600 square miles), herein referred to as the Beartooth study area. The entire area is within the drainage basin of the Yellowstone River. Most of it is in Custer National Forest, and parts are in Gallatin and Shoshone National Forests.

The Beartooth Mountains are a block mainly of amphibolite-facies Precambrian granitic gneiss, amphibolite, and subordinate metasedimentary rocks intruded by many Precambrian mafic dikes. The block is about 120 kilometers (75 miles) long and 40 to 65 kilometers (25 to 40 miles) wide. Paleozoic and Mesozoic sedimentary rocks, about 3,000 meters (10,000 feet) in combined thickness, are exposed around the periphery of the mountains but have been almost completely eroded from the interior; within the Beartooth study area, the total outcrop area of these rocks is less than 26 square kilometers (10 square miles). The Precambrian rocks are intruded by numerous silicic dikes and plugs of Tertiary and possibly Cretaceous age and, along the west edge of the study area, are overlain by small patches of Tertiary volcanic rocks, part of the extensive Absaroka volcanic field to the southwest. The total extent of Tertiary rocks is less than 8 square kilometers (3 square miles).

The Beartooth block was uplifted as much as 4,500 to 6,000 meters (15,000 to 20,000 feet) above the adjoining basins along a system of reverse and normal faults in Late Cretaceous and early Tertiary time. The present rugged topography of extensive high plateaus, jagged peaks and divides, and deep steep-walled canyons resulted from fluvial and glacial erosion that followed regional uplift in the late Tertiary. Much of the bedrock is now covered by glacial deposits, rock glaciers, talus, and felsenmeer.

An aeromagnetic survey of the Beartooth study area made in 1969 revealed several positive anomalies. Some are attributable to Tertiary intrusive rocks, and others to the ultramafic zone of the Stillwater Complex on the northeast edge of the area. But the sources of other anomalies within the Precambrian gneiss terrane are uncertain; they may be caused by facies changes

within the Precambrian rocks or by concealed intrusive bodies. The anomalies within the Beartooth study area do not seem either to be associated with or to suggest the occurrence of mineral deposits.

The areas in, adjoining, or near the Beartooth study area known to contain mineral resources are the Cooke City (or New World) district on the southwest edge (gold, silver, copper, lead, zinc, platinum, and palladium), the Stillwater Complex on the northeast edge (chromium, copper, nickel, and platinum-group metals), and the Red Lodge district at the east edge (chromium). The Independence district near the west edge has produced a little gold and silver, and the Horseshoe Mountain area contains deposits of gold and silver from which no production has been reported. Within the study area the only mineral production has been chromite from the Red Lodge district and, reportedly, a few tons of copper ore from near Goose Lake at the northeast edge of the Cooke City district. County records show that more than 500 mining claims have been located in the Beartooth study area since 1881, most of them in the Goose Lake area; however, this total includes many relocations. Most are lode claims, and only five have been patented.

The geologic study included collection of more than 2,000 samples, comprised about equally of stream sediments and rocks. Average sampling density was about 1 per 0.7 square kilometers (3.3 per square mile). Most of the samples were analyzed spectrographically for 30 elements, all the stream-sediment samples were analyzed chemically for gold and citrate-soluble heavy metals, and more than 100 rock samples were analyzed chemically for gold, silver, copper, lead, zinc, and molybdenum. Ninety-five rock samples and 10 stream-sediment samples were analyzed by neutron-activation analyses for thorium and uranium, and 12 rock samples were analyzed for uranium equivalent. Threshold values for selected elements were determined by use of lognormal probability plots where appropriate, as well as by other methods, and the geographic distribution of samples containing above-threshold (anomalous) amounts of beryllium, boron, cobalt, copper, gold, lead, molybdenum, niobium, silver, tin, tungsten, zinc, and citrate-soluble heavy metals is summarized on six geochemical maps.

Anomalous amounts of these elements, as well as of chromium, lanthanum, and nickel, were found in many samples, but most appear to represent only very small volumes of rock, and none represents any hitherto unknown mineralized area of appreciable extent. On the other hand, the mineralized areas of Cooke City district and the Stillwater Complex were clearly reflected in anomalous metal contents of stream sediments derived from them. No extensive areas of altered rock, such as those commonly present in mineralized areas of the Rocky Mountains, were recognized.

Goose Lake basin in underlain by a syenite stock containing values in copper, silver, platinum, palladium, and gold. The mineralized zone, as judged from stockpiled material at the Copper King workings, contains chalcopyrite-cemented breccia and disseminated chalcopyrite in medium-grained syenite. One section of diamond-drill core 38 meters (125 feet) long reportedly contained a weighted average of 0.31 percent copper, 4.1 grams gold per metric tonne (0.12 ounce gold per ton), and 8.9 grams silver per metric tonne (0.26 ounce silver per ton). Additional subsurface data are needed to define the mineralized character, grade, and volume of the deposit.

Several bodies of chromite-bearing serpentinized ultramafic rock occur in the Hellroaring Plateau and Silver Run Plateau areas of the Red Lodge mining district. First chromite claims were located in 1916. During the 1940's about 40,000 metric tonnes (44,000 tons) of chromite ore that had a high iron content was produced from the Hellroaring Plateau deposits. There has been no production from deposits on the Silver Run Plateau. About 70,000 metric tonnes (77,000 tons) of chromite resources averaging 12.8 percent chromic oxide is estimated for the deposits in the two areas. These chrome resources are small in comparison to those of the nearby Stillwater Complex.

Part of the Stillwater Complex occurs along the northern boundary of the study area and consists of ultramafic rocks containing chrome, nickel, copper, platinum, and other noble metals. Within the study area, part of the complex underlies small areas along the West Fork Stillwater River and on the north end of Fishtail Plateau.

No resources potential for nonmetallic or industrial minerals was found, and the nearly complete absence of sedimentary rocks precludes the existence of mineral deposits typically associated with them, such as clay, gypsum, limestone, and phosphate rock. Deposits of sand and gravel are mostly small, and all are difficult of access. No coal-, petroleum-, or natural gas-bearing rocks are known to occur within the study area, and the likelihood of their occurrence at accessible depth anywhere beneath the area is very remote. The potential for geothermal energy is low because indicators, such as hot springs or geysers, hot spring deposits, or very young volcanic rocks, are lacking.

INTRODUCTION

The Beartooth Primitive Area is in the central part of the Beartooth Mountains just northeast of Yellowstone National Park. The area studied consists of the officially designated Beartooth Primitive Area of 235,000 acres (950 km^2 or 365 mi^2) entirely in south-central Montana, as well as another area of about 610 km^2 (235 mi^2), the study of which was requested by the U.S. Forest Service. About 105 km^2 (40 mi^2) of this additional area is in northwestern Wyoming, and the rest is in Montana. This combined area of some 1,560 km^2 (600 mi^2) will be referred to subsequently as the Beartooth study area (fig. 1). The area thus defined is northwest trending and roughly

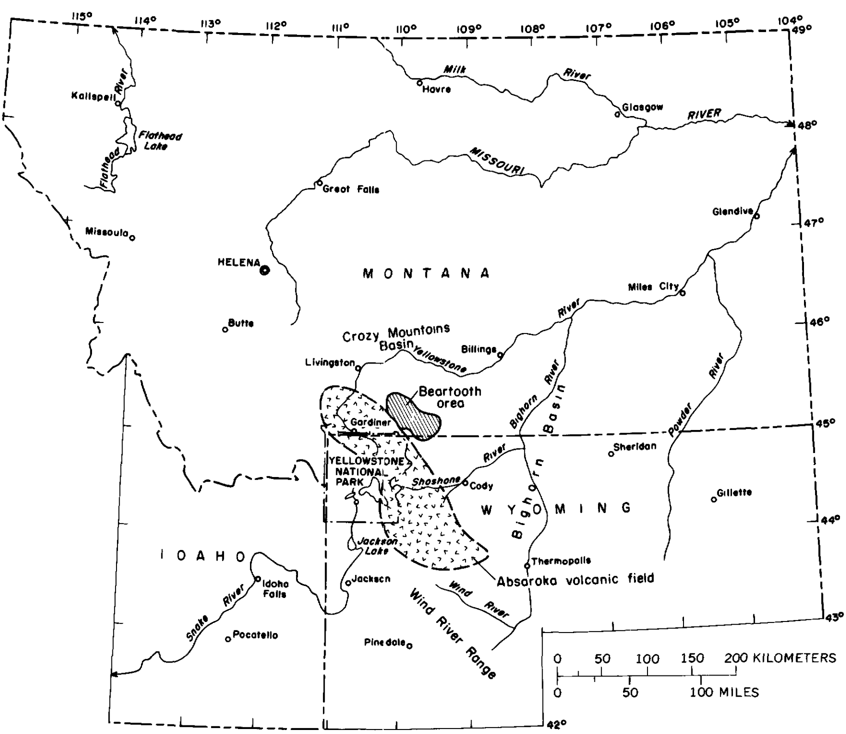


FIGURE 1.—Index map of Montana and parts of Wyoming and Idaho, showing location of Beartooth Primitive Area and vicinity.

oval shaped, is about 65 km (40 mi) long by 22-32 km (14-20 mi) wide, and comprises parts of Carbon, Park, Stillwater, and Sweet Grass Counties in Montana and part of Park County in Wyoming. It is largely within Custer National Forest, but the westernmost 78 km^2 (30 mi^2) is in Gallatin National Forest, and the part southwest of the crest of the Beartooth Mountains is in Gallatin and Shoshone National Forests. The entire Beartooth study area is drained by tributaries of the Yellowstone River, the principal ones being the Boulder River and its branches on the west, the Stillwater River, Rock Creek, and their branches on the northeast, and Slough Creek and Clarks Fork of the Yellowstone River on the southwest (fig. 2).

Access to the Beartooth study area is provided by several roads. The nearest highways are U.S. Highway 10 (Interstate Highway 90), north of the area between Billings and Livingston, Mont., and U.S. Highway 212, which extends along the south side of the area from Laurel to Cooke City, Mont., and to the northeast entrance to Yellowstone Park. From Big Timber, on U.S. Highway 10, a paved road leads south up the Boulder River to Fourmile Guard Station and continues as a gravel road to the abandoned mining settlement of Independence. Another paved road extends southwest from Columbus, Mont., on U.S. Highway 10, to Woodbine Campground and the trailhead on the Stillwater River. Branches from the Stillwater road at Absarokee extend up West Rosebud Creek to the Mystic Lake hydroelectric plant of the Montana Power Co. and up East Rosebud Creek to East Rosebud Lake and its summer colony of Alpine. From Red Lodge, on U.S. Highway 212, a gravel road leads west up West Fork Rock Creek to the trailhead near the summer colony of Camp Senia, and from Richel Lodge, on the same highway southwest of Red Lodge, a gravel road extends a short distance up the Lake Fork Rock Creek to another trailhead. Just southwest of Richel Lodge a gravel road leads to several campgrounds on Rock Creek and to a precipitation gage on upper Rock Creek. A branch from this road climbs to the south lobe of Hellroaring Plateau and to a group of small inactive chromite mines.

The section of U.S. Highway 212 between Red Lodge and Cooke City is known as the Beartooth Highway and is surely one of the most spectacular mountain roads in the United States. From Red Lodge the road follows Rock Creek upstream to about Wyoming Creek, whence it climbs nearly 1,200 m (4,000 ft) up the southeast wall of Rock Creek canyon to Line Creek Plateau and the crest of the Beartooth Mountains at Beartooth Pass. From the pass the road descends more gently into the canyon of the Clarks Fork of the Yellowstone, ascends this valley to a broad divide between the Clarks Fork and Soda Butte Creek at Colter Pass, and continues to Cooke City, Silver Gate, and the northeast entrance to Yellowstone National Park.

Within the Beartooth study area only a sparse network of trails exists. Access to the northeast flank of the mountains, by far the largest and most rugged part of the area, is provided by a few widely spaced trails along the

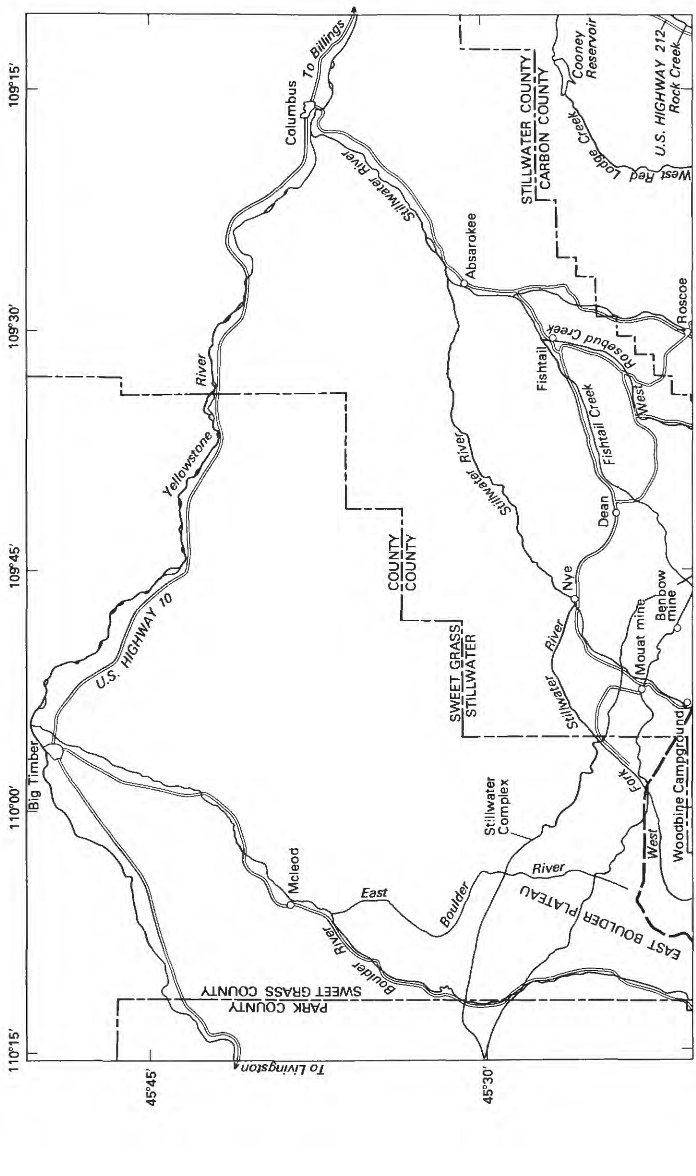
West Fork Stillwater and the Stillwater Rivers, and West Rosebud Creek. From East Rosebud Lake an excellent and heavily used new trail, the Beartooth Trail, goes up East Rosebud Creek through outstanding scenery, crosses the mountains near Fossil Lake, and descends via Russell Creek and Kersey Lake to the Beartooth Highway just east of Cooke City. Trails up the West Fork and Lake Fork Rock Creek meet at Sundance Pass. A few other trails provide access to the northeast side of the area but are little used.

The southwest flank of the Beartooth Mountains is much less rugged than the northeast side and is served by a more closely spaced system of trails; nevertheless, much of the region can be reached only by off-trail travel.

The topography of the northeast flank of the Beartooth Mountains within the Beartooth study area is dominated by broad plateaus that are surmounted by jagged alpine peaks and deeply dissected by widely spaced steep-walled glaciated canyons. Altitudes range from about 1,700 m (5,500 ft) on the lower Stillwater River to 3,900 m (12,799 ft) at Granite Peak, the highest point in Montana. Many peaks along and near the crest of the range exceed 3,600 m (12,000 ft) in altitude, and extensive plateau areas lie at altitudes of more than 3,000 m (10,000 ft). The plateaus are undoubtedly the most characteristic feature of the Beartooth Mountains, and in no other alpine mountain mass in the United States are such high-altitude rock-strewn surfaces so widely preserved and grandly displayed (fig. 3). Many are named. The best known are, from northwest to southeast: East Boulder, Lake, Stillwater, Fishtail, Froze-to-Death (a locally used name), East Rosebud, Red Lodge Creek, Silver Run, and Hellroaring Plateaus. Also, many unnamed smaller plateaus contribute significantly to the Beartooth scenery. These plateaus and their origin are more fully described by Simons and Armbrustmacher (1976). Lakes are abundant at altitudes mainly above 2,750 m (9,000 ft) but, except in a few areas—such as Lake Plateau, upper East Rosebud Creek, and Hellroaring Plateau—are widely scattered. The largest lake in the Beartooth area, Mystic Lake, is 3.2 km (2 mi) long, but fewer than a dozen lakes are as much as 1.6 km (1 mi) across.

The southwest flank of the Beartooth Mountains has a strikingly different topography from that of the northeast flank. Instead of high plateaus and deep canyons, the dominant characteristic is a rolling rocky surface of generally moderate relief that slopes gently southwestward, is dotted with countless lakes, most less than 0.8 km (0.5 mi) across, and is drained by a closely spaced system of small streams. The most prominent topographic feature is Beartooth Butte, a large isolated mass of sedimentary rock which rises 300-600 m (1,000-2,000 ft) above the surrounding terrain just north of Beartooth Highway.

The magnificent alpine scenery of the Beartooth area is mainly the result of glaciation, which began in the Pleistocene Epoch and has continued on a reduced scale to the present time. The most conspicuous glacial features are the matterhorn peaks, cirques, and knife-edge ridges, or arêtes, along many


109°15'
109°30'
109°45'
110°00'
110°15'
45°45'
45°30'
To Billings
Columbus
Stillwater River
Absarokee
STILLWATER COUNTY
CARBON COUNTY
Cooney Reservoir
U.S. HIGHWAY 212
Rock Creek
West Red Lodge Creek
Roscoe
Rosebud Creek
Fishtail
Fishtail Creek
West
Dean
Nye
Benbow mine
Mouat mine
Woodbine Campground
Yellowstone River
U.S. HIGHWAY 10
SWEET GRASS COUNTY
STILLWATER COUNTY
Big Timber
Stillwater Complex
West Fork
Mcleod
East Boulder River
Boulder River
EAST BOULDER PLATEAU
SWEET GRASS COUNTY
PARK COUNTY
To Livingston

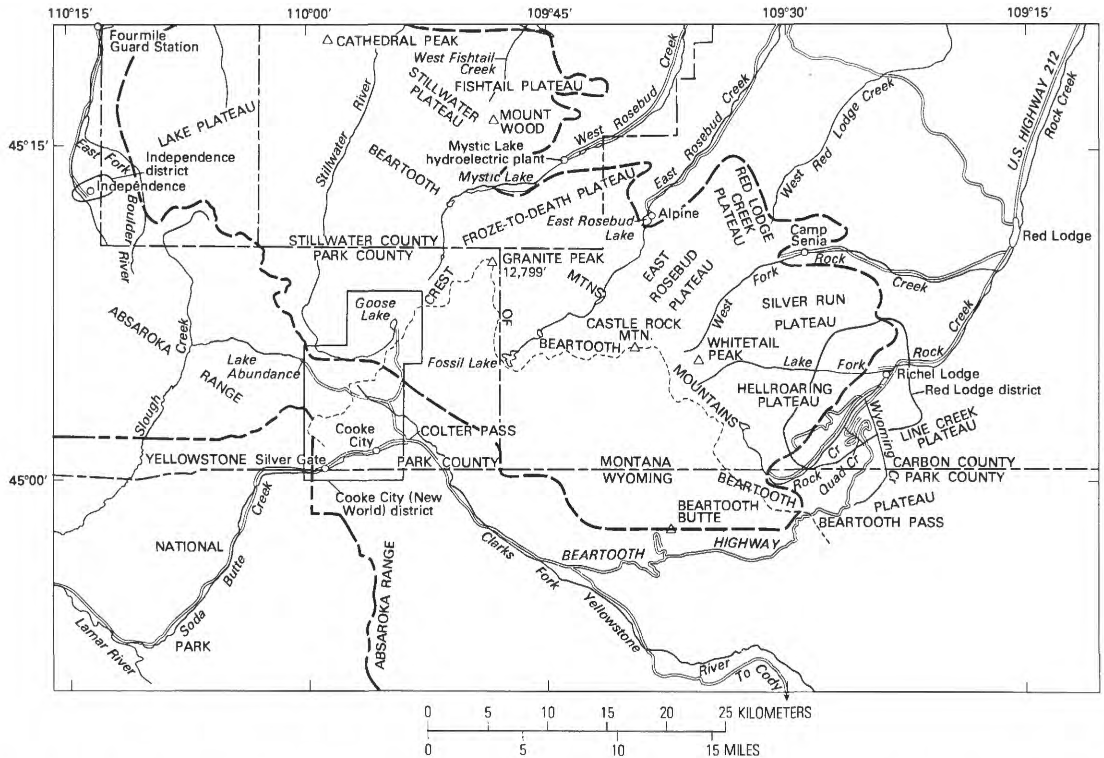


FIGURE 2.—Index map of the Beartooth Primitive Area and vicinity, showing principal drainages, other topographic features, and access roads. Heavy dashed line is boundary of the study area.

FIGURE 3.—Beartooth crest and southwest flank of Beartooth Mountains, viewed northwestward, at an altitude of 3,730 m (12,250 ft), from Beartooth Plateau 1.6 km (1 mi) northwest of outlet of Moon Lake. Dissected surface of Beartooth Plateau slopes gently to the southwest (left). Some flat-topped remnants of the plateau and their distances are identified.

FIGURE 4.—Double cirque at head of Phantom Creek, viewed west-southwestward from point about 1.3 km (0.8 mi) west of Mount Hole-in-the-Wall. Froze-to-Death plateau in background, Tempest Mountain (3,800 m; 12,478 ft in altitude) at far left center; width of plateau in view is 2 km (1.3 mi). Turgulse Lake in background, Froze-to-Death Lake in immediate foreground. Cirque wall behind Turgulse Lake is about 425 m (1,400 ft) high.

FIGURE 5.—Deeply glaciated headwater area of Lake Fork Rock Creek, viewed southwest from Silver Run Plateau just east of September Morn Lake. First and Second Rock Lakes in foreground, Whitetail Peak at extreme right; vertical distance from Second Rock Lake to summit of peak is 1,100 m (3,500 ft). Note extensive accumulations of talus in lower part of canyon, also large rock glacier issuing from cirque above and to right of upper lake.

drainage divides, particularly along the crest of the mountains (fig. 4), and the deep U-shaped canyons and tributary hanging valleys of the Stillwater River and West Rosebud, East Rosebud, and Rock Creeks (fig. 5). Sizable glaciers still exist north of the range crest at the heads of West and East Rosebud Creeks, West and Lake Forks of Rock Creek, and Stillwater River (fig. 6), as well as south of the crest at Castle Rock Mountain. Numerous rock basins excavated by glaciers down to an altitude as low as 2,300 m (7,500 ft) are now occupied by lakes, and a few lakes are impounded behind glacial moraines, but large moraine-dammed lakes at lower altitudes, such as those along the southwest flank of the Wind River Range to the south, are lacking. Rounded, polished, and striated rock surfaces typical of glaciated terrain abound throughout the area, especially at higher altitudes. In much of the Beartooth area southwest of the mountain crest, extensive rounded and smoothed rock outcrops, a myriad of rock basin lakes and swamps, and the peculiar disordered drainage pattern all indicate the former presence of an ice cap (fig. 7).

The climate of the Beartooth study area is rigorous. Snowfall during the winter is heavy, and deep snow may persist in sheltered places until late summer or fall. Because of snow accumulations, travel in the higher country generally cannot begin before July; in 1971, for example, Sundance Pass (3,350 m; 11,000 ft) between West and Lake Forks Rock Creek was not free

FIGURE 6.—Wolf Mountain glacier, viewed south from just west of Big Mountain, mid-August 1972. Wolf Mountain (3,600 m; 11,850 ft) is in background at right center. This glacier is one of the largest in the Beartooth Mountains and is one of the very few in which ice was exposed during the period of fieldwork of this study.

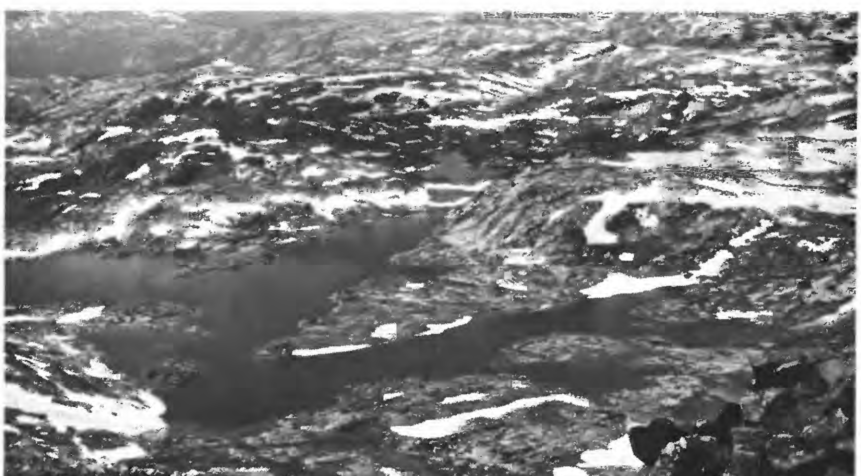


FIGURE 7.—Fossil Lake (3,015 m; 9,900 ft) viewed westward from Mount Dewey. The lake lies just east of a broad pass on the Beartooth crest in an area of hummocky topography that indicates the former presence of an ice cap.

of snow until late August. Unsettled weather and the risk of severe snowstorms make for hazardous travelling conditions from early September on. During July and August, however, the climate is ideal—days are warm and sunny, nights usually cool, and the only interruptions are occasional showers or thunderstorms.

Except for a small production of chromite from Hellroaring Plateau and reportedly a small amount of copper from Goose Lake basin, no mining has ever been done in the study area, and the only mineral exploration in recent years has been along the northernmost border of the area and around Goose Lake.

PREVIOUS INVESTIGATIONS

The geology of the Beartooth Mountains and surroundings has been studied since the 1890's, and a considerable volume of literature attests to the geologic interest of the region. However, only about one-quarter of the Beartooth study area itself has been mapped geologically, and much of the mapped area is represented only by an unpublished map of J. R. Butler (written commun., 1972).

The earliest geologic report to mention the Beartooth Mountains apparently is by Hayden (1873, p. 44-49), who visited the "Clark's Fork mines" (presumably in the Cooke City, or New World, mining district). The first geologic map to show part of the Beartooth Mountains was of the Livingston quadrangle (Iddings and Weed, 1894) which included that part of the Beartooth study area west of long 110°00′ (the part within the present Mount Douglas and Cutoff Mountain quadrangles). Small parts of the Beartooth Mountains are shown on geologic maps by Eldridge (1894) and Lovering (1930). The paper by Foose, Wise, and Garbarini (1961) on the structural geology of the Beartooth region is a basic reference on the subject.

The geologic setting and structural geology of the Beartooth region has been discussed by many authors, including (in chronological order) Hague (1899), Darton (1907), Emmons (1908), Woodruff (1909), Calvert (1917), Dake (1918), Bevan (1923), Hughes (1933), Bucher and others (1933, 1934), Thom and others (1934, 1935), Wilson (1934, 1936), Chamberlin (1935, 1940, 1945), Rouse and others (1937), Lammers (1937, 1939), Skeels (1939), Vhay (1940), Thom (1952), Alpha and Fanshawe (1954), Richards (1957), Parsons (1958), Poldervaart and Bentley (1958), Wise (1958), Foose (1958, 1960), Giletti (1964), Casella (1969), and Pierce and Nelson (1971).

The Beartooth Research Project, started by Arie Poldervaart in 1952, has yielded several publications and geologic maps that cover parts of the Beartooth study area or contiguous areas. Among these are papers by Eckelmann and Poldervaart (1957) on the Quad Creek area just southeast of the Beartooth study area; Spencer (1958, 1959), on fracture patterns in the southeast part of the area; Harris (1959), on the Gardner Lake area around

Beartooth Pass; Casella (1964), on part of Line Creek Plateau; Butler (1966), on the Cathedral Peak area of about 90 km^2 (35 mi^2) at the northwest end of the area; and Larsen and others (1966), on the geology of about 50 km^2 (20 mi^2) north and east of Beartooth Butte.

The Stillwater Complex and its associated chromite deposits are by far the most thoroughly studied geologic features of the Beartooth Mountains. Although the presence of ultramafic rocks of the complex was recorded during early work in the region (Westgate, 1921, p. 69-83; Diller, 1920, p. 142-144), recognition that they were part of an immense layered igneous complex is credited to Peoples (1933), who also named the complex. A large volume of literature has subsequently appeared on both the geology and the petrology of the complex and on the layered chromite deposits in its lower part (Peoples, 1936; Howland and others, 1936, 1949; Schafer, 1937, p. 7-20; Peoples and Howland, 1940; Allsman and Newman, 1944; Wimmler, 1948; Roby, 1949; Howland, 1955; Hess, 1960; Jackson and others, 1960; Jones and others, 1960; Jackson, 1961; Price, 1963; Page and others, 1969; Page and Nokleberg, 1970).

The U.S. Bureau of Mines trenched and sampled various sections of the chromite-bearing zones of the complex during the early 1940's. Page and Jackson (1967) studied the platinum-group metal content of the chromite zones, and Page and Nokleberg (1970) mapped the complex in detail.

At the time of this study, Anaconda Co. was mapping, sampling, and diamond drilling parts of the copper-nickel-rich basal section near the Mouat mine about 3.2 km (2 mi) north of the study area boundary. At this same time companies, including American Metal Climax, Inc., Cypress Mines Corp., Johns Manville Corp., and Newmont Mining Corp., were also exploring or had acquired claims on other parts of the Stillwater Complex.

The chromite deposits of Hellroaring Plateau southwest of Red Lodge were reported on briefly by Westgate (1921, p. 83-84), Schafer (1937, p. 21-34), Conwell (1942), and Herdlick (1948), and comprehensively by James (1946).

In 1959, the Bear Creek Mining Co. made geophysical and geochemical surveys in the Goose Lake basin near the Copper King property. Seven diamond drill holes were put down in 1960. Kerr-McGee Corp. drilled several more holes in 1972, but the results are not available.

PRESENT INVESTIGATION AND ACKNOWLEDGMENTS

Geologic mapping and sampling of the Beartooth study area were done by the U.S. Geological Survey, and investigation of known mineral deposits and mining claims was made by the U.S. Bureau of Mines. Fieldwork of the Geological Survey was carried out during 2 months in 1970 by F. S. Simons and K. L. Wier, and 2 months in the summers of both 1971 and 1972 by Simons and T. J. Armbrustmacher. Assisting in the fieldwork were D. K.

Riley and R. H. Schneider in 1970 and G. K. Lee and M. B. Sawyer in 1971 and 1972.

Fieldwork by the U.S. Bureau of Mines was done during the summers of 1969 and 1970 and for brief periods during the summers of 1971 and 1972. Sixteen man-months were spent in the area. The study was made by the following permanent U.S. Bureau of Mines personnel: Ronald Van Noy, Nicholas Zilka, Frank Federspiel, James Ridenour, and Gary Kingston. Field assistants were Lyle Henage, Gary Berg, and William Posey.

Reconnaissance geologic mapping was done on 1:62,500-scale topographic maps and on aerial photographs at several scales from about 1:40,000 to 1:60,000. A planimetric base map at a scale of 1:125,000 was prepared from the 1:62,500 topographic maps and the geology was compiled on this base (pl. 1). An aeromagnetic survey of the Beartooth study area was made by the U.S. Geological Survey in 1969 and the results are shown on plate 1: aeromagnetic interpretation was made by Lennart A. Anderson of the U.S. Geological Survey.

Geochemical sampling was done concurrently with geologic mapping, and a total of 990 stream-sediment samples and 1,053 rock samples were collected. Localities of all samples collected during this study, as well as of 48 stream-sediment samples collected during study of the Absaroka Primitive Area (Wedow and others, 1973), are shown on plate 2; the Absaroka sample numbers are prefixed by the letter Q or R. Thin sections of about 600 rocks were studied by petrographic microscope.

Most of the analytical work of the U.S. Geological Survey was performed in the field under the direct supervision of J. G. Frisken in 1970-71 and J. G. Viets in 1972. Semiquantitative spectrographic analyses of all samples were made by G. W. Day with the assistance of R. W. Babcock, E. R. Cooley, J. A. Domenico, and R. T. Hopkins, who used the methods described by Grimes and Marranzino (1968). Chemical analyses were made by Frisken and Viets with the assistance of R. B. Carten, J. D. Hoffman, M. A. Lisboa, R. M. O'Leary, and A. J. Toevs, who used the atomic-absorption methods of Ward and others (1969) and the colorimetric tests of Ward, Lakin, Canney, and others (1963). Analyses for uranium and thorium were made in the U.S. Geological Survey Laboratories in Denver, Colo.; those for uranium equivalent were done by R. L. Rahill, Wayne Mountjoy, and E. J. Finnelly, and neutron-activation analyses for uranium and thorium were done by H. T. Millard and D.A. Bickford. Analyses for platinum and palladium were made by R. R. Carlson and E. R. Cooley by means of the fire assay-spectrographic method of Dorrzapf and Brown (1970).

The computer storage, retrieval, and statistical program work was completed under the direction of L. O. Wilch with the assistance of R. J. Smith.

During the 1970 season, the geologic investigation was accomplished mainly by foot or horseback traverses from a series of base camps supplied by pack train; a helicopter was used for 2 days in late August. In 1971 a helicopter was used during August and early September, and in 1972 all the work, except for 2 weeks in early July, was supported by helicopter.

The objective of the U.S. Bureau of Mines was to determine the economic potential of mineral deposits within the study area. County records of Park, Sweet Grass, Stillwater, and Carbon Counties, Mont., and Park County, Wyo., were searched to determine the number and location of mining claims within the study area. Patented claim records and survey plats were obtained from the U.S. Bureau of Land Management, Billings, Mont. Mineral production data for the years 1902 to the present were obtained from U.S. Bureau of Mines statistical files; other sources are quoted where necessary. Mines and prospects were mapped, examined, and sampled. Excluded from the study are sand and gravel deposits and occurrences of rock suitable for building stone. These commodities are readily accessible in other areas that are closer to markets. Potential placer deposits were tested by reconnaissance pan sampling, but no potentially valuable detrital minerals were found.

All lode samples were routinely checked by fire assay. Selected samples were evaluated by semiquantitative spectrographic analysis. Anomalous quantities of potentially economic interest were further checked by colorimetric, atomic-absorption, or X-ray fluorescence methods. Most of the analytical work was done at the U.S. Bureau of Mines Reno Metallurgy Research Center, Reno, Nev.

We wish to acknowledge the help of U.S. Forest Service officials, R. W. Miller, Deputy Forest Supervisor, Custer National Forest; Gary Wetzsteon, District Ranger and Gwen McKittrick, Oran Zabest, John Anthony, and Walt Krimmer of the Beartooth (Red Lodge) Ranger District; Frank Solomonsen, District Ranger, Big Timber Ranger District; John Lavin, Forest Supervisor, and Ray Hall and Tom Quinn, Shoshone National Forest; Robert Gibson, Gallatin National Forest; and Dave Morton, District Ranger, Gardiner Ranger District.

During the study we received complete cooperation from property owners and from most mining company personnel. In particular, we wish to acknowledge the help given us by the Anaconda Co., Montana Division; Kerr-McGee Corp.; and Margaret Reeb, Cooke City, Mont.

Our U.S. Geological Survey colleagues N. J Page and J. E. Elliott provided most of the geologic data presented in this report on the geology around the Stillwater Complex and in the Goose Lake region, respectively.

Professor J. R. Butler of the University of North Carolina graciously permitted use of his unpublished geologic map of the western part of the Beartooth study area.

GEOLOGY AND MINERAL RESOURCES

By FRANK S. SIMONS and THEODORE J. ARMBRUSTMACHER, U.S. Geological Survey

GEOLOGY

The Beartooth Mountains are a northwest-trending uplifted block, mainly of highly resistant Precambrian metamorphic rocks, about 120 km (75 mi) long and 40-65 km (25-40 mi) wide (fig. 8). Precambrian rocks underlie two main areas—a larger one along the northeast side of the mountains and a smaller one in the southwest corner. Between these areas the Precambrian rocks are concealed by Paleozoic and younger rocks. At a few places within the Precambrian terrane, small patches of younger rocks persist as erosional remnants.

The east and northeast sides of the Beartooth block are defined by the steeply dipping Beartooth fault, and part of the southwest side near Gardiner is defined by the Gardiner fault. Along these faults the Precambrian rocks have been uplifted about 4,500-6,000 m (15,000-20,000 ft) against sedimentary rocks ranging in age from Cambrian to Late Jurassic (Foose and others, 1961, p. 1148-1149; Pierce, 1965). Part of the southwest edge of the block is concealed by Tertiary volcanic rocks of the Absaroka volcanic field. The west edge of the block is bounded by the Deep Creek fault, most of which is buried beneath alluvium of the Yellowstone River valley.

The Beartooth study area is within the northeast outcrop area of Precambrian rocks and is almost entirely underlain by Precambrian metamorphic rocks. Other rocks, exclusive of surficial deposits, such as talus and glacial moraine, occupy less than 2 percent of the area; these include the Precambrian Stillwater Complex and quartz monzonite on the Stillwater River and West Fishtail Creek, Paleozoic sedimentary rocks on Bearthooth Butte and Beartooth and Fishtail Plateaus, Paleozoic and Mesozoic sedimentary rocks at the south end of East Boulder Plateau, and Tertiary volcanic rocks at several places on the divide between the Stillwater River to the east and the East Fork Boulder River and Slough Creek to the west.

PRECAMBRIAN W ROCKS

Metamorphic and igneous rocks of Precambrian age underlie more than 98 percent of the Beartooth study area. Most of these rocks are granitic gneiss, hornblende gneiss, and amphibolite; diabase and dolerite dikes are very abundant and widespread but constitute only a small proportion of the Precambrian terrane; several other Precambrian rock types are largely restricted to the northwesternmost part of the area; and the remaining Precambrian rocks are of insignificant areal extent.

GRANITIC GNEISS

Granitic gneiss, migmatite, pegmatite, microgranite or aplite, and orbicular rocks, herein subsumed under the title granitic gneiss, are by far

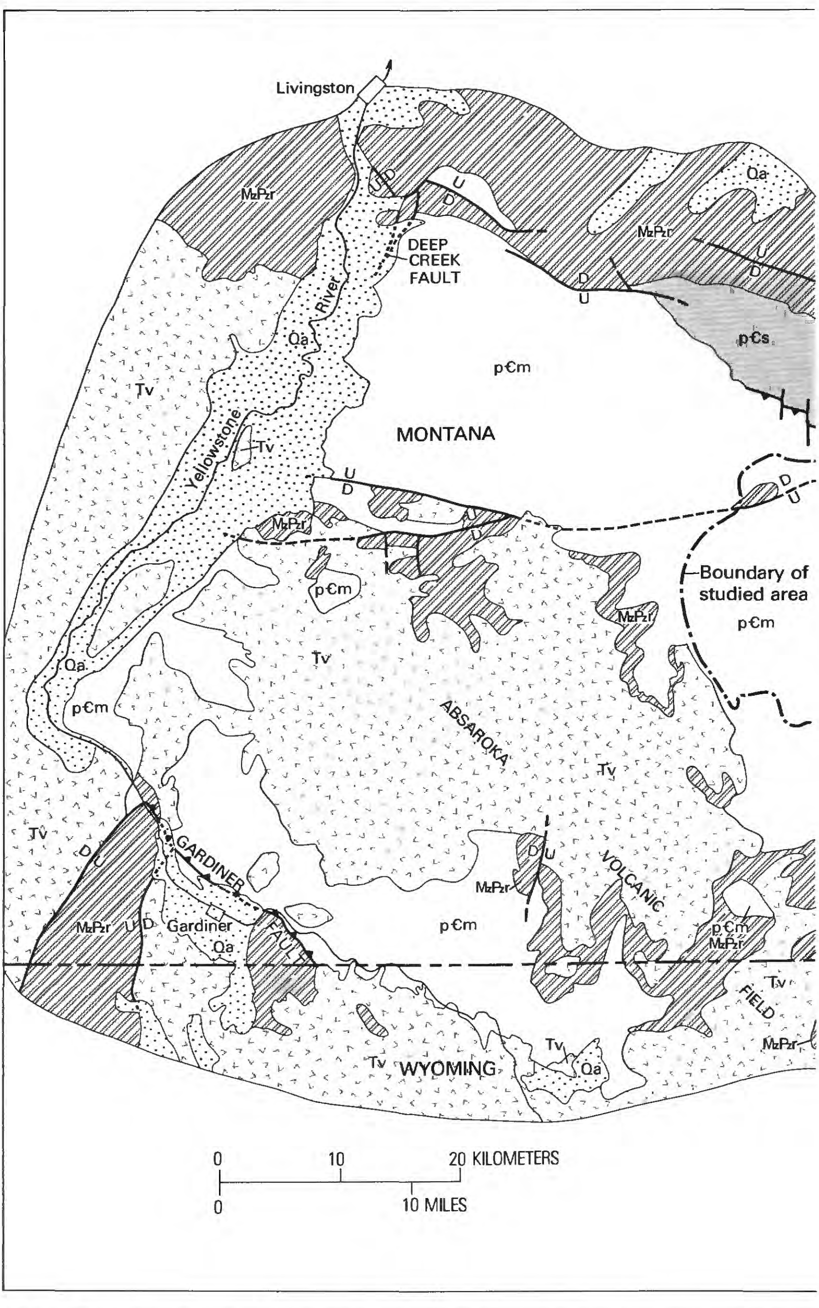
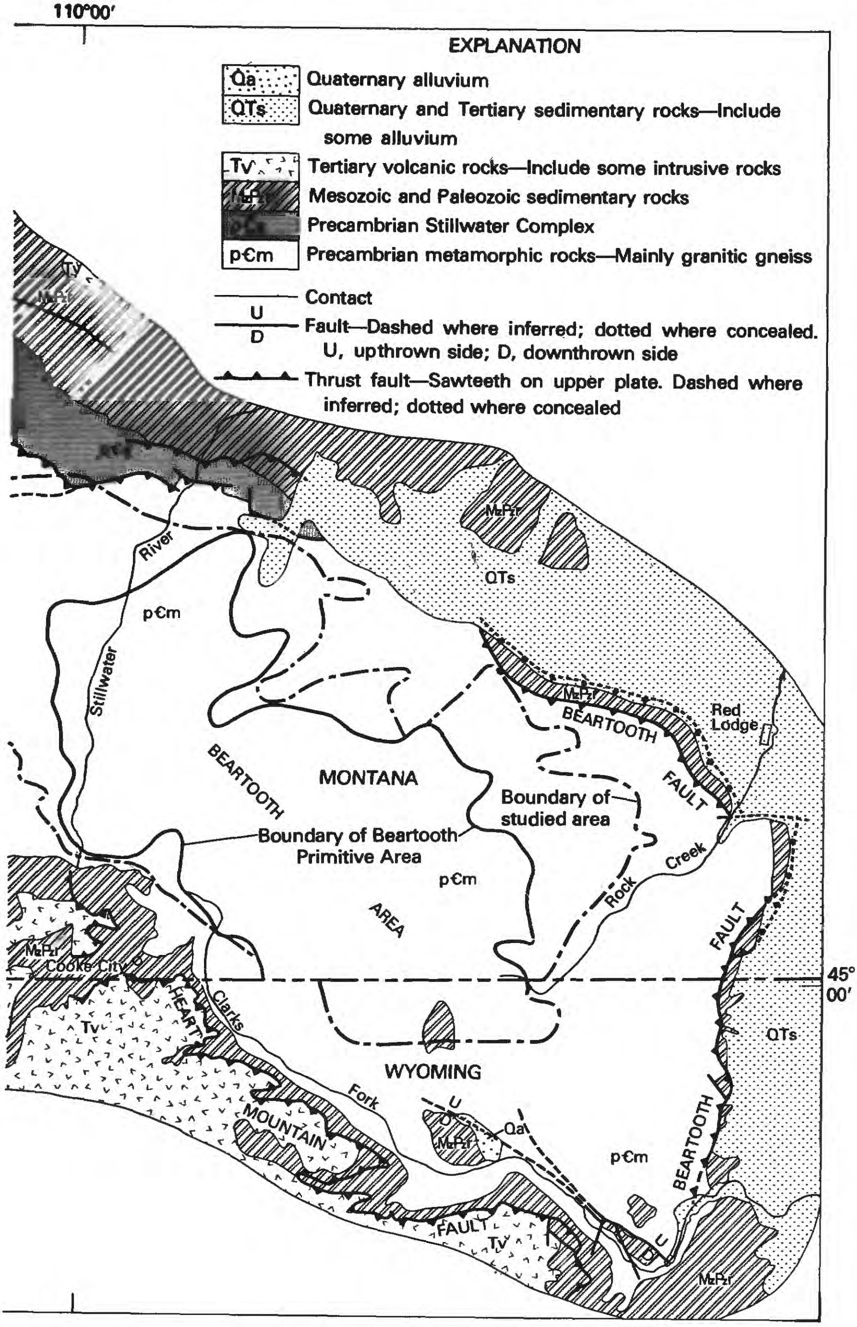


FIGURE 8.—Generalized geologic map of the Beartooth Mountains and vicinity. Modified from W. G. Pierce (written commun., 1972),



Foose, Wise, and Garbarini (1961), Love, Weitz, and Hose (1955), Pierce and Nelson (1971), and Ross, Andrews, and Witkind (1955).

the most abundant rocks in the Beartooth study area and probably constitute 90 percent or more of the bedrock of the area. Pegmatite and aplite are widespread, but they make up much less than 1 percent of the granitic gneiss terrane, and orbicular rocks are of insignificant areal extent.

Gray, light-gray, pinkish-gray, and pink gneisses are the dominant rocks. Most have a distinctly planar or gneissic structure resulting from preferred orientation of certain minerals—mainly biotite and, less commonly, hornblende or feldspar. Biotite content of most gneisses ranges from a trace to 10 percent and only rarely is as high as 15 percent. Biotite is distributed homogeneously in many gneisses; in others, however, it is concentrated to a variable extent into layers, lenses, and pods, and these layered rocks are termed "migmatites." As the amount of biotite diminishes, gneissic structure becomes less pronounced but may still be recognizable because of preferred orientation of feldspar grains or a vague layering resulting from varying proportions of quartz and feldspar.

In the most conspicuously layered rocks (the migmatites), planar structure is defined by alternating layers of biotite-rich and biotite-poor gneiss; such layers range in thickness from a few millimeters to several meters and may have either sharp or gradational boundaries with each other. Although a layer or a group of layers may be continuous for a distance of a meter or more, they typically are discontinuous and uneven; biotite-rich layers may pinch out abruptly, or fade out gradually into lighter colored gneiss. Lenses or pods of layered rock commonly are intruded on a small scale by granitic material.

Migmatites occur throughout the gneiss terrane of the Beartooth study area, but, although their relative abundance varies from place to place, no systematic variation was recognized. Poldervaart and Bentley (1958, p. 8) believed that migmatites are more abundant in the eastern half of the area and to the north of Cooke City and less abundant in the core of the range; however, our observations do not confirm this belief, nor do they support the concept of a gneiss core and migmatite mantle mentioned by Eckelmann and Poldervaart (1957, p. 1257).

Large bodies of granitic intrusive rock having clear crosscutting relations to the gneisses were not seen in the Beartooth study area and have been reported from only one place in adjoining areas. Quartz monzonitic rocks along the West Fork Stillwater and the Stillwater Rivers and West Fishtail Creek were believed by Page and Nokleberg (1972, p. D133) to be younger than, and intrusive into, the gneiss complex; within the Beartooth study area the relationship between quartz monzonite and gneiss is uncertain. (See section entitled "Quartz Monzonite.") Although abundant dikes of microgranite or aplite and the widespread agmatites within the gneisses testify to at least local mobilization of granitic material, most of these bodies are very small, and no extensive masses of unfoliated rock occur within the rocks shown as granitic gneiss on plate 1; one of the largest exposures of apparently unfoliated granitic rock is in the canyon wall south of Pyramid

Mountain. Almost all outcrops of appreciable size have a grossly layered aspect; the layering is particularly well displayed in the walls of some cirques and deeply glaciated canyons (fig. 9).

Most of the granitic gneiss is medium grained (1-5 mm) to coarse grained (> 5 mm) and has a texture that ranges from even grained (sparse) to heteroblastic (very common) and porphyroblastic (common). Porphyroblasts of plagioclase and microcline are typically 3 to 5 mm across, but grains of microcline 1 cm or more across are not uncommon. The gneisses contain various proportions of plagioclase, quartz, and biotite; more than 95 percent of them contain microcline; and many contain small amounts of muscovite.

Modes were calculated for 240 specimens of granitic gneiss by use of a point counter on thin sections; an average of more than 1,100 points was counted per section. Figure 10 is a modal plot of quartz, total feldspar, and total mafic minerals for 331 samples of these rocks and also for 111 samples of hornblende-bearing rocks. The diagram shows that the granitic gneisses have a restricted range of mineral composition and that most of the mineralogic variation is in the quartz to feldspar ratio.

Chemical analyses of granitic gneisses from the Beartooth Mountains and of other rocks for comparison, are given in table 1, and analyses of selected minor elements are given in table 2.

FIGURE 9.—Large-scale layering in granitic gneiss and amphibolite, west wall of cirque north of September Morn Lake, viewed N. 75° W. from Silver Run Plateau. Southwest lobe of plateau is in background. Layering dips about 25° SW.

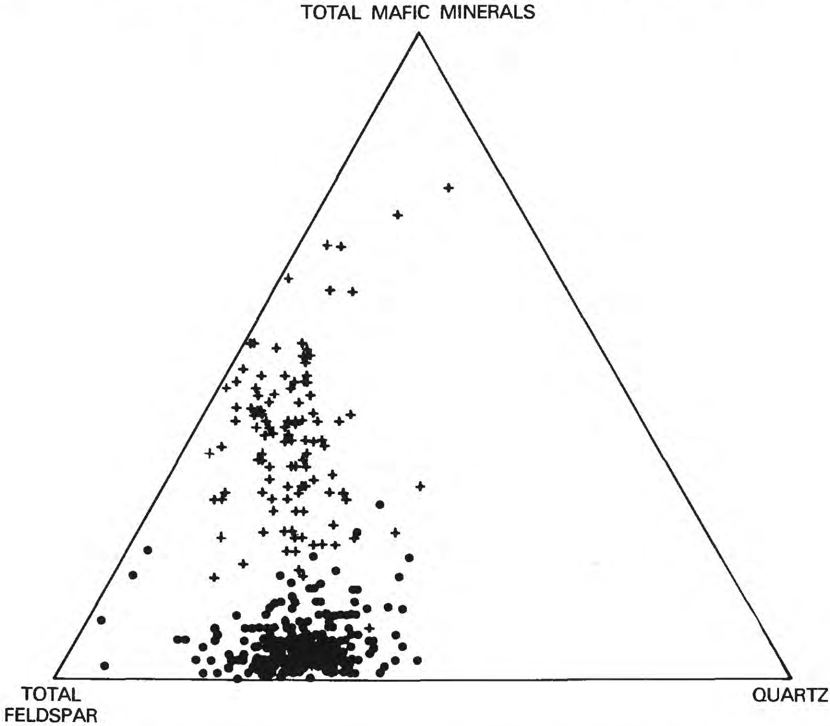


FIGURE 10.—Modal plot of 240 granitic gneisses (dots) and 111 hornblende-bearing rocks (crosses), Beartooth Primitive Area and vicinity.

The major-element composition of the gneisses in the Beartooth study area provides little evidence as to their origin; they are chemically similar to granodiorite and ryodacite, except for being somewhat lower in Fe_2O_3, FeO, MgO, and CaO, and similar to graywacke, except for being lower in Fe_2O_3, FeO, and MgO and higher in Na_2O. The minor-element contents of all rocks listed in table 2 are even more similar, except for notably higher chromium, copper, and nickel in average graywacke, and they shed little light on the problem of origin of the granitic gneisses. Nevertheless, the widespread and conspicuous layering shown by much of the gneiss, the abundant layers and lenses of hornblende gneiss and amphibolite, the scattered occurrences of biotite schist, metaquartzite, and other metasedimentary rocks, and the aforementioned lack of large-scale intrusive relations suggest strongly that the gneiss was formed, by some kind of in place metamorphism, from an originally layered sequence that included some shale and sandstone or arkose, as well as basaltic lava flows or tuffs. (See p. F25.) Most of the sequence may have been lava flows and tuffs of approximately rhyodacitic composition.

Pegmatitic rocks occur throughout the gneiss terrane in the Beartooth

TABLE 1.—*Chemical analyses of granitic gneisses from the Beartooth Mountains and of other rocks*

[Data are in percent. Leaders (....) indicate no data. *, Total includes 0.3 percent SO_3, 0.1 percent S, and 0.1 percent C.]

	1	2	3	4
SiO_2	72.57	66.88	66.27	66.7
Al_2O_3	15.22	15.66	15.39	13.5
Fe_2O_3	.48	1.33	2.14	1.6
FeO	1.03	2.59	2.23	3.5
MgO	.58	1.57	1.57	2.1
CaO	2.22	3.56	3.68	2.5
Na_2O	4.18	3.84	4.13	2.9
K_2O	2.87	3.07	3.01	2.0
H_2O-	.03	....	....	.6
H_2O+	.31	.65	.68	2.4
TiO_2	.17	.57	.66	.6
P_2O_5	.03	.21	.17	.2
MnO	.02	.07	.07	.1
CO_2	.08	....	....	1.2
Total	99.79	100.00	100.00	*100.4

DESCRIPTIONS

1. Granitic gneisses, Beartooth Mountains; average of 12 analyses (Butler, 1969, table 2, col. E).
2. Average granodiorite (Nockolds, 1954, table 2, col. III).
3. Average rhyodacite plus rhyodacite obsidian (Nockolds, 1954, table 2, col. IV).
4. Graywacke; average of 61 analyses (Pettijohn, 1963, p. S15, table 12).

TABLE 2.—*Analyses of selected minor elements in granitic gneisses from the Beartooth Mountains and in other rocks*

[Data are in parts per million. Leaders (....) indicate no data; <, less than]

	1	2	3	4
Ba	700	500	1000	500
Co	10	10	10	20
Cr	<10	20	30	140
Cu	15	30	20	40
La	20	....	30	....
Ni	10	20	10	50
Pb	25	15	20	15
Sc	<10	10	10	10
Sr	300	450	500	450
V	30	100	100	70
Y	<10	30	15	30
Zr	85	140	100	140

DESCRIPTIONS

1. Average of 331 granitic gneisses, Beartooth Primitive Area and vicinity; semiquantitative spectrographic analyses.
2. Average granodiorite (Taylor, 1965, tables 6, 11, 15, 19, 21, and 22).
3. Mean of Mesozoic plutonic rocks, Sierra Nevada, Calif. (Dodge, 1972).
4. Average graywacke (Taylor, 1965, tables 6, 11, 15, 19, 21, and 22).

study area and seem to be especially abundant on Lake Plateau, along the divide between the Stillwater River and Slough Creek north of Lake Abundance, and around Lake at Falls and Granite Lake. The largest body of pegmatite seen, 150 m (500 ft) or more long, is along the northeast shore of a pond, 0.6 km (0.4 mi) west-southwest of the outlet of Lake Elaine.

Pegmatites occur as sharp-walled dikes that transect foliation of the enclosing gneiss, as lenses and pods along foliation, and as irregular masses having no apparent relation to wallrock structure. Pegmatite dikes both cut and are cut by aplite dikes. In many places, pegmatites are along contacts between amphibolite and gneiss or are otherwise closely associated with amphibolites.

All pegmatites examined are of the simple type, composed mainly of quartz, pink microcline, and white plagioclase; biotite and muscovite are common, and ilmenite or magnetite are abundant in a few pegmatites. No other minerals were recognized during this study, but the small amounts of beryllium and niobium found in stream-sediment samples from the headwaters of East Rosebud Creek suggest the possible occurrence of pegmatites containing these elements there. Beryl, in crystals as much as 25 cm (10 in.) long, has been reported from a pegmatite 0.4 (0.25 mi) south of Black Stone Lake (Harris, 1959, p. 1200; location given in Gast and others, 1958, p. 332); cubic crystals of uraninite were reported by Eckelmann and Poldervaart (1957, p. 1242) in a pegmatite about 1.6 km (1 mi) north of where Clarks Fork Yellowstone River is crossed by U.S. Highway 212; garnet was reported by Butler (1966, p. 54) from the Cathedral Peak area; and apatite was reported by Eckelmann and Poldervaart (1957. p. 1242) from the Quad Creek area.

Small dikes of fine-grained granite or aplite occur sporadically throughout the Beartooth study area. Abundant aplite dikes cutting gneiss are spectacularly displayed in the cliffs along Star Creek south of Green Lake.

Orbicular rocks occur at a few places in the Beartooth study area and appear to be most abundant in the region north and east of Beartooth Butte, where a dozen or more outcrops as much as 110 m (360 ft) long and 27 m (90 ft) wide have been studied in detail by Leveson (1963). Orbicular rocks were found during the present study just south of a pond 4 km (2.5 mi) N. 10° E. of Silver Lake, near a pond northeast of Martin Lake (fig. 11), and on the divide between Wounded Man and Slough Creeks just south of Pinnacle Mountain; at the last locality, complete or near-complete orbicules are weathered out of the enclosing rock and occur as loose baseball-size rough spheres.

Isotopic age determinations on various minerals and granitic gneiss of the Beartooth terrane have been made by several workers and the results are summarized by Giletti (1968) and Nunes and Tilton (1971). The principal findings are as follows: Gast, Kulp, and Long (1958, p. 326-328) concluded, on the basis of Rb-Sr and K-Ar age determinations on biotite and microcline from norite and amphibolite in the southeastern Beartooth Mountains, that "the ages reported here represent a single geologic event, namely, that of the major metamorphism and granitization at about 2,750 m.y. [million years] ago." Catanzaro and Kulp (1964, p. 99, 116-119, 122) measured U-Pb ages on zicons from granitic gneiss, migmatite, and amphibolite from the

FIGURE 11.—Orbicular gneiss, north side of lake 2.6 km (1.6 mi) N. 50° E. of Martin Lake (Lake Creek drainage). Orbicules consist of alternating shells of hornblende and feldspar; the largest is about 13 cm (5 in.) in diameter. Gneiss is cut by pegmatite dike 15-20 cm (6-8 in.) wide (just left of hammer) that is bordered by a conspicuous pink selvage of altered gneiss.

southeastern Beartooth Mountains (their samples 1, 4, 5, 6, and GL) and from near Sioux Charley Lake on the Stillwater River (their sample SG); they concluded that the zicons studied consisted of detrital cores at least 3,120 m.y. old and of overgrowths about 2,700 m.y. old, the latter date being correlated with metamorphism of the gneisses and formation of the pegmatites. Nunes and Tilton (1971, p. 2240) analyzed zircons from granitic gneiss, also from near Sioux Charley Lake, and concluded that cores of zircon grains were at least 3,140 m.y. old and that overgrowths were about 2,750 m.y. old, these results are similar to those determined by Catanzaro and Kulp.

Muscovite from two pegmatites in the gneiss terrane, both southeast of but near the Beartooth study area, has been dated by the K-Ar method at 2,470± 50 m.y. and 2,520±50 m.y., and uraninite from a pegmatite about 1.6 km (1 mi) north of the crossing of U.S. Highway 212 over the Clarks Fork of the Yellowstone gave a Pb^{207}/Pb^{206} model age of 2,700±20 m.y. (Gast and others, 1958, p. 326).

The gneisses apparently are 2,700 m.y. old or more, inasmuch as they enclose pegmatites containing several minerals of about that age (Gast and others, 1958, p. 326-328). They probably are at least 2,750 m.y. old because overgrowths on presumed detrital zircons in the gneiss are interpreted to be of about that age, and they may be much older, because cores of these detrital zircons are interpreted to be at least 3,140 m.y. old (this age is presumably that of the source terrane and is a minimum; Nunes and Tilton, 1971, p. 2240.

AMPHIBOLITE AND HORNBLENDE GNEISS

Hornblende-bearing gneissic rocks are found throughout the Precambrian terrane of the Beartooth study area. Rocks containing less than about 20 percent of hornblende are termed "hornblende gneiss," whereas those containing more are called "amphibolite." On plate 1, occurrences of these rocks shown west of the Stillwater River are from Butler (1966, pl. 1; written commun., 1972) and those in the southeastern part of the area are from Larsen, Poldervaart, and Kirchmayer (1966, pl. 1), Harris (1959, pl. 5), and R. D. Bentley (in Casella, 1969, pl. 1). The very intricate relations of these rocks to the enclosing granitic gneisses and, hence, the time that would have been needed to map them precluded any attempt by us to map most of the occurrences in the intervening area, and only a few of the larger bodies are shown on plate 1. Hornblende-bearing rocks seem to be more abundant in the southeastern part of the area than elsewhere.

The hornblende-bearing rocks are mainly roughly tabular bodies that are parallel to the foliation of the granitic gneisses; some are distinctly foliated themselves. These bodies range in size from less than 1 m (3 ft) long and a few centimeters thick to huge masses at least 100 m (30 ft) thick and probably several kilometers long. Hornblendic rocks also constitute blocks of various shapes and sizes that have sharp contacts with their host rocks; among these occurrences are groups of angular fragments as in the agmatites, partly disrupted or boudinaged tabular masses that crosscut foliation, and irregular bodies whose relation to host-rock foliation is unclear. These rocks in general show little or no foliation but may have a pronounced lineation defined by hornblende prisms.

Hornblende-bearing rocks are mainly medium grained (1-5 mm), but both fine- and coarse-grained types are known. Most have a homeoblastic texture, but some are porphyroblastic. About 95 percent of the 150 rocks for which mineral composition was determiend quantitatively are made up largely of quartz, plagioclase, hornblende, and biotite; about 25 percent, mainly hornblende gneisses, also contain a little microcline; and about 10 percent contain clinopyroxene. Orthopyroxene is a constituent of four rocks, chlorite of three, and garnet and epidote of one. Accessory minerals are allanite, apatite, epidote, opaque minerals, sphene, and zircon.

The mineralogical composition of the hornblende-bearing rocks is summarized in a modal plot (fig. 10). Nearly all the rocks contain more than 15 percent mafic minerals, more than 40 percent feldspar, and less than 30 percent quartz. Only seven contain 60 percent or more of mafic minerals.

The dikelike bodies, as well as some or all of the irregular weakly or nonfoliated bodies of amphibolite, are probably metamorphosed mafic igneous rocks. However, the origin of the more abundant tabular and locally foliated amphibolites is more conjectural; Eckelmann and Poldervaart

(1957, p. 1251-1252) suggested possible derivation from mafic tuff or dolomitic shale, whereas Butler (1969, p. 86-87) favored tholeiitic basalt flows as the parent rock.

Chemical analyses of amphibolites from the Beartooth Mountains and of some other rocks, for comparison, are given in table 3, and analyses of selected minor elements are given in table 4. The major element composition of the amphibolites is clearly closer to that of average North American continental tholeiite (table 3, col. 3) than it is to those of possible sedimentary parent rocks (table 3, cols. 4-7), especially with regard to the contents of Fe_2O_3+FeO and of MgO, and the ratio of Na_2O to K_2O. The minor-element composition also suggests, particularly in reference to chromium and to a lesser extent to cobalt and nickel, that the amphibolites were derived from basaltic igneous rocks—lava flows or tuffs—rather than from sedimentary rocks. More detailed studies of the geochemistry of the amphibolites have been made by Armbrustmacher and Simons (1977).

BIOTITE SCHIST

Biotite schist and related rocks have been reported from many places in the Beartooth Mountains, but they seem to be much more abundant in the northwestern part of the mountains than elsewhere. Sizable areas were mapped by J. R. Butler north and east of Cathedral Peak (1966, pl. 1) and along the West Fork Stillwater River (written commun., 1972). McMannis, Palmquist, and Reed (1971) reported extensive areas of schist between the Boulder and Yellowstone Rivers. Within the Beartooth study area, biotite schist is widespread but not abundant. The only two outcrop areas, just northwest of Twin Peaks and on the ridge between Middle and South Forks Wounded Man Creek, appear on plate 1 with those already noted by Butler. Other occurrences of schist either were not large enough to be mapped or had such intricate and gradational relations to the much more abundant biotite gneiss and other rocks as to preclude mapping them separately.

Biotite schist is interlayered with other rocks, particularly biotite gneiss and nonschistose metasedimentary rocks. Bodies of schist are mostly small, but some are as much as 5 km (3 mi) long and 1.6 km (1 mi) wide. The schists are mostly fine-grained rocks (0.1-0.5 mm) although some contain porphyroblasts of garnet or biotite as much as 3 mm across. Schistosity is well developed in most, and the texture is lepidoblastic, but in a few the schistosity is weak, and the texture tends toward granoblastic. Some biotite schists have distinct alternating light and dark layers.

The biotite schists have the most varied mineralogy of the Beartooth Precambrian rocks. All contain major amounts (>10 percent) of quartz, plagioclase, and biotite, and most contain garnet and (or) cordierite. Staurolite, sillimanite, and hornblende are less common minerals, but nevertheless they occur in many schists. Accessory minerals are epidote, zircon, iron ores, apatite, muscovite, and sphene.

TABLE 3.—*Chemical analyses of amphibolites from the Beartooth Mountains and of other rocks*

[Data are in percent. Leaders (....) indicate no data]

Sample No.	1	2	3	4	5	6	7	8
SiO_2	55.5	51.35	57.54	50.8	58.10	57.3	66.7	64.63
Al_2O_3	16.1	15.08	15.50	15.8	15.40	15.2	13.5	15.48
Fe_2O_3	2.8	2.55	2.29	2.7	4.02	6.6	1.6	6.54
FeO	5.0	8.33	5.01	8.6	2.45	([1])	3.5	....
MgO	5.7	7.57	5.92	6.5	2.44	4.9	2.1	3.12
CaO	6.9	9.35	6.40	9.8	3.11	11.3	2.5	2.22
Na_2O	3.4	2.25	3.13	2.5	1.30	1.3	2.9	3.74
K_2O	1.7	.87	1.89	.77	3.24	3.2	2.0	2.44
H_2O-	.10	.10	.04	....	5.00	....	.6	....
H_2O+	1.3	1.21	.81	.75		....	2.4	....
TiO_2	.78	.71	.63	1.5	.65	....	.6	.62
P_2O_5	.32	.23	.16	.24	.17	.2	.2	....
MnO	.12	.21	.13	.16	....	....	.1	....
CO_2	.04	.01	.17	....	2.63	....	1.2	....
Total	99.76	99.82	99.62	100.12	[2]100.00	100.0	[3]100.4	98.59

[1]Total shown for Fe_2O_3 also includes FeO.
[2]Total includes 0.64 percent SO_3, 0.05 percent BaO, and 0.80 percent C.
[3]Total includes 0.3 percent SO_3, 0.1 percent S, and 0.1 percent C.

DESCRIPTIONS

1. Average central Beartooth amphibolite (Armbrustmacher and Simons, 1977, table 4, col. 1).
2. Amphibolites, eastern and central Beartooth Mountains; average of 7 analyses (Butler, 1969, table 3, col. A; some of these rocks are called para-amphilibolites in the source papers).
3. Biotite-quartz amphibolites, eastern and central Beartooth Mountains; average of 7 analyses (Butler, 1969, table 2, col. B).
4. Continental tholeiites, North America; average of 173 analyses (Manson, 1967, p. 223).
5. Average shale (Clarke and Washington, 1924, p. 32).
6. Average shale plus 20 percent of Precambrian limestone (Eckelmann and Poldervaart, 1957, p. 1252, table 7, index II).
7. Graywacke, average of 61 analyses (Pettijohn, 1963, p. S15, table 12).
8. Precambrian graywacke, southern Wind River Range, Wyo; average of 23 analyses (Condie, 1967, table 2, col. 1).

TABLE 4.—*Analyses of selected minor elements in amphibolites from the Beartooth Mountains and in other rocks*

[Data are in parts per million. Leaders (....) indicate no data]

	1	2	3	4
Ba	500	244	700	500
Co	30	39	20	20
Cr	225	160	100	140
Cu	40	127	50	40
La	25	....	20	....
Ni	80	85	70	50
Pb	10	....	20	15
Sc	30	33	15	10
Sr	400	450	300	450
V	200	251	130	70
Y	20	32	25	30
Zr	70	108	160	140

DESCRIPTIONS

1. Average of 97 amphibolites, Beartooth Primitive Area and vicinity; semiquantitative spectrographic analyses.
2. Mean tholeiitic basalt (Prinz, 1967, table 11, col. 6).
3. Average shale (Taylor, 1965, tables 6, 11, 15, 19, 21, and 22).
4. Average graywacke (Taylor, 1965, tables 6, 11, 15, 19, 21, and 22).

SILICEOUS METASEDIMENTARY ROCKS

Siliceous metasedimentary rocks have been reported by virtually all workers in the Beartooth Precambrian terrane. These rocks are mainly quartzite but also include feldspathic or biotitic quartzite, ferruginous quartzite, and iron-formation. Only the most quartz-rich of these rocks constitute a well-defined group; as biotite content increases, these quartz-rich rocks pass transitionally into biotite schist, and as feldspar content increases, they become fine-grained gneiss. The most extensive occurrences are in the northwestern part of the Beartooth Mountains, particularly near the base of the Stillwater Complex (Page and Nokleberg, 1970) and in the region between the Yellowstone and Boulder Rivers (McMannis and others, 1971). Quartzite lenses as much as 600 m (2,000 ft) long and 75 m (250 ft) wide are shown within the gneiss terrane of the Quad Creek area by Eckelmann and Poldervaart (1957, pl.5), and in this same area, lenses of iron-formation attain a length of 15 m (50 ft) and a width of 3 m (10 ft) (Eckelmann and Poldervaart, 1957, p. 1238). Most reported occurrences of siliceous metasedimentary rocks, however, are much smaller.

In the Beartooth study area, few outcrops of siliceous metasedimentary rocks were seen, but the fairly common occurrence of these rocks in talus and other rock debris suggests that they are more widespread than the apparent outcrop abundance might indicate. The largest outcrop areas shown on plate 1—about 0.8 km (0.5 mi) long and 180-210 m (600-700 ft) wide—are on Lake Plateau at the head of the south branch of Flood Creek. Several smaller outcrops no more than 600 m (2,000 ft) long that are shown along the southeast edge of Hellroaring Plateau were recognized by James (1946, pl. 53). Other outcrop areas are too small to be shown on plate 1.

The rocks range in color from white to light gray, light greenish gray, and dark gray. Outcrops of rocks rich in pyrite or pyrrhotite, magnetite, or hematite are filmed by brown iron oxide. Grain size ranges from very fine to coarse; in typical gray ferruginous metaquartzite from south of Courthouse Mountain, northeast of Duggan Lake (fig. 12), and on Big Mountain, most grains are less than 1 mm across, whereas meta-arkose at Fish and Elephant Lakes and southeast of Courthouse Mountain is made up of millimeter-size grains, and ferruginous metaquartzite north and northeast of Lake Abundance has quartz grains several millimeters across.

FELDSPATHIZED GNEISS

Small dikelike bodies and irregular masses of very conspicuous bright reddish-orange rock that consists mainly of potassium feldspar (orthoclase) and hematite occur on Lake and Stillwater Plateaus, at the heads of Storm, Woodbine, and Hellroaring (East Rosebud Creek drainage) Creeks, and north of Fossil Lake. The largest mass, at the head of the canyon of Woodbine Creek, is about 90 m (300 ft) wide and perhaps as much as 450 m (1,500 ft) long; the others are much smaller. Field relations of the

FIGURE 12.—Lens of finely layered metaquartzite (gray) and magnetic iron-formation (dark gray) in gneiss (light gray). Beartooth Trail 0.5 km (0.3 mi) northeast of Duggan Lake. Viewed westward, rocks dip 65° N. Brunton compass is 7.6 cm (3 in.) across.

well-exposed body 1.1 km (0.7 mi) southeast of Lake Mountain indicate that it has formed by alteration and partial replacement of gneiss.

Feldspathized gneiss is medium to coarse grained, is moderate orange pink to moderate reddish brown, and is commonly somewhat vuggy. Outcrops are locally speckled with yellow iron oxide. Flesh-colored orthoclase in grains as much as 1 cm (0.4 in.) across appears to make up more than 95 percent of most of these rocks; and at some localities it may constitute as much as 99 percent. The only other mineral present in appreciable amount is hematite, which occurs both as discrete tiny aggregates and as disseminations through orthoclase; the color of the feldspar is due to these microscopic inclusions of hematite.

ULTRAMAFIC ROCKS

Small lenses and pods of ultramafic rocks have been reported from many places in the gneiss terrane of the Beartooth Mountains. Most of these are in the terrane of Hellroaring and Line Creek Plateaus and of the southeasternmost part of Silver Run Plateau, all in the southeastern part of the mountains (James, 1946; Casella, 1964, p. 973; 1969, p. 60; Skinner, 1969). The rocks consist of various proportions of olivine, enstatite, amphibole, serpentine, talc, chlorite, and spinel. The ultramafic lenses are as much as 600 m (2,000 ft) long and 60 m (200 ft) wide, but most are much smaller. They have been interpreted as tectonic inclusions in gneiss, possibly derived from dikes and sills emplaced in the parent rock of the gneiss (James, 1946, p. 165-166; Casella, 1969, p. 60; Skinner, 1969, p. 38-42). The serpentinite pods in the gneiss terrane of Hellroaring and Line Creek Plateaus are the host rocks for chromite deposits that have yielded a small production.

Within the Beartooth study area, most of the ultramafic bodies are along the southeastern border on Silver Run and Hellroaring Plateaus; the distribution of these rocks as shown on plate 1 is from James (1946, pl. 53). Small pods of ultramafic rock also occur near Moon Lake, 1.1 km (0.7 mi) west-southwest of Wall Lake, and on the edge of Hellroaring Plateau 0.8 km (0.5 mi) northwest of Mount Rearguard. The rocks at Moon Lake are exposed only in inaccessible cliffs northeast of the lake but are abundant components of talus accumulations below the cliffs. They are mainly coarse grained (0.5-10 mm) sheared and fractured peridotite or dunite. The rock at Wall Lake is a very dark gray medium-grained peridotite, and the rock northwest of Mount Rearguard consists almost entirely of hornblende.

HORNFELS

The western part of the Stillwater Complex as far east as Crescent Creek is underlain by an extensive body of hornfelsed sedimentary rocks, and scattered outcrops of the same rocks are found nearly as far east as Chrome Lake (Page and Nokleberg, 1970). Within the Beartooth study area, these rocks occur only on the north side of the West Fork Stillwater River from about 1.6 km (1 mi) east of Crescent Creek to East Boulder Plateau, and underlie an area of about 15-18 km^2 (6-7 mi^2) on plate 1. All contacts with other Precambrian rocks, except the mafic dikes, are faults. The hornfelses were mainly sediments that were intruded and metamorphosed by the Stillwater Complex.

The eastern part of the outcrop area of hornfels shown on plate 1, starting about 3 km (2 mi) west of Crescent Creek, is underlain mainly by the anthophyllite-biotite-cordierite hornfels unit of Page and Nokleberg (1970); small areas near Crescent Creek are underlain by the cordierite-orthopyroxene-biotite hornfels unit of those authors. The western and more extensive part of the outcrop area is underlain by the biotite-cordierite hornfels unit (Page and Nokleberg, 1970).

A little hornfels also occurs in the Beartooth study area 1.3 km (0.8 mi) northeast of Fish Lake and at the head of the east cirque of Lightning Creek.

STILLWATER COMPLEX

The Stillwater Complex is a mafic and ultramafic stratiform igneous body more than 5,500 m (18,000 ft) thick that is exposed along the northeast edge of the Beartooth Mountains between the Boulder River and West Fishtail Creek. The outcrop area is about 50 km (30 mi) long and attains a width of nearly 8 km (5 mi). Jackson (1961, p. 2) summarized the emplacement of the complex, as follows:

"In Precambrian time the parent magma of the complex was intruded as a horizontal sill into pelitic sedimentary rocks of unknown age, which were metamorphosed to cordierite-hypersthene-biotite-quartz hornfels. After it crystallized, the complex was locally intruded by granite, tilted about 25° in the eastern part, beveled by erosion, and buried by sediments ranging from Middle Cambrian through Mesozoic in age. All these rocks were later deformed during the Laramide orogeny, and the complex now stands nearly vertical."

Within the Beartooth study area, the complex underlies slightly more than 2.6 km^2 (1 mi^2), mainly on the north side of the West Fork Stillwater River east of Crescent Creek, where it is represented by the basal zone and both the peridotite member (lower) and the bronzitite member (upper) of the overlying ultramafic zone (Page and others, 1973a).

The complex intruded and hornfelsed rocks that contain detrital zircons at least 3,140 m.y. old (Nunes and Tilton, 1971, p. 2238-2440) and is intruded by quartz monzonite dated at 2,750 m.y. (Nunes and Tilton, 1971, p. 2237-2239). Determinations of lead-uranium ages on zircons from norite of the basal zone of the complex indicate that the complex was emplaced about 2,750 m.y. ago (Nunes and Tilton, 1971, p. 2236-2238; however, the nature of these zircons is uncertain (N. J Page, written commun., 1972), and the complex may therefore be somewhat older than 2,750 m.y.

QUARTZ MONZONITE

Quartz monzonite and associated rocks of Precambrian age intrude gneiss, metasedimentary rocks, and Stillwater Complex along the north edge of the Beartooth study area between the West Fork Stillwater River and West Fishtail Creek. Except for the mafic dikes, the quartz monzonite is the youngest Precambrian rock in the area. It underlies about 20 km^2 (8 mi^2) of the area shown on plate 1, mostly the northern part of Stillwater Plateau.

The quartz monzonite has been studied in detail by Page and Nokleberg (1972). According to these authors, the rocks grouped as quartz monzonite on plate 1 comprise coarse-grained equigranular to porphyritic quartz monzonite (grain size 5 mm), medium- and fine-grained quartz monzonite (grain size <1-5 mm), hornblende quartz diorite, and aplite.

The largest area of outcrop of the quartz monzonite shown on plate 1 is on Stillwater Plateau. However, it is very difficult to separate the rock mapped by Page and Nokleberg (1970) as quartz monzonite at the north end of the plateau from migmatitic granodiorite gneiss at the south end, and inasmuch as the gneiss and quartz monzonite are gradational over a wide area, the contact between them as shown on plate 1 is only approximate. All rocks from the Stillwater Plateau are very similar mineralogically and consist of plagioclase, quartz, microcline, brown biotite, and muscovite, and accessory epidote, apatite, zircon, opaque minerals, and, rarely, sphene.

Zircons from the quartz monzonite have been dated by the uranium-lead method at 2,700-2,750 m.y. (Nunes and Tilton, 1971, p. 2237-2239).

PRECAMBRIAN W, X, Y, AND Z

MAFIC DIKES

Dikes and small intrusions of mafic rocks are widespread in the Precambrian terrane of the Beartooth study area (pl. 1) and are particularly abundant in the headwaters of West Rosebud and Phantom Creeks, on Silver Run Plateau, and north and northeast of Beartooth Butte. The mafic bodies are divided into four groups: metadolerite, quartz dolerite, alkalic olivine dolerite, and rocks which are indeterminate or are undetermined because of lack of information. The first three groups correspond approximately to the Archean metadolerite, "late" Precambrian quartz dolerite, and Tertiary(?) olivine dolerite groups, respectively, of Prinz (1964).

Assignment of a rock to a particular group is based mainly on petrographic characteristics as determined with the microscope, but certain field criteria also are useful for this purpose. Rocks of the metadolerite group tend to be a fairly uniform dark grayish brown on fresh surfaces because their plagioclase is rather dark, whereas most quartz dolerites and alkalic olivine dolerites show a distinct diabasic texture because of the presence of white plagioclase. Metadolerite dikes frequently are not vertical, and some are nearly flat lying, as for instance the sill-like body along West Fishtail Creek. These dikes also may have a rather sinuous outcrop pattern, as illustrated by the large body between Upper Aero Lake and Broadwater Lake. In contrast, quartz dolerite dikes are commonly vertical or nearly vertical, and most seem to have a linear outcrop pattern, as shown, for example, by the north-trending dike between Whitetail Peak and Native Lake. Irregularly shaped intrusions, such as the Upper Aero Lake-Broadwater Lake dike, the small plug on the northeast flank of Saddleback Mountain, and the intrusives on Hellroaring Plateau (James, 1946) all consist of rocks of the metadolerite group; on the other hand, intrusive bodies of the quartz dolerite group are all dikes.

The large metadolerite dike on Pyramid Mountain and the Upper Aero Lake-Broadwater Lake metadolerite intrusion are cut by quartz dolerite dikes, and the relative ages of the two groups are thus established. North of Fossil Lake, a quartz dolerite dike is cut by a younger quartz dolerite dike that shows a chilled contact against the older dike. Dikes of all groups cut across the gneissic foliation of the host rock.

Cylindrical columnar jointing was observed in about a dozen dikes; most of the dikes, including all the best examples, are of quartz dolerite. This type of jointing is particularly well shown along the entire length of a dike which extends from Whitetail Peak (and perhaps farther north) southward to Native Lake and perhaps beneath Beartooth Butte as far south as the Beartooth Highway (Armbrustmacher and Simons, 1975); this dike is referred to by Prinz and Bentley (1964) as the Cloverleaf Lakes dike. Another excellent example of cylindrical jointing was seen on the south flank of Mystic Mountain (Armbrustmacher and Simons, 1975).

The mafic dikes range in thickness from a few centimeters to as much as 150 m (500 ft), and the longest is at least 11 km (7 mi), probably 18 km (11 mi), and possibly as much as 23 km (14 mi) long. The dikes commonly show chilled borders against wallrocks; the chilled zone is typically somewhat porphyritic and in places is several tens of centimeters thick. Contacts locally are strongly sheared. Contact metamorphic effects on gneiss wallrocks of both metadolerite and quartz dolerite dikes are similar and are generally minor.

Rocks of the metadolerite group comprise metadolerite, porphyritic metadolerite, and metanorite. The metadolerites are medium- to fine-grained holocrystalline rocks that commonly have a subophitic texture. They consist of clouded plagioclase, augite, hypersthene or pigeonite, hornblende, biotite, a little olivine, and accessory magnetite, ilmenite, pyrite, apatite, epidote, and zircon.

Porphyritic metadolerites resemble metadolerite but contain rounded phenocrysts of plagioclase, most of which are about 2-3 cm (1 in.) across but some of which attain sizes of 15-20 cm (6-8 in.) across. In some places, phenocrysts are widely scattered throughout the metadolerite matrix and at others are densely concentrated to form the rock informally referred to as leopard rock (Prinz, 1964, p. 1226). In several dikes the phenocrysts are absent from the outer parts of the dike but are highly concentrated near the center, presumably by some kind of flowage differentiation (Komar, 1972).

The metanorites are holocrystalline rocks of gabbroic or ophitic texture and typically are made up of grains 1-2 mm across. They consist of hypersthene, augite, interstitial clouded plagioclase, and minor amounts of late quartz, opaque minerals, olivine, and apatite.

Rocks of the quartz dolerite group are holocrystalline, and most have an ophitic texture. They consist of plagioclase, augite, pigeonite (or rarely, hypersthene), quartz, opaque minerals, hornblende, and biotite.

Dikes belonging to the alkalic olivine dolerite group are few. They consist of clear, partly saussuritized plagioclase, distinctively pink pleochroic titaniferous augite, abundant olivine, and minor amounts of potassium feldspar, quartz, and opaque minerals.

Semiquantitative spectrographic analytical data on selected elements in 343 samples of mafic dikes in the Beartooth study area are summarized in table 5. Comparison of data on the quartz dolerite and metadolerite groups indicates that the metadolerite group is differentiated and that more primitive petrologic types occur in that group.

TABLE 5.—*Semiquantitative spectrographic analyses of mafic dikes in the Beartooth Primitive Area and vicinity and analysis of average tholeiite*

[Arithmetic means given for all rock groups except mafic dikes, for which geometric means are given. Leaders (....) indicate no data; <, less than]

Element	Metadolerite group (156 rocks)	Quartz dolerite group (110 rocks)	All mafic dikes of Beartooth Primitive Area and vicinity (343 rocks)	All tholeiites (Prinz, 1967, p. 278-280)
		Percent		
Fe	11.9	11.5	....	....
Mg	6.9	5.1	....	....
Ca	9.0	6.9	....	....
Ti	1.2	.7	0.6	....
		Parts per million		
Mn	1,580	1,540	....	....
Ba	320	350	285	244
Co	58	58	53	39
Cr	395	230	185	160
Cu	112	101	85	123
La	<20	<20	....	....
Ni	130	77	80	84
Sc	36	41	36	31
Sr	187	170	180	450
V	262	281	250	251
Y	26	26	25	30
Zr	94	110	90	108

As shown in table 5, the trace-element signature of the mafic dike rocks of the Beartooth study area is generally similar to that of average tholeiite as summarized by Prinz (1967, p. 278-280); however, the Beartooth rocks contain considerably more chromium and cobalt and much less strontium.

Isotopic ages of a large number of mafic dikes from the southeastern part of the Beartooth Mountains were determined by Mueller (1971) and Baadsgaard and Mueller (1973). Their data show a scattering of ages between 2,600 and 700 m.y., but, by combining the age data with those on chemical and petrographic characteristics, they concluded that dikes were emplaced during at least three intrusive episodes, about 2,550, 1,300, and 740 m.y. ago.

PALEOZOIC ROCKS

Sedimentary rocks of Paleozoic age are exposed more or less continuously around the entire perimeter of the Precambrian core of the Beartooth Mountains, and a few erosional remnants or downfaulted inliers occur within the Precambrian core itself. These rocks range in age from Middle Cambrian (Flathead Sandstone) to Permian (Park City Formation or Phosphoria Formation) and have an aggregate thickness of about 900 m (3,000 ft). The stratigraphy of the Paleozoic rocks is summarized by Foose, Wise, and Garbarini (1961, p. 1146-1147, table 1), Pierce (1965), Pierce and Nelson (1971), and Page, Simons, and Dohrenwend (1973a, b).

Within the Beartooth study area the largest extent of Paleozoic rocks is on Beartooth Butte, where beds ranging in age from Cambrian to Devonian are inferred to underlie an area of about 13 km^2 (5 mi^2); (Pierce and Nelson, 1971). Small patches of Paleozoic rocks crop out at the north end of Fishtail Plateau, on Beartooth Plateau, between Beartooth Plateau and Beartooth Butte, and about 4 km (2.5 mi) north of Lake Abundance; their aggregate outcrop area is about 2.6 km^2 (1 mi^2). These rocks were not studied by us and will not be further described.

MESOZOIC ROCKS

Sedimentary rocks of Mesozoic age are widely distributed along the east, northeast, and northwest flanks of the Beartooth Mountains and around Gardiner. They range in age from Triassic (Chugwater Formation) to Late Cretaceous (Livingston Group), and have an aggregate thickness of about 2,100 m (7,000 ft). The Mesozoic stratigraphic section is summarized by Foose, Wise, and Garbarini, (1961, p. 1147, table 1) and by Pierce (1965).

Within the Beartooth study area, Mesozoic rocks are found only at the south end of East Boulder Plateau, where they underlie an area of about 0.6 km^2 (0.25 mi^2) north of Trail Creek. Rocks of Jurassic and Cretaceous age are reported by Foose, Wise, and Garbarini (1961, pl. 1) and by Page, Simons, and Dohrenwend (1973a). These rocks were not studied during this investigation and will not be further discussed.

TERTIARY ROCKS

INTRUSIVE ROCKS

Dikes and small plugs, mainly of latitic or dacitic composition intrude Precambrian rocks in the western and southwestern parts of Lake Plateau, between Turgulse and Rainbow Lakes (East Rosebud Creek drainage), and along the southeast edge of the study area northwest of Rock Creek. They seem to be notably absent from a belt 9-11 km (6-7 mi) wide that is southwest of a line between Sky Top Lakes and Beartooth Pass, and also from an area at least 8 km (5 mi) wide on both sides of the Stillwater River from the north edge of the area as far south as Big Park Guard Station. They are presumed to be of Tertiary age, but some may be a little older; some are very similar to the volcanic rocks described in the following section and may be intrusive equivalents of extrusive rocks now removed by erosion.

Most of the intrusive rocks may be grouped into four general lithologic types, as follows:

1. Pale-red, grayish-red, or pale-brown fine-grained sparsely porphyritic latite. Dikes of this group occur around Rainbow Lakes on Lake Plateau, on Froze-to-Death plateau, and between Arch and Rainbow Lakes (East Rosebud Creek drainage), and a small plug cuts altered gneiss in Rainbow Creek just below the lower of the two Rainbow Lakes. All the dikes appear to be 3-6 m (10-20 ft) wide, and the longest was traced about 1.6 km (1 mi). Rocks of this group consist of small phenocrysts of sodic plagioclase and, less commonly, of sanidine enclosed in a fine-grained very dusty groundmass that appears to be mostly feldspar.
2. Grayish-red, pale-red, and light-brownish-gray coarsely porphyritic latite. This group of rocks forms many dikes, plugs, and irregular bodies in the region around Rainbow, Arch, and Turgulse Lakes and also occurs 16-24 km (10-15 mi) to the east as dikes at the head of West Red Lodge and Timberline Creeks and as a plug(?) northeast of Richel Lodge. The numerous porphyry dikes and plugs shown by James (1946) on his geologic map of the Red Lodge chromite district are of similar rocks. Dikes range in width from 3 to 23 m (10 to 75 ft) and are as much as 3 km (2 mi) long. Plugs or thick dikes are as much as 450 m (1,500 ft) in greatest horizontal dimension, but most are no more than a few tens of meters across. No extrusive equivalents of these rocks were seen. This group of rocks is characterized by abundant phenocrysts (25-50 percent by volume) of colorless plagioclase and pink potassium feldspar as much as 1 cm across in a very fine grained groundmass.
3. Light-olive-gray, pale-red, or light-brownish-gray coarsely porphyritic hornblende latite. This distinctive rock crops out at several places on the plateau between Hellroaring and Rock Creeks; near the end of the road to the chromite deposits south of Hellroaring Creek, outcrops of porphyry outline what appears to be a discontinuous ring dike 1.2 km

(0.75 mi) or so in diameter. A similar rock makes up an irregular body about 0.8 km (0.5 mi) across just east of Fish Lake on Lake Plateau; and a dike about 1.6 km (1 mi) long and as much as 60 m (200 ft) wide crosses Silver Run Plateau midway between Basin Creek Lake and Lake Gertrude. A typical rock consists of phenocrysts 5-10 mm across of pale-pink potassium feldspar, smaller grains of colorless plagioclase, and millimeter-size crystals of hornblende in a pale-red fine-grained matrix.

4. Medium-light-gray to dark-gray porphyritic dacite or andesite. Dikes and small plugs of these rocks are found mainly along or near the west edge of the study area between Upsidedown Creek and Lake of the Woods but also were seen farther east near Wolf and Courthouse Mountains and on Silver Run Plateau north of Lost Lake. Dikes are as much as 15 m (50 ft) thick and 0.8 km (0.5 mi) long, and the largest plug, on the plateau south of Upsidedown Creek, appears to be about 450 m (1,500 ft) across; this body is considered by J. R. Butler (written commun., 1972) to be part of a cone sheet. The rocks consist of sparse to abundant phenocrysts of feldspar as much as 1 cm across, and most contain minor amounts of millimeter-size phenocrysts of biotite, amphibole, or quartz embedded in a medium- to fine-grained gray matrix.

In addition to the four groups of intrusive rocks, several other rock types occur in only one or two places. All these rocks are distinctly different from the others in the area. Several dikes of light-gray to medium-light-gray sparsely porphyritic fine-grained latite are exposed around Zimmer Lake. These dikes are 4.5-7.6 m (15-25 ft) thick and extend for as much as 1.6 km (1 mi) across the canyon of Zimmer Creek. They contain abundant pyrite, and their outcrops are heavily coated with iron oxide. A dike of olivine basalt 3-3.6 m (10-12 ft) wide crops out for about 0.8 km (0.5 mi) on the plateau 1.6 km (1 mi) west of Lake Columbine. The rock contains small grains of olivine, pyroxene(?), and plagioclase (An_{45}) set in a dark-gray groundmass.

Rouse, Hess, Foote, Vhay, and Wilson (1937) described porphyry intrusions of the Beartooth Mountains, most of them northeast and east of the Beartooth study area and outside the mountains themselves. Some of these rocks have a general petrographic similarity to the rocks just described in groups 1, 2, and 3. On the basis of stratigraphic evidence, these authors assigned a Late Cretaceous age to the porphyries; the possibility exists, therefore, that some of the porphyritic intrusives of the Beartooth study area, particularly those of groups 1 and 2, are of that age rather than of Tertiary age.

VOLCANIC ROCKS

Volcanic rocks of Tertiary age are widespread around the southwest and west sides of the Beartooth Mountains, but in the Beartooth study area they are restricted to three small outcrop areas and a questionable fourth one, totaling about 5 km^2 (2 mi^2), on the west edge of the study area. The volcanics everywhere lie unconformably on Precambrian metamorphic rocks. The rocks at the head of Slough Creek are assigned by Rubel (1971) to his "Group I and II volcanics" and are correlated with the Cathedral Cliffs Formation of Eocene age. The Cathedral Cliffs Formation is a lower unit of the Washburn Group of the Absaroka Volcanic Supergroup of Smedes and Prostka (1972).

The volcanic rocks comprise light-gray, dark-gray, olive-gray, greenish-gray, and greenish-purple lava flows, breccia, and tuff. Lava flows are platy porphyritic rocks that contain abundant phenocrysts of feldspar, biotite and, less commonly, amphibole. Much of the breccia is coarse rusty weathering rock that contains not only blocks of volcanic rock but also abundant fragments of Paleozoic(?) sedimentary rock. A typical volcanic block is dark-gray fine-grained andesite composed of phenocrysts of plagioclase and augite in an intergranular matrix of the same minerals. Tuff appears to be most abundant at the base of the volcanic section. It is mostly a fine-grained light-colored rock—yellowish gray to light brownish gray—that contains sparse to abundant small grains of feldspar, biotite, amphibole, and, rarely, quartz.

QUATERNARY DEPOSITS

Deposits of Quarternary age are very widespread in the Beartooth study area. They comprise morainal deposits and glacial till of Pleistocene and Holocene age, as well as rock glaciers, talus, alluvium, and landslide deposits, all of which are mostly of Holocene age.

GLACIAL DEPOSITS

Glacial deposits in the Beartooth study area are shown as two units on the geologic map—morainal deposits, which occur along valley floors and walls throughout the area, and glacial till on the south end of East Boulder Plateau and around Beartooth Lake.

Morainal Deposits

Moraines or remnants of moraines exist in nearly every valley above 2,750 m (9,000 ft) and also extend along some main valleys for several kilometers northeast of the mountain front and to altitudes below 1,500 m (5,000 ft). Only the largest or most conspicuous moraines are shown on the geologic map (pl. 1).

Within the Beartooth study area the most extensive moraines are along lower West Fishtail and Timberline Creeks; other large moraines are in Basin and Hellroaring (East Rosebud Creek drainage) Creeks and below Grasshopper Glacier (Lake Fork Rock Creek drainage).

The oldest moraines are typified by those in West Fishtail Creek south and east of Chrome Lake (alt 2,600 m, or 8,500 ft, and less). These moraines are smoothly rounded to slightly hummocky and are locally very swampy, have very bouldery surfaces, and support a dense growth of good-sized pine and spruce. Lateral moraines along West Fishtail Creek are as much as 150-180 m (500-600 ft) high. Moraines of this group are mainly or entirely at altitudes below 2,750 m (9,000 ft) and are tentatively assigned an early to middle Pinedale age (Richmond, 1965, p. 224-225).

Moraines of intermediate age are typified by the lateral moraines along the middle course of Saderbalm Creek (alt 2,700-2,400 m; 8,750-8,000 ft), in a south-sloping tributary of North Fork Wounded Man Creek east of Barrier Lake (alt 2,970-2,820 m; 9,750-9,250 ft), in the tributary canyon of Lake Fork Rock Creek 3.2 km (2 mi) east of September Morn Lake (alt 3,000-2,860 m; 9,800-9,400 ft), and below Shelf Lake (alt 3,000-2,930 m; 9,800-9,600 ft). These moraines have a rough hummocky and very bouldery surface and either are barren or support a very sparse growth of small trees. Moraines of this group are mainly at altitudes of from 3,000 to 2,750 m (10,000 to 9,000 ft), although some are as low as 2,400 m (8,000 ft). They are possibly of late Pinedale age.

The youngest moraines are at the foot of existing glaciers or short distances downcanyon from the glaciers, or are in recently deglaciated cirques. They have very rough rocky surfaces that support little or no vegetation and are only slightly, if at all, modified by erosion; end moraines are not breached, and some impound small lakes. The best examples are the lateral and terminal moraines of Grasshopper Glacier above Black Canyon Lake (Lake Fork Rock Creek drainage) (alt 3,350-2,930 m; 11,000-9,600 ft). These moraines all lie between altitudes of 3,500 and 3,000 m (11,500 and 9,900 ft) and are of Neoglacial age.

Glacial Till

Deposits of glacial till that have little morainal form have been reported from several places in the Beartooth study area, but none was studied by us. Glacial till covers an area of about 8 km^2 (3 mi^2) on the south end of East Boulder Plateau at altitudes of 2,860 to 2,750 m (9,400 to 9,000 ft). The till surface is covered with alpine turf and is dotted with partly buried boulders of Precambrian metamorphic rocks, some 3 m (10 ft) or more across. This till was first recognized by Bevan (1945).

Morainal deposits comprising glacial till and fluvioglacial deposits cover about 5 km^2 (2 mi^2) around Beartooth Lake and Beartooth Butte (Pierce and Nelson, 1971), and thick deposits of glacial till are well exposed in roadcuts along the Beartooth Highway between Lake and Muddy Creeks.

Most of the plateaus on the northeast flank of the Beartooth Mountains appear to be unglaciated, at least by ice of the later glaciations, as indicated by the presence of many erosional remnants known as tors. However, sparse glacial erratics attest to the local presence of a recent ice cap on a few plateau surfaces between Rock and Hellroaring Creeks in the southeastern part of the Beartooth study area. Large erratics rest on felsenmeer on Hellroaring Plateau southeast of Shelf Lake, on frost-riven amphibolite at the end of the ridge 1.1 km (0.7 mi) east of the end of the road in upper Rock Creek, and on felsenmeer at several places on the plateau south of Hellroaring Creek at altitudes of 3,000-3,100 m (9,900-10,200 ft).

ROCK GLACIERS

Rock glaciers, slowly moving tonguelike masses of angular rock fragments, occupy parts of nearly every cirque and high-level valley on the northeast flank of the mountains in the Beartooth study area; none of any consequence was seen on the southwest flank. The largest rock glacier in the area, in the large cirque northwest of Silver Lake, is about 2.8 km (1.75 mi) long, and several are 2.4 km (1.5 mi) long, but most are about 0.8-1.2 km (0.5-0.75 mi) long. Most of the rock glaciers have concentric transverse flow ridges over much of their length, particularly near their lower ends; such ridges are well shown by the large glacier at the head of West Rosebud Creek. Some rock glaciers also have conspicuous longitudinal flow ridges which are well displayed; for example, those shown by the long glacier in the north branch of Glacier Creek. Presumably, some of the rock glaciers—especially those well-developed flow ridges—have cores of ice, but neither ice nor wet fronts, such as those noted by Tweto, Bryant, and Wilson (1970, p. C21-C22) in the Gore Range in Colorado, were seen.

TALUS

Accumulations of talus are ubiquitous along the base of cliffs and at the mouths of major drainages throughout the Beartooth study area. The largest talus cones are at the mouths of Spread and Armstrong Creeks; these cones have coalesced to form a dam that impounds East Rosebud Lake, one of the largest lakes in the study area. In the main valleys, most of the talus cones support growths of conifers over much of their surface and apparently are receiving little new material. Some, however, are actively forming at present; the cone at the southeast end of Mystic Lake is receiving much debris from a fracture zone southeast of the lake, and the cone east of Silver Lake is so young that the rock debris is barren, even of lichens.

ALLUVIUM

Some valleys of sufficiently gentle gradient are partly floored with alluvium, but in most places stream gradients are so high that all but the coarsest material has been swept away. The largest accumulations of alluvium are along the lower stretches of the main canyons on the northeast flank of the mountains, those of the West Fork Stillwater and the Stillwater Rivers. Alluvial fill is as much as 0.6 km (0.4 mi) wide in places on the Stillwater River.

LANDSLIDE DEPOSITS

Landslide deposits seem to be scarce in the Beartooth area, despite steep slopes and rugged terrain; apparently, the rather uniformly hard and resistant rocks of the region inhibit landslides. The large mass of very coarse debris that forms the dam behind which Barrier Lake is impounded in North Fork Wounded Man Creek is interpreted as a landslide deposit derived from the south edge of Two Sisters Plateau, and much of the material in the alluvial fan at East Rosebud Lake probably was contributed by a large landslide from the south side of Spread Creek. Large areas underlain by landslide debris are shown on Beartooth Butte by Pierce and Nelson (1971).

FELSENMEER

Large areas on all the vast unglaciated plateaus of the Beartooth Mountains are covered with felsenmeer, an accumulation of angular blocks and slabs of frost-riven rock. The blocks seem to have moved little if any distance from their source and, thus, are representative of the underlying bedrock. Some areas of felsenmeer have enough soil developed on them to support alpine turf or even small shrubs or trees, but many are simply rough and rocky expanses of jagged blocks practically devoid of soil or plant cover (fig. 13). The thickness of felsenmeer is not known with certainty anywhere, but exposures along plateau rims and in gullies that cross plateau edges suggest that the felsenmeer may be several meters thick. Felsenmeer grades downward into solid bedrock through a zone in which interstitial sandy and silty material becomes increasingly abundant; however, no exposures of the complete sequence were found.

STRUCTURE

The regional geologic setting and structure of the Beartooth Mountains is described by Foose, Wise, and Garbarini (1961). In brief, the Beartooth Mountains are a block of Precambrian metamorphic and igneous rocks that

FIGURE 13.—Felsenmeer on the plateau west-northwest of Mount Inabnit at an altitude about 3,500 m (11,600 ft). Only very sparse soil has developed on this expanse of frost-riven rock fragments. Viewed northwestward from point just west of Mount Inabnit.

has been uplifted along thrust faults or steep-dipping reverse faults as much as 4,500-6,000 m (15,000-20,000 ft) structurally above the Bighorn Basin to the east and 3,000-4,500 m (10,000-15,000 ft) above the Crazy Mountains Basin to the north (Foose and others, 1961, p. 1148-1150). Part of the southwest edge of the block is defined by the Gardiner reverse fault (Wilson, 1934), along which structural relief is at least 3,600 m (12,000 ft). The west edge of the block is delineated in part by the Deep Creek fault; this fault is largely concealed beneath alluvium of the Yellowstone River valley, but it appears to be a steep-dipping fault along which structural relief may be as much as 4,500 m (15,000 ft) according to Foose, Wise, and Garbarini (1961, p. 1162), or as much as 5,500-6,000 m (18,000-20,000 ft) according to Bonini, Kelley, and Hughes (1972, p. 126). Precambrian rocks beneath the sedimentary cover have been warped into a north-northwesterly trending asymmetric anticline that dips gently along its southwest flank and more steeply along its northeast flank. According to Foose, Wise, and Garbarini (1961, p. 1164-1165), uplift of the Beartooth block began in the Late Cretaceous and continued through the Paleocene, and by middle Eocene time the block had attained its present structural relief. The present topography, however, resulted from glaciation and from other erosion subsequent to regional uplift in later Tertiary time.

Within the Beartooth study area, most of the structures are of Precambrian age; these include small- and large-scale folds, as well as many faults and joints.

All workers who have studied the gneisses of the Beartooth area have recognized at least two sets of folds—small isoclinal folds that have wavelengths of from a few centimeters to a few meters and larger open folds that have wavelengths of hundreds of meters or more. Small isoclinal folds are most conspicuous in the compositionally layered migmatitic gneiss and migmatite, and indeed they seem to be present in most outcrops of these rocks. Axial planes and limbs of the folds are parallel to the layering, and the folds commonly are sheared out and rootless (fig. 14); they resemble passive-flow folds as described and illustrated by Donath and Parker (1964, p. 55-59, fig. 8).

Large open folds have been mapped in several places in the southeastern part of the Beartooth Mountains and the findings are summarized by Larsen, Poldervaart, and Kirchmayer (1966, p. 1286-1289). Butler (1966, p. 56-57) also recognized large folds in the Cathedral Peak area. In general these folds have wavelengths of 1.6-3 km (1-2 mi) and plunge gently in a southerly to southeasterly direction; north-northwesterly plunging folds also are reported from just south of the Mill Creek-Stillwater fault zone by Butler (1966, p. 57). Although no large folds were mapped in the central part of the Beartooth area during this study, some evidence of large-scale folding was noted, and our findings do confirm a general southerly dip for the gneisses; almost all of the 30 or more observations of large-scale layering recorded on plate 1 indicate southeasterly to southwesterly dips of 30° or less.

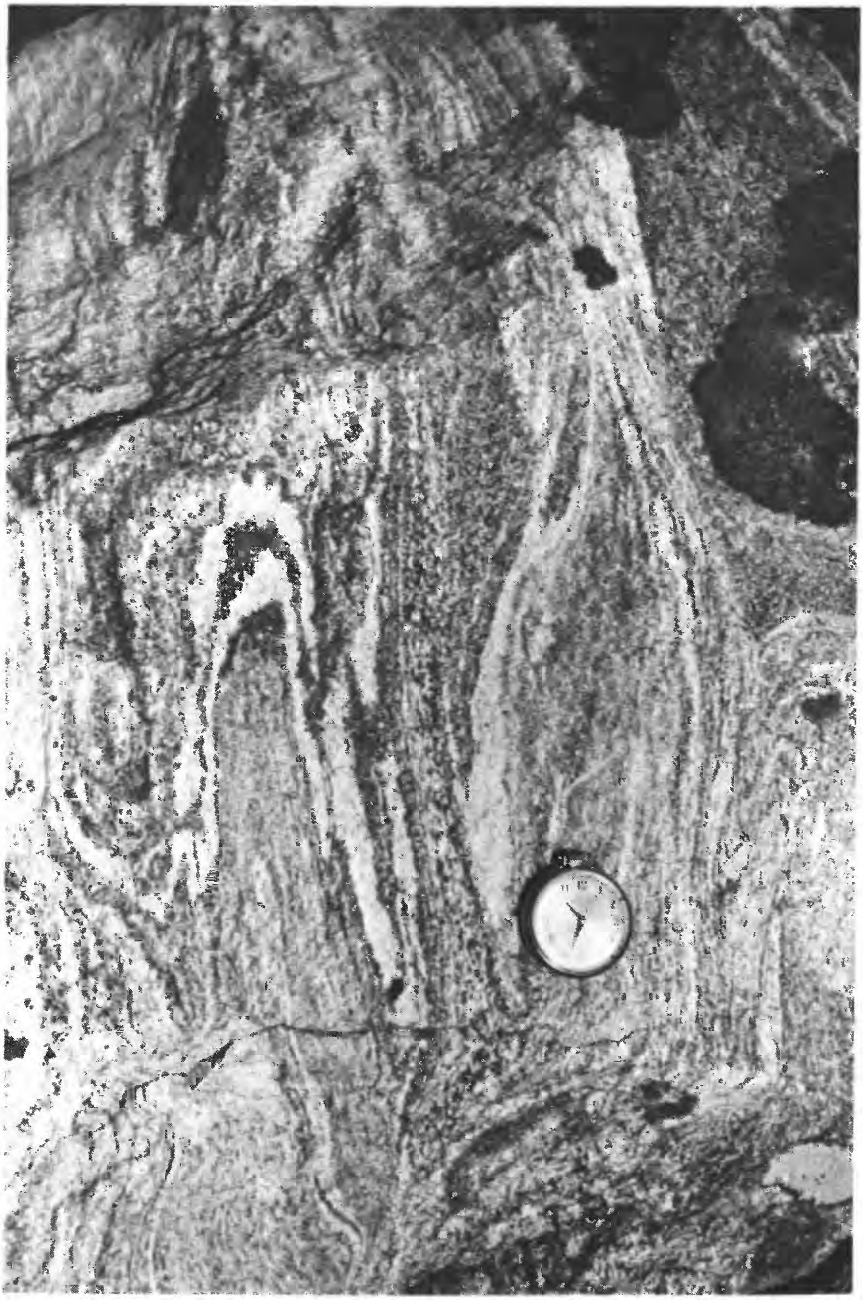


FIGURE 14.—Isoclinally folded migmatitic biotite gneiss, just south of Crow Lake. Note pronounced thickening of layers in hinges of folds at left and shearing out of folds at center. Pocket watch for scale.

Faults, shear zones, and fracture zones undoubtedly are very abundant in the Beartooth Precambrian terrane, but because most of the rocks they cut are homogeneous they are difficult to recognize, and only a few were definitely identified in the field. Linear structures of uncertain nature, many of them more easily observed in aerial photographs than on the ground, are shown as lineaments on plate 1. Some faults, such as those on the east lobe of Fishtail Plateau, on Hellroaring Plateau southeast of Lost Lake, and just south of Thunder Mountain, are marked by sheared greenish-gray or iron-stained quartz. A few others, such as those at the head of Storm Creek and on Bowback Mountain, have mylonite zones along them. Most faults, however, are marked only by sparse and inconspicuous outcrops of fractured and recrystallized gneiss or, much more commonly, by the presence of topographic lows. Some faults may be intruded by dikes, but generally it is impossible to determine whether the fracture occupied by a dike is a fault or merely a joint.

Lineaments of the area may be divided into three broad groups, one that trends within 25 ° of north, another that trends near east-west, and a third that has diverse trends. A zone of fractured and recrystallized gneiss marks the northerly trending West Fork Stillwater River lineament on the broad divide at the head of the river northwest of Wounded Man Lake; the other lineaments of this group were recognized mainly on the basis of topographic expression. Several east-trending lineaments—Lake Columbine, Hodges Mountain-Big Mountain, and Fox Lake-Jorden Lake—differ from those of the north-trending group in that they are marked by broad zones of iron-stained fractured rocks.

Faults shown on plate 1 that involve the Stillwater Complex and related rocks are from Page, Simons, and Dohrenwend (1973a, b) and will not be discussed.

The only structures of any consequence known to be younger than Precambrian are the Mill Creek-Stillwater fault zone (Foose and others, 1961, pl. 1, p. 1154) which offsets rocks as young as Early Cretaceous; several faults of apparently small displacement, perhaps 150 m (500 ft), that cut Paleozoic rocks on or near Beartooth Butte (Pierce and Nelson, 1971); and a northeasterly trending fault of unknown but presumably small displacement that cuts Tertiary volcanic rocks 0.6 km (0.35 mi) northwest of Timberline Mountain.

INTERPRETATION OF AEROMAGNETIC DATA,

By Lennart A. Anderson

In September 1969 the U.S. Geological Survey made an aeromagnetic survey of the Beartooth study area and vicinity in order to assist in the evaluation of the mineral-resources potential of the region. The area surveyed is bounded approximately by lats 44°55′ and 45°25′ and longs 109°20′ and 110°15′. Flightlines were oriented north-south, were spaced approximately 1.6 km (1 mi) apart, and varied in length from about 77 to 106 km (48 to 66 mi). The survey was flown at a constant barometric elevation of 4,100 m (13,500 ft), and a fluxgate magnetometer was used to obtain a total-intensity magnetic profile along individual traverses. The compiled magnetic data, contoured on a 20-gamma interval, are shown on the geologic map (pl. 1).

The magnetic pattern revealed by contouring is complex, particularly over the eastern and central parts of the area. Some of the magnetic anomalies can be correlated with intrusive rock and topographic features, but most must be attributed either to variation in the magnetic mineral content within the gneiss or to buried intrusive rocks of unknown origin. In the adjoining regions the sources of the magnetic anomalies are somewhat more apparent.

The Beartooth Mountains crustal block strikes northwest and extends beyond the east and west boundaries of the surveyed area. In the north-central part of the mapped area, northwest-trending magnetic gradients delineate the north edge of the block. The observed difference in magnetic intensity is the result of the higher topographic position of the Beartooth Mountains as well as a significant decrease in the magnetic mineral content of the sedimentary rocks to the northeast. Magnetic intensity values recorded over these sedimentary rocks are the lowest within the entire mapped area. Farther northwest, the crustal block is bounded by the Stillwater Complex, a tilted remnant of a differentiated Precambrian stratiform igneous complex.

The trace of the northwest-trending elongate positive anomaly is truncated by the northern boundary of the map; the anomaly is probably caused by the ultramafic zone within the Stillwater Complex. A topographic high, known as Iron Mountain, correlates with the magnetic high within the main anomaly. Stillwater ultramafic rocks exist within thin thrust slices southeast of the anomalous area but produce no discernible magnetic pattern because of the low volume of rock present. Furthermore, according to N. J Page (written commun., 1974), these rocks have a generally lower magnetite content than is found in their counterparts to the northwest.

On the west edge of the Beartooth study area are two similar-appearing magnetic anomalies. The southern anomaly straddles Monument and Haystack Peaks and can readily be attributed to an exposed Tertiary intrusive. The source of the northern anomaly is imbedded within gneiss and is unknown, but, because of the shape of the anomaly and its proximity to a known intrusive, it seems reasonable to consider it to be caused by a body of rock similar to that causing the southern anomaly. The center of the northern anomaly is near the southwest flank of Hicks Peak, and the lower intensity contour lines are bowed northward to delineate a plateaulike structure. Although it is possible that high topographic relief is responsible for the configuration of the anomaly, most other areas that have equal relief do not produce anomalies and, therefore, the anomaly must be ascribed either to an intrusive body or, less likely, to a local increase in magnetic minerals within the gneiss.

The southern boundary of the Beartooth crustal block is obscured by Tertiary volcanic rocks of the Absaroka volcanic field. These rocks, comprising extrusive as well as intrusive rocks, typically have a distinct magnetic expression. Although most of the largest anomalies are associated with deep-rooted intrusive rocks, the highest measured magnetic intensities are at Pilot Peak near the south-central margin of the mapped area. Pilot Peak is composed of extrusive volcanic rocks, but a buried near-surface intrusive may be the principal cause of the anomaly. Index Peak, just to the north, has little magnetic expression, and despite the fact that it is 120 m (400 ft) lower in elevation, it would probably have a greater effect on the shape of the total anomaly if extrusive rocks were the sole magnetic source.

The Beartooth study area as shown on plate 1 is underlain almost entirely by Precambrian crystalline rocks, consisting of granitic gneisses, amphibolites, mafic dikes, and minor biotite schist, iron-formation, and small irregular masses of mafic and ultramafic rocks. Typically, gneiss and amphibolite do not have a sufficient content of magnetic minerals to produce the magnetic intensities observed over the Beartooth crustal block, and observations of the surface indicate that the iron-formation and mafic intrusives are too small and localized to generate anomalies of the areal extent seen on the map. In order to obtain data on what would be required in terms of magnetic susceptibility, depth of burial, and approximate shape of a magnetic body, a computer modeling study was made of a prominent east-west striking anomaly located near the eastern boundary of the area. This anomaly conforms in general to a topographic feature known as Silver Run Plateau, and therefore, it was also necessary to test topography alone as a possible source of the anomaly. Two-dimensional modeling, using profiles drawn through the center of the anomaly, showed that topography by itself could not generate the observed anomaly. The final analysis indicated that a south-dipping mass of high magnetic susceptibility approximately 4 km (2.5 mi) wide was required to simulate the observed profile anomaly and that a magnetic susceptibility contrast of about $1x13^{-3}$ emu (electromagnetic units) was needed to match the amplitude of the profile anomaly. Depth estimates place the magnetic body at or near the surface.

A logical explanation of the anomaly, based on interpretation of the model, would be that the anomaly is caused by an intrusive body concealed beneath a thin covering of gneiss. However, in view of the extreme elevation differences near the area of the anomaly, it seems likely that such an intrusive body would be exposed somewhere in the steep canyon walls. Mafic dikes are abundant on Silver Run Plateau but they are much too small to be seen magnetically at the elevation at which the survey was flown. Similar considerations apply to the bulk of the anomalies within the study area, particularly those shown in the central part of the map.

In order to evaluate the possibility that variations among the typical Beartooth rocks themselves might be adequate to produce the required magnetic contrasts, magnetic-susceptibility measurements were made on several samples of gneiss and amphibolite. Measurements on mafic dike rock were also made. Sixteen samples of gneiss had a susceptibility range of from less than 10^{-5} to 1.54×10^{-3} emu, the geometric mean equaling 1.53×10^{-4} emu. The measured range on 14 mafic dike samples was from 3.3×10^{-5} to 4.8×10^{-3} emu, the mean value being 3.1×10^{-4} emu; 5 amphibolite samples had a geometric mean of 3.5×10^{-4} emu, individual values ranging from 2.9×10^{-5} to 2.3×10^{-3} emu. The mean values of magnetic susceptibility measured on each rock type suggest that no one variety of rock can account for the intensity of the observed anomalies. However, the maximum susceptibility of each rock type is greater than that required to simulate the Silver Run Plateau anomaly. The problem with attributing the cause of the anomalies to variations among these rocks is that the mineral content within a single rock unit would, in general, be expected to vary gradationally, whereas the model constructed on the basis of the Silver Run Plateau anomaly requires a sharp contrast that is caused typically by intrusive rocks.

The Precambrian rocks are intruded by many Tertiary dikes, particularly in the eastern part of the study area, and it may be argued that buried masses of similar rock are the most probable causes of the Silver Run Plateau and other anomalies associated with the Beartooth uplift. However, the small and scattered outcrops of these rocks do not suggest very strongly the near-surface occurrence of a large mass, and until further evidence becomes available, no firm conclusions can be made regarding the nature of the magnetic source rock.

The general pattern of the contoured aeromagnetic data within the area gives the impression that the Beartooth rocks may be underlain by a magnetic sub-basement. The inferred magnetic rock can hypothetically be enclosed by the 2,800-gamma contour, except where the magnetic field is distorted by volcanic rock southwest of the Beartooth study area boundary. Localized anomalies within the 2,800-gamma contour are possibly caused by cupolalike features, some deeply buried and others at or near the surface.

The large, low-gradient anomaly situated over Jordan Mountain and Two Sisters in the western part of the Beartooth study area is representative of a deep-seated magnetic body. Although the anomaly is over a topographic high, local relief has little or no effect on the shape of the magnetic feature, except to the east, where the magnetic field is distorted by Twin Peaks. Farther east, the anomaly over Mount Hague and Mount Wood may be topographically controlled, at least in part, but the steep magnetic gradient indicates the possible cause of the anomaly to be a deep-rooted magnetic rock whose northern edge is near the surface.

The main magnetic feature in the south-central part of the Beartooth study area is a northeast-trending anomaly circumscribed by the 3,200-gamma contour. This anomaly, which extends beyond the southern boundary of the area, outlines a near-surface magnetic mass whose irregular upper surface culminates in a double summit. Isolated anomalies along the northern flank of the anomaly can be correlated with topography.

A series of anomalies of low magnetic intensity occur in the region between the magnetic highs of the central area and the large positive magnetic anomalies near the east edge of the mapped area. The low-intensity anomalies are alined in a northeasterly direction and coincide approximately with zones of high topographic relief. The magnetic mineral content of the rocks within this area is low, similar to that of the granitic gneisses used in the laboratory measurements of magnetic susceptibility.

Two anomalies of high magnetic intensity are along the eastern boundary of the study area. The northernmost is the Silver Run Plateau anomaly, which has already been discussed. The other anomaly, at the southeast corner of the area, is similar, but its irregular shape suggests the presence of a more complex buried intrusive.

Smaller anomalies exist throughout the entire Beartooth study area, some related to topography and others not. Because of the sharp, well-defined contour pattern produced by most of the measured anomalies, the anomalies are attributed to buried intrusive rock of greater magnetic susceptibility than that typical of the known surface rock. On the other hand, laboratory measurements indicate that all the common rock types in the Beartooth Mountains have a sufficient range of susceptibility to generate magnetic intensities equivalent to those shown on the map. Therefore, until more data can be obtained on the subsurface geology of the area, no definite conclusion can be made as to the nature of the anomaly-producing magnetic rock.

Magnetic variations within the area do not seem to indicate intrusives that might be associated with mineralization at depth.

MINERAL RESOURCES

HISTORY AND PRODUCTION

Areas near the Beartooth study area that are known to contain mineral resources are the Cooke City (or New World) district on the southwest edge of the area, the Stillwater Complex near the north end, the Red Lodge chromite district on the southeast edge, and the Independence district to the west. Some prospecting also has been done at Horseshoe Mountain southwest of the study area. The only mineral production from the Beartooth study area itself was 450-540 t (500-600 tons) of chromite ore from the southern part of Hellroaring Plateau and, reportedly, a few tons of copper ore from near Goose Lake.

The Cooke City district is mainly northwest of Cooke City, between that settlement and Lulu Pass at the head of the Stillwater River. It has been described by Lovering (1930) and Reed (1950, p. 34-47). Production from the district is estimated at 1,871,000 g (66,000 oz) of gold, 14 million g (500,000 oz) of silver, 1,800,000 kg (4 million lb) of copper, 1,350,000 kg (3 million lb) of lead, and 540,000 kg (1,200,000 lb) of zinc (Wedow and others, 1973). These metals were produced from veins and replacement deposits, mainly in carbonate rocks of Cambrian age and associated with monzonite stocks and breccia pipes of Tertiary age.

Copper deposits around Goose Lake are described by Lovering (1930, p. 59-64, 74) and Reed (1950, p. 47-49). They comprise the Copper King deposit between Goose and Little Goose Lakes and auriferous quartz-galena-sphalerite veins southwest of Goose Lake. According to Lovering, the Copper King is a magmatic sulfide deposit that consists of chalcopyrite-bearing syenite that contains a little silver and platinum. The deposit has been explored by drilling, but most of the results are not available. Production has been reported as a few tons of ore.

Ore deposits of the Stillwater Complex are those of chromite, copper, nickel, and platinum-group metals. The chromite deposits are stratiform and consist of about 13 zones of chromitite ranging in thickness from 3 cm to 3.6 m (0.1 to 12 ft), enclosed in the ultramafic zone of the complex (Jackson, 1961). Some of the chromitite zones have been traced laterally as much as 25 km (15 mi). The deposits have been described by many investigators (for example, Peoples and Howland, 1940; Howland and others, 1949; Howland, 1955). Reserves of the complex as of 1962 are estimated at equivalent to 2,290,000 t (2,520,000 tons) of Cr_2O_3, or about 5,500,000 t (6 million tons) of ore averaging 43 percent Cr_2O_3 and having a rather low Cr : Fe ration of 1.5 : 1 (Jackson, 1963, p. 59).

The basal zone of the complex has long been known to contain sulfides of copper and nickel, and at a public hearing of the Subcommittee on Minerals, Materials, and Fuels of the United States Senate Committee on Interior and Insular Affairs, held in Billings, Mont., on August 18, 1971, the Anaconda Co. announced discovery of 136 million t (150 million tons) of ore containing 0.25 percent each of copper and nickel.

Chromite deposits of the Red Lodge district are irregular pods and lenses of chromite in small bodies pf serpentinite on Hellroaring, Silver Run, and Line Creek Plateaus (James, 1946). The largest chromite body mined contained about 32,000 t (35,000 tons). The deposits were mined during 1941-43, and about 20,000 t (22,000 tons) of lump ore and 10,900 t (12,000 tons) of concentrate were produced. According to James (1946, p. 178-179), reserves in 1943 were about 17,000 t (19,000 tons) of ore containing from 24 to 40 percent of Cr_2O_3 and having a Cr:Fe ratio of from 0.6:1 to 1.8:1. These Cr:Fe ratios are much too low to meet current industrial specifications. The resources of chromite ore deposits of Hellroaring and Silver Run Plateaus are estimated to be about 70,000 t (77,000 tons) and to average 12.8 percent of Cr_2O_3.

The Independence (Cowles) district is reported to have been active during several short periods between 1894 and 1934. Total output is unknown but apparently was a few tens of ounces of gold and a few hundred ounces of silver (Reed, 1950, p. 54-58). The ore deposits are narrow quartz veins that contain pyrite, traces of chalcopyrite, galena, molybdenite, gold, and silver. Wallrock is mostly granodiorite and diorite of the Haystack stock and related rocks (Emmons, 1908).

The geology and the mineral deposits of the Horseshoe Mountain area are described by Wedow, Gaskill, Peterson, Bannister, and Pattee (1973). The deposits are mainly gold- and silver-bearing pyritic quartz veins or silicified zones in Tertiary volcanic and intrusive rocks. No production is known.

SAMPLING AND ANALYTICAL PROGRAM

A geochemical sampling program was carried out by the U.S. Geological Survey group concurrently with the geologic mapping, and 2,043 samples was collected. Of these, 1,053 constituted rock samples, and 990, were stream-sediment samples. Some of the results of the sampling were summarized in preceding sections on Precambrian and Tertiary rocks, and some others are summarized in this section by means of geochemical maps, histograms, graphs, and tables.

Stream-sediment samples were collected from most tributaries to main drainages, and a few were collected from trunk streams. Most samples, as collected, weighed from 100 to 200 g (4 to 8 oz). All were dried and screened, and the minus-80-mesh fraction of each was analyzed for citrate-soluble heavy metals (mainly zinc and some copper, lead, and cobalt) by a colorimetric method and analyzed for gold by atomic absorption. Ten samples were analyzed for uranium and thorium by neutron activation. Semiquantitative spectrographic analyses of all samples were made for 30 elements; these elements, their chemical symbols, and the lower limit of detectability are given in table 6. The bulk composition of these samples as revealed by the spectrograph is presumed to be related to the gross composition of the parent rocks in the corresponding drainage basin, and the citrate-soluble heavy-metals content is a measure of the amount of these metals that has been dissolved in stream water and then adsorbed and concentrated on the surfaces of the mineral grains in the sampled material. Inasmuch as the fine-grained materials—clay, silt, and organic muck—are the most effective adsorbents, they were sought perferentially along all streams, and, indeed, the sample locality was determined in many places by the availability of these sediments. Along many of the steeply sloping drainages so typical of the Beartooth Mountains, however, the finest grained material obtainable was sand, and along a few torrential streams no material finer than gravel could be found.

Identification numbers of 16 stream-sediment samples were lost during analysis; localities for these samples are shown on plate 2, but no analytical data can be assigned to them. Nevertheless, only one of them (either sample 784, 785, or 786), from the east headwater creeks of Silver Run, contained unusual amounts of any element, 150 ppm (parts per million) copper and 15 ppm molybdenum. Sample numbers and drainage basins from which the samples were collected are as follows: Nos. 767-771 (West Red Lodge Creek); 781, 783, and 784-786 (Silver Run-West Fork Rock Creek); 782 (Ingles Creek-West Fork Rock Creek); 787-789 (Basin Creek-West Fork Rock Creek); and 797 and 789 (west of Sentinel Falls-West Fork Rock Creek).

TABLE 6.—*Lower limits of detectability of elements determined by the semiquantitative spectrographic method used in analyzing samples from the Beartooth Primitive Area and vicinity*

Element name and symbol	Lower limit of detectability	Element name and symbol	Lower limit of detectability
Percent		**Parts per million**	
Calcium (Ca)	0.05	Chromium (Cr)	10
Iron (Fe)	.05	Copper (Cu)	5
Magnesium (Mg)	.02	Lanthanum (La)	20
Titanium (Ti)	.002	Molybdenum (Mo)	5
		Niobium (Nb)	20
Parts per million			
		Nickel (Ni)	5
Manganese (Mn)	10	Lead (Pb)	10
Silver (Ag)	.5	Antimony (Sb)	100
Arsenic (As)	200	Scandium (Sc)	5
Gold (Au)	10	Tin (Sn)	10
Boron (B)	10		
		Strontium (Sr)	100
Barium (Ba)	20	Vanadium (V)	10
Beryllium (Be)	1	Tungsten (W)	50
Bismuth (Bi)	10	Yttrium (Y)	10
Cadmium (Cd)	20	Zinc (Zn)	200
Cobalt (Co)	5	Zirconium (Zr)	10

The density of stream-sediment sampling (the number of samples per unit area) depends to some extent on the nature of the drainage pattern. Thus, over much of the northeast flank of the mountains, stream courses are widely spaced, and sample density is relatively low, whereas on the southwest flank, in contrast, drainages are more closely spaced, and sample density is higher. The average density of all sampling is about 1 sample per 1.5 square kilometers, but density on the northeast flank is only about 1 sample per 2 square kilometers, whereas that on the southwest flank is about 1 sample per 1.1 square kilometers.

Rock samples made up 103 samples of visibly mineralized or otherwise altered rocks and 849 specimens of typical (apparently unaltered or unmineralized) rocks. Another 101 rock samples were collected for petrographic study only.

Samples of mineralized or altered rock were collected from outcrops wherever possible, but many, particularly those along plateau edges, consisted of loose rock chips. In every place the most heavily iron stained or otherwise most strongly altered material was selected. Samples weighed from 0.25 to 0.5 kg (0.5 to 1 lb). All were analyzed by atomic absorption for copper, gold, lead, silver, and zinc, by a colorimetric method for molybdenum, and spectrographically for 30 elements. In addition, 91 samples were analyzed for uranium and thorium by neutron activation, 12 samples were analyzed for uranium equivalent by the beta-gamma scanner method, and 2 samples were analyzed for uranium by a fluorimetric method.

Samples of typical rocks were collected in part to establish the minor-element "signature" of the Beartooth study area rocks; they consisted of 332 samples of gneiss, 97 samples of amphibolite, 343 samples of mafic dikes, 15 samples of biotite schist, 10 samples of other Precambrian rocks, and 52 samples of Tertiary felsic dikes. Most of these samples were analyzed only by semiquantitative spectroscopy; however, 11 samples of mafic and ultramafic rocks were analyzed quantitatively for platinum and palladium, and 4 samples of gneiss were analyzed for uranium and thorium by neutron activation.

All analytical data except those for uranium and thorium were stored on magnetic tape via an IBM 360 computer, and these data are available from the National Technical Information Service (Simons and others, 1973).

Several terms common to a discussion of geochemical data are used in this report, as follows: *Background* is the range of analytically determined amounts of a particular element or group of elements that is expectable or normal for 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 the threshold amounts of a given component are termed *anomalous.*

The threshold value may be established in several ways. For a symmetrically distributed sample population (either normal or lognormal), it is commonly taken to be the mean value plus two standard deviations (or the geometric mean multiplied by the square of the geometric deviation), and samples containing at least this amount thus constitute about 2.5 percent of the sample population. For mixtures of two or more geochemical populations, such as materials derived from a mineralized area of relatively small extent—an ore deposit—mixed with materials of background composition derived from a broad area (a situation of obvious interest in geochemical exploration), threshold values may be determined by plotting cumulative frequency curves on a lognormal probability graph. The method has been discussed by Lepeltier (1969), Ericksen, Wedow, Eaton, and Leland (1970, p. E51, E59-E60), and by Wedow, Gaskill, Peterson, Bannister, and Pattee (1973). In brief, if a set of geochemical data are distributed lognormally (as seems to be generally true), it will appear as a straight line on a lognormal probability plot. If two or more populations are represented in the set in highly disproportionate amounts, as in the example mentioned above, then the lognormal probability plot will show an inflection at a value above which the higher values of materials derived from mineralized rocks are no longer concealed by the lower values of background materials. The value at this inflection may be taken as a threshold value. An example of the use of these plots will be given in the next section.

RESULTS OF STREAM—SEDIMENT SAMPLING

For convenience in discussion, the stream-sediment samples are divided into 24 groups corresponding to the drainage basins from which they were collected. These basins are outlined, identified, and designated by letter in figure 15.

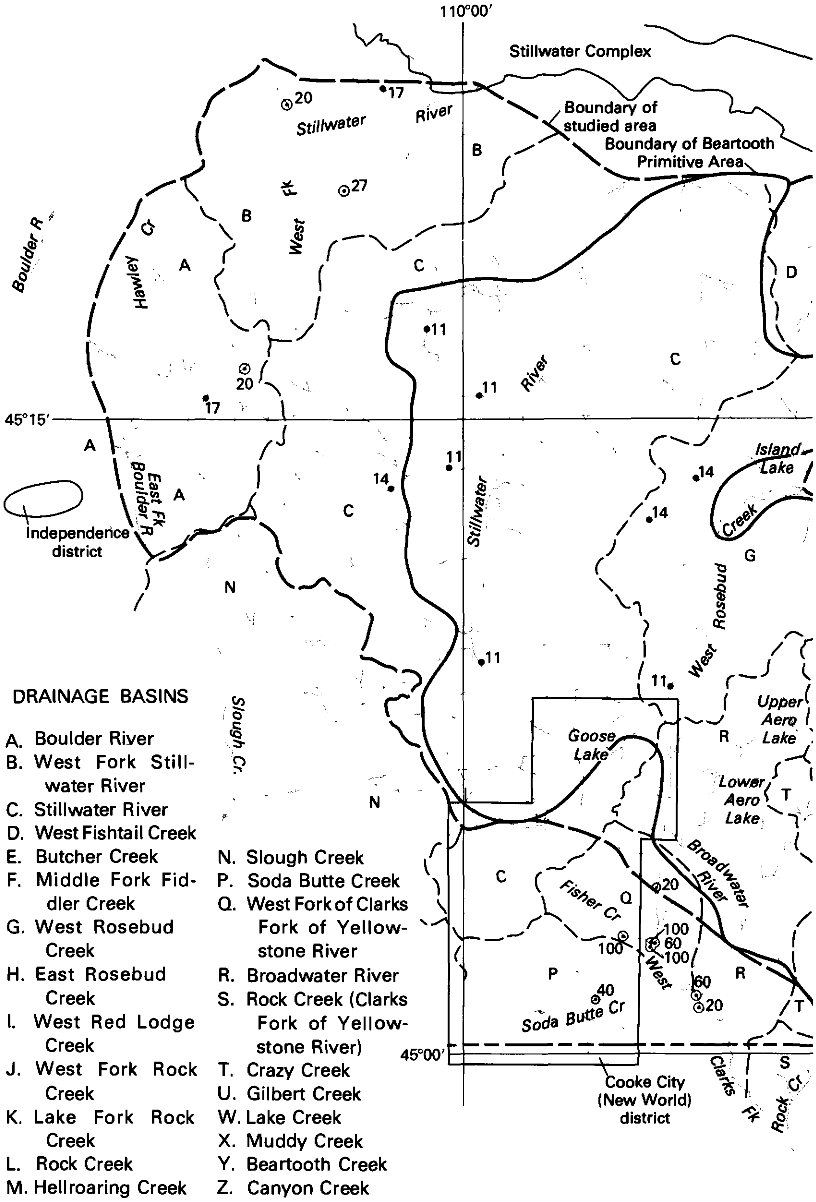
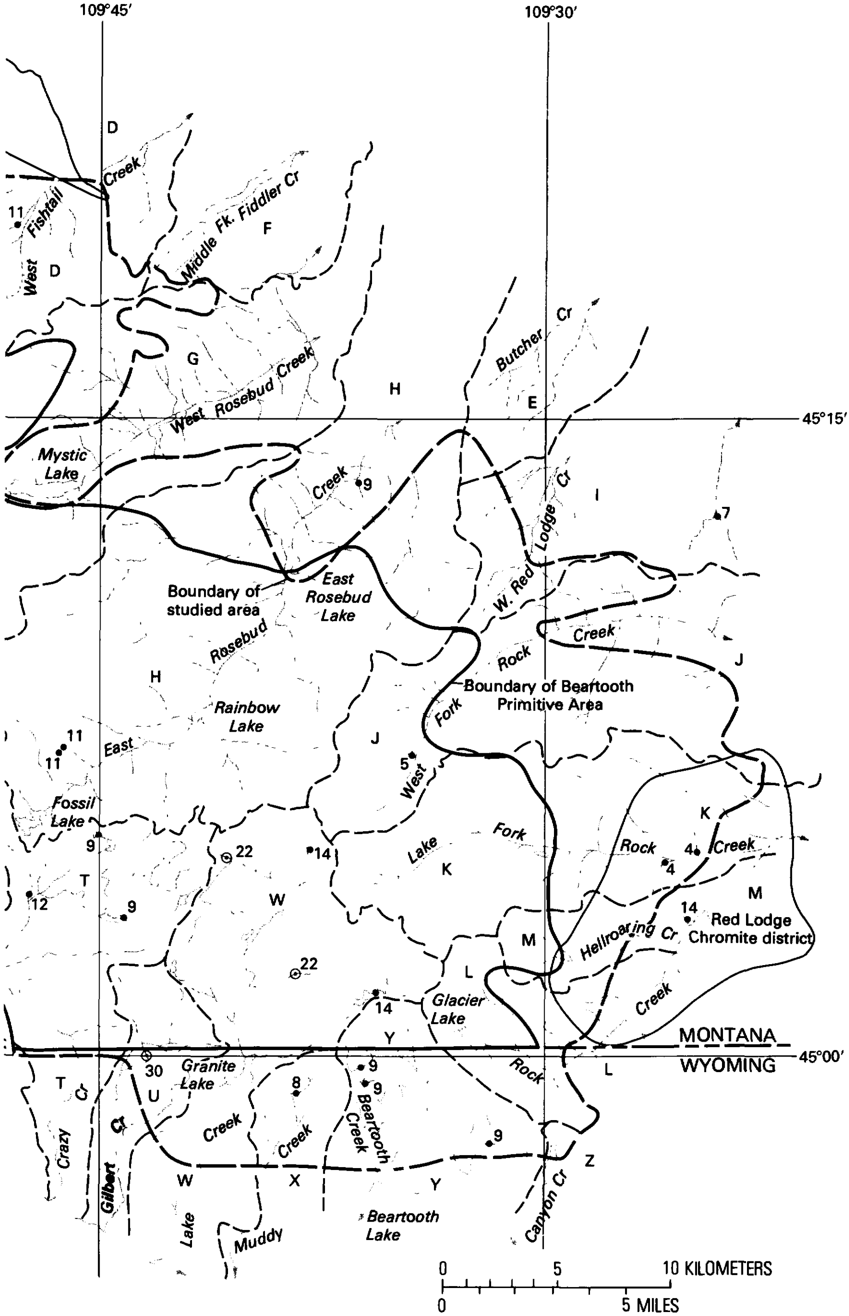


FIGURE 15.—Principal drainage basins and localities for stream-sediment samples (dots) Area and vicinity. Values are shown beside symbols.



containing more than threshold amounts of citrate-soluble heavy metals, Beartooth Primitive
Samples containing more than 18 ppm are circled (o).

Analyses for citrate-soluble heavy metals are statistically summarized in table 7. The upper limit values shown are approximately equal to the mean plus two standard deviations; this quantity was chosen arbitrarily as the threshold value. The total number of samples containing more than these amounts—that is, the anomalous samples—is 42, and the locations of these samples, together with their citrate-soluble heavy-metals content, appear on figure 15.

Table 7 shows that the mean citrate-soluble heavy-metals content of samples from different drainage basins apparently varies appreciably from 1.6 to 6.1 ppm; hence, the threshold varies from basin to basin.

If all stream-sediment samples are considered to have been derived from a virtually homogeneous terrane (and for most of the Beartooth samples this assumption seems to be valid), then the threshold citrate-soluble heavy-metals content for all samples, calculated in the same manner as for

TABLE 7.—*Citrate-soluble heavy-metals content of stream-sediment samples, by drainage basin*

[Leaders indicate not calculated]

Drainage basin	Number of samples	Mean (ppm)	Standard deviation (ppm)	Median (ppm)	Upper limit of background (threshold) (ppm)	Number of samples containing more than threshold amounts
A	51	5.4	3.5	6	12	2
B	52	6.1	4.4	6	15	3
C	152	4.6	2.9	5	10	5
D	15	4.2	2.9	5	10	1
E	3	3.0	...	...	...	[1]0
F	4	3.0	...	...	...	[1]0
G	71	3.8	2.9	3	10	3
H	123	2.3	1.6	2	6	3
I	19	2.6	1.5	3	6	1
J	52	2.3	.8	2	4	1
K	33	1.6	.8	2	3	2
L	30	2.9	2.7	3	8	1
M	14	2.0	1.1	3	4	0
N	32	2.6	1.2	3	5	0
P	1	40	...	...	...	1
Q	14	30	41	10	[2]10	5
R	59	4.9	8.1	5	[2]10	2
S	3	2.2	...	...	...	[1]0
T	74	3.6	2.2	4	8	3
U	20	5.3	6.4	5	[3]10	1
W	101	5.1	4.1	5	13	4
X	13	2.5	2.0	3	7	1
Y	63	3.4	2.4	3	8	3
Z	4	2.5	...	...	...	[1]0
All samples (excluding N)	971	4.3	6.9	4	18	14

[1] Highest value 5 ppm.
[2] Values range from 2 to 60 ppm; 10 ppm or more is arbitrarily considered to be above threshold.
[3] Values range from 2 to 30 ppm; 10 ppm or more is arbitrarily considered to be above threshold.

the individual drainage basins and without regard for any analytical bias, is 18 ppm. Only 14 samples contained more than this amount; these samples are identified separately in figure 15.

Histograms showing the content of 7 minor elements (cobalt, chromium, copper, lanthanum, nickel, lead, and vanadium) in 971 stream-sediment samples are given in figure 16. Medians were determined by locating the 50-percent point on a cumulative-frequency curve. The minor elements silver, molybdenum, niobium, tin, and tungsten were detected in only a few samples, and the minor elements arsenic, gold, bismuth, cadmium, antimony, and zinc were not detected in any sample. Beryllium was detected in 619 samples but in 533 of them was present only at the detection limit, 1 ppm. Boron was detected in 501 samples, of which 426 contained only 10

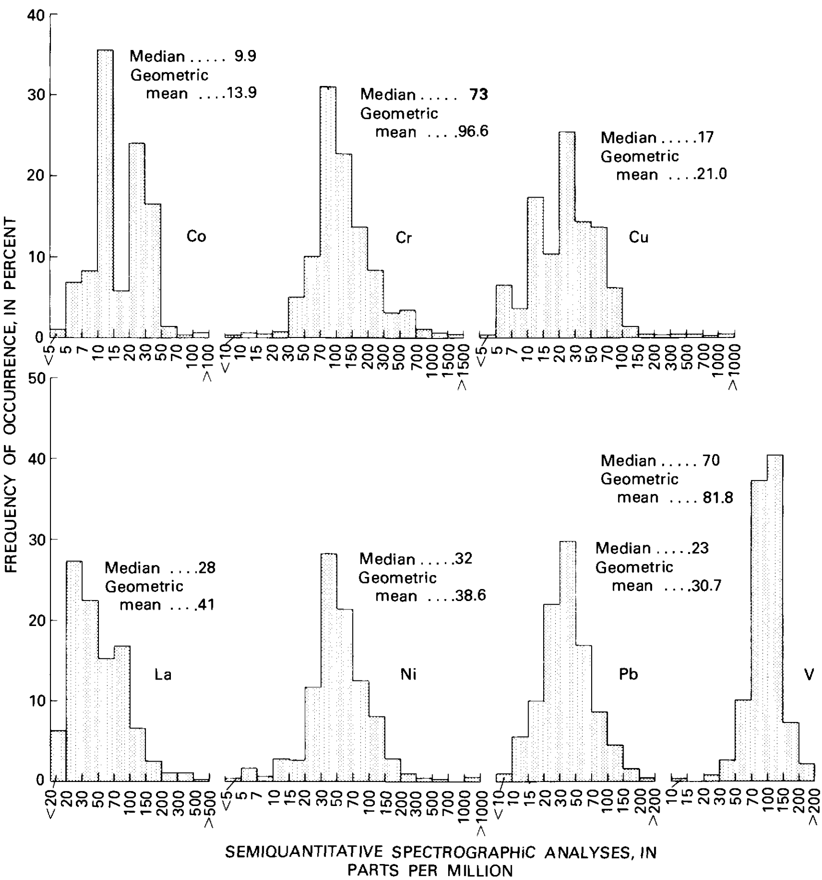


FIGURE 16.—Histograms showing content of 7 minor elements (cobalt, chromium, copper, lanthanum, nickel, lead, and vanadium) in 971 stream-sediment samples, Beartooth Primitive Area and vicinity.

ppm, the limit of detection. The remaining minor elements barium, scandium, strontium, yttrium, and zirconium and the major elements calcium, iron, magnesium, manganese, and titanium are not deemed to be significant for evaluation of the mineral potential of the Beartooth study area and are not further considered.

Analytical data on the cobalt, chromium, copper, nickel, and lead content of stream-sediment samples and of common rock types in the Beartooth study area are summarized in tables 8 and 9 and in figure 17. Figure 17 shows clearly that the contents of nickel and chromium vary sympathetically in

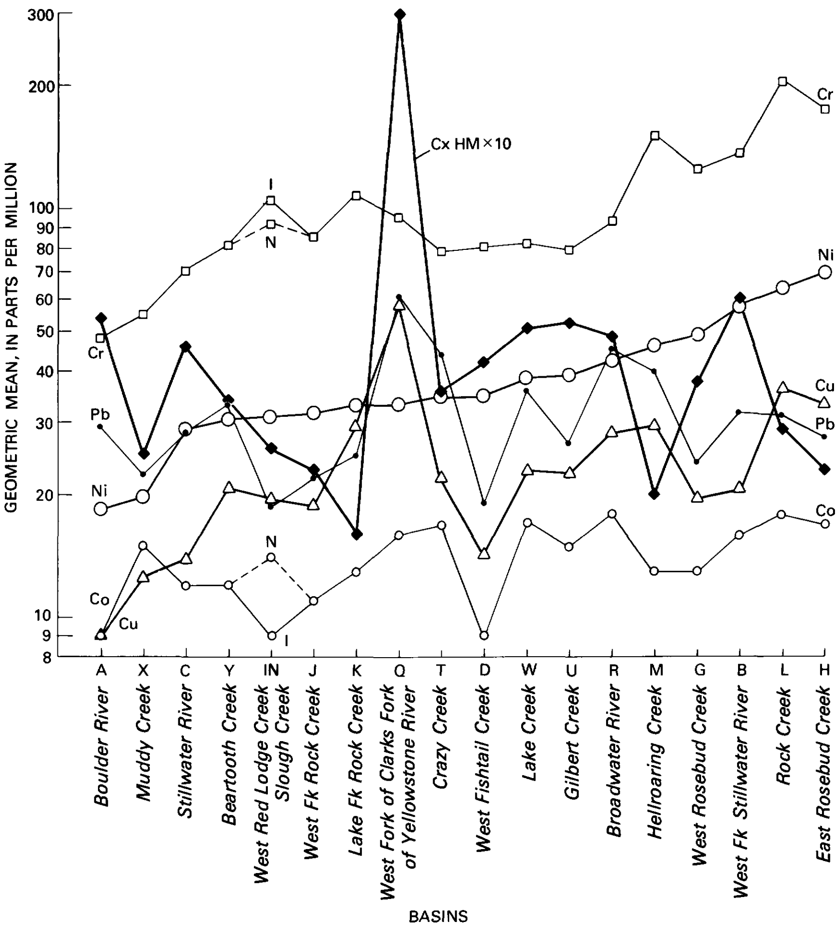


FIGURE 17.—Semilog graph showing geometric means of cobalt, chromium, copper, nickel, and lead, and arithmetic means of citrate-soluble heavy metals, in stream-sediment samples, Beartooth Primitive area and vicinity, plotted by drainage basin. CxHM content shown is 10 times actual content. Basins are arranged from left to right in order of increasing nickel content of average samples.

TABLE 8.— *Semiquantitative spectrographic analyses, in parts per million, of cobalt, chromium, copper, nickel, and lead in stream-sediment samples, by drainage basin*

Drainage basin (fig. 5)	No. of samples	Cobalt			Chromium			Copper			Nickel			Lead		
		Geometric mean	Geometric deviation	Median	Geometric mean	Geometric deviation	Median	Geometric mean	Geometric deviation	Median	Geometric mean	Geometric deviation	Median	Geometric mean	Geometric deviation	Median
A	51	9	1.4	8	48	1.7	50	9	1.4	7	19	1.6	15	29	1.5	25
B	52	16	2.3	10	138	2.7	100	21	3.1	15	59	3.3	50	32	2.0	25
C	152	12	1.6	10	70	1.7	60	14	2.0	10	29	1.9	25	28	1.7	20
D	15	9	1.4	7	81	2.5	70	14	1.6	10	35	1.7	30	19	1.4	15
E 1/	3	8	--------	------	113	---------	------	23	---------	------	30	---------	------	23	---------	------
F 1/	4	30	--------	------	65	---------	------	17	---------	------	22	---------	------	26	---------	------
G	71	13	1.6	10	126	2.2	100	20	2.6	15	49	1.8	50	27	1.8	20
H	123	17	1.5	15	177	1.7	150	33	1.8	30	70	1.7	70	28	2.1	20
I	19	9	1.9	7	105	2.0	70	20	2.0	15	31	1.7	25	19	1.8	15
J	52	11	1.8	8	86	1.8	70	19	2.6	15	32	1.8	30	22	1.6	20
K	33	13	1.8	10	109	1.6	100	29	2.1	20	33	1.5	30	25	1.8	20
L	30	18	1.7	15	206	2.3	150	37	1.8	30	64	1.8	50	31	1.8	25
M	14	13	1.9	10	152	2.7	150	30	1.8	30	47	2.6	50	40	1.7	30
N 1/	32	14	11.0	10	91	71	70	20	24	10	31	24	20	---------	---------	------
P	1	30	--------	------	150	---------	------	500	---------	------	70	---------	------	150	---------	------
Q	14	16	1.6	15	96	1.4	70	58	5.7	20	33	1.5	30	61	1.9	60
R	59	18	1.7	20	94	1.5	70	28	2.4	20	43	1.8	40	45	1.7	30
S 1/	3	16	--------	------	147	---------	------	42	---------	------	60	---------	------	26	---------	------
T	74	17	1.7	15	79	1.5	70	22	1.5	20	35	1.7	30	44	1.7	30
U	20	15	1.9	15	80	1.9	70	22	2.0	20	39	2.3	30	27	1.5	20
W	101	17	1.7	15	82	1.5	70	23	1.7	20	39	1.8	30	36	1.8	30
X	13	15	1.9	15	55	2.2	60	12	1.8	10	20	2.4	20	22	1.5	20
Y	63	12	1.7	10	82	1.5	70	21	1.6	20	31	2.0	30	33	1.8	25
Z 1/	4	25	--------	------	112	---------	------	21	---------	------	67	---------	------	30	---------	------
All samples (excluding N)	971	14	1.8	10	97	2.0	75	21	2.3	17	39	2.1	30	31	1.8	23

1/ Arithmetic mean and standard deviation.

TABLE 9.—*Cobalt, chromium, copper, nickel, and lead content of granitic gneisses, amphibolites, and mafic dikes in the Beartooth Primitive Area and vicinity*

[Results of semiquantitative spectrographic analyses were calculated for geometric means and are given in parts per million]

Rock type	Co	Cr	Cu	Ni	Pb
Granitic gneiss	10	(1)	15	10	25
Amphibolite	30	225	40	80	10
Mafic dikes	50	200	85	80	(1)

[1]Insufficient observations to calculate mean; median is about 10 ppm.

sediment samples and that both are within ranges expectable in sediments derived from a terrane containing abundant amphibolites and mafic dikes. Copper shows a more erratic variation, but it is much like chromium, except for the samples from Fisher Creek (basin Q); this creek drains much of the mineralized area of the Cooke City mining district, and its basin lies entirely outside the Beartooth study area. The copper values in general also reflect the copper content of the source rocks. Cobalt varies much like copper except in samples from basin Q. Lead content, for the most part, varies similarly to copper from basin to basin; however, it seems to be concentrated slightly in the sediment samples as compared with the source rocks. Citrate-soluble heavy metals show a distinctly different variation pattern, but—except in samples from basin Q—the variation is within fairly narrow limits, about 2 to 6 ppm. In summary (1) the presence of copper-lead-zinc deposits along Fisher Creek (basin Q) is clearly reflected by the relatively high content of copper, lead, and citrate-soluble heavy metals of stream sediments from that basin; (2) sediment samples from other major drainage basins contain, on the average, only about one-half as much copper and lead as do those from basin Q and much less than one-half as much citrate-soluble heavy metals; and (3) the contents of cobalt, chromium, and nickel are consistently within the range expectable in sediments derived from Beartooth source rocks, and the contents of copper and lead are, in general, also within the expectable range.

Gold was detected in 19 stream-sediment samples in amounts ranging from 0.02 to 3 ppm. Localities for these samples are shown in figure 18. All samples containing >1 ppm of gold are from Fisher Creek or from the West Fork Clarks Fork of the Yellowstone River just below the confluence with Fisher Creek. The only other samples containing >0.5 ppm of gold are from the inlet of Farley Lake (1 ppm) and from a west-flowing tributary of East Rosebud Creek 0.6 km (0.4 mi) south of the inlet of East Rosebud Lake (0.65 ppm). Five other samples contain 0.20 ppm or more, and the nine remaining contain <0.20 ppm.

Silver in amounts of more than 0.5 ppm was found in 75 stream-sediment samples; localities for these samples are shown in figure 19. Only 16 samples contain >1 ppm; 2 samples contain 7 ppm, and 1 sample contains 15 ppm. The samples high in silver clearly are concentrated in the upper parts of drainage basins southwest of the Beartooth crest, mainly in Lake Creek and Crazy Creek drainage basins.

The distribution of copper in stream-sediment samples is shown by a cumulative frequency curve in figure 20, and curves for cobalt, chromium, nickel, and lead are shown for comparison. The copper curve shows a distinct bend between 70 ppm and 100 ppm, and the value of 70 ppm is the threshold selected for copper; copper contents in excess of 70 ppm are considered anomalous, and the corresponding sample localities are shown in figure 21. The nickel curve shows a similar but less pronounced bend between 150 and 200 ppm, and the curve for cobalt shows a bend between 30 and 50 ppm. The curve for chromium shows several bends that are only minor, and the lead curve is virtually a straight line.

All samples containing 500 ppm or more of copper are from streams draining either the Cooke City mining district (Fisher and Miller Creeks and the Clarks Fork Yellowstone River) or areas underlain in part by the Stillwater Complex (Crescent Creek). All the samples containing 1,000 ppm nickel, and all but one containing 100 ppm cobalt, are from Crescent Creek. The only other sample containing as much as 500 ppm nickel is from a stream draining an area on Hellroaring Plateau that contains some small chromite deposits. The only other sample containing 100 ppm cobalt is from East Fork Fiddler Creek; only the uppermost part of this drainage is within the Beartooth study area, and the known geology gives no clue to a possible source for the cobalt.

The degree of association of copper, cobalt, and nickel is summarized in table 10. The samples highest in nickel (samples 33, 34, 35; 1,000 ppm) also contain the maximum determined cobalt content (100 ppm) and at least 300 ppm of copper. These samples are all from Crescent Creek.

Lead in amounts of more than 100 ppm was detected in 18 stream-sediment samples (fig. 22). Of these samples, three also contain >70 ppm of

TABLE 10.—*Degree of association of copper, cobalt, and nickel in stream-sediment samples*

Metal content of anomalous samples	Number of samples	Number of samples anomalous for nickel or cobalt that are also anomalous copper	Number of samples anomalous for both nickel and cobalt	Number of samples anomalous for all three elements
>70 ppm copper	29	0	0	5 (17 percent)
>30 ppm cobalt	19	7 (37 percent)	6 (32 percent)	5 (26 percent)
>150 ppm nickel	15	5 (33 percent)	6 (40 percent)	5 (33 percent)

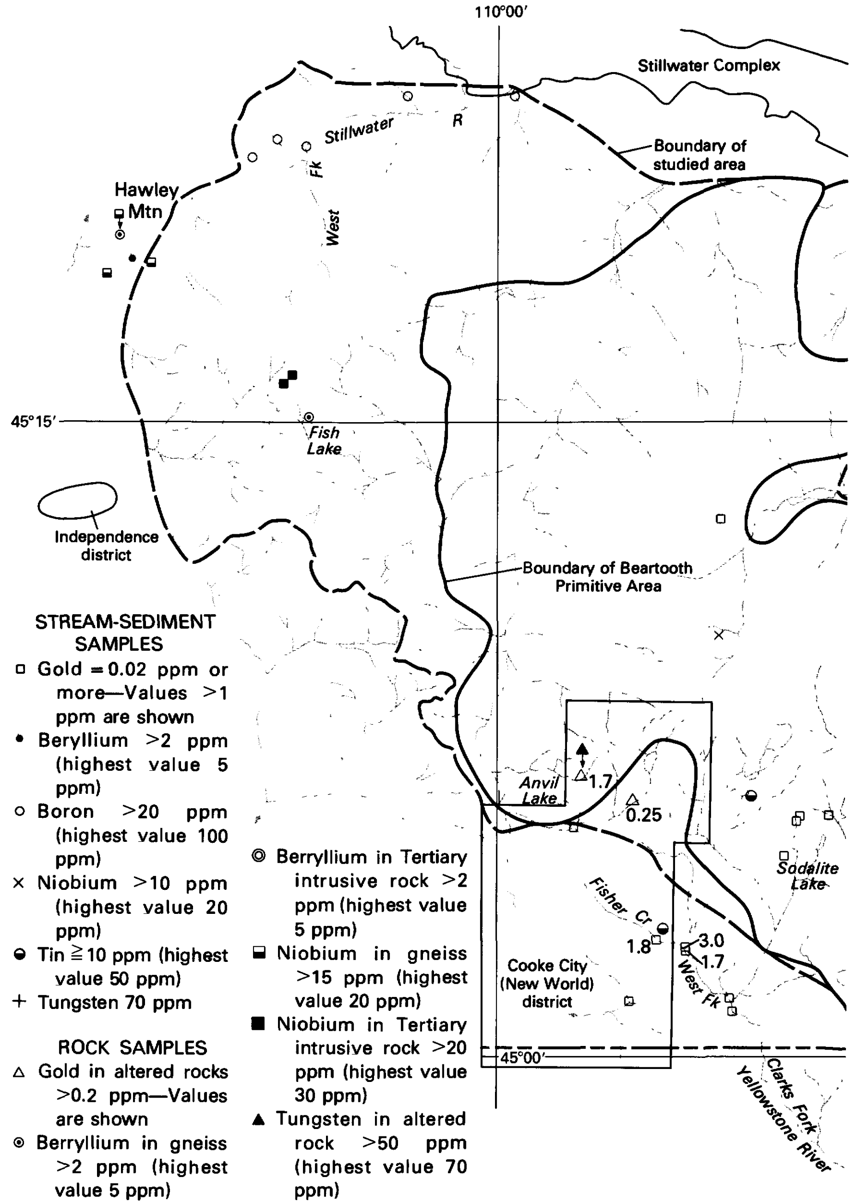
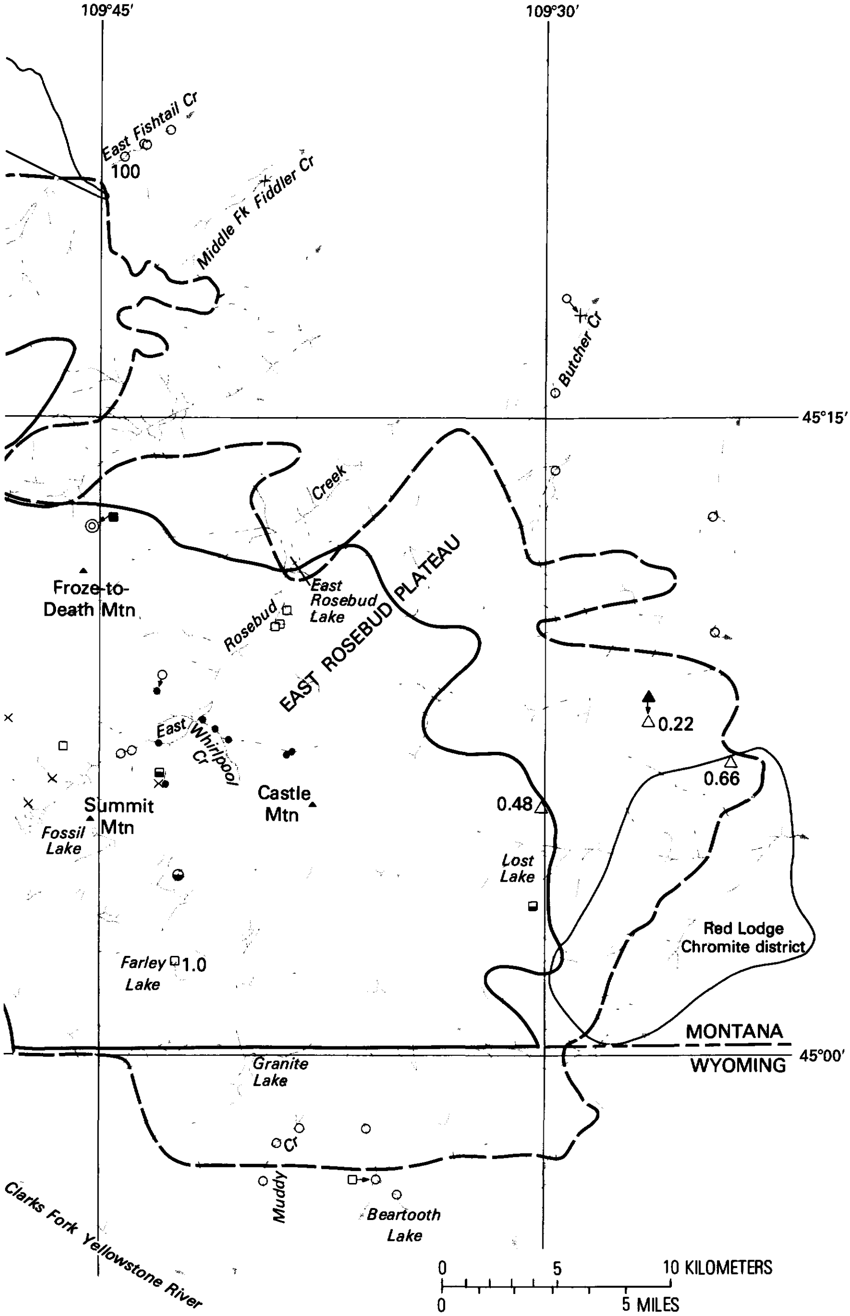


FIGURE 18.—Localities for stream-sediment and rock samples that contain gold, beryllium,



boron, niobium, tin, and tungsten in the Beartooth Primitive Area and vicinity.

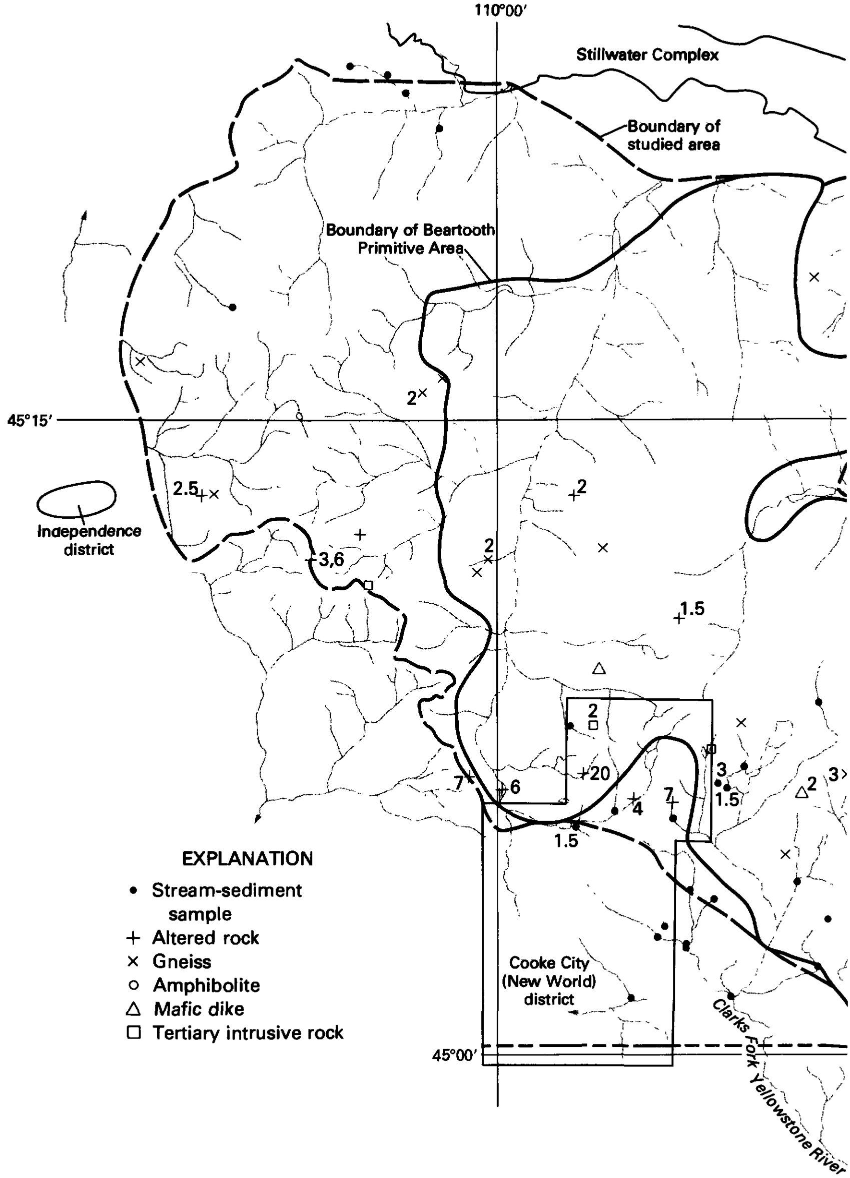
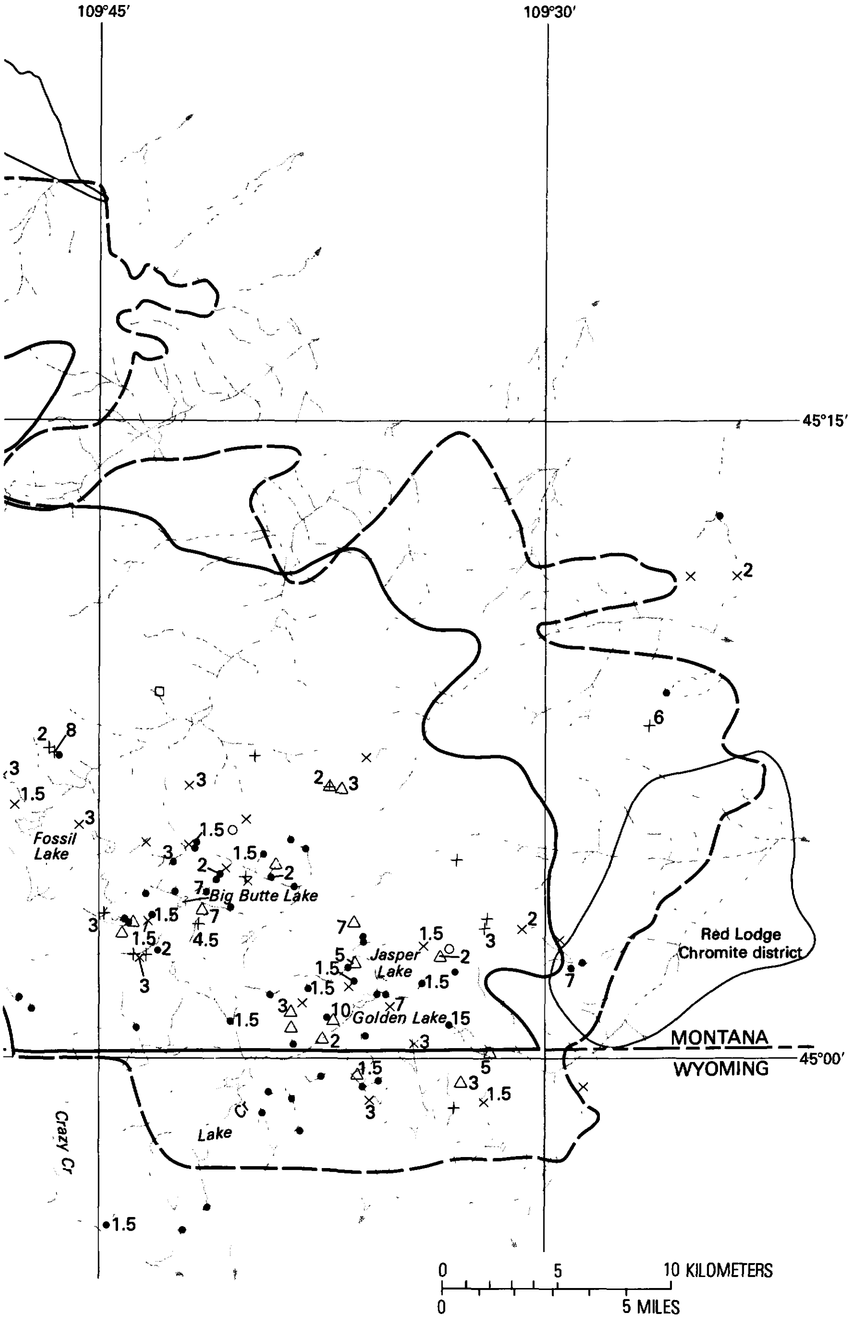


FIGURE 19.—Localities for stream-sediment and rock samples that



contain for >0.5 ppm silver, Beartooth Primitive Area and vicinity.

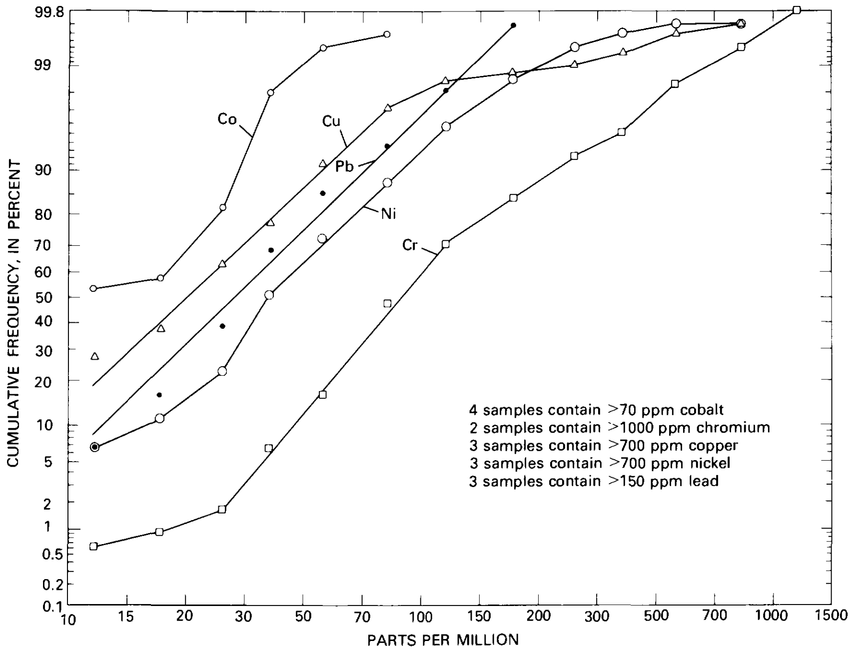


FIGURE 20.—Lognormal probability plot showing cumulative frequency distribution of cobalt, chromium, copper, nickel, and lead in 971 stream-sediment samples.

copper, three contain >0.5 ppm of silver, and four contain 5 ppm or more of molybdenum. Only three samples contain as much as 200 ppm of lead.

Molybdenum in amounts of 5 ppm or more was detected in 43 samples; localities for these samples are shown in figure 23. Of these eight contained at least 15 ppm, and the highest value found was 30 ppm. Fourteen samples, or 33 percent of the total, also contained at least 100 ppm of copper. In addition to the usual cluster of high values in sediments from streams draining the Cooke City mining district, clusters occur in the east headwater drainage area of Crazy Creek (basin T) and along Whirlpool Creek (East Rosebud Creek drainage, basin H). No unusual amounts of molybdenum were detected in any rocks of these basins.

Beryllium was detected in amounts of more than 2 ppm in nine samples; localities for these samples are shown in figure 18. The highest measured value was 5 ppm. All but one of these samples came from the headwaters of East Rosebud Creek, five of them from Whirlpool Creek. Beryllium-bearing pegmatites thus may occur somewhere in this region, particularly along the north side of the Beartooth crest between Summit and Castle Mountains, but none was recognized.

Boron was detected in about half the analyzed stream sediments, mostly in amounts at or just above the lower detection limit of 10 ppm. Most of the boron presumably is in tourmaline, a complex borosilicate that occurs commonly in certain high-temperature mineral deposits and in pegmatites (Boyle, 1971). Boron was found in amounts greater than 20 ppm in 22 stream-sediment samples; localities for these samples are shown in figure 18. The highest boron content found, 100 ppm, was in sample 336, collected near the head of East Fishtail Creek. Samples anomalous in boron are conspicuously absent from most of the central part of the Beartooth study area and are concentrated to some extent along lower West Fork Stillwater River, East Fishtail Creek, Muddy Creek, and creeks entering Beartooth Lake. The distribution of boron as reflected by these samples does not seem to be related to that of any other element of interest.

Niobium was detected in six samples in amounts of more than 10 ppm; localities for these samples are shown in figure 18. The highest value determined was 20 ppm. All but one sample came from the headwaters of East Rosebud Creek, but only one of them also contained more than 2 ppm beryllium. Niobium-bearing pegmatites or other rocks may possibly be present in the general vicinity of Fossil Lake, but none was found. Only one of the five gneiss samples containing as much as 20 ppm niobium is from this area.

Tin was detected in only three samples, in amounts of 20 ppm (two samples) and 50 ppm. Sample localities are shown in figure 18. The sample containing 50 ppm (No. 1059) is from a small creek in an area that has some abandoned cabins and, thus, may be contaminated.

Tungsten (70 ppm) was detected in only two samples (fig. 18). The localities of both samples, on Middle Fork Fiddler Creek and on Butcher Creek, are several miles northeast of the Beartooth study area boundary.

Ten samples of sediment from streams that drain areas along the west edge of the study area contain known or suspected deposits of radioactive minerals. These samples were analyzed for uranium and thorium, and the results appear in table 11. The highest uranium contents are in samples from the mouth of Ruby Creek (126 ppm), from Hawley Creek (76 ppm), and from the mouth of a creek just south of Upsidedown Creek (41 ppm). All these localities are outside the Beartooth study area. These and other areas of anomalous radioactivity near the west side of the study area have been studied by J. E. Elliott of the U.S. Geological Survey (oral commun., 1975).

RESULTS OF ROCK SAMPLING

Two general groups of rocks were sampled—mineralized or otherwise altered rocks and rocks typical of the Beartooth study area. Spectrographic data on many elements in rocks have been summarized in preceding sections,

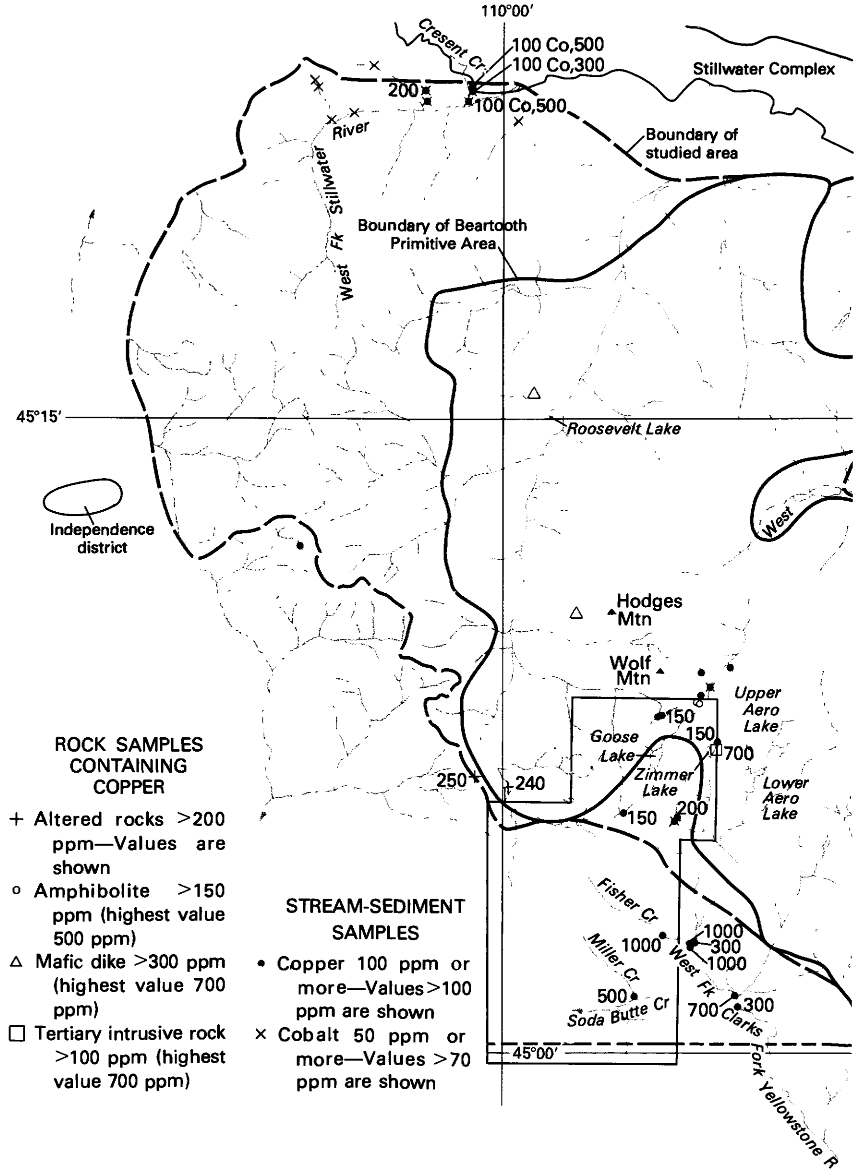
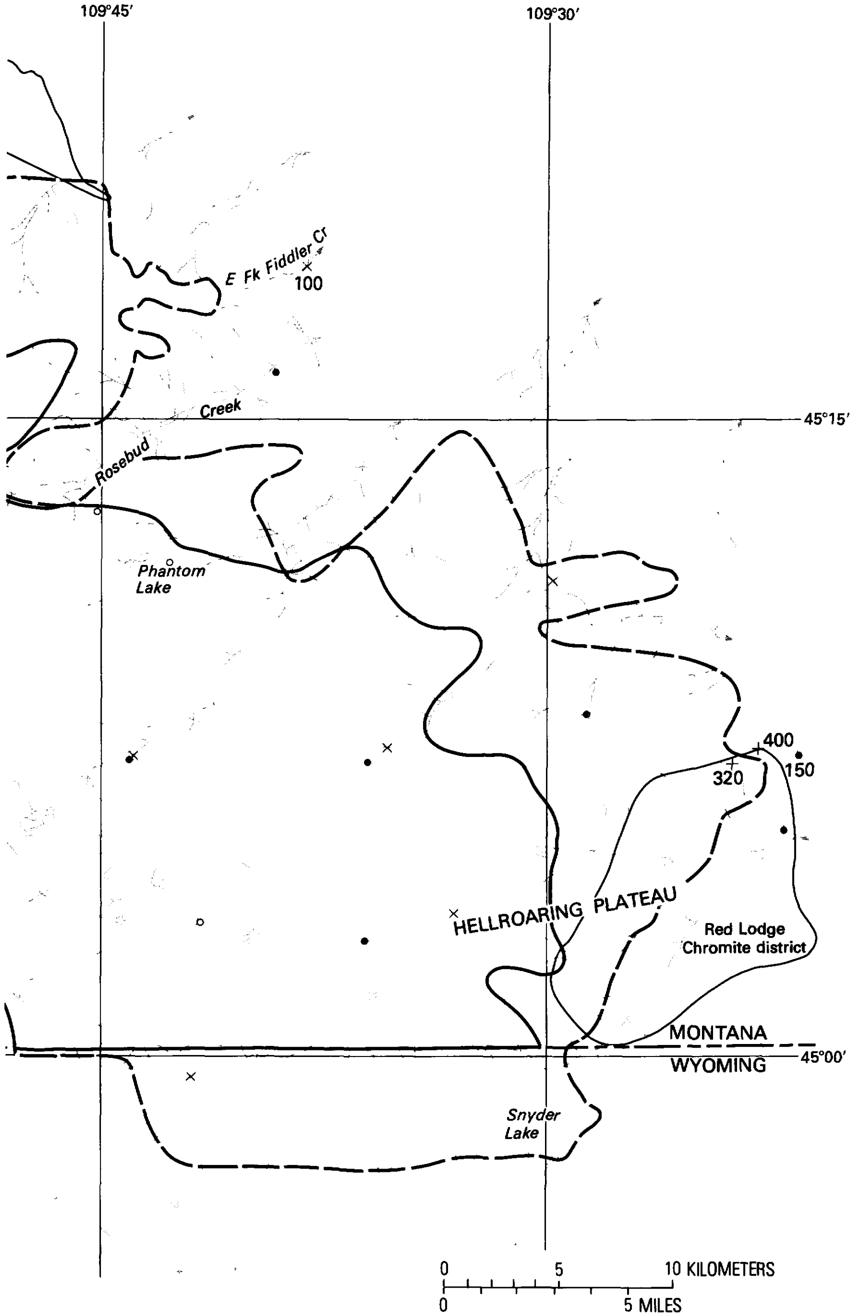


FIGURE 21.—Localities for stream-sediment and rock samples that



contain copper and cobalt, Beartooth Primitive Area and vicinity.

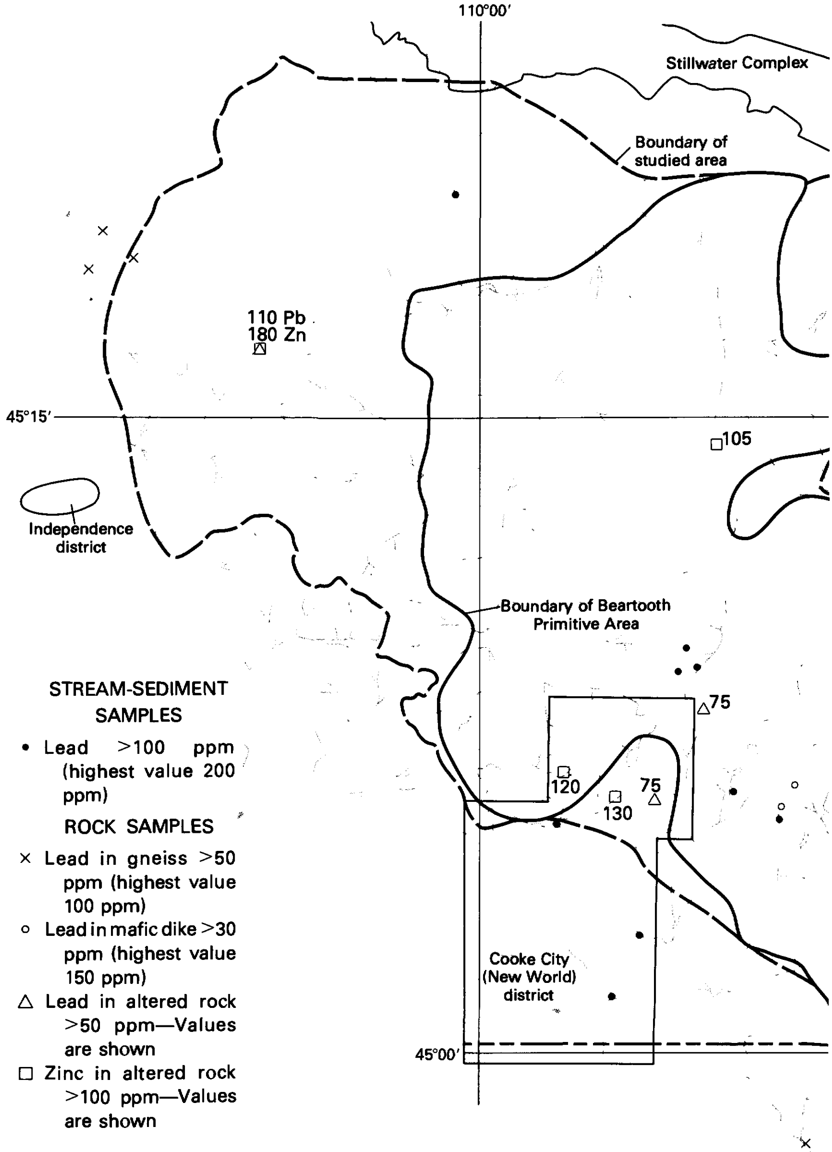
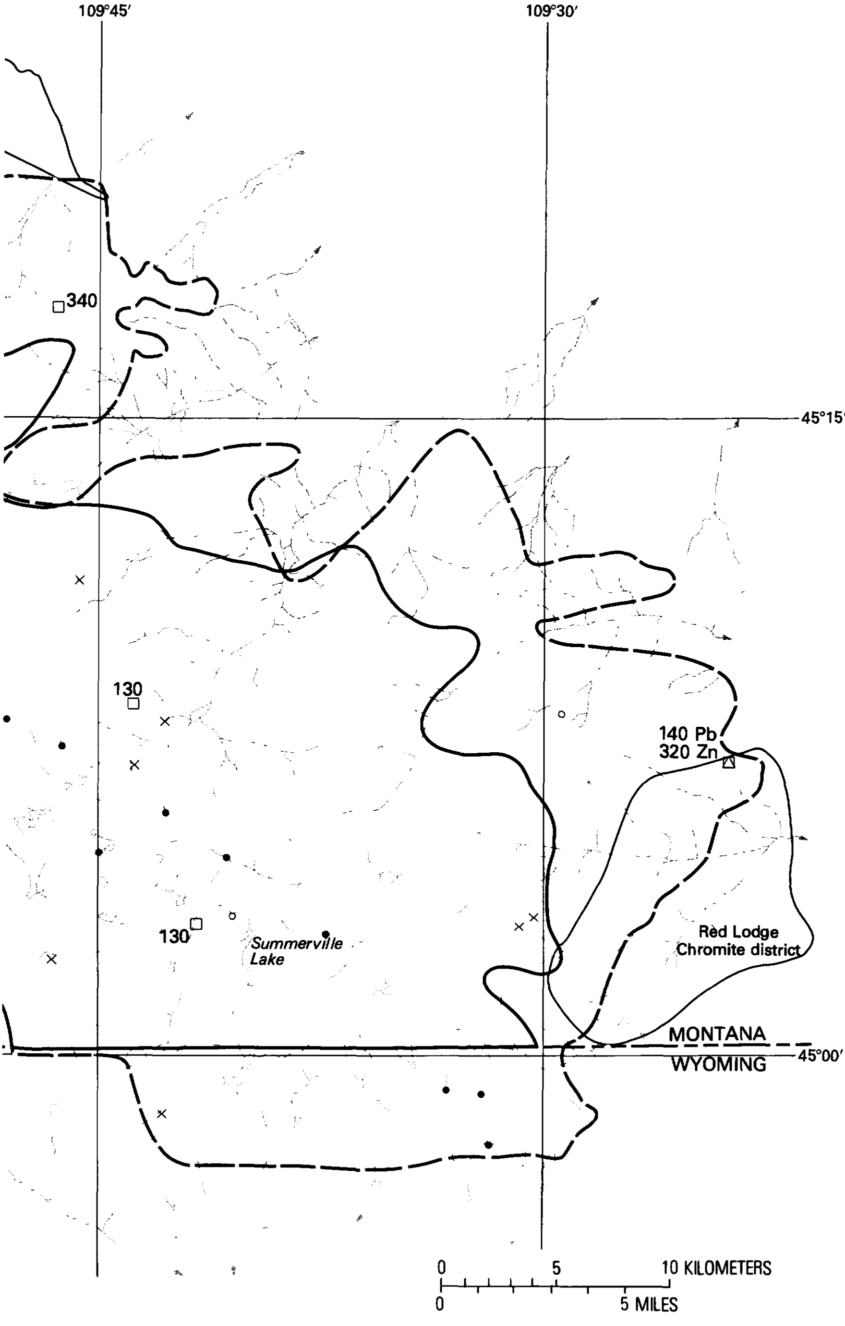


FIGURE 22.—Localities for stream-sediment and rock samples



that contain lead and zinc, Beartooth Primitive Area and vicinity.

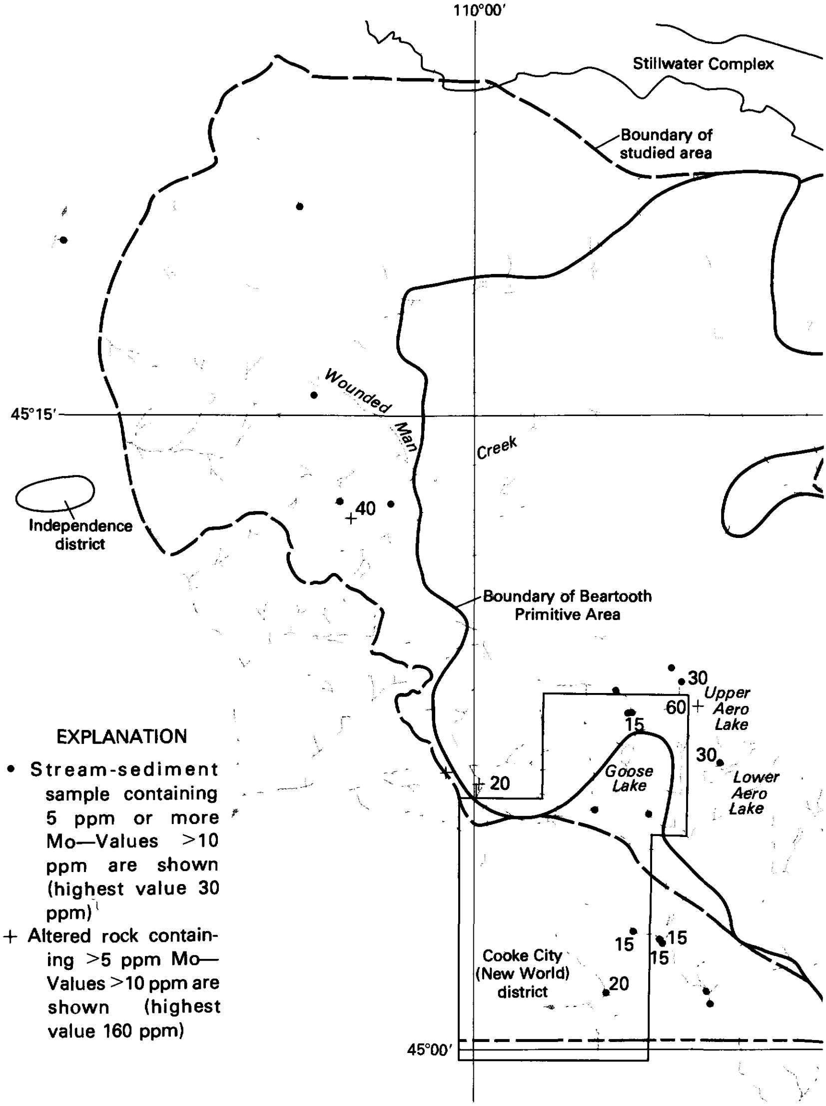
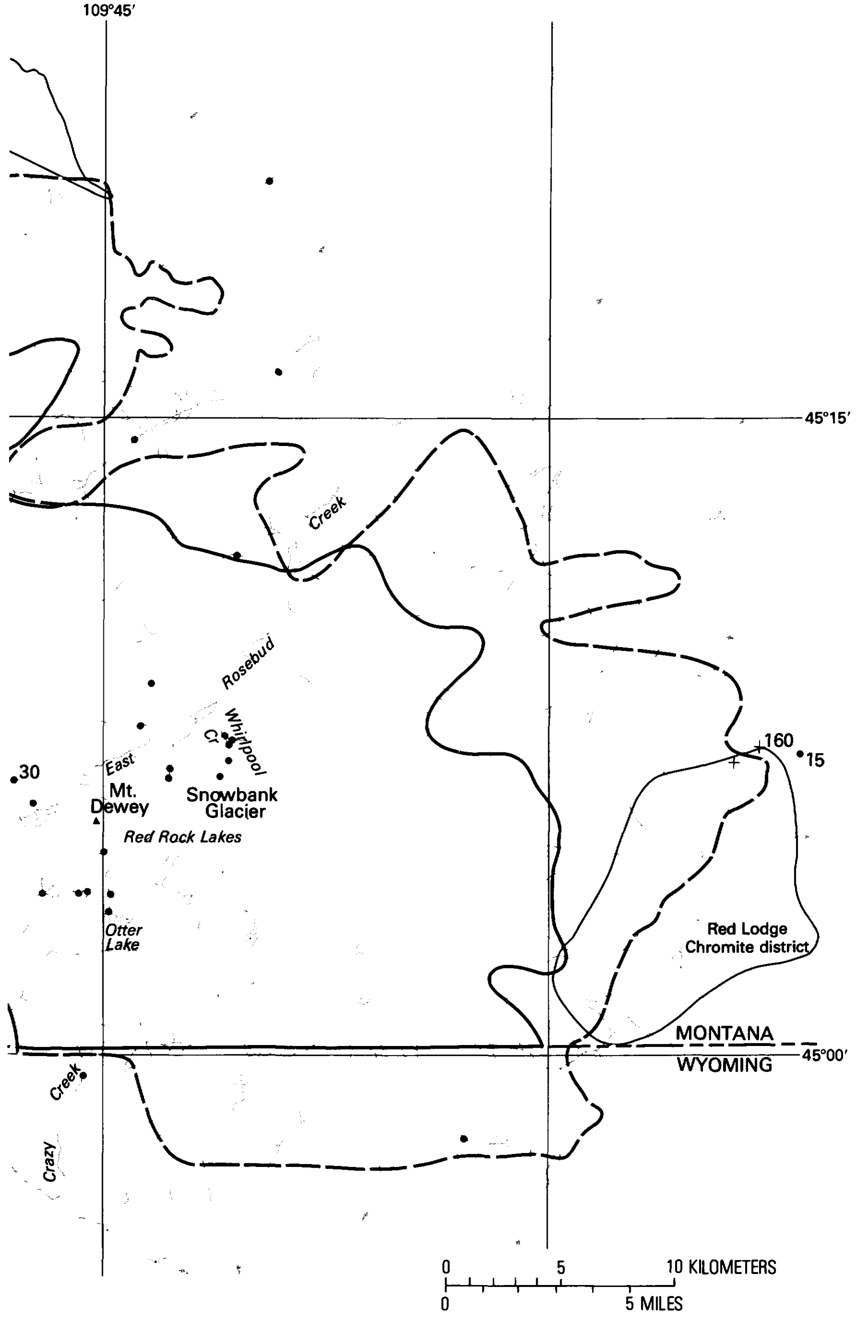


FIGURE 23.—Localities for stream-sediment and rock samples



that contain molybdenum, Beartooth Primitive Area and vicinity.

TABLE 11.—*Uranium and thorium contents of stream-sediment and rock samples from the west side of the Beartooth Primitive Area and vicinity*

[Neutron activation analyses by H. T. Millard and D. A. Bickford. Data are in parts per million]

Sample No.	Uranium	Thorium
Stream-sediment samples		
112	2	9
113	18	11
148	24	29
149	126	13
152	22	30
153	41	15
154	3	8
729	76	58
730	4	18
731	25	30
Rock samples		
1034	8	60
1930	12	106
1939	23	112
1940	14	110

and only those elements particularly pertinent to mineral evaluation will be considered in this section. Threshold amounts for selected elements are listed in table 12, and localities of all samples containing more than these amounts of beryllium, copper, gold, lead, molybdenum, niobium, silver, and zinc are shown in figures 18, 19, 21, 22, and 23.

SAMPLING OF MINERALIZED OR ALTERED ROCKS

Sample localities of 103 mineralized or altered rocks are designated separately on plate 2. All chemical analytical data on these rocks, except those for uranium and thorium, together with spectrographic analytical data on silver, barium, cobalt, chromium, lanthanum, manganese, nickel, lead, strontium, and vanadium, are given in table 13. The elements beryllium, boron, bismuth, molybdenum, niobium, tin, tungsten, and zinc were detected spectrographically in only a few samples; data for these elements are given in table 14. Arsenic, gold, cadmium, and antimony were not detected spectrographically in any sample. Uranium and thorium were determined for 91 samples, and uranium equivalent was determined for 12 samples; results are given in table 15. Other elements are not deemed significant for mineral evaluation.

TABLE 12.—*Threshold values for selected elements in rocks of the Beartooth Primitive Area and vicinity*

[Data are in parts per million. Spectrographic data except where noted. Threshold for spectrographic data equals approximately the geometric mean multiplied by the square of the geometric deviation, reduced to the nearest value reported in spectrographic analysis. Number of samples containing more than the threshold amount is given in parentheses. n.d., not detected in any sample]

Element	Threshold value				
	Altered rock[1]	Gneiss	Amphibolite	Mafic dikes	Tertiary intrusive rocks
Ag	0.5(25)	[2]0.5(34)	....(2)	....(18)	....(4)
Au	.2(5)	n.d.	n.d.	n.d.	n.d.
Be	....	[2]2(2)	....(0)	....(0)	....(1)
Co	....	30(5)	70(3)	100(1)	20(1)
Cr	....	[3]70(27)	1,500(3)	1,500(6)	[3]70(9)
Cu	200(4)	100(0)	150(5)	300(2)	150(1)
La	....	[3]100(9)	[3]100(1)	[3]70(2)	[3]50(0)
Mo	5(6)	n.d.	n.d.	n.d.	n.d.
Nb	....	[3]15(5)	n.d.	n.d.	20(3)
Ni	....	70(17)	500(5)	300(12)	70(2)
Pb	50(4)	50(11)	[3]30(0)	[3]50(4)	70(1)
V	....	200(0)	300(4)	500(1)	200(0)
Zn	100(8)	n.d.	n.d.	n.d.	n.d.

[1]Chemical analyses; all threshold values are arbitrary.
[2]Arbitrary value for all groups of rocks; insufficient observations.
[3]Arbitrary value for this group of rocks; insufficient observations.

SAMPLING OF APPARENTLY TYPICAL UNALTERED ROCKS

Results of spectrographic analyses of 849 samples of typical Beartooth rocks, other than those data summarized in the section on geology, will be discussed briefly. Among the elements of interest in geochemical exploration, beryllium, chromium, cobalt, copper, lanthanum, lead, nickel, niobium, silver, and vanadium were detected in many samples. Threshold values for these elements in dominant rock types of the Beartooth area were given in table 12 and mean contents of most of them were given in tables 2, 4, and 5. Boron was detected in only five samples and tin in only one. Antimony, arsenic, bismuth, cadmium, gold, molybdenum, tungsten, and zinc were not detected in any sample (the very poor spectrographic sensitivity for antimony, arsenic, gold, and zinc virtually precludes their detection in ordinary rocks (table 6)). Four samples of gneiss were analyzed for uranium and thorium, and the results appear in table 10.

Beryllium occurs in amounts greater than threshold in only three rocks: gneiss near Fish Lake (sample 92, 5 ppm), gneiss 1.4 km (0.9 mi) southwest of Hawley Mountain (sample 1940, 3 ppm), and a Tertiary latite porphyry dike 9-12 m (30-40 ft) thick that is exposed 2 km (1.2 mi) north of Froze-to-Death Mountain (sample 913, 5 ppm) (fig. 18). None of these beryllium contents differs notably from those summarized by Parker (1967, p. D13) for similar rocks.

TABLE 13.—*Semiquantitative spectrographic analyses and chemical analyses of selected elements in 103 samples of mineralized or altered rocks, Beartooth Primitive Area and vicinity*

[Data are given in parts per million. N, not detected; L, detected but below limit of determination; G, greater than; S, semiquantitative spectrographic analyses; A, atomic adsorption; C, colorimetric test]

SAMPLE	S-MN	S-AG	S-BA	S-CO	S-CR	S-CU	S-LA	S-NI	S-PB	S-SR	S-V	A-AU	A-CU	A-PB	A-ZN	A-AS	C-MO
0029	50	0.5 N	20 L	10	10 L	5	20 N	5	10 N	100 N	10	0.05 N	5	20	5	0.5 N	4
0031	150	0.5 N	50	5	50	5	20 N	20	15	100 N	20	0.05 N	5	25	50	0.5 N	4
0073	20	0.5 N	100	5	10 L	5	20 N	5	10 N	100	10	0.05 N	5 L	5 N	5	0.5 N	4 L
0076	100	0.5 N	1000	5	20	5	20	10	20	100	70	0.05 N	5	10	20	0.5 N	4 L
0094	70	0.5 N	500	5	10 L	5	20	5	20	100	15	0.05 N	5 L	10	15	0.5 N	4 L
0096A	150	0.5 N	500	5	10 L	5	70	7	20	100	10	0.05 N	5	30	30	0.5 N	4 L
0096B	100	0.5 N	200	5	10 L	5	20 N	5	30	100 N	5	0.05 N	5 L	15	30	0.5 N	4 L
0118	70	0.5 L	300	5	10 L	10	20 N	5	15	100 N	5	0.10	15	15	10	0.5 N	4 L
0121	1500	0.5 N	100	50	300	15	20	70	30	100 N	200	0.05 N	35	110	180	0.5 N	4 L
0161	150	0.5 N	700	20	100	7	70	70	10 L	150	30	0.05 L	10	10	20	0.5 N	4 L
0203	500	0.5 N	1000	5	10	5	30	5	50	300	30	0.02 L	5 L	10	35	0.5 N	2
0208	700	0.5	1000	5	10	50	50	7	50	300	30	0.02 L	60	10	35	0.5 L	2 L
0210	200	0.5 N	2000	5	10	15	50	5	30	300	30	0.02 L	5 L	5	90	0.5 N	2 L
0230	2000	0.5	700	30	150	300	20 N	70	300	100	200	0.66	320	140	320	0.5	6
0231	70	1.0	70	30	10	700	20 N	5 L	15	100 N	200	0.02 L	400	15	20	0.5	160
0267	200	0.5 N	700	5	10	30	30	5	30	200	30	0.02 L	5 L	10	25	0.5 L	2 L
0268	500	0.5 N	5000	5	30	5	30	10	30	100	30	0.02 L	30	5	40	0.5 N	2 L
0303	500	0.5 N	1000	10	30	30	50	10	50	100	70	0.02 L	15	5	35	0.5 N	2 L
0353	200	0.5 N	300	5	50	5	30	20	10	200	50	0.02 L	5	10	25	0.5 N	2 L
0358	700	0.5 N	1500	20	700	50	150	50	70	300	200	0.02 L	5 L	15	80	0.5 N	2 L
0359	500	0.5 N	100	20	50	5	50	70	10 N	100	150	0.02 L	5 L	5	40	0.5 L	2 L
0360	200	0.5 N	1000	5	10	5	30	5	50	300	30	0.02 L	70	5	20	0.5 L	2 L
0361	1000	0.5	500	20	200	70	50	50	70	200	200	0.02 L	5	15	130	0.5 N	2 L
0385	700	0.5 N	1000	10	50	10	30	20	30	200	100	0.02 L	15	5	30	0.5 N	2 L
0430	200	1.0	700	10	150	30	30	50	150	200	100	0.02 L	5	75	40	0.5 L	60
0446	700	0.5 N	700	10	30	20	30	30	50	200	100	0.02 L	5 L	10	45	0.5 N	2 L
0452	70	0.5 N	30	5	10	10	20 N	5	10 N	100 N	30	0.02 L	5 L	5	10	0.5 N	2 L
0461	70	0.5 N	1000	5 N	10 N	5	20 N	5	50	300	10	0.48	5 L	5	10	0.5 N	2 L
0471	700	0.5 N	200	5	20	5	50	5	10	100	70	0.02 L	5 L	5	10	0.5 N	2 L
0472	70	0.5 N	150	5	10	5	30	5	10	100	30	0.02 L	5 L	5 L	10	0.5 N	2 L
0476	150	0.5 N	1000	5	10	7	50	15	20	300	30	0.02 L	5 L	5 L	15	0.5 N	2 L
0477	1000	0.5 N	300	20	1000	5 L	20	200	30	300	200	0.02 L	5 L	20	110	0.5 N	2 L
0498	1000	0.5 N	500	10	200	5	100	30	30	300	100	0.02 L	5 L	20	45	0.5 N	2 L
0501	500	2.0	300	5	300	5	100	15	10	200	50	0.02 L	5 L	5 L	30	0.5 N	2 L
0509	70	0.5 N	700	5	20	10	20 N	5	30	300	30	0.02 L	5 L	5 L	12	0.5 N	2 L

0510	100	0.5 N	100	5	10 N	5	70	5	10	100 N	30	0.02 L	5 L	5 L	12	0.5 N	2 L
0513	70	0.5 N	700	5 N	10 N	10	20 N	5	15	100	20	0.02 L	5 L	5 L	10	0.5 N	2 L
0596	30	0.5 N	50	5 N	10	5	20 N	5	10 N	100 N	10	0.02 L	5 L	5 L	10	0.5 N	2 L
0763	2000	0.5 N	150	10	10 N	5	20 N	5	30	700	20	0.02 L	5 L	20	35	0.5 N	2 L
0792	700	0.5 N	100	50	5000 G	5 L	20 N	3000	10 N	100 N	200	0.02 L	5 L	5	60	0.5 N	2 L
0893	700	0.5 N	70	30	70	10	1000 G	70	10	500	200	0.02 L	5 L	5	60	0.5 N	2 L
0988	300	0.5 N	300	10	50	30	30	10	20	100	50	0.02 L	5	10	340	0.5 L	2 L
1004	700	0.5 N	700	20	70	20	70	30	30	300	200	0.02 L	5 L	5	15	0.5 N	2 L
1009	1500	0.5 N	200	10	50	30	70	10	30	200	150	0.02 L	20	15	70	0.5 L	2 L
1025	100	0.5 N	20	7	10	30	20 N	5	10 N	100 N	30	0.02 L	5 L	5 L	5	0.5 L	2 L
1035	700	10.0	300	30	200	100	20	50	70	100	200	0.22	85	25	20	6.0	2 L
1068	100	0.5 N	1000	5	10 N	7	20 N	5	20	700	10	0.05 L	5	5	30	0.5 L	2 L
1120	100	0.5 N	3000	5	10 N	50	20	7	30	300	10	0.05 L	5	10	25	0.5 L	2 N
1125	100	0.5 N	1000	5	10 N	20	20 N	5	15	200	10	0.05 N	5 L	5	20	0.5 L	2 N
1132	150	0.5 N	2000	5	10 L	10	20	5	20	150	10	0.05 N	10	5	30	0.5 L	2 N
1238	700	0.5 N	1500	5	10	5	30	7	10	200	30	0.05 L	5	5	30	0.5 L	2 L
1243	5000 G	0.5 N	70	20	10	50	20 N	5	10 N	100 N	10	0.05 N	30	5 L	25	1.0	2 L
1255	1000	7.0	300	20	1000	200	20	100	100	100 N	1000	0.10	170	75	70	7.0	2 L
1285	70	0.5 N	1000	5	10	10	30	5	10	200	20	0.05 N	5	5	30	0.5 L	2 L
1290	2000	0.5	200	50	300	100	20 N	100	30	100 N	300	0.25	75	40	130	4.0	2 L
1302	1000	15.0	200	30	1000	200	30	300	30	150	100	1.70	150	40	120	20.0	2
1316	700	0.5 N	150	7	200	200	20 N	30	10	100	200	0.05 N	140	10	130	4.5	2 L
1339	1000	0.5 N	100	10	150	300	20 N	70	30	100 N	70	0.05	250	50	45	7.0	10
1386	2000	1.0	200	5	200	150	20	10	15	100 N	100	0.10	90	5	25	3.0	2 L
1395	150	0.5 N	2000	5	10	10	20	5	20	300	30	0.05 L	10	5	25	0.5 L	2 N
1405	70	0.5 N	50	5 N	10 L	20	20	5	10 L	100 N	20	0.05 L	5 L	5 L	25	0.5 N	2 L
1413	150	0.5	1000	5	10	15	20	5	20	300	20	0.10	5 L	10	50	0.5 N	2 N
1415	50	1.0	700	5	10	20	20	5	15	200	30	0.05 L	10	5	10	0.5	40
1434	150	0.5	1000	5	10 N	5	20 N	5	15	300	20	0.05 L	5 L	5	40	0.5 N	2 N
1436	30	1.0	500	5 L	10 L	20	20 N	5	30	100	20	0.10	30	45	55	1.0	2 N
1437	150	0.5	1000	5	10	5	20 N	5	15	500	30	0.05 L	10	5	25	0.5 N	2
1440	50	0.5 N	700	5	10	30	50	5	15	300	30	0.05 L	10	5	10	0.5	2 L
1470	70	0.5 N	1000	5	10 L	5	100	7	15	100	30	0.05 L	5 L	5	45	0.5 N	2 L
1503	150	0.5 N	700	5	10 L	20	20	5	15	300	10	0.05 L	5 L	10	20	0.5 L	2 N
1581	500	0.5	700	7	15	10	50	10	20	100 N	100	0.05 L	5 L	20	25	0.5	2 L
1607	200	0.5 L	5000 G	5	10	30	70	5	15	700	30	0.05 L	35	5	30	1.0	2 N
1608	150	1.0	1000	7	10 L	20	30	7	15	100	30	0.05 L	5	5	50	1.0	2 L
1615	200	0.5 N	500	5	10	15	20 N	20	10	100 N	30	0.05 L	5 L	5	20	0.5 L	2 L
1618	700	0.5 N	700	30	150	30	50	100	10	100	100	0.05 L	20	10	20	1.0	2 L
1626	50	0.5 N	700	5	10 N	10	20 N	5	20	100	10	0.05 L	5 L	5	5	0.5 L	2 L
1644	1500	0.5 N	300	30	15	5	30	50	30	300	200	0.05 L	5	30	45	2.0	2
1649	300	0.7	300	10	15	20	30	10	10	100	50	0.05 L	5	15	25	1.0	2 L
1683	200	0.5 N	1500	5	15	15	20 N	50	10	100	20	0.05 L	15	5	15	0.5	2 L
1764	5000	0.5 N	100	7	50	300	30	20	10 L	100 N	70	0.05	240	10	20	6.0	20

TABLE 13.—*Semiquantitative spectrographic analyses and chemical analyses of selected elements in 103 samples of mineralized or altered rocks, Beartooth Primitive Area and vicinity*—Continued

SAMPLE	S-MN	S-AG	S-BA	S-CO	S-CR	S-CU	S-LA	S-NI	S-PB	S-SR	S-V	A-AU	A-CU	A-PB	A-ZN	A-AG	C-MO
1797	200	0.5 N	700	5	10 N	7	20 N	5	30	100	10	0.05 L	5 L	15	10	0.5 N	2 L
1798	700	0.5	300	10	10	100	30	10	20	150	70	0.05 L	5	15	30	2.0	2 L
1802	200	0.5 N	150	5	10 N	5	20	5	10 N	100 N	50	0.05 L	5	5	15	0.5 L	2 L
1805	500	0.5 N	700	7	50	15	30	15	10	700	100	0.05 L	15	5	30	1.5	2 L
1825	500	1.0	700	7	10	150	30	15	20	100	70	0.05 L	65	15	25	3.0	2 L
1826	150	0.5 N	500	7	70	15	30	50	10 L	100 N	70	0.05 L	10	5	25	1.0	2 L
1831	150	1.0	1000	5	10 N	15	20	5 L	50	100	10	0.05 L	5 L	20	20	0.5	2 L
1833	50	1.0	700	5	10	5	20	5	10	150	30	0.05 L	5 N	5	10	0.5 L	2 L
1834	150	0.5 N	700	5	10	7	30	5 L	15	150	50	0.05 L	5 L	5	15	0.5 L	2 L
1836	300	0.5 N	150	7	10	20	20 N	7	10	100 N	150	0.05 L	5 L	10	20	0.5 L	2 L
1859	150	0.5	300	5	30	15	20	10	10	150	20	0.05 L	5 L	5	15	0.5 L	2
1896	200	0.5 N	500	5	10 L	7	20 N	5	15	100	20	0.05 N	5 L	5	10	0.5 L	2 L
1897	1000	1.0	300	30	70	30	20	50	30	100	150	0.05 N	25	25	35	2.5	2 L
1899	300	0.5	3000	5 N	10 N	7	20 N	5	20	500	10	0.05 N	5	10	20	0.5	2 L
1912	1500	0.5	70	7	10 L	7	20 N	50	50	150	50	0.05 N	5	40	45	3.0	2 L
1913	300	0.7	700	7	20	200	20 N	200	15	200	150	0.05	180	15	20	6.0	2 L
1916	50	1.5	500	5 N	10 N	5	20 N	5	15	100	10	0.05 N	5 L	5 L	10	0.5 L	2 L
1935	1000	0.5 N	1500	7	10	15	30	5	30	300	100	0.05 N	10	5	40	1.5	2 L
1938	200	0.5 N	100	5	10 L	5	70	5	10 N	100	30	0.05 N	5 L	5 L	20	0.5 L	2 L
1955	1000	0.5 N	300	7	70	70	100	30	30	100 N	200	0.05 L	45	5	35	8.0	2 L
1956	1000	0.5 N	150	10	50	20	30	30	30	200	150	0.05 N	5	25	35	2.0	2 L
1957	50	0.5 N	300	5	10 N	10	20 N	5	30	100 N	10	0.05 N	5 L	10	5	0.5 L	2 L
1978	150	0.5	500	5	10	10	20 N	5	20	150	20	0.05 N	5	5	15	0.5 L	2 L
2008	200	0.5 N	700	7	10	5 L	20	10	30	200	30	0.05 L	5	10	30	0.5 N	2 N

TABLE 14.—*Spectrographic analytical data for selected elements in samples of mineralized or altered rocks, Beartooth Primitive Area and vicinity*

[If chemical analysis was also made, result is given in parentheses]

Sample No.	Element detected	Amount (ppm)	Sample No.	Element detected	Amount (ppm)
31	B	10	1501	B	20
94	B	10	510	Nb	10
121	B	10	596	Nb	10
161	B	15	1004	Nb	10
	Be	5	1009	B	10
				Nb	10
210	Nb	10			
	Zn	500 (90)	1035	B	10
230	Bi	30		W	70
	Sn	200	1255	Bi	10
231	Mo	150 (160)	1302	W	70
			1339	Mo	7
353	Nb	10		Zn	200 (45)
358	Nb	30			
359	B	20	1415	Mo	70 (40)
	Be	7	1764	Mo	7 (20)
361	B	10	1797	B	20
			1896	B	10
430	Mo	70 (60)			
452	Nb	10	1897	B	15
471	Be	3	1938	B	10
	Nb	10	1955	B	10
498	B	20	2008	Nb	20
	Nb	10			

Chromium is present in amounts ranging from 2,000 to 5,000 ppm in four amphibolites, three of them on or near Froze-to-Death Plateau (samples 140, 357, 914) and the fourth just southwest of Dude Lake (sample 427) and is present in amounts of 2,000 to 3,000 ppm in samples of five ultramafic rocks from the Moon Lake cirque (samples 528, 1991, 1992, 1993, 1994). These same rocks also contain 700-2,000 ppm of nickel. Chromium also occurs in amounts of 2,000-5,000 ppm in five mafic dikes (samples 551, 950, 986, 1039, and 1512); in all of these dikes the nickel content is at least 300 ppm, and in the two dikes that contain 5,000 ppm of copper, the nickel contents are 1,000 and 2,000 ppm. These amounts of chromium and nickel seem to be high but are not greatly different from the averages reported for both elements in ultramafic rocks by Taylor (1965, p. 170) and Parker (1967, p. D13).

Cobalt was found at levels appreciably above threshold in only one rock, a dike of porphyritic quartz dolerite 9-12 m (30-40 ft) wide that crosses the ridge 1.3 km (0.8 mi) west of Wolf Mountain (sample 1345). This dike contains 150 ppm of cobalt, as well as 1,000 ppm of chromium, 200 ppm of copper, and 1,500 ppm of nickel. The cobalt content is about twice the maximum reported by Prinz (1967, p. 278) for rocks of similar composition.

TABLE 15.—*Uranium and thorium contents of 103 samples of mineralized or altered rocks, Beartooth Primitive Area and vicinity*

[Data are in parts per million. Neutron activation analyses unless otherwise noted; <, less than; leaders (....), no analysis]

Sample No.	Uranium	Thorium	Sample No.	Uranium	Thorium
29	<10	...	1255	1.7	14.8
31	<10	...	1285	1.1	18.0
73	[1]60, [2]<10	...	1290	3.8	...
76	[1]60, [2]<10	...	1302	1.4	46.6
94	20	...	1316	1.5	46.5
96A	[1]20	...	1339	9.2	...
96B	[1]20	...	1386	1.8	...
118	[1]40	...	1395	1.4	5.6
121	[1]10	...	1405	1.0	20.4
161	2.8	28.0	1413	2.0	...
203	1.1	23.5	1415	1.3	8.7
208	.9	14.2	1434	1.6	13.6
210	.5	17.6	1436	1.8	6.8
230	4.6	1.3	1437	1.2	8.2
231	7.4	2.0	1440	2.1	13.6
267	.6	21.3	1470	1.4	18.6
268	1.6	19.9	1503	2.0	22.0
303	2.6	23.3	1581	1.4	11.2
353	.8	18.7	1607	1.1	20.1
358	8.9	25.0	1608	1.0	21.7
359	2.6	6.8	1615	4.7	7.0
360	1.1	8.5	1618	2.7	13.3
361	3.5	7.8	1626	.6	12.3
385	2.9	9.3	1644	.7	4.7
430	1.4	15.8	1649	2.1	3.8
446	1.9	13.5	1683	3.4	...
452	.5	2.7	1764	4.8	20.7
461	.6	12.6	1797	1.6	5.4
471	1.5	18.1	1798	1.1	7.1
472	[1]70	...	1802	2.9	4.1
476	[1]50	...	1805	1.4	3.2
477	1.1	10.5	1825	3.2	12.3
498	1.4	10.3	1826	1.1	16.9
501	[1]40	...	1831	3.0	25.3
509	1.32	10.2	1833	2.1	11.3
510	4.4	47.3	1834	3.0	40.2
513	.5	13.4	1836	3.1	16.6
596	...	3.2	1859	2.3	7.1
763	.2	3.9	1896	1.4	17.6
792	2.3	...	1897	3.0	7.8
893	3.3	72.9	1899	1.1	...
988	2.3	19.2	1912	2.9	12.3
1004	.8	10.8	1913	1.8	9.4
1009	5.5	...	1916	1.3	13.7
1025	8.7	24.6	1935	1.2	9.9
1035	2.1	...	1938	.8	17.5
1068	.9	19.9	1955	4.8	8.5
1120	1.2	11.1	1956	1.3	13.2
1125	.8	15.4	1957	1.9	6.2
1132	1.0	18.3	1978	1.3	6.7
1238	1.5	...	2008	1.7	22.9
1243	...	7.8			

[1]Uranium equivalent, determined by beta-gamma scanner method.
[2]Uranium, determined by fluorimetric method.

The dike is fresh and contains abundant pyrite, and the cobalt content is thought to be primary.

Copper was detected in amounts greater than threshold in eight samples, the localities for these samples are shown in figure 21. The highest amounts reported were 700 ppm, in metadolerite dikes from 1.3 km (0.8 mi) northwest of Roosevelt Lake (sample 607) and 1.6 km (1 mi) west of Hodges Mountain (sample 1438), respectively, both of which contain pyrite but no visible chalcopyrite; and 500 ppm, in an amphibolite 1.3 km (0.8 mi) east of Phantom Lake (sample 357), which contains sparse tiny flecks of chalcopyrite. None of these rocks shows any evidence of hydrothermal alteration, and the copper content is believed to be primary even though the amount of copper is about twice that reported for similar rocks by Prinz (1967, p. 278). Copper was also detected in the amount of 700 ppm in a somewhat altered Tertiary porphyritic latite dike 5-6 m (15-20 ft) thick at Zimmer Lake (sample 1265). The dike contains abundant pyrite and a little chalcopyrite(?). Gneiss in this area appears to be somewhat altered, but a stream sediment sample from the inlet of Zimmer Lake contains only 7 ppm citrate-soluble heavy metals and 100 ppm copper, both values well below threshold for the drainage basin (R).

Lanthanum was detected in above-threshold amounts in 12 rocks. The highest lanthanum content was 300 ppm, in a gneiss 1.3 km (0.8 mi) south-southeast of Snyder Lake (sample 2018). Although amounts of lanthanum in these rocks are somewhat greater than the averages for similar rocks given by Parker (1967, p. D14), they are not otherwise noteworthy.

Lead was detected in above-threshold amounts in 11 samples of gneiss and 4 samples of mafic dikes; localities for these samples are shown on figure 22. Only two samples of gneiss had as much as 100 ppm of lead, and in only one rock, a quartz-dolerite dike 1 km (0.6 mi) northwest of Summerville Lake (sample 1533), was the lead content (150 ppm) appreciably above threshold. Note that the mean lead content of gneisses in the Beartooth area (25 ppm) is somewhat higher than the averages for rocks of similar composition (granites and granodiorites) given by Parker (1967, p. D14) and is about twice the average content for continental crust given by Taylor (1965, p. 183). The relatively high lead content presumably is related to the abundance of microcline in the gneisses.

Niobium occurs in above-threshold amounts in five samples of Precambrian gneiss and three samples of Tertiary porphyritic latite dikes (fig. 18). The highest niobium content, 30 ppm, is in the latite dikes, one of which (sample 913) also contains the highest beryllium content (5 ppm) detected in Beartooth rocks. None of these amounts differs appreciably from the niobium contents of similar rocks as summarized by Parker (1967, p. D13).

Silver in amounts of more than 0.5 ppm was detected in 58 samples, and localities for these samples are shown in figure 19. Only 15 samples contained more than 2 ppm. The highest values found were 10 ppm in a large metadolerite dike near a pond 1.6 km (1 mi) southwest of Golden Lake (sample 1704), and 7 ppm in gneiss 1.1 km (0.7 mi) east of Golden Lake (sample 1726), in a metadolerite dike 1 km (0.6 mi) east of Big Butte Lake (sample 1314), and in a quartz-dolerite dike 3 km (2 mi) north-northwest of Jasper Lake (sample 1654). Although silver contents, even as low as 1 ppm, are at least one order of magnitude higher than the averages reported for most rocks by Parker (1967, p. D13), those of the Beartooth rocks are far below economic concentration, and the rocks themselves provide no evidence as to whether or not silver is a primary constituent.

Tin was detected in only one rock, as gneiss 2 km (1.2 mi) south-southeast of Granite Lake (sample 1087); the reported tin content was 15 ppm.

Four samples of biotite gneiss from the west side of the study area were analyzed for uranium and thorium, and the results are given in table 11. Both elements are much more abundant in these rocks than in similar rocks found elsewhere in the study area, which may be seen by comparing the data of table 11 with those of table 15.

Vanadium was detected in amounts above threshold in four amphibolites and one mafic dike. The highest vanadium content measured was 700 ppm, in a sample from a quartz dolerite dike 0.6 km (0.4 mi) east of Snow Lake (sample 1816). None of the amounts found was appreciably above the range of vanadium contents recorded for similar rocks by Prinz (1967, p. 279).

Samples of 11 mafic and ultramafic rocks were analyzed quantitatively for platinum and palladium, and results are given in table 16. Detection limits for the fire-assay-spectrographic method used to analyze the Beartooth samples are 0.005 ppm for platinum and 0.002 ppm for palladium. The palladium content of the amphibolites and dolerites is similar to that reported by Parker, whereas their platinum content is about one order of magnitude lower. However, the platinum and palladium contents of the two ultramafic rocks are far below those reported by Parker (1967, p. D13-D14) and Wright and Fleischer (1965, p. A1, table 11) for similar rocks.

TABLE 16.—*Platinum and palladium contents of ultramafic and mafic rocks, Beartooth Primitive Area and vicinity, and of average ultramafic rocks and basalts*

[Values are parts per million; <, less than]

Sample No.	Rock type	Platinum	Palladium
1992	Pyroxenite	<0.005	<0.002
1993	....do	<.005	<.002
140	Amphibolite	<.005	<.002
357	....do	<.005	<.007
914	....do.	.030	.050
427	Dolerite	<.005	<.002
551	....do.	<.005	<.002
986	....do	<.005	.002
1039	....do.	.020	.020
1512	....do	.030	.030
1816	....do.	.015	.020
Average ultramafic rock[1]		.200	.120
Average basalt[1]		.100	.020

[1]From Parker, 1967, p. D13-D14.

SUMMARY OF SAMPLING RESULTS

None of the sampling done during this study revealed the presence of any hitherto unknown mineralized area containing any element in substantially higher than threshold amount. Although anomalous amounts of many elements were detected in one or more samples, most of these samples are believed to represent very local concentrations of the element found rather than to indicate pervasive mineralization. On the other hand, the presence of mineralized areas, such as the Cooke City district and the terrane underlain by the Stillwater Complex, is clearly reflected by stream-sediment samples, the first by citrate-soluble heavy-metals analyses, the other by spectrographic analyses; thus, the sampling and analytical methods used are apparently sufficiently sensitive to distinguish mineralized areas of more than very local extent.

No large areas or volumes of altered rock such as those commonly associated with mineral deposits in the Rocky Mountains were found, and indeed the freshness of rocks over the 1,550 km^2 (600 mi^2) of the Beartooth study area is remarkable. In many places, such as around Shepard Mountain and on Mount Rearguard, rock outcrops are iron stained, and the rocks appear to be altered; however, upon examination the rusty color is seen to be due to very thin films of iron oxide that coat fracture surfaces and apparently result largely from the oxidation of biotite contained in the rocks.

Stream-sediment samples containing more than threshold amounts of citrate-soluble heavy metals are widely scattered over the area except for a concentration downstream from the Cooke City mining district (fig. 15), and do not seem, therefore, to point out any substantial concentrations of zinc, copper, lead, or cobalt. Gold was detected in only 19 stream-sediment samples. Except for samples from below the Cooke City district, the gold-bearing samples were not those that have a high citrate-soluble heavy-metals content. Again, no notable clustering of gold-bearing samples is apparent, although groups of three gold-bearing samples were collected northwest of Sodalite Lake and on or near East Rosebud Creek west of East Rosebud Plateau.

Rocks of the Beartooth study area contain for the most part only ordinary amounts of copper, as is clear from figure 21. Except for the usual scattered high values in stream sediments and various rock types, the only concentrations of samples containing above-threshold amounts of copper are (1) on south-flowing tributaries of the West Fork Stillwater River, reflecting the presence upstream of rocks of the Stillwater Complex, (2) at the head of West Rosebud Creek, reflecting the presence of a large metadolerite body at the head of the drainage, and (3) in stream sediments derived from rocks in the Cooke City mining district.

Molybdenum appears to be associated with copper in the Goose Lake-Aero Lakes-Cooke City region, in which 12 of the 15 samples anomalous in molybdenum were also found to be anomalous in copper. Elsewhere, no association between the two metals is evident; samples containing above-threshold amounts of molybdenum are somewhat concentrated in the headwaters of East Rosebud Creek, in the Red Rock Lakes and Otter Lake headwaters of Crazy Creek, and to a lesser extent in the headwaters of Wounded Man Creek, but none of these samples has an anomalous content of copper. The source of the anomalous molybdenum in two of the stream-sediment samples from Wounded Man Creek probably is the zone of altered rock of sample 1413; however, possible source rocks for the East Rosebud Creek and Crazy Creek samples, which may be in the area between Mount Dewey and Snowbank Glacier, were not recognized.

Although, as noted previously, the background lead content of rocks in the Beartooth study area is somewhat higher than expectable, the number of samples (37) containing above-threshold amounts is small, and these samples are widely scattered (fig. 22). The eight samples in which zinc was detected are also widely scattered; all are of altered rocks, and only two also contain anomalous amounts of lead.

Samples that contain silver in above-threshold amounts are noticeably concentrated along the southwest side of the Beartooth crest from Fossil Lake southeast to the edge of the Beartooth study area. These samples comprise mainly gneiss, mafic dikes, and stream sediments. This entire area thus seems to be somewhat anomalous in silver, but despite the relatively high density of sampling, no clearly defined concentration of rocks high in silver is apparent. The silver content of even the highest grade sample (1704, 10 ppm) is much too low to be of economic interest.

Gold was detected in only five rock samples, all of them of altered rock. The highest gold content was 1.7 ppm, in sample 1302, from a breccia zone in a mafic dike near Anvil Lake. None of the samples, except perhaps sample 461 north of Lost Lake, is representative of more than a very small volume of rock.

The uranium content of 89 samples of mineralized or altered rocks, as determined by neutron activation analysis, ranges from less than 1 ppm to 9.2 ppm; 70 samples contain less than 3 ppm, 14 contain 3 to 5 ppm, and only 5 contain more than 5 ppm. The average uranium content is 2.91 ppm. No analyzed rock from the Beartooth study area contains an unusual amount of uranium. According to Parker (1967, p. D14) the average uranium content of three groups of granitic rocks is 3 to 3.5 ppm. Thorium contents also are ordinary; in 81 samples they range from 1.3 to 72.9 ppm with 63 samples containing less than 20 ppm. The average thorium content is 15.3 ppm. Parker (1967, p. D14) shows the average thorium content of three groups of granitic rocks to be 18, 8.5, and 17 ppm, respectively.

Results of sampling for beryllium, chromium, cobalt, lanthanum, nickel, niobium, tin, tungsten, and vanadium have already been mentioned briefly; none of the results merits further discussion.

NONMETALLIC OR INDUSTRIAL MINERALS AND MATERIALS

No deposits of nonmetallic minerals, other than the so-called common varieties, are known in the study area, and no potential for any was recognized during this study. Fluorite was recognized in minute quantities at only one place, and sillimanite occurs in many places, but, so far as is known, in only trace amounts. No concentrations of placer minerals, such as zircon, monazite, ilmenite, and rutile, which were large enough to be of economic interest, were found, although titanium and zirconium were detected in all stream sediments and in amounts as high as 0.7 and 0.1 percent, respectively. The virtual absence of sedimentary rocks in the area precludes the existence of workable deposits of clay, gypsum and related minerals, limestone, phosphate rock, and silica sand.

Small amounts of sand and gravel have been deposited along the lower stretches of the Stillwater and the West Fork Stillwater Rivers within the Beartooth study area, but in both these places the sand and gravel deposits lie upriver from deep, narrow canyons and are difficult to access. Other river canyons are either too narrow to contain sizable gravel deposits or have been swept clean of gravel- or sand-size debris. Gravel has been mined at many places near the Beartooth Mountain front, particularly between Red Lodge and the front, and the relatively easy accessibility of such deposits means that those within the Beartooth study area are unlikely to ever be of commercial interest.

Much of the Precambrian rock of the Beartooth study area, particularly the more massive microcline-rich gneiss, is very beautiful and would make acceptable building stone, but the same rocks are available and more accessible outside the study area.

PETROLEUM AND NATURAL GAS

Some of the earliest exploration for petroleum in Montana was done west and south of Roscoe, and indeed the first well drilled in the State was a few kilometres south of Roscoe and about 3 km (2 mi) north of the Beartooth study area (Erdmann, 1963, p. 25). However, no petroleum or natural gas has been found in this area. Petroleum has been produced from several fields east of Red Lodge (Belfrey, Clarks Fork North, and Dry Creek in Montana and Elk Basin and Frannie in Wyoming), but all are many kilometres east of the Beartooth study area. Within the study area the total outcrop area of rocks most likely to contain petroleum deposits—sedimentary rocks of Paleozoic or younger age—is small, and these rocks are so deeply eroded that any oil or gas they might have contained has escaped or has been flushed out by ground water.

The east side and northeast corner of the block of Precambrian rocks that constitutes most of the Beartooth Mountains are bounded by the Beartooth fault. This fault is nearly vertical in the canyon of the Clarks Fork Yellowstone River; at higher structural levels farther north it becomes a reverse fault that dips steeply west; southwest of Red Lodge it is a thrust fault that dips 30°-45° toward the mountains; and farther northwest it apparently becomes a steeply dipping reverse fault (Foose and others, 1961, p. 1156-1159). It is thus possible that potential petroleum-bearing sedimentary rocks are concealed beneath a plate of Precambrian rocks that has been thrust eastward and northeastward. However, Foose, Wise, and Garbarini (1961, p. 1159) believed that (1) the maximum horizontal displacement on the Beartooth fault is at the northeast corner of the Precambrian block, which lies at least 5 km (3 mi) east of the Beartooth study area, and (2) the Beartooth fault steepens with depth. If their interpretations are correct, then the likelihood of younger rocks extending beneath the Precambrian rocks as far west as the study area is remote, and, even if they did, the younger rocks would lie at very great depths, probably at more than 5 km (3 mi).

COAL

Bituminous coal has been mined from the Paleocene Fort Union Formation near Red Lodge and Bearcreek village (Darton, 1907; Combo and others, 1949, p. 13-14), from Upper Cretaceous rocks, probably Eagle Sandstone, in the Electric field 8 km (5 mi) northwest of Gardiner (Combo and others, 1949, p. 14), and from Eagle Sandstone in the Stillwater field northeast of Nye (Combo and others, 1949, p. 13). None of these formations is present in the Beartooth study area.

GEOTHERMAL ENERGY

No surface indicators of possible subsurface sources of geothermal energy, such as hot springs or geysers, hot-spring deposits of siliceous sinter or calcareous tufa, or volcanic rocks of late Tertiary or Quarternary age, are known in the Beartooth study area. No measurements of geothermal gradient are known to have been made in the area. Inasmuch as almost the entire study area is underlain by Precambrian metamorphic and igneous rocks, the likelihood of the existence of suitable reservoirs for geothermal energy is exceedingly remote, and the potential for such energy in the area is therefore low.

ECONOMIC APPRAISAL

By Ronald M. Van Noy, Nicholas T. Zilka, Frank E. Federspiel, and James Ridenour
U.S. Bureau of Mines

SETTING

The Beartooth study area includes parts of the Cooke City (referred to in many reports as the New World), Red Lodge, and Stillwater mining districts and is adjacent to the Independence mining district.

The Cooke City district is at the south-central edge of the study area, but only the northern part extends into the area. The part inside the study area includes Goose Lake (glacial) basin and Goose Creek, a tributary of the Stillwater River. The district was discovered in the 1860's, but no claims were recorded until 1870. The district has had a total production of gold, silver, copper, lead, and zinc valued at nearly $4 million. The only production recorded from Goose Lake basin is reportedly a few tons of copper ore.

The Goose Lake area contains deposits with values in copper, gold, silver, platinum, palladium, lead, and tungsten. The most promising deposit in the area occurs in a syenite stock at the north end of Goose Lake. The mineralized portion of the stock is covered in part by the Copper King, Lake View, Copper Queen, and Calumet patented claims. Copper, gold, silver, platinum and palladium values were found in stockpiled material at the caved Copper King shaft. Copper, gold, and silver enriched rock was intersected by diamond drilling. The principal mineral is chalcopyrite, which occurs as disseminations in the country rock and as vein fillings in brecciated syenite. The size and grade of the deposit are not adequately defined, but it is considered an important exploration target.

The Red Lodge district contains several chromite-bearing serpentinized lenses of ultramafic rock in granitic gneiss. The lenses are exposed at the edge of Hellroaring, Silver Run, and Line Creek Plateaus along the east side of the study area. Except for the Highline deposit to the east of the study area, the deposits are all at or near the study area boundary. During the early 1940's, about 34,500 t (38,000 tons) of chromite ore was mined, and the concentrate produced therefrom was valued at nearly $600,000 (Zoldok and Henkes, 1971); a 5,000-t (5,500-ton) stockpile remains.

The Stillwater mining district contains the Stillwater Complex, a band about 50 km (30 mi) long of ultramafic rocks and anorthosite that have values in chromium, copper, nickel, platinum, palladium, and other noble metals. The complex lies, in part, along the north edge of the study area, and small segments may extend a short distance into the area. During the 1940's, the Anaconda Co. and the American Chrome Co. produced about 900,000 t (over 1 million tons) of chromite concentrate, of which about 820,000 t (900,000 tons) are stockpiled in the area. The other mineral values have not been exploited, but several exploration companies are active in the area.

The Independence mining district is just west of the study area. It has produced minor gold, silver, and copper from pyritic-quartz veins and lead from replacement bodies. The mineralized zones have not been traced into the Beartooth study area.

COMMODITIES

Commodities found within the study area are gold, silver, copper, nickel, chromium, platinum-group metals, lead, and tungsten. All but lead and tungsten have potential economic significance.

Chromite has been mined in the study area and a small resource remains unmined in the Hellroaring and Silver Run Plateaus of the Red Lodge mining district. Chromite may also occur in a small part of the Stillwater Complex which is in the study area near the West Fork Stillwater River.

Copper, silver, gold, and platinum-group metals occur in sulfide zones in the Goose Lake basin. A small part of the copper-nickel-bearing basal section of the Stillwater Complex might be in the study area. The size and grade of these potential resources are undefined, but it is likely that none of the metals could be mined profitably as a single product.

Data on mines, prospects, and claims that were sampled in the Beartooth study area are summarized in table 17.

GOOSE LAKE AREA

The Goose Lake area includes the northern part of the Cooke City mining district and some adjoining area (pl. 2). Goose Lake is at an elevation of about 3,000 m (9,800 ft) and is in a glacial basin surrounded by knife-edged ridges which attain elevations of over 3,350 m (11,000 ft). The basin floor is covered by morainal, colluvial, and alluvial materials, and outcrops are sparse. Snow covers much of the basin until mid-July and the first snow may fall as early as September. Access to Goose Creek basin is by 18 km (11 mi) of road from Cooke City, the final 11 km (7 mi) an extremely rough four-wheel-drive trail. The Goose Creek area is accessible only by unmaintained trails.

Since the first mining claims were recorded in 1881, an estimated 400 claims have been recorded, many of which are probably relocations, Five of them have been patented—four at the north end of Goose Lake, and one on Goose Creek (pl. 2, No. 103). Most were staked for copper, gold, and silver, and several claims in the Goose Lake basin were staked during the 1950's for uranium.

The mineralization is associated with syenite, gabbro, basalt, and monzonite porphyry that intrude Precambrian granitic gneiss. Emplacement of some of the intrusives was controlled by faults and joints. Shear zones away from the syenite stock in the basin are also mineralized. Samples from a shear zone, stockpiled at the Copper Glance property (fig. 24, No. 53), contain silver, copper, lead, and a trace of gold; slight radioactivity was also detected.

A small shear zone located just northeast of Green Lake (fig. 24, No. 83) contains some of the highest amounts of gold, silver, and copper found in the study area. The deposit is too small, however, to be economically significant.

Scheelite was found in a shear zone, 60 cm (2 ft) thick, composed of cataclastic quartz (fig. 24, No. 96). The zone can be traced for only a few meters along the strike and represents a very small tonnage. This is the only tungsten occurrence found in the study area.

Claims along lower Goose Creek (pl. 2) were presumably located to cover northern extensions of productive gold-silver deposits south of the study area. Prospect workings north of the river, including those of the Acme patented claim (pl. 2, No. 103), are now caved, and no mineral values for samples taken from the small stockpiles and dumps are significant.

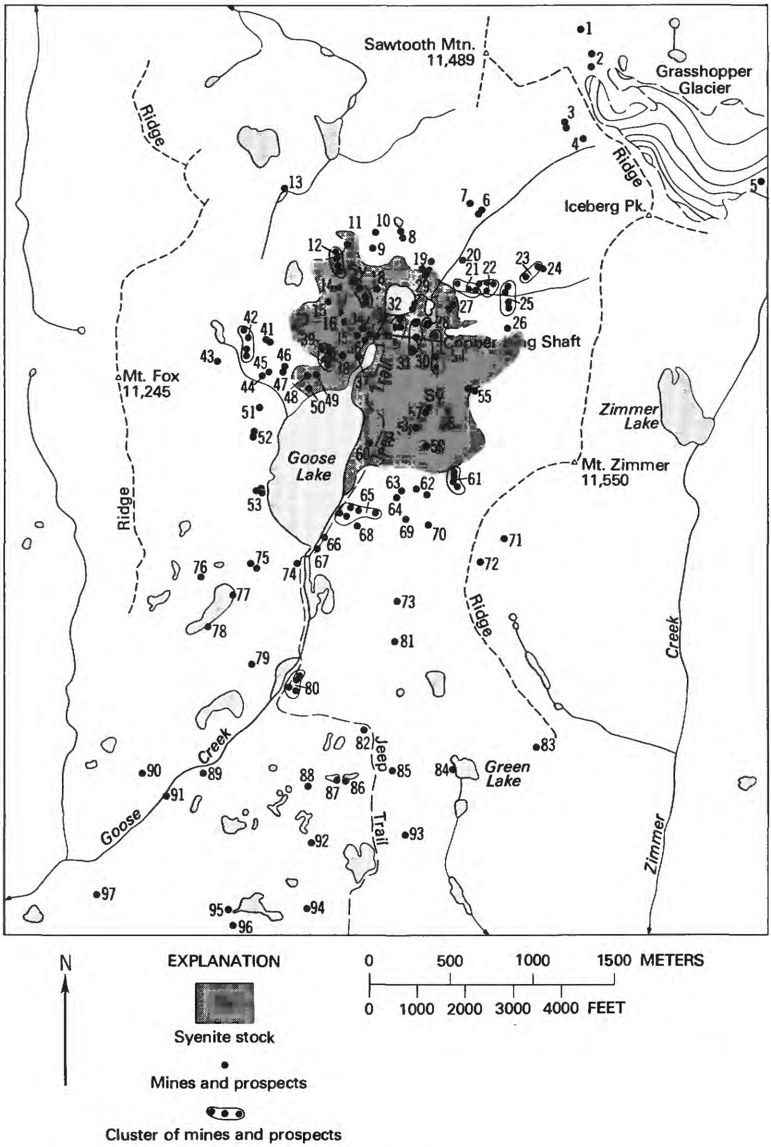


FIGURE 24.—Workings sampled in the Goose Lake basin. Numbers refer to mining properties described in table 17.

Goose Lake basin contains many caved or sloughed workings, and bedrock and mineralized structures are rarely exposed. Most samples are from stockpiles and dumps. Figure 24 shows all the sampled workings in and near the basin, and a summary description of each site is found in table 17. The Copper King and Copper Glance claims are within the Goose Lake basin.

TABLE 17.—*Mines, prospects, and claims sampled in the Beartooth Primitive Area and vicinity, Montana*

[Map Nos. 1-97 refer to fig. 24; Nos. 98-131 refer to pl. 2]

Map No.	Property name	Geology	Workings	Sample and assay data
1	------------------------	Sparse sulfides and magnetite in gabbro dike.	One pit------------------	One chip sample across dike; no gold, silver, or other valuable metals.
2	------------------------	A northeast-trending shear zone 6 m (20 ft) thick in mafic rock; contains pyrite, chalcopyrite, and quartz.	----do-------------------	One chip sample across shear zone; trace gold, 6 g (0.2 oz) silver per ton. Three chip samples of mafic rock; trace gold, 6-12 g (0.2-0.4 oz) silver per ton.
3	------------------------	A sulfide-bearing shear zone 2.5 m (8 ft) thick, strikes N. 30° E. and dips 70° NW. in granitic gneiss. Euhedral quartz crystals on dump of lowest trench.	Two trenches; one caved adit.	One chip sample across shear zone; trace gold, 9 g (0.3 oz) silver per ton. One dump grab sample; trace gold, 6 g (0.2 oz) silver per ton.
4	------------------------	A northeast-trending shear zone in granodiorite. Dump material contains disseminated galena.	One trench---------------	One grab sample; 0.9 g (0.03 oz) gold, 6 g (0.2 oz) silver per ton, 0.2 percent lead.
5	Hecta--------------------	Iron-oxide-stained sheared gabbro with euhedral quartz crystals in vugs.	Two caved pits-----------	One chip and one grab sample; trace gold, 9 and 12 g (0.3 and 0.4 oz) silver per ton.
6	------------------------	Fractured syenite containing fine-grained sulfides.	Three trenches-----------	One chip sample; trace gold, 9 g (0.3 oz) silver per ton, 0.07 percent copper. Two grab samples; trace gold, 6 and 9 g (0.2 and 0.4 oz) silver per ton.
7	------------------------	A narrow shear zone in gabbro, strikes N. 35° E., dips 65° SE., and contains disseminated sulfides.	One adit 7 m (22 ft) long	Two chip samples of shear zone; trace gold, as much as 6 g (0.2 oz) silver per ton, as much as 0.75 percent titanium. One grab sample; trace gold, 9 g (0.3 oz) silver per ton.
8	------------------------	Iron-oxide-stained granitic rock and syenite in float; no mineralized structure exposed.	Three trenches; one pit--	Two dump grab samples; trace gold, as much as 9 g (0.3 oz) silver per ton.
9	------------------------	Granitic rocks and basaltic dike rock in float.	One sloughed trench------	One grab sample; trace gold, 6 g (0.2 oz) silver per ton.
10	------------------------	Iron-oxide-stained syenite as float; no mineralized structure exposed.	One trench---------------	One grab sample; trace gold, 6 g (0.2 oz) silver per ton.
11	------------------------	A vertical shear zone 30 cm (1 ft) thick intersects a horizontal shear zone at the face of an adit. Some sulfides observed in country rock near the portal.	One short adit-----------	One chip sample; trace gold, 6 g (0.2 oz) silver per ton.
12	McBride------------------	A shear zone trends north and dips vertically in syenite. The zone is iron- and manganese-oxide stained, with sulfides. It is 1.5 m (5 ft) thick and exposed for about 25 m (80 ft) along strike.	Two trenches; five pits--	Three chip samples across shear zone; trace gold, as much as 12 g (0.4 oz) silver per ton, 0.04 percent copper. Three select grab samples of sheared rock; trace gold 9 g (0.3 oz) silver per ton.

13	Lonesome Pine------------	Brecciated quartz body cemented with a yellow ocher. Some of the quartz is recrystallized and vuggy; euhedral quartz is common. No sulfides seen.	One pit------------------	Two chip samples; trace gold, 6 and 16 g (0.2 and 0.5 oz) silver per ton.
14	-------------------------	A shear zone 1.2-1.5 m (4-5 ft) thick containing a quartz vein 12-15 cm (5-6 in.) thick with sulfides in brecciated syenite.	Two pits-----------------	One chip sample across shear zone; trace gold 6 g (0.2 oz) silver per ton, 0.05 percent copper. One grab sample; trace gold, 9 g (0.3 oz) silver per ton.
15	-------------------------	A mafic dike 1.8 m (6 ft) thick strikes N. 50° W. and dips vertically in syenite. Dike contains finely disseminated sulfides.	One trench---------------	One chip sample across dike; trace gold, 9 g (0.3 oz) silver per ton.
16	-------------------------	Brecciated sulfide-bearing iron-oxide-stained syenite. Sulfides are irregularly distributed through the rock.	----do-------------------	One grab sample; trace gold, 12 g (0.4 oz) silver per ton, 0.01 percent copper.
17	Lake View----------------	Two northwest-trending steeply dipping shear zones in syenite. Zones are 1.2 and 1.8 m (4 and 6 ft) thick and contain finely disseminated sulfides.	One adit 9 m (29 ft) long; four trenches.	One chip sample across shear zone 1.8 m (6 ft) thick; trace gold, and 6 g (0.2 oz) silver per ton. Three select grab samples of sheared rock; trace gold, as much as 9 g (0.3 oz) silver per ton.
18	-------------------------	Medium- to fine-grained porphyritic syenite, iron- and manganese-oxide stained along fractures.	One trench---------------	One grab sample of country rock; trace gold, 6 g (0.2 oz) silver per ton.
19	George-------------------	A mafic dike trends northerly in syenite. Quartz crystals and sulfides occur along the contact. Other rock types in float include sulfide-bearing gabbro and granitic rocks.	Seven trenches; six pits-	Two chip samples of dike rock; trace gold, 6 and 9 g (0.2 and 0.3 oz) silver per ton. Four grab samples; trace gold, 6-155 g (0.2-5.0 oz) silver per ton, as much as 0.4 percent copper.
20	-------------------------	Sulfide-bearing gabbro as float--------------	One trench---------------	One grab sample; trace gold, 9 g (0.3 oz) silver per ton.
21	Calumet------------------	Sulfide-bearing sheared syenite porphyry and gabbro on dumps.	Two trenches; two pits; one caved adit.	Three grab samples; trace gold, 9-22 g (0.3-0.7 oz) silver per ton. One sample contained 2.0 percent copper.
22	Giant Extension----------	A series of parallel shear zones strike N. 35° E. and dip 55° NW. in gabbro. Zones are 60-120 cm (2-4 ft) thick. Iron-oxide-stained gabbro and syenite with sulfides on dumps.	Two caved adits; four trenches.	One chip sample across one shear zone; trace gold, 9 g (0.3 oz) silver per ton. Three grab samples; trace gold, as much as 9 g (0.3 oz) silver per ton, 1.17 percent titanium.
23	-------------------------	A shear zone 1.2 m (4 ft) thick trending N. 70° E. in gabbro.	One trench; one pit------	One chip sample across shear zone and one select grab sample; trace gold, 9 g (0.3 oz) silver per ton.
24	-------------------------	A shear zone as much as 15 m (50 ft) thick contains sulfides. Zone trends N. 70° E. and cuts granitic rock.	One trench---------------	One select grab sample; trace gold, 12 g (0.4 oz) silver per ton.
25	Giant--------------------	Basalt, syenite, and granitic rock as float. No mineralized structured exposed.	Five trenches------------	Five grab samples; trace gold, 6-9 g (0.2-0.3 oz) silver per ton, 0.93 to 1.05 percent titanium.
26	Hercules-----------------	Granitic gneiss and gabbro as float. No mineralized structure exposed.	Two trenches; one caved adit.	One grab sample; trace gold, 12 g (0.4 oz) silver per ton.

TABLE 17.—*Mines, prospects, and claims sampled in the Beartooth Primitive Area and vicinity, Montana*—Continued

Map No.	Property name	Geology	Workings	Sample and assay data
27	------------------------	Granitic rock and syenite float. No mineralized structure observed.	Two trenches------------	Two grab samples; trace gold, 9 g (0.3 oz) silver per ton.
28	------------------------	No bedrock exposed. Float includes quartz monzonite, gabbroic gneiss, and diabase.	One trench--------------	One grab sample of dump; trace gold, 9 g (0.3 oz) silver per ton.
29	George Extension---------	A shear zone 1.2 m (4 ft) thick trends northeast in syenite. Finely disseminated sulfides in shear zone.	Two trenches; two pits---	Two grab samples of sheared zone; trace gold, 6 and 9 g (0.2 and 0.3 oz) silver per ton.
30	Jupiter-Talisman---------	Shear zones in syenite. Northernmost zone strikes N. 25° E., dips 80° SE., and is as much as 7.5 m (25 ft) thick. Southernmost zone strikes N. 25° W., dips vertically and is 4.5 m (15 ft) thick. Iron-oxide-stained quartz breccia occurs in narrow shear zones between north and south shear zones.	Six trenches; six pits---	One chip sample of each shear zone; trace gold, as much as 12 g (0.4 oz) silver per ton. One grab sample of quartz breccia; trace gold, 9 g (0.3 oz) silver per ton.
31	Copper King-------------	See text.		
32	Copper Queen------------	Iron-oxide-stained syenite containing quartz veinlets.	One trench--------------	One grab sample; trace gold, 9 g (0.3 oz) silver per ton, 0.07 percent copper.
33	------------------------	Sulfide-bearing hornblende syenite, iron- and manganese-oxide stain along fracture surfaces.	One caved shaft----------	One dump grab sample; trace gold, 6 g (0.2 oz) silver per ton.
34	------------------------	Quartz vein apparently in syenite with mafic inclusions.	Two trenches------------	One grab sample of quartz vein material, one grab sample of country rock; trace gold, 9 and 16 g (0.3 and 0.5 oz) silver per ton, respectively.
35	------------------------	No bedrock exposed. Syenite in float.	One trench---------------	One random grab sample; trace gold, 9 g (0.3 oz) silver per ton.
36	------------------------	Iron- and manganese-oxide staining along fractures in syenite containing very fine grained sulfides.	----do------------------	One random grab sample; trace gold, 9 g (0.3 oz) silver per ton, 0.03 percent copper.
37	------------------------	Iron- and manganese-oxide staining along fractures in syenite containing very fine grained sulfides.	----do------------------	One chip sample; trace gold, 6 g (0.2 oz) silver per ton.
38	------------------------	Iron-oxide-stained sheared syenite. No bedrock exposed; some sulfides.	----do------------------	One dump grab sample; trace gold, 12 g (0.4 oz) silver per ton.
39	Little Jonnie-----------	A basalt dike strikes N. 45° W. in granitic rock. Syenite and granitic gneiss as float. No sulfide minerals seen.	Five trenches; two sloughed pits.	One chip sample of dike; trace gold, 9 g (0.3 oz) silver per ton. Five dump grab samples; trace gold, 6-12 g (0.2-0.4 oz) silver per ton.
40	------------------------	No bedrock exposed; granitic country rock.	One sloughed trench------	One grab sample; trace gold, 6 g (0.2 oz) silver per ton.

41	------------------------	Granitic gneiss containing sulfides in stringers and on fracture faces.	Two trenches------------	One chip sample and one grab sample; trace gold, 9 g (0.3 oz) silver per ton.
42	Mercer group------------	North-trending shear zones and a basalt dike in altered granite and latite. An adit 20 m (67 ft) long crosscuts a shear zone 1 m (3 ft) thick. An adit 4.3 m (14 ft) long crosscuts a shear zone 60 cm (2 ft) thick and a quartz-pyrite pod 60 cm (2 ft) thick.	Two adits, 20 m (67 ft) and 4.3 m (14 ft) long; four pits.	One chip sample of shear zone in longer adit; trace gold and silver. One chip sample and one stockpile grab sample of quartz-pyrite pod material from shorter adit; trace gold, 16 and 12 g (0.5 and 0.4 oz) silver per ton; stockpile grab, 0.11 percent lead. Two chip samples of dike; trace gold, 6-9 g (0.2-0.3 oz) silver per ton.
43	Hiball Uranium----------	An iron- and manganese-oxide-stained rhyolite strikes N. 50° E. and dips 70° SE.	One pit-----------------	One chip sample; trace gold, 6 g (0.2 oz) silver per ton. No radioactivity detected.
44	------------------------	Limonite and recrystallized quartz breccia.	One trench--------------	One grab sample; trace gold, 9 g (0.3 oz) silver per ton.
45	------------------------	----do------------------------------------	----do------------------	One grab sample; trace gold and silver.
46	Kerr-McGee Pot No. 6-----	No bedrock exposed. Float consists of granitic gneiss and basalt dike rock.	One pit-----------------	One grab sample; trace gold, 9 g (0.3 oz) silver per ton.
47	Kerr-McGee Pot No. 8-----	----do------------------------------------	----do------------------	Do.
48	------------------------	An iron-oxide-stained shear zone 60 cm (2 ft) thick trends N. 10° W. and dips vertically in granitic rock.	One bulldozer trench-----	One chip sample across shear zone; trace gold, 12 g (0.4 oz) silver per ton.
49	------------------------	Granitic country rock; no mineralized structure exposed.	----do------------------	One random chip sample; trace gold, 6 g (0.2 oz) silver per ton.
50	Kerr-McGee Pot No. 4 and No. 5.	No bedrock exposed. Granodiorite, syenite, and granitic gneiss as float.	Two pits----------------	Two grab samples; trace gold, 6 g (0.2 oz) silver per ton.
51	Comet-Lone Star----------	A sulfide-bearing siliceous shear zone trending N. 30° E.	One pit-----------------	One select grab sample; trace gold, 31 g (1.0 oz) silver per ton, 0.5 percent lead.
52	Uranium Glance-----------	A sulfide-bearing pegmatite in granitic rock. Pegmatite trends N. 30° E., is 1.5-1.8 m (5-6 ft) thick, and is exposed for 11 m (35 ft) along strike.	Two pits----------------	Two chip samples across pegmatite; trace gold, 9-31 g (0.3-1.0 oz) silver per ton, as much as 1.0 percent lead. One select grab sample; trace gold, 60 g (1.9 oz) silver per ton, 1.0 percent lead. No radioactivity detected.
53	Copper Glance-----------	See text.		
54	Unus--------------------	A vertical shear zone 7.5 m (25 ft) thick strikes N. 65° E. in syenite porphyry. A vertical shear zone 1.2 m (4 ft) thick strikes N. 35° W. and is exposed at the portal of a caved adit.	One caved adit; one trench; three pits.	One chip sample across each shear zone; trace gold, and as much as 9 g (0.3 oz) silver per ton. One grab sample; trace gold, 6 g (0.2 oz) silver per ton.
55	------------------------	Two shear zones 60 cm (2 ft) thick in adit; one strikes N. 70° E. and dips vertically. The other is nearly horizontal for the length of the adit. Country rock is syenite porphyry.	One adit 10 m (32 ft) long; one sloughed trench.	One chip sample of vertical shear zone; trace gold, 9 g (0.3 oz) silver per ton. One chip sample of horizontal shear zone; trace gold, 6 g (0.2 oz) silver per ton. Two dump grab samples; trace gold, 6 g (0.2 oz) silver per ton.

TABLE 17.—*Mines, prospects, and claims sampled in the Beartooth Primitive Area and vicinity, Montana*—Continued

Map No.	Property name	Geology	Workings	Sample and assay data
56	Georgia	Iron-oxide-stained syenite porphyry as float.	One sloughed pit	One grab sample; trace gold, 6 g (0.2 oz) silver per ton.
57	Black Rock	A northeast-trending shear zone 1.8 m (6 ft) thick in syenite porphyry. Country rock is highly fractured with thick iron-oxide stain on fracture surfaces.	One trench; one pit	One chip sample across shear zone, one grab sample; trace gold, 6 and 9 g (0.2 and 0.3 oz) silver per ton.
58		No bedrock exposed. Stockpiled material is brecciated quartz with sulfides and minor limonite.	Two cuts; one trench; one caved adit.	One grab sample; trace gold, 12 g (0.4 oz) silver per ton.
59	White Quartz	Syenite with weathered amphibolite xenoliths	One trench	One grab sample; trace gold, 9 g (0.3 oz) silver per ton.
60	Copper Sentinel	Syenite with sulfides in stockpile	One caved adit adit	Do.
61	Lorraine	A vertical shear zone 60 cm (2 ft) thick in adit strikes N. 42° W. in diabase. A vertical shear zone, explored by trenches, strikes N. 25° W., dips vertically in syenite, and is as much as 3 m (10 ft) thick.	One adit 6.7 m (22 ft) long; three trenches.	One chip sample across shear zone 60 cm (2 ft) thick, one select grab sample of sheared material; trace gold, 6 and 9 g (0.2 and 0.3 oz) silver per ton. Select grab sample; 1.26 percent titanium. Two chip samples, one grab sample of shear zone 3 m (10 ft) thick; trace gold, 9-19 g (0.3-0.6 oz) silver per ton.
62		A vertical east-trending shear zone 1.5 m (5 ft) thick in iron-oxide-stained granitic gneiss. Shear zone contains quartz with finely disseminated sulfide minerals.	Two trenches	One chip sample across shear zone, one select grab sample; trace gold, 6 and 9 g (0.2 and 0.3 oz) silver per ton.
63		Iron-oxide-stained granitic rock as float. No bedrock exposed.	One pit	One grab sample; trace gold, 9 g (0.3 oz) silver per ton.
64		Two narrow shear zones, one trending N. 5° W. and one trending east, are enclosed in iron-oxide-stained granitic gneiss and monzonite.	One trench	One chip sample of both shear zones; trace gold, 9 g (0.3 oz) silver per ton.
65	Copper Idol	A shear zone 1.8 m (6 ft) thick trends east, dips 70° N. in granitic rock. The shear zone is exposed above the portals of two adits about 150 m (500 ft) apart. Fine-grained sulfide minerals in shear zone.	Two caved adits; five trenches.	Two chip samples across shear zone, three grab samples; trace gold, as much as 12 g (0.4 oz) silver per ton.
66		A shear zone trending east dips 80° N. in granite and monzonite. Zone is 1.8 m (6 ft) thick.	One caved adit	One chip sample across shear zone; trace gold, 12 g (0.4 oz) silver per ton.
67		Gabbro and granitic gneiss as float. No mineralized structure exposed.	Two trenches	One grab sample; trace gold, 6 g (0.2 oz) silver per ton.
68	OBW	A shear zone 1.8 m (6 ft) thick strikes N. 83° W. and dips 70° NE. in granitic rock; exposed at the portal of the adit.	One caved adit; one sloughed trench.	One chip sample across shear zone, one grab sample; trace gold, 6 and 9 g (0.2 and 0.3 oz) silver per ton.

69	------------------------	Sheared syenite as float. No mineralized structure exposed.	Two trenches------------	One grab sample; trace gold, 9 g (0.3 oz) silver per ton.
70	Dora Quartz--------------	A vertical shear zone strikes N. 42° E. in biotite-rich granitic rock. Zone is 60 cm (2 ft) thick.	----do------------------	One grab sample of shear zone; trace gold, 9 g (0.3 oz) silver per ton.
71	------------------------	Iron-oxide felsite and granitic rock with minor sulfide minerals. No bedrock exposed.	Three trenches----------	Three grab samples from stockpiles; no gold, silver, or copper detected.
72	------------------------	Iron-oxide-stained shear zone 30-60 cm (1-2 ft) thick in monzonite porphyry.	One pit-----------------	One chip sample 60 cm (2 ft) long; no gold, silver, or copper detected.
73	------------------------	A contact between a mafic body and pegmatitic granite.	One trench--------------	One select grab sample; trace gold, 9 g (0.3 oz) silver per ton.
74	Uranium Homestead--------	An east-trending shear zone in quartz monzonite and amphibolite.	----do------------------	One chip sample across shear zone; trace gold, 9 g (0.3 oz) silver per ton. No radioactivity detected.
75	Uranium Acre-------------	A quartz- and pyrite-bearing shear zone strikes N. 10° W. and dips 80° NE. in granitic gneiss. Zone is exposed for about 120 m (400 ft) along strike.	Three trenches----------	Two chip samples of shear zone; trace gold, 6 and 9 g (0.2 and 0.3 oz) silver per ton. One select grab sample; trace gold, 6 g (0.2 oz) silver per ton. No radioactivity detected.
76	------------------------	A vertical shear zone strikes N. 30° E. in granitic rock and is exposed for 120 m (400 ft) along strike. Zone averages 3 m (10 ft) thick.	None--------------------	One chip sample across shear zone; trace gold, 9 g (0.3 oz) silver per ton.
77	------------------------	A shear zone strikes N. 30° E. and dips 80° SE. in granitic rock. The zone is iron-oxide stained and as much as 3.7 m (12 ft) thick; it is exposed intermittently for about 300 m (1,000 ft) along strike.	----do------------------	Two chip samples across shear zone; trace gold, 9 g (0.3 oz) silver per ton.
78	------------------------	An iron-oxide-stained shear zone 90 cm (3 ft) thick strikes N. 20° E. and dips vertically in granitic rock.	----do------------------	One chip sample across shear zone; trace gold, 9 g (0.3 oz) silver per ton.
79	------------------------	An iron-oxide-stained basalt dike as much as 90 cm (3 ft) thick strikes N. 80° E. and dips near vertically.	One pit-----------------	One chip sample across dike; trace gold, 6 g (0.2 oz) silver per ton.
80	------------------------	Granitic country rock; sulfide-bearing quartz in small stockpiles.	Four trenches; two caved adits.	Five select grab samples; trace gold, 3-19 g (0.1-0.6 oz) silver per ton.
81	------------------------	Two intersecting shear zones 2.4 m (8 ft) and 1.2 m (4 ft) thick in amphibolite.	One pit-----------------	A composite sample of both shear zones; trace gold, 12 g (0.4 oz) silver per ton.
82	------------------------	A basalt dike strikes N. 30° E. and dips 50° SW in granitic gneiss. Dike is 30 cm (1 ft) thick.	----do------------------	One chip sample across dike; trace gold, 12 g (0.4 oz) silver per ton. A select grab sample; trace gold, 6 g (0.2 oz) silver per ton.
83	East Green Lake prospect-	A shear zone 6-38 cm (0.2-1.5 ft) thick strikes N. 40° E. and dips 40° SE. in granitic gneiss. The zone contains iron and copper sulfides with copper-carbonate and iron-oxide stains and is exposed for 3.7 m (12 ft) along strike.	----do------------------	One chip sample across shear zone; 1 g (0.03 oz) gold per ton, 93 g (3.0 oz) silver per ton, 1.34 percent copper, 0.10 percent lead. One select grab sample; 2.5 g (0.08 oz) gold per ton, 400 g (12.8 oz) silver per ton, 5.80 percent copper, 0.19 percent vanadium.

TABLE 17.—*Mines, prospects, and claims samples in the Beartooth Primitive Area and vicinity, Montana*—Continued

Map No.	Property name	Geology	Workings	Sample and assay data
84	Green Lake prospect------	A shear zone strikes N. 85° W. and dips 40° SE., associated with a major joint, in mica schist.	One caved adit----------	One chip sample across shear zone; trace gold and silver.
85	Lazy Beetle-------------	An east-trending shear zone 30-60 cm (1-2 ft) thick contains vuggy quartz with sulfides and occurs in migmatite.	One adit 6.7 m (22 ft) long; three pits; one caved shaft.	Two chip samples across shear zone; trace gold, 12 and 200 g (0.4 and 6.5 oz) silver per ton, as much as 0.14 percent copper.
86	------------------------	A shear zone in granitic rock is 20-50 cm (7-18 in.) thick and contains vuggy quartz and sulfides. Near contact with granite gneiss and basalt dike.	One trench--------------	One chip sample of shear zone; trace gold, 28 g (0.9 oz) silver per ton, 1.72 percent copper.
87	------------------------	A shear zone 20-50 cm (8-18 in.) thick contains a 7.5-cm- (3-in.-) thick quartz lens with sulfides. Zone strikes N. 50° E. through E. to S. 70° E. and dips 25° to 35° southerly. Country rock is granite.	One pit; one trench------	One chip sample across shear zone; trace gold, 6 g (0.2 oz) silver per ton, 0.006 percent copper. One select grab sample; trace gold, 6 g (0.2 oz) silver per ton.
88	------------------------	Iron-oxide-stained sheared granitic rock. Structures trend N. 70° E. and dip 50° SE.	One pit-----------------	One chip sample of sheared material; trace gold and silver.
89	Ontario claim-----------	An iron-oxide-stained shear zone 3 m (10 ft) thick strikes N. 20° E. and dips 40° SE. in granitic rock. Shear zone intersects a basalt dike at right angles in main trench.	Four trenches-----------	Two chip samples of shear zone; trace gold, 12 g (0.4 oz) silver per ton. Chip sample across dike; trace gold, 9 g (0.3 oz) silver per ton.
90	------------------------	Iron-oxide-stained mafic dikes 1.5 m (5 ft) thick strike N. 75° E. and dip near vertically in granitic rock.	One pit-----------------	One chip sample across dike; trace gold, 9 g (0.3 oz) silver per ton.
91	------------------------	No visible mineralized structure; granitic country rock.	One caved adit----------	One grab sample; trace gold, 9 g (0.3 oz) silver per ton.
92	------------------------	A shear zone 1 m (3 ft) thick strikes N. 78° W. and dips 60° SW. in granitic gneiss.	One pit-----------------	One chip sample across shear zone; trace gold, 9 g (0.3 oz) silver per ton.
93	------------------------	An iron-oxide-stained and sheared quartz lens as much as 0.8 m (2.5 ft) thick strikes N. 55° W. and dips 20° SW. in granite. Lens appears to be a quartz zenolith 2.5 m (8 ft) long, and contains pyrite and chalcopyrite.	----do------------------	One chip sample across quartz lens; trace gold and silver, 0.06 percent copper.
94	------------------------	Two parallel mafic dikes strike N. 60° W. and dip SW. One dike is 4.5 m (15 ft) thick and is in granitic gneiss. The other dike is 1.5 m (5 ft) thick and has intruded amphibolite and metasedimentary rocks.	----do------------------	One chip sample of each dike; trace gold, 9 g (0.3 oz) silver per ton.
95	------------------------	A brecciated fault zone 1.2 m (4 ft) thick strikes N. 80° E. and dips vertically in granitic rock.	----do------------------	One select grab sample; trace gold and silver.

96	------------------------	A shear zone 60 cm (2 ft) thick in granitic gneiss strikes N. 78° W. and dips 55° SW. Shear zone contains some iron sulfides and scheelite.	----do------------------	Two chip samples across shear zone; trace gold, as much as 3 g (0.1 oz) silver per ton, 0.01-0.23 percent WO_3, and 0.06-0.11 percent copper.
97	------------------------	A mafic dike 1.5 m (5 ft) thick strikes N. 70° W. and dips 80° SW. in granitic rock.	Three pits--------------	One chip and one grab sample of dike; trace gold and silver.
98	------------------------	A northwest-trending steeply dipping shear zone containing pegmatite cuts granitic gneiss. The pegmatite is 1.5-3 m (5-10 ft) thick and contains finely disseminated sulfides.	Four pits---------------	One chip sample; trace gold and silver.
99	Greenback---------------	A pegmatite 1-3 m (3-10 ft) thick interspersed with diabase dikes in dark well-foliated gneissic rock. The pegmatite strikes N. 70° W., dips steeply, and crops out for 40 m (130 ft). The diabase dikes range from 5 to 60 cm (2-24 in.) in thickness and contain disseminated pyrite.	One pit-----------------	Two chip samples across the pegmatite; trace gold, as much as 12 g (0.4 oz) silver per ton. One grab sample of the diabase dikes; trace gold, 6 g (0.2 oz) silver per ton.
100	Beavertrail-------------	A west-trending shear zone 30-60 cm (1.2 ft) thick in schist and gneissic rock is exposed in the south adit. No structures are exposed by the north adit.	Two adits 3 m (10 ft) long.	Two chip samples across shear zone; trace gold, as much as 9 g (0.3 oz) silver per ton, 0.02 percent copper. One grab sample of stockpile of north adit; trace gold and silver, 0.04 percent copper.
101	Near confluence of Goose Creek and Stillwater River.	Iron-oxide-stained granitic rocks. No mineralized structure or metallic minerals seen.	One pit-----------------	One grab sample; no gold or silver detected.
102	Goose Creek-------------	Slightly iron-oxide-stained granitic rocks. No mineralized structure or ore minerals were seen.	One caved pit-----------	One grab sample; no metals detected.
103	C. C. and Acme claims----	A north-trending shear zone 1-1.5 m (3-5 ft) thick in granitic rock. Shear zone contains quartz stringers as much as 1.5 cm (0.5 in.) thick and is traceable for 135 m (450 ft) between workings.	Three pits; one shaft; one caved adit.	One chip sample across the shear zone; trace gold, no silver detected. One dump sample of vein quartz; trace gold, 19 g (0.6 oz) silver per ton. One chip sample and one grab sample from dump; trace gold, 9 g (0.3 oz) silver per ton.
104	Wally Jr.---------------	A northeast-trending steeply dipping shear zone in granitic gneiss. The zone is as much as 1.2 m (4 ft) thick and contains quartz. It is exposed the length of the adit.	One adit 25 m (80 ft) long.	Three chip samples of shear zone; trace gold, as much as 9 g (0.3 oz) silver per ton, 0.02 percent copper and lead.
105	------------------------	A north-trending basalt dike 2.5 m (8 ft) thick in granitic gneiss. The dike is coated with iron oxides.	Three pits--------------	One chip sample across dike; trace gold and silver, 0.2 percent lead.
106	Mutt Lake---------------	An east-trending basalt dike in the western workings. An east-trending shear zone 2.5 (8 ft) thick in eastern workings. Country rock is granitic gneiss. Stockpile at eastern workings contains sulfides of copper and lead.	Six pits; one shaft 3 m (10 ft) deep.	One chip sample across shear zone; trace gold and silver. One select grab sample of stockpile; trace gold and silver, 0.02 percent copper, 0.3 percent lead.

TABLE 17.—*Mines, prospects, and claims sampled in the Beartooth Primitive Area and vicinity, Montana*—Continued

Map No.	Property name	Geology	Workings	Sample and assay data
107	Sky Top Creek------------	A sulfide-bearing mineralized shear zone 1.2 m (4 ft) thick in granitic rock.	One trench; one caved adit.	One chip sample across shear zone; trace gold, 6 g (0.2 oz) silver per ton.
108	Early Vacation group-----	Nine uranium claims cover biotite-hornblende granite and pegmatite dikes.	None--------------------	Two chip samples; trace gold and silver. No anomalous radioactivity.
109	Rearguard----------------	Quartz pods are found along the contact of diabase and trachyte dikes. The quartz contains blebs of chalcopyrite and bornite as much as 1.5 cm (0.5 in.) in diameter.	----do------------------	One chip sample of quartz; trace gold and silver, 0.4 percent copper.
110	Gallon Jug No. 4---------	See text.		
111	Gallon Jug No. 1---------	See text.		
112	Gallon Jug No. 2---------	See text.		
113	Drill and Gallon Jug-----	See text.		
114	North Star No. 1---------	See text.		
115	Shovel-------------------	See text.		
116	Pick---------------------	See text.		
117	Little Nell group--------	See text.		
118	Four Chromes group-------	See text.		
119.	C. R. Discovery----------	A uranium claim on hornblende-biotite granite gneiss.	One pit-----------------	No significant radioactivity.
120	Edsel--------------------	See text.		
121	Wapiti Mountain group----	Several quartz veins in hornblende granite. The veins contain chlorite, magnetite, and malachite.	One shaft; five pits-----	Five samples (average); trace gold, 5 g (0.16 oz) silver per ton.
122	Silver Run---------------	Bedrock is not exposed; amphibolite on dump of workings.	One pit-----------------	One dump sample; trace gold and silver.
123	Ingles Creek-------------	Diabase dike is exposed for 75 m (245 ft) in trench.	One trench--------------	One chip along trench; trace gold, 2 g (0.06 oz) silver per ton.
124	Lake Mary----------------	A fault zone contains iron-oxide-stained chloritized brecciated granite.	One pit-----------------	One chip sample across zone; trace gold and silver.
125	Pyramid Mountain group---	Claims are on talus composed of blocks of granitic gneiss and serpentinized mafic remnants. One piece of mafic rock in float contained chrysotile asbestos veinlets as wide as 1 cm (0.2 in.).	None--------------------	Two samples of float; trace gold and silver.
126	Jim Hawkes---------------	A shear zone 30-60 cm (1-2 ft) thick with some gouge. No metallic minerals noted. Country rock is mafic and pegmatite dikes in granitic gneiss.	One adit 9 m (30 ft) long.	Two chip samples across shear zone; trace and 6 g (0.2 oz) silver per ton, 0.01 percent copper; no gold detected.
127	Hawkes lode--------------	A shear zone 2.5 m (8 ft) thick trends northwest, dips southwest in hornblende-biotite granite, and is exposed for the length of the adit. The zone contains quartz stringers and veins with minor sulfide minerals.	One adit 30 m (100 ft) long.	Three chip samples across quartz veins (average); trace gold, 3 g (0.10 oz) silver per ton.

128	Groundhog	A chromite band 60 cm (2 ft) thick overlying a leopard-patterned chromite band 0.9-1.2 m (3-4 ft) thick. Country rock is harzburgite. Prospect is situated just outside of study area boundary.	Several pits	One chip sample of chromite band; 32.31 percent chromic oxide.
129	------------------------	Iron-oxide-stained shear zone about 3 m (10 ft) thick in granitic gneiss.	Two pits 35 m (110 ft) apart.	Two chip samples; trace gold and silver.
130	East Rainbow	A fault zone in granite contains iron-oxide-stained granite breccia.	One trench; two pits	One chip sample of zone; trace gold and silver.
131	Rainbow	Several pegmatite dikes as thick as 60 cm (2 ft) in granite.	One pit	One dump sample; trace gold and silver.

COPPER KING CLAIM

The Copper King claim (fig. 24, No. 31), at the north end of Goose Lake, was located in 1904 and patented in 1906 along with three other nearby claims.

The Copper King Mining and Development Co. was organized in 1904, and a road from Cooke City to the mine site was constructed (Lovering, 1930, p. 46). A two-compartment shaft near the edge of the lake was reported to have been dug to a depth of about 18-30 m (60-100 ft). The shaft intersected 6 m (20 ft) of copper-rich syenite near the collar (O. B. Hart, written commun., 1948) and also bottomed in copper-rich rock. The shaft bottomed below the level of Goose Lake, where it was flooded. A 16-t (18-ton) ore shipment reportedly was made in 1907, but the grade and destination of the material is not known. In 1959 the Bear Creek Mining Co., a subsidiary of Kennecott Copper Co., explored the area around the Copper King shaft using geochemical and geophysical methods and, in 1960, drilled seven exploratory holes. The lease on the property was reportedly dropped because no large ore body that could be mined by surface methods was found (Margaret Reeb, written commun., 1971).

In 1970 Kerr-McGee Corp. optioned the property and relocated 19 claims which covered the basin on both sides of Goose Lake. Numerous discovery trenches were dug, and in 1971, at least four exploratory holes were drilled. The property then reverted to the owner.

Outcrops of a syenite stock that contains sulfide minerals attracted early interest. The stock is poorly exposed for about 1,500 m (5,000 ft) to the east and nearly 1,300 m (4,300 ft) to the north (fig. 24). It underlies the north end of Goose Lake basin, including the north end of the lake. Surface expressions of several lineaments trend northwest and northeast through the stock, but their relationship to the mineralization is unknown. Numerous pits, trenches, adits, and shallow shafts have been dug in the stock, but most are now caved, and bedrock is covered.

The syenite is medium grained, and most of it contains minor sulfide minerals. The highest grade rock was found in a 41-t (45-ton) stockpile near the main Copper King shaft and in a small stockpile of a second shaft situated 80 m (270 ft) to the northeast. Material in the main stockpile indicates that the Copper King shaft apparently intersected a breccia zone in syenite that contained chalcopyrite and minor pyrite. Some syenite in the stockpile also contains disseminated chalcopyrite and some of the breccia contains veins of chalcopyrite as much as 4.5 cm (1.75 in.) thick. Chalcopyrite in the stockpile was coated with iron oxides except for a few randomly oriented, iridescently tarnished crystal faces. Malachite occurs sporadically on the weathered rock surfaces.

All the diamond drill holes made by Bear Creek Mining Co. reportedly intersected some sulfide minerals, but only one intersected a mineralized zone that had economic possibilities. It was located at a gabbro-syenite contact about 700 m (2,300 ft) northeast of the Copper King shaft and was drilled 110 m (370 ft). The core contained syenite near the collar, gabbro intruded by syenite dikes to a depth of 110 m (370 ft), and quartz monzonite at the bottom. The highest grade material intersected was in the interval from 75 m (245 ft) to the bottom of the hole, a total of 38 m (125 ft). Copper content ranged from 0.12 to 0.69 percent, with a weighted-by-length average of 0.31 percent copper; gold ranged from a trace to 7 g/t (0.2 oz/ton), with a weighted-by-length average of 4 g/t (0.12 oz/ton); silver ranged from 3 to 17 g/t (0.1 to 0.5 oz/ton) and had a weighted-by-length average of 9 g/t (0.26 oz/ton). This hole represents the easternmost extent of the known mineralized rock. Mineralized rock in the stockpile assumed to be from the main shaft represents the westernmost extent of the potentially economic mineralized zone. It is not known, however, whether the mineralized zone is continuous between the shaft and the drill hole.

Part of Kerr-McGee's drilling was west and southwest of the Copper King shaft, but information on this exploration is not available.

A random grab sample of the stockpile at the main shaft contained 1 g/t (0.03 oz/ton) platinum, 0.9 g/t (0.026 oz/ton) palladium, 0.3 g/t (0.01 oz/ton) gold, 37 g/t (1.1 oz/ton) silver, and 6.8 percent copper. A random grab sample of the dump material surrounding the collar of the shaft contained a trace of gold, 10 g/t (0.3 oz/ton) silver, and 0.16 percent copper. The most unusual sample obtained in the basin was from a small scattered stockpile at the small caved shaft just northeast of the main shaft. The material, which probably came from the shaft, consisted of syenite and a few sulfide minerals and contained 44 g/t (1.30 oz/ton) platinum, 36 g/t (1.06 oz/ton) palladium, 102 g/t (3.0 oz/ton) silver, 3.2 percent copper, and a trace of gold. Samples across limited exposures of syenite and from a cut that exposes a shear zone 3 m (10 ft) thick near the small shaft contained only a minor amount of copper, a trace of gold, 10 to 14 g/t (0.3 to 0.4 oz/ton) silver, and 0.3 g/t (0.001 oz/ton) platinum, but no detectable palladium.

The property is a potential source of copper, gold, silver, and platinum-group metals, but an estimate of the potential resources could not be made because the extent of the mineralized zone and the distribution of metals of value are not known. Additional exploration is necessary to determine the extent and average grade of the mineralized zone of the Copper King and adjacent properties.

COPPER GLANCE CLAIM

The Copper Glance claim (fig. 24, No. 53) is at the southwestern edge of Goose Lake and is accessible by 0.8 km (0.5 mi) of rough trail from the main Cooke City dirt road. The claim, located in 1910, was developed by two adits and several surface cuts. The upper adit is partially flooded and caved at the portal. The lower adit, situated directly below, is caved. The country rock is granite gneiss and amphibolite. The upper adit is about 35 m (120 ft) long and intersects two shear zones. The most prominent zone is 3 m (10 ft) thick and is exposed 25 m (80 ft) from the portal; it strikes N. 5° E. and dips 55° W. It consists of sheared granitic rock with an abundance of gouge. Only part of the zone was sampled because of the unsafe condition of the adit in the vicinity of the shear zone. A 1.8-m (6-ft) chip sample contained a trace of gold and 7 g/t (0.2 oz/ton) silver and shows a trace of radioactivity. The other shear zone contains quartz breccia and is exposed at the portal of the adit. It strikes N. 35° E., dips 60° SE., and is about 2.5 m (8 ft) thick. A chip sample taken across the zone contained a trace of gold and 7 g/t (0.2 oz/ton) silver.

The lower adit exposed a sheeted zone 3 m (10 ft) thick that contains quartz veins with pyrite, galena, sphalerite, chalcopyrite, and boulangerite (Lovering, 1930, p. 74). Drill cuttings contained 21 g/t (0.61 oz/ton) gold, 55 g/t (1.62 oz/ton) silver, and 0.3 percent lead.

Stockpiled material contained pyrite, galena, and secondary quartz crystals in vugs in an iron oxide cemented quartz breccia. A scintillometer reading indicated a maximum of 0.4 milliröntgens per hour about 10 times the background reading. Samples of the stockpile contain a trace of gold, 27-130 g/t (0.8-3.8 oz/ton) silver, and 0.66-2.21 percent lead; one sample contained 0.22 percent copper. The source of the radioactivity is not known.

The stockpiled material does not seem to be the same as that exposed in the upper adit and probably came from nearby caved cuts or trenches. Reopening of the caved workings might reveal the mineralized rock from which the stockpile originated.

RED LODGE MINING DISTRICT

The Red Lodge mining district is on the east edge of the Beartooth study area a few miles southwest of Red Lodge. Chromite deposits in the district occur at five localities on Silver Run, Hellroaring, and Line Creek Plateaus (fig. 25). The Line Creek Plateau is east of the study area. The deposits are exposed at the edges of plateaus at an elevation of about 3,000 m (10,000 ft). The deposits on Hellroaring and Line Creek Plateaus are accessible by road, but the others are accessible only by trail.

The Four Chromes group (fig. 25, No. 118) was located in 1916, and the others were discovered between 1920 and 1931. During the early 1940's, the U.S. Vanadium Corp. mined 39,800 t (43,800 tons) of chromite ore from the Hellroaring group (fig. 25, Nos. 110-116) and about 21,800 t (24,000 tons) from the Highline group (fig. 25). No production has been recorded from the properties on Silver Run Plateau.

Chromite is in small masses of ultramafic rock enclosed in granitic gneiss. Both ultramafic and granitic rocks were intruded by diabase, trachyte, pegmatite, and aplite dikes. Schafer (1937, p. 25) believed that the ultramafic bodies were separated by faulting.

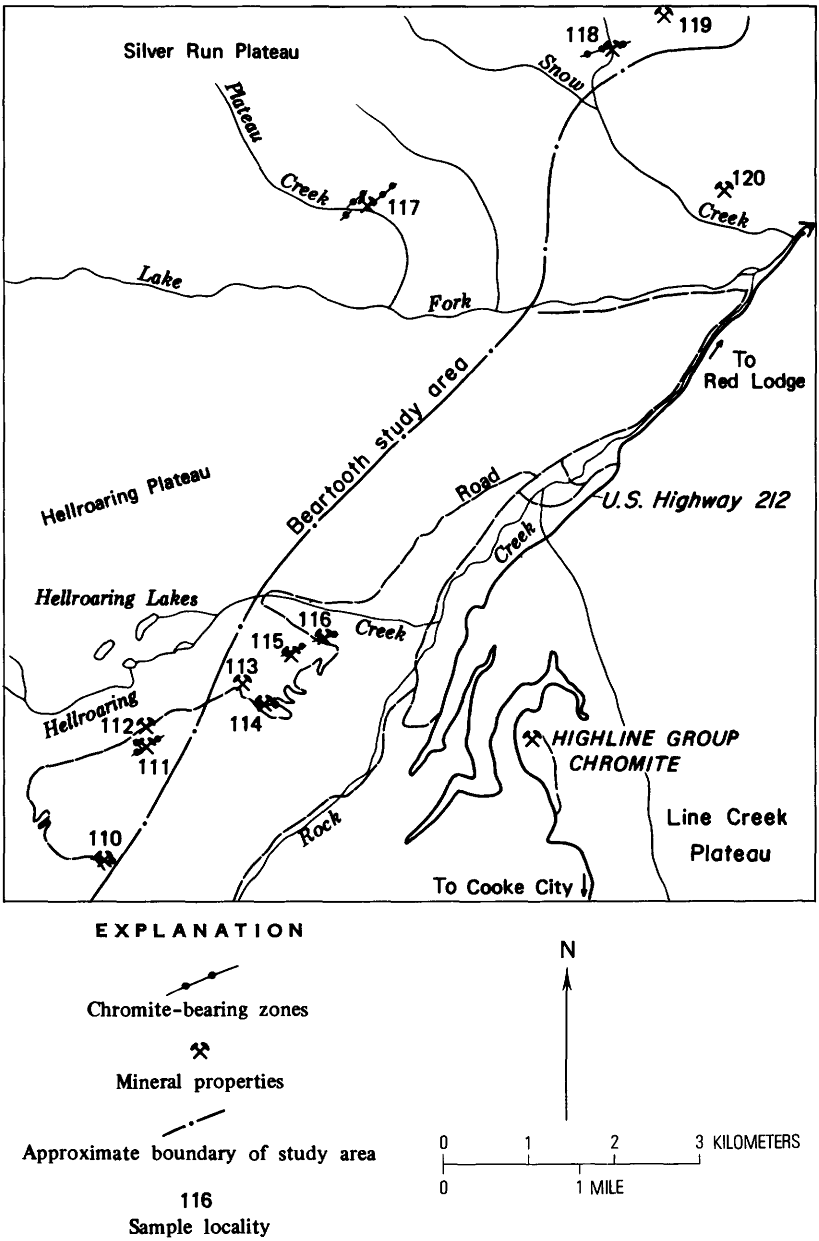


FIGURE 25.—Chromite deposits in the Hellroaring, Silver Run, and Line Creek Plateaus, Red Lodge mining district.

The chromite occurs in pods and lenses and as scattered grains within serpentinized parts of the ultramafic rocks. Other associated minerals are magnetite, olivine, pyroxene, chlorite, actinolite-tremolite, talc, plagioclase, and chrome garnet (uvarovite). Analyses of two chromite concentrates, one from the Hellroaring group and the other from the Little Nell deposit (fig. 25, No. 117), showed 34.02 and 31.67 percent chromium and 22.00 and 24.20 percent iron, respectively. The chromium to iron ratios were 1.55:1 and 1.31:1, respectively.

Some chromite-bearing lenses have been almost completely mined. About 70,000 t (77,000 tons) of chromite ore averaging 12.8 percent Cr_2O_3 is estimated for the remaining parts of the lenses. These deposits are small, but the remaining ore could possibly be mined economically by surface methods. In comparison with the large chrome resources remaining in the Stillwater Complex nearby, the Red Lodge deposits are insignificant.

HELLROARING GROUP

The Hellroaring group (pl. 2; fig. 25, Nos. 110-116) consists of at least 29 claims. Chromite-bearing zones are exposed on several of the claims. According to Herdlick (1948, p 11) about 31,750 t (35,000 tons) of chromite ore, averaging 25 percent Cr_2O_3, was mined from the open pit at the North Star No. 1 claim (fig. 25, No. 114; fig. 26). The chromite has an average chromium to iron ratio of 1.8:1. Three chromite-bearing lenses in faulted serpentinite are exposed in the pit. The largest lens is 32 m (105 ft) long, 3 m (10 ft) thick, and at least 9 m (30 ft) deep. Samples from the lenses averaged about 12 percent Cr_2O_3. A sample from one of the smaller zones contained 18.1 percent Cr_2O_3. An estimated 2,900 t (3,200 tons) of chromite-rich rock remains at the North Star No. 1 claim.

Two random grab samples from a 5,000-t (5,500-ton) stockpile at the main road near the North Star No. 1 workings averaged 29.2 percent Cr_2O_3 with a chromium to iron ration of 1.54:1. Deposits contributing to this stockpile are unknown, but most of the material probably came from the North Star No. 1 pit.

The serpentinite exposed at the North Star No. 1 claim continues southwest across the plateau through the Gallon Jug and Drill claims (fig. 25, Nos. 111-112; fig. 27). The serpentinite and adjacent rocks are intensely faulted and folded. Open-pit mining of several chromite lenses produced

Data for samples shown in figure 26

Sample				
No.	Type	Length (feet)	Description	Cr_2O_3 (percent)
1-----	Chip----	5.0	Across chromite lens------	18.1
2-----	do------	47.0	Along chromite lens-------	9.8
3-----	do------	42.0	do-----------------------	22.9
4-----	do------	14.0	Across chromite lens------	4.1

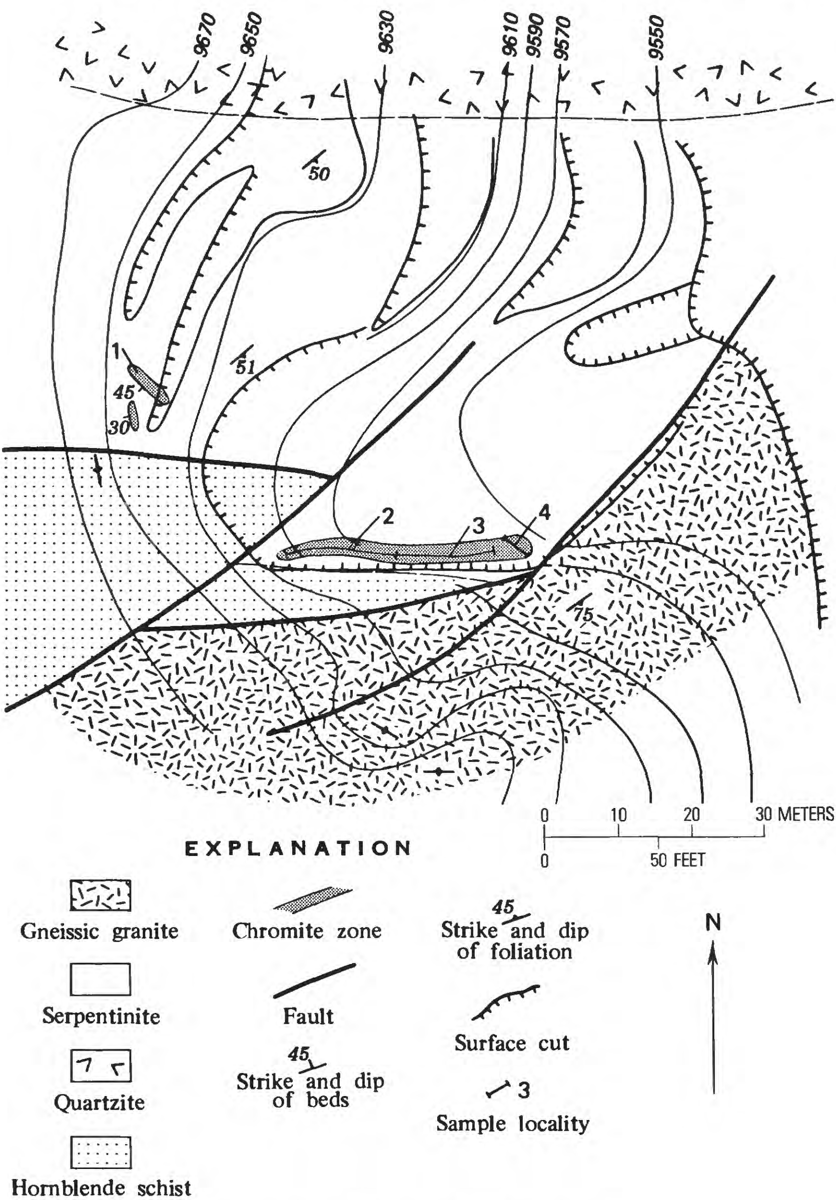


FIGURE 26.—North Star No. 1 workings.

1,537 t (1,691 tons) of ore. Two chromite-bearing lenses 30 m (100 ft) long and 1.5 m (5 ft) thick and several smaller lenses remain at the property. Chromite occurs as veinlets and scattered grains in a groundmass of saussuritized plagioclase and serpentinized olivine and pyroxene. Uvarovite occurs locally. Chip samples from the two largest lenses averaged about 5.5

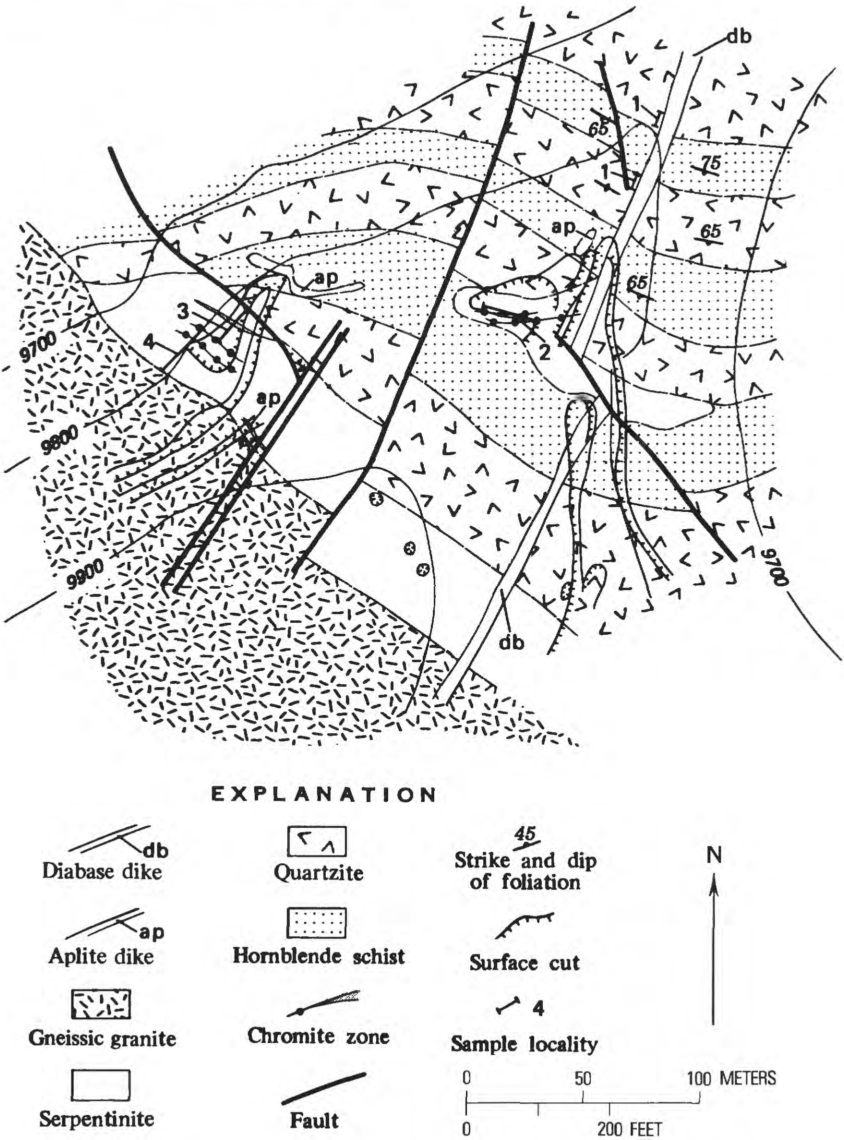


FIGURE 27.—Drill and Gallon Jug workings.

percent Cr_2O_3. A total of 4,535 t (5,000 tons) of resources of this grade is estimated to be present in these deposits. A magnetic survey by James (1946, p. 175) extended 250 m (800 ft) along the serpentinite exposed between the Drill and North Star No. 1 pits, and he reported a few very high readings, comparable to those obtained over the known ore bodies.

Several chromite-bearing lenses are exposed on the Gallon Jug Nos. 1 and 2 claims (fig. 28). The largest zone is exposed in a series of trenches on the Gallon Jug No. 2 claim (fig. 25, No. 112; fig. 28); 1,166 t (1,283 tons) of chromite ore was mined from this claim in 1942 (James, 1946, p. 184). The zone is lens shaped and may be as much as 60 m (200 ft) long and 8 m (25 ft) thick. It is composed of chromite-bearing pods and disseminated grains in serpentinized and chloritized peridotite and is cut by diabase and aplite dikes. We estimate that the zone contains about 22,700 t (25,000 tons) chromite averaging 11.3 percent Cr_2O_3. Magnetic surveys in search of possible buried chromite deposits to the west were inconclusive because of the presence of magnetically responsive diabase (James, 1946, p. 177).

A small body of serpentinite containing chromite-bearing lenses crops out in the southwest corner of the Gallon Jug No. 1 claim (fig. 25, No. 111; fig. 29). A sample taken across the lenses assayed 15.0 percent Cr_2O_3. Two large lenses of chromite-bearing peridotite were exposed during the road building at the Gallon Jug No. 1 claim (fig. 29). One lens is 1.5 m (5 ft) thick and 45 m (150 ft) long, and the other is 4.5 m (15 ft) thick and 75 m (250 ft) long. Total potential resources from both lenses are estimated to be about 36,000 t (40,000 tons) of chromite-bearing rock, averaging about 14 percent Cr_2O_3.

About 480 t (530 tons) of chromite ore was mined from trenches at the Gallon Jug No. 4 claim (fig. 25, No. 110) in 1943 (James, 1946, p. 186). Five chromite-bearing lenses are exposed at present (fig. 30). The two largest lenses are exposed in the eastern part of the workings; one is 1.5 m (5 ft) thick and 30 m (100 ft) long and the other is 0.9 m (3 ft) thick and 23 m (75 ft) long. Three smaller lenses as much as 15 m (50 ft) long occur along a fault at the center of the workings. An estimated 3,500 t (3,900 tons) of chromite-bearing rock averaging about 16 percent Cr_2O_3 remains at the property.

The Pick claim (fig. 25, No. 116) was developed by two adits and an open pit. One adit is 46 m (150 ft) long and was driven along a serpentinite-porphyry dike contact. A chromite lens about 24 m (80 ft) long and as much as 4.5 m (15 ft) thick was stoped from near the face of the adit to the surface, a vertical distance of 21 m (70 ft) (James, 1946, p. 180). The

Data for samples shown in figure 27

Sample		Length (feet)	Description	Cr_2O_3 (percent)	Silver (ounce per ton)
No.	Type				
1---	Chip---	40.0	Altered quartzite at dike contact-----------	--	0.3
2---	do-----	85.0	Chromite-bearing zone in serpentine----------	7.1	--
3---	do-----	60.0	do-----------------------	1.6	--
4---	do-----	80.0	do-----------------------	8.8	--

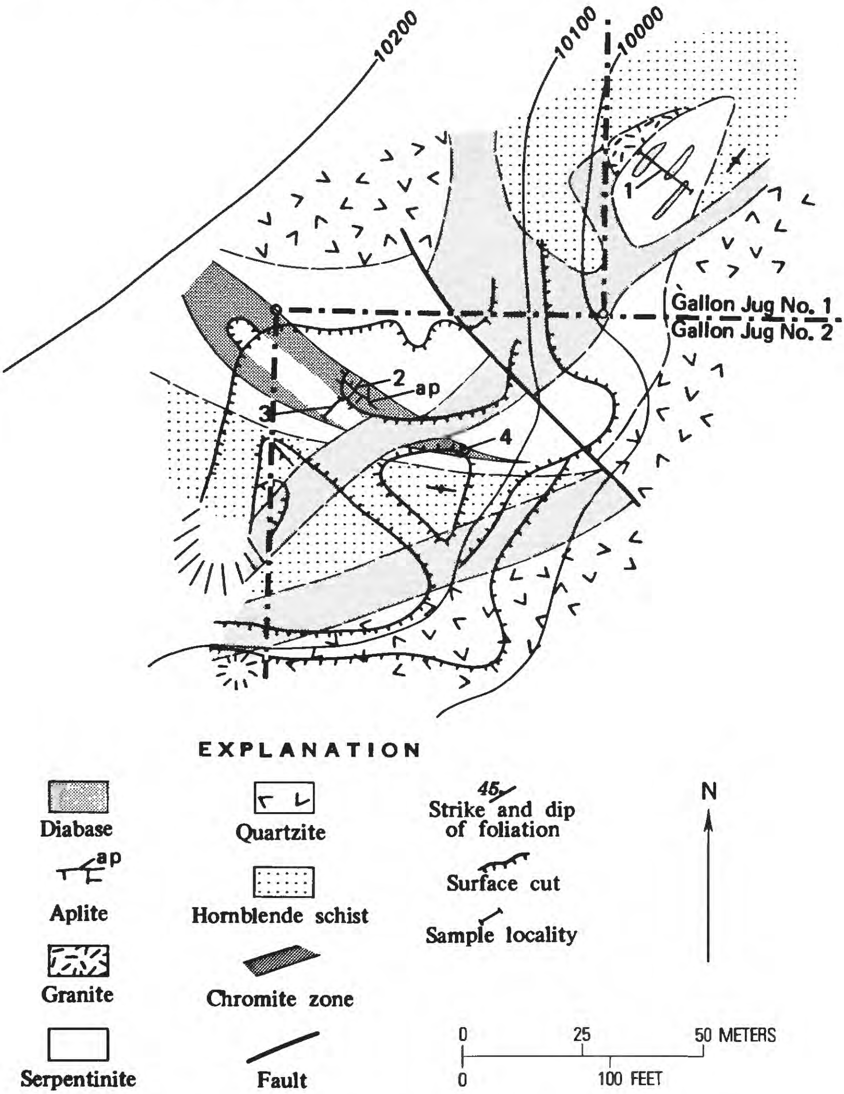


FIGURE 28.—Gallon Jug Nos. 1 and 2 claims. Modified from James (1946).

lens, which produced 4,857 t (5,343 tons) of chromite ore, was apparently mined out. A 115-m-long (380-ft-long) adit was driven 52 m (170 ft) below the upper adit to crosscut the chromite orebody but only a thin chromite-bearing stringer was intersected (James, 1946, p. 180). The workings of the claim are now caved and inaccessible.

A 27-m (90-ft) adit was driven on the Shovel claim to explore for the source of chromite-bearing float (fig. 25, No. 115). Chromite-bearing rock was encountered at 7.6 m (25 ft) from the portal and was then mined by

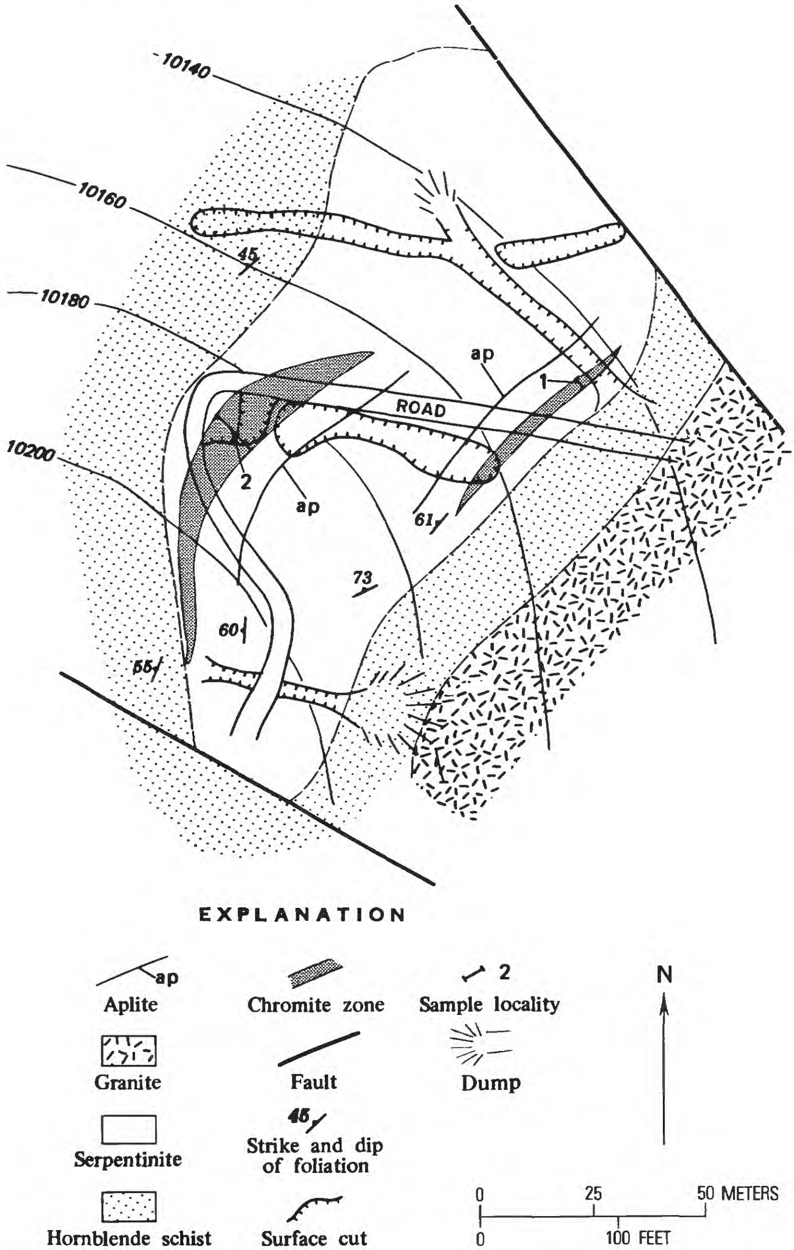


FIGURE 29.—Gallon Jug No. 1 workings.

underhand stoping. The lens was completely mined out and chromite-bearing material is now found only on the dump. The adit crosscuts three quartz-filled shear zones. A sample from the thickest—5 cm (2 in.)—shear

Data for samples shown in figure 28

Sample No.	Sample Type	Length (feet)	Description	Cr_2O_3 (percent)
1----	Chip----	45.0	Chromite-bearing zone--	15.0
2----	do------	18.0	do--------------------	13.7
3----	do------	13.0	do--------------------	17.2
4----	do------	10.0	do--------------------	3.1

Data for samples shown in figure 29

Sample No.	Sample Type	Length (feet)	Description	Cr_2O_3 (percent)
1------	Chip	10.0	Chromite lens----	1.0
2------	do------	35.0	do---------------	26.9

Data for samples shown in figure 30

Sample No.	Sample Type	Length (feet)	Description	Cr_2O_3 (percent)
1-----	Chip----	5.0	Chromite lens-----------	28.6
2-----	do------	7.5	do---------------------	.2
3-----	do------	8.0	do---------------------	8.6
4-----	do------	4.5	do---------------------	25.8

zone contained 1.23 percent copper. A magnetic survey by James (1946, p. 175) indicated that several small serpentine bodies are concealed beneath the overburden for some distance southwest of the adit. Some serpentine float is in this area.

LITTLE NELL GROUP

The Little Nell group of claims (fig. 25, No. 117) is on Plateau Creek, 3 km (2 mi) north-northeast of the Hellroaring group.

Three adits, a shaft, and several cuts were driven on serpentinized ultramafic bodies in contact with granite and monzonite-porphyry intrusives (fig. 31). A large fault along Plateau Creek offsets the rock units. Chromite occurs with tremolite, actinolite, and talc in small pods scattered through the serpentinite. The best exposure of the mineralized zone is a sheared lens 60-cm (2-ft) thick at the face of an adit 8 m (26 ft) long southwest of a cabin. Two stockpiles at the portal contain 12.4 t (13.6 tons) of ore. A representative grab sample contained 29.3 percent Cr_2O_3 and had a chromium to iron ratio of 1.31:1. A few hundred pounds stockpiled on the dump of a caved adit 46 m (150 ft) long near the creek contained 24.7 percent

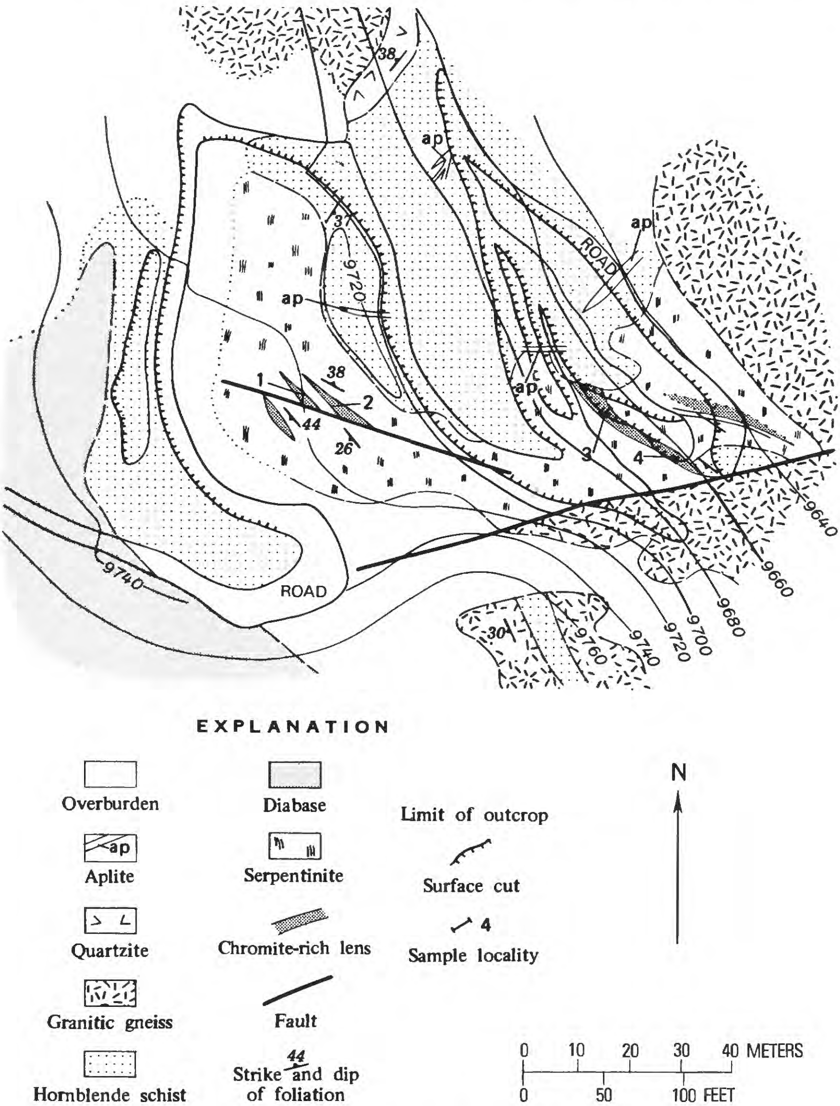


FIGURE 30.—Gallon Jug No. 4 workings.

Cr_2O_3. A half-ton stockpile on the dump of a caved adit north of the creek contained 23.4 percent Cr_2O_3. Small amounts of chromite-bearing rock are at the shaft north of the creek, in a pit southwest of the cabin, and at a cut on a pegmatite-serpentinite contact northwest of the cabin.

The chromite-bearing bodies are poorly exposed but appear to occur along a line that trends toward the Four Chromes property 3 km (2 mi) northeast. It is possible that other small chromite-bearing bodies are in the area between the two properties.

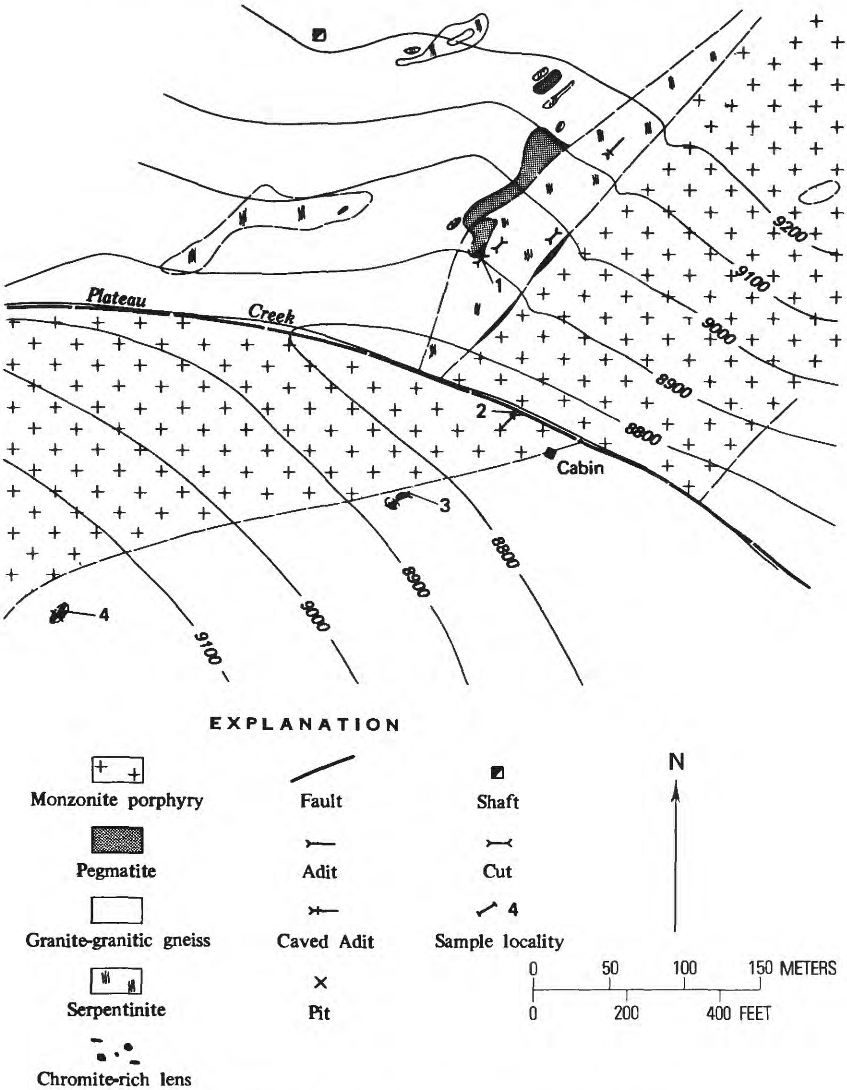


FIGURE 31.—Little Nell Group. Modified from James (1946).

Data for samples shown in figure 31

Sample No.	Sample Type	Length (feet)	Description	Cr_2O_3 (percent)
1-----	Grab----	--	Chromite stockpile-----------	23.4
2-----	do------	--	do---------------------------	24.7
3-----	do------	--	do---------------------------	29.3
4-----	do------	--	Serpentinized peridotite with minor chromite---------------	.4

FOUR CHROMES GROUP

The Four Chromes group, 3 km (2 mi) northeast of the Little Nell group (fig. 25, No. 118), originally consisted of seven claims, but part of the property was relocated in 1940 by Montana Chrome, Inc., as the Wendell Wilkie group.

The claims are on a series of serpentinite bodies that are mainly in granite cut by numerous faults and dikes. The main serpentinite exposure (fig. 32) is lens shaped, is about 35 m (115 ft) long, and averages 18 m (60 ft) across. Chromite occurs in pods randomly distributed in the serpentinite. The largest pod crops out in a pit about 90 m (300 ft) east of the creek and is 6 m (20 ft) long and 3.7 m (12 ft) thick. A sample taken across the pod contained 26.45 percent Cr_2O_3 (Schafer, 1937, p. 32). Trenching in 1942 by Herdlick (1948, p. 9) uncovered several additional chromite-rich lenses, but none exceeded 2.4 m (8 ft) in length and 60 cm (2 ft) in thickness. Samples from the trenches averaged 6.16 percent Cr_2O_3. The property also has a small resource of low-grade chromite.

EDSEL CLAIM

The Edsel claim, 1.6 km (1 mi) east-southeast of the Four Chromes group (fig. 25, No. 120), covers small bodies of ultramafic rock in hornblende-bearing granitic gneiss. Both rock types are faulted and intruded by diabase and trachyte porphyry dikes. Chromite is found in two pits as stringers and in two zones of serpentinized peridotite as disseminated grains. The zones are both about 1.2 m (4 ft) thick and 4.5 m (15 ft) long. A sample taken across them contained 0.46 percent Cr_2O_3. The northern and southern extensions of the zones are covered by talus. A 73-m (240-ft) adit was driven to intersect the peridotite at depth but penetrated fractured porphyry only.

STILLWATER DISTRICT

The Stillwater district is on the north edge of the Beartooth study area. All mineral production of the district has come from the Stillwater Complex, a belt of ultramafic rocks and anorthosite, 1.6-8 km (1-5 mi) wide and about 48 km (30 mi) long. The complex lies along the northern boundary of the study area, and small segments may extend into the study area.

The complex as generalized by Howland, Peoples, and Sampson (1936) is composed of four zones: an upper zone consisting of anorthosite about 1,100 m (3,500 ft) thick; a banded zone consisting of norite and gabbro, about 1,500 m (5,000 ft) thick; an ultramafic zone consisting of bronzitite, harzburgite, and dunite, 750 m (2,500 ft) thick; and a basal zone of hornfels, norite, and other contact rocks, as much as 90 m (300 ft) thick. All the known metal-bearing zones of the complex have been claimed.

Metals of economic interest found in the complex include chromium, copper, nickel, and platinum-group metals. Chromite occurs in the ultramafic zone as persistent bands as much as 15 m (50 ft) thick. Those that have been mined range in thickness from less than 1 m (3.2 ft) to about 3.6 m (12 ft) (Wimmler, 1948, p. 11). Nickel and copper are sporadically

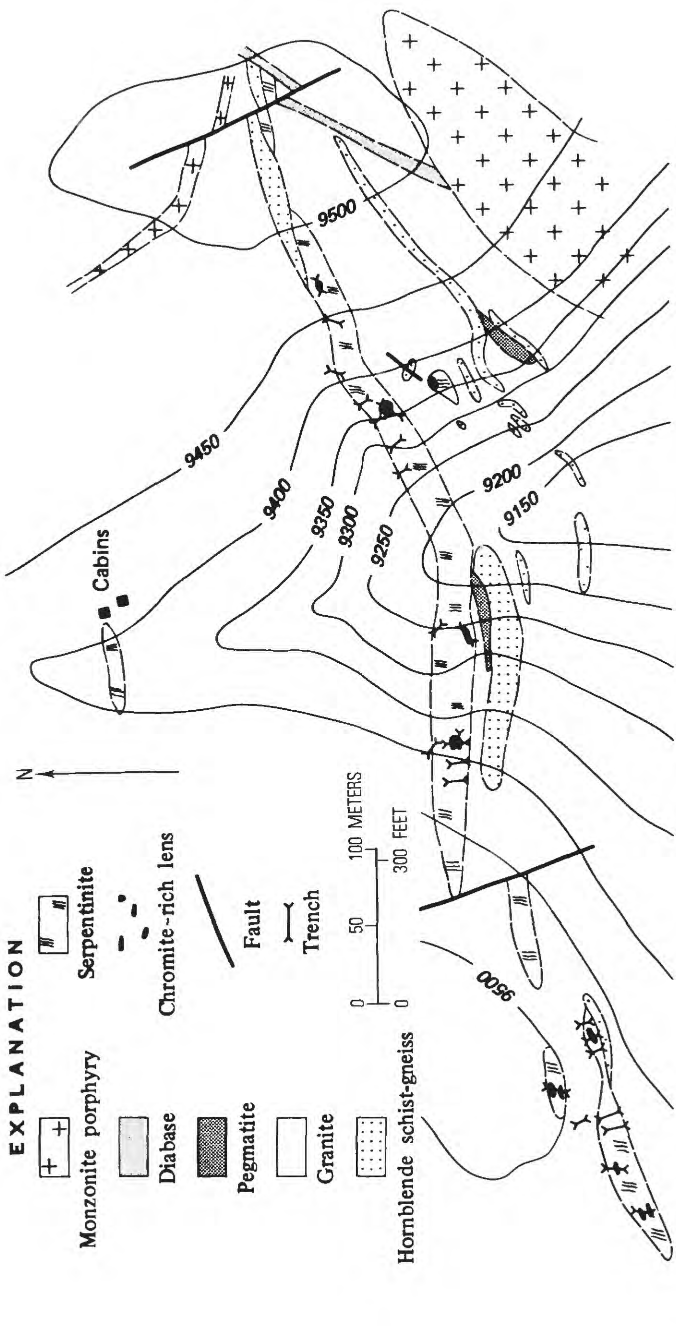


FIGURE 32.—Four Chromes group. Modified from James (1946).

concentrated along the basal zone of the complex in pods and in lenses of pentlandite, pyrrhotite, and chalcopyrite in hornfels. Platinum-group metals occur in some chromite bands and with sulfides in the banded and ultramafic zones.

The Mouat and Benbow mines, situated 3-4.8 km (2-3 mi) north of the study area, have produced more than 900,000 t (about 1 million tons) of chromite ore since 1942. A stockpile near the Mouat mill contains more than 900,000 t of chromite concentrate averaging 38.0 percent Cr_2O_3; chromium to iron ratio ranges between 1.61:1 and 1.91:1. The stockpi e was produced for the Defense Minerals Procurement Agency, but production ceased in 1961 when the terms of the contract were filled. The Stillwater Complex contains the largest chromite resource in the United States, but its chromium to iron ratio is too low to meet current metallurgical grade requirements. The copper, nickel, iron, and platinum resources are largely undefined but seem to be large.

Recently, several mining companies have been conducting minerals-exploration programs on the complex. The Anaconda Co. investigated the copper-nickel mineralization in the basal section of the complex, just north of the study area, near the Stillwater and the West Fork Stillwater Rivers. The company reported finding reserves of more than 1,350,000 t (150 million tons) containing 0.25 percent copper and 0.25 percent nickel (Dayton, 1971).

Outcrops of chromite-bearing ultramafic rocks along the West Fork Stillwater River near locality No. 128 (pl. 2) trend into the study area (Page and Nokleberg, 1970). In the Crescent Creek area, the basal zone of this part of the complex contains copper and nickel.

The Groundhog claim (pl. 2, No. 128) is located on the ultramafic zone on the study-area boundary. A chromite band 60 cm (2 ft) thick, overlying a leopard-patterned chromite band 0.9-1.2 m (3-4 ft) thick, is exposed in a partially caved trench. A sample that was taken across the chromite band contained 32.31 percent Cr_2O_3.

That part of the Stillwater Complex which may underlie the study area is small relative to the total mass of the complex. If, however, it contains metal values similar to those in other sections, it is a potential resource.

CONCLUSIONS

The mineralized zones occur at the periphery of the study area. No localities with any mineral potential are known within the central part of the area.

The remaining chromite resources in the Red Lodge district are small and of low grade. Most zones are easily accessible, however, and could be exploited by surface-mining methods.

A potentially valuable deposit that contains copper, silver, gold, and platinum-group metals occurs in the Goose Lake area. Its extent and grade, however, have not been adequately defined. If mined, it is likely that it would require underground methods subject to serious flooding from Goose Lake.

Small segments of the metal-bearing Stillwater Complex that extend into the study area may contain potential values in chromium, copper, nickel, and platinum-group metals that could be exploited by surface-mining methods.

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INDEX

[Italic page numbers indicate major references]

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