STUDIES RELATED TO WILDERNESS

PRIMITIVE AREAS

CLOUD PEAK, WYOMING

GEOLOGICAL SURVEY BULLETIN 1371-C

Mineral Resources of the Cloud Peak Primitive Area, Wyoming

By THOR H. KIILSGAARD *and* GEORGE E. ERICKSEN,
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U.S. BUREAU of MINES

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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 bulletin reports the results of a mineral survey in the Cloud Peak Primitive Area and vicinity, Wyoming. The area discussed in the report includes the primitive area, as defined, and some bordering areas that may come under discussion when the area is considered for wilderness status.

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MINERAL RESOURCES OF THE CLOUD PEAK PRIMITIVE AREA, WYOMING

By THOR H. KIILSGAARD and GEORGE E. ERICKSEN, U.S. Geological Survey, and by LOWELL L. PATTEN and CARL L. BIENIEWSKI, U.S. Bureau of Mines

SUMMARY

A mineral survey of the Cloud Peak Primitive Area and vicinity, Wyoming, was made in 1970 by the U.S. Geological Survey and the U.S. Bureau of Mines. An aeromagnetic survey was made the same year by the Geological Survey. The study area is along the crest of the scenic Bighorn Range in Bighorn, Johnson, and Sheridan Counties, Wyo. It includes the officially designated Cloud Peak Primitive Area of 137,000 acres plus an additional contiguous 95,000 acres, the study of which was requested by the U.S. Forest Service. The total area studied is 232,000 acres.

The Cloud Peak study area is underlain almost entirely by igneous and metamorphic rocks of Precambrian age. The only exception is an area along the southwestern boundary where Precambrian rocks are overlain by a sequence of Paleozoic sedimentary rocks that dip westward into the Bighorn Basin. The Precambrian rocks are offset by many faults; some are of Precambrian age but many others were formed during uplift of the Bighorn Range in Late Cretaceous-early Tertiary and later time. Higher parts of the range were glaciated during Pleistocene time and large moraines cover bedrock in the lower parts of the range.

The mineral potential of the area was investigated by studying the record of mining activity, by examining the geology, by searching for evidence of mineral deposits, and by extensive sampling and analysis of rocks showing indications of mineralization and of sediments in streams. The geological, geophysical, and geochemical studies indicate that metallic mineral deposits of commercial value do not occur in the area.

Prospecting began in the area during the latter part of the last century. Many localities were prospected but there is neither evidence of actual mining nor recorded mineral production from the area. Samples from the various prospects do not contain appreciable quantities of metals, and none of the prospects that were seen warrant further exploration. All values obtained from the stream-sediment samples are within the expected range of values for rock types exposed in the respective drainage basins. The area has no potential for coal, oil or gas, or for appreciable quantities of nonmetallic minerals.

There are no patented mining claims in the area, although county records indicate that unpatented claims have been located in and near the area.

INTRODUCTION

This report describes the findings of a mineral survey of the Cloud Peak Primitive Area, Wyo., and certain additional contiguous lands, the study of which was requested by the U.S. Forest Service. The Cloud Peak Primitive Area contains 137,000 acres, and with the additional tracts of 95,000 acres, the total area studied is 232,000 acres or about 362 square miles. We have not attempted to distinguish the officially designated Cloud Peak Primitive Area from the additional tracts, and the terms "study area," "map area," and "primitive area" all refer to the entire area that was investigated. The study area lies along the crest of the Bighorn Range, north-central Wyoming. It is within the Bighorn National Forest, in Bighorn, Johnson, and Sheridan Counties, Wyo.

CHARACTER AND ACCESS

The Bighorn Mountains are a major northwest-trending mountain range, the crest of which, for the most part, is a relatively smooth, flat to gently inclined, undulating surface. Higher parts of the range were glaciated extensively during Pleistocene time, resulting in U-shaped valleys that drain eastward and westward. Lower reaches of these and other valleys along the flanks of the Bighorns are V-shaped from recent erosion. Deep cirques with precipitous headwalls have been scoured at the heads of glaciated valleys, particularly along the eastern side, and they tend to give parts of the smooth crest of the range a scalloped margin.

Highest peaks of the Bighorns are Cloud Peak (13,167 ft) and Blacktooth Mountain (13,005 ft). The crest of the range, however, is generally 10,500 to 12,000 feet in altitude. Boundaries of the study area are mostly between altitudes of 9,000 and 10,000 feet, although on the western side the boundary is as low as 6,400 feet. Most of the range is formed of gneiss and granite of Precambrian age; these are crystalline rocks that resist erosion. The flanks of the range, however, are composed of sedimentary rocks of Paleozoic and Mesozoic age. These softer rocks were tilted by uplift of the range and in places form hogbacks and steep-walled canyons.

Principal streams draining the primitive area are Tensleep Creek on the southwest; Paint Rock, Medicine Lodge, and Shell Creeks on the west; and Goose, Kearney, Rock, and Clear Creeks on the east. Dozens of lakes ranging in size from less than an acre to about 100 acres (Lake Solitude) dot the area. Many of them are cirque lakes that formed in rock basins scoured by glacial ice.

Others are morainal lakes, some of which lack surface outlets but are drained by underground flow through the unconsolidated rock debris. Many small morainal lakes in the southeast part of the area (pl. 1) are in hummocky terrain and lack a coordinated drainage system. A few lakes near the boundary of the study area are man-made reservoirs and are used to impound water for irrigation purposes.

The Cloud Peak Primitive Area is accessible by oil-surfaced highway from the towns of Buffalo and Sheridan on the east and Greybull and Worland on the west (fig. 1). U.S. Highway 14 crosses the range to the north, and U.S. Highway 16 crosses just

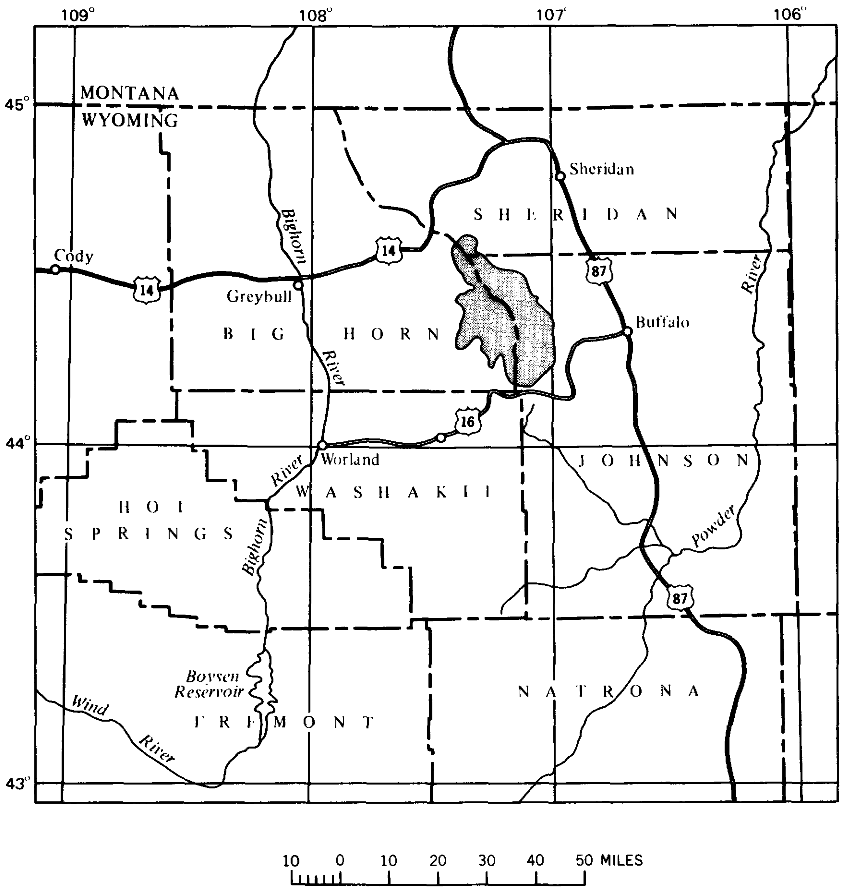

FIGURE 1.—Index map of northern Wyoming, showing location of the Cloud Peak study area (patterned).

south of the area. Gravel surfaced roads, maintained only in the summer, extend from these highways and from other routes to points near the study area boundary. A network of Forest Service trails extends from end of roads into the primitive area. Only two maintained trails cross the crest of the range. These are through Florence Pass in the southern part of the area and Geneva Pass in the central part (pl. 2). The northern part of the area may be crossed at Edelman Pass, via a trail along Medicine Lodge and Edelman Creeks, but this trail is not maintained and is difficult to traverse with pack horses. Popular trails into the heart of the area extend from West Tensleep campground on the south and from Battle Park and points on Paint Rock Creek on the west. Trails along Big Goose Creek, Kearney Creek, and Clear Creek provide access from road ends along the east side of the range.

CLIMATE AND VEGETATION

The climate of the Cloud Peak Primitive Area is characterized by long snowy winters and short dry summers. Average annual precipitation in the Bighorns is 27 inches; most of this is snow. Snowfall may be expected in every month of the year, but the heavy snows normally do not fall until late October or November; higher areas may remain snow covered and relatively inaccessible until July. Drifts and small snowfields may remain on shady slopes near the crest of the range throughout the summer. A small glacier is on the east side of Cloud Peak, and a few small snowfields persist from one summer to another.

The crest of the Bighorn Mountains is above tree line, which is about 10,200 feet. This high zone is characterized by thin soils that support a variety of grasses and sparse shrubs, interspersed with talus slopes and fields of angular boulders loosened from bedrock by frost wedging. Part of the area below tree line is heavily forested, Lodgepole pine (*Pinus contorta*) and Engelmann spruce (*Picea engelmanni*) are by far the dominant species. Interspersed in wooded areas and on many higher benches and ridges are beautiful grassy parks that furnish excellent summer graze for cattle and sheep as well as for abundant deer and elk. During June and July these open parks display a striking array of wild flowers, the colors of which, augmented by green grassy slopes and majestic grandeur of the mountain background, lend an air of lyrical beauty to the primitive area.

PREVIOUS INVESTIGATIONS

Little geologic work has been published on the Cloud Peak study area, although much has been completed elsewhere in the Bighorn Mountains. The most extensive study was by Darton (1906a), who reported on the geology of the mountains. The glacial features were described by R. D. Salisbury (in Darton, 1906a, p. 71–91). Demorest (1941) commented on structural features in the northern part of the area, and Osterwald (1955, 1959) reported on the structure and petrology of parts of the area. Heimlich and Banks (1968) give radiometric age determinations of rocks in the area.

PRESENT INVESTIGATIONS

Investigations of the primitive area by the Geological Survey were made in 1970, from July 1 to September 15. The work was done by Thor H. Kiilsgaard and George E. Ericksen assisted by Mike F. Gregorich and Walter L. Pomeroy. An aeromagnetic survey of the area was made in the fall of 1970. The fieldwork entailed several hundred miles of horseback and foot traverses. A helicopter was used to reach localities in the southeastern part of the area.

The mineral survey included reconnaissance geologic mapping for the purpose of checking and updating existing maps; the principal effort, however, was devoted to geochemical sampling. Stream-sediment samples were obtained from the main streams and from most tributaries; panned-concentrate samples were taken from many streams. Common rock types were sampled as were visibly altered rocks or rocks that displayed evidence of having been subjected to mineralizing processes. All known mineralized occurrences were sampled. A total of 766 samples were collected and analyzed. Analytical work was done in a mobile field laboratory under the direction of James Frisken, and at the Denver, Colo., laboratories of the Geological Survey.

Bureau of Mines work included examination of pertinent literature on mineral deposits and mining activity and a search for mining claim locations in the records of Big Horn, Johnson and Sheridan Counties, Wyo. Records of the Bureau of Land Management, Cheyenne, Wyo., were checked for patented mining claims and mineral leases. Field investigation by the Bureau of Mines began in mid-June and ended in September 1970. The work was done by Lowell L. Patten and Carl L. Bieniewski assisted by Benjamin C. Pollard, Jr. and James Snodgrass. A reconnaissance of the area and detailed examinations were made of mining claims and prospect workings. Sampling was concentrated at prospect workings and mining claim sites. Analyses were done by the Bureau of Mines, Geological Survey, and a commercial assayer.

ACKNOWLEDGMENTS

We wish to express our appreciation to the U.S. Forest Service staff at the Bighorn National Forest for their excellent cooperation in all phases of the work. We particularly wish to thank Ranger Calvin Wray, Tyrrell Ranger Station, for the many courtesies extended to the Geological Survey field party. Special thanks also are due Fred Fichtner, District Ranger, Sheridan, Wyo. Appreciation also is expressed to courthouse personnel of Bighorn, Johnson, and Sheridan Counties and to others living near the area who rendered assistance to the project.

The geological work benefited greatly from the efforts of T. J. Armbrustmacher, Geological Survey, who studied samples of the mafic dikes and who prepared table 1. We also wish to thank James Frisken and other analysts for their assistance.

We are especially grateful to packer Al Abbott, A and L Outfitters, for his unstinting efforts in moving our field camps and in taking care of our horses. The Bureau of Mines team benefitted from the able assistance of Glenn Sorenson, packer and guide from Arvada, Wyo.

GEOLOGY

GEOLOGIC SETTING AND HISTORY

The Bighorn Range consists of an exposed northwest-trending core of metamorphic and igneous rocks of Precambrian age with a thick overlying sequence of Paleozoic and Mesozoic sedimentary rocks along its flanks. The sedimentary rocks dip away from the core into bordering basins where they are covered by continental sedimentary rocks of Tertiary age that lap onto the sides of the range and in some localities onto the crystalline core.

The crystalline rocks of the core exhibit a long and complex Precambrian history of regional metamorphism, plutonism, and tectonism; subsequent erosion formed a rather uniform surface of low relief. During Paleozoic and most of Mesozoic time the Precambrian rocks were part of a stable platform upon which a thick succession of sedimentary rocks were deposited. The present-day Bighorn Range began to form in Late Cretaceous time, by upwarping of the range and downwarping of large basins to the east and west. This Laramide orogenic deformation contributed to the formation of other mountain ranges in Wyoming (Love, 1960, p. 205). Keefer (1970, p. D1) noted that in central Wyoming the Laramide deformation culminated in early Eocene time, in high mountains that were uplifted along reverse faults.

As the ancestral Bighorn Range was uplifted, the sedimentary rocks were arched and eroded to expose the Precambrian core. The adjacent basins were filled by sediment eroded from the uplifted Bighorns and from other ranges, and by volcanic debris from intense Cenozoic volcanic activity west of the Bighorns. Erosion reduced the ranges to a region of low relief and sedimentary deposits eventually buried the mountains; a vast plain of aggradation was developed that Love (1960, p. 210) described as apparently extending unbroken from the Wind River Mountains eastward to the Wyoming State line. In the Bighorn Range, sedimentary rocks of Miocene age rest unconformably on an eroded surface of Precambrian rocks (M. C. McKenna, written commun., 1968). To the south, in the Granite Mountains, several hundred feet above the highest Pliocene strata, there is an erosional surface that bevels Precambrian rocks and which probably was continuous with the highest surface of Pliocene fill (Love, 1960, p. 212). Although the surface has been raised by regional uplift and faulting, it is considered by Love to have been continuous with high level surfaces found in several ranges of northwestern Wyoming. Relics of such an erosional surface are distinct along the crest of the Wind River Range, in the Popo Agie and Glacier Primitive Areas. The relative flat tops of the Bighorn Range, particularly in the interval of 11,000 to 12,000 feet, are a characteristic feature of the range and may be remnants of such a beveled surface (fig. 2).

Regional uplift, renewed in late Pliocene or early Pleistocene time, was accompanied by faulting and broad folding, and buried mountain ranges were exhumed (Love, 1960, p. 212). Faulting and minor tilting in the Bighorn Range is indicated by displacement of segments of the beveled Precambrian surface. Erosion removed Tertiary sediments from the emerging range, and subsequent late Pleistocene glaciers covered most of the higher parts of the range

FIGURE 2.—View looking south along the crest of the Bighorn Range. Tip of Blacktooth Mountain is in the left rear. Note the beveled surface in foreground, on the flat-topped butte in center, and on skyline crest of range.

and scoured existing canyons and deposited moraines along the flanks of the range.

PRECAMBRIAN ROCKS

The Cloud Peak Primitive Area is underlain by a complex of Precambrian rocks (pl. 1), which form the core of the Bighorn Range. In this report, these rocks are divided into two groups: (1) metamorphic rocks, predominantly gneiss but locally including migmatite, amphibolite, and schist, and (2) granitic rocks. The gneiss is highly variable, ranging from faintly banded gneissic granite to sharply banded gneiss (fig. 3) and migmatite. Gray biotite granite is the principal granitic rock, although red granite, gray quartz diorite, and quartz monzonite are common. These rocks grade into one another in mineral composition and in texture. The granitic rocks grade from massive nonfoliated or slightly foliated rocks to gneissic granite. Inclusions of older amphibolite, schist, and gneiss are common in the granitic rocks. Mafic dikes cut all other Precambrian rocks.

Variations in composition of the gneissic rocks are sharp locally, as are local contacts between gneissic and granitic rocks, but on a broader scale the gneissic and granitic rocks tend to grade into one another. Regionally, granitic rock is dominant in the northern part

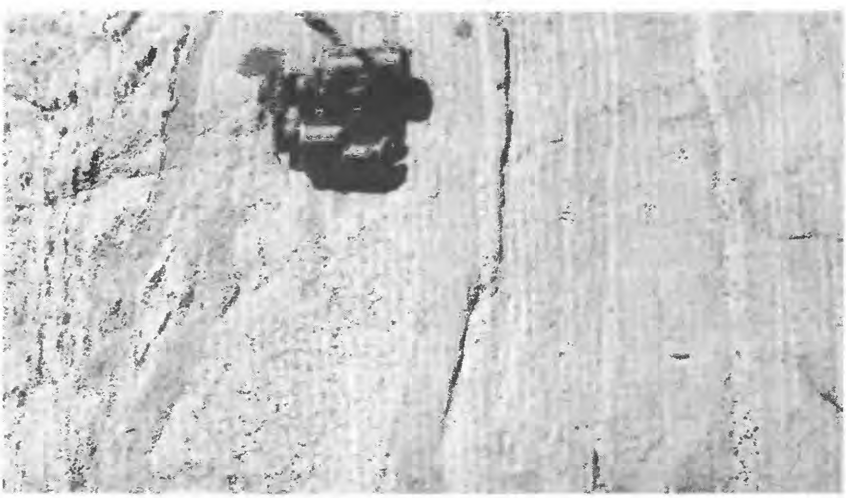

FIGURE 3.—Banded gneiss along the crest of the Bighorns near the head of Paint Rock Creek. Light bands are chiefly feldspar and quartz. Parallel alinement of biotite and hornblende darken broader bands. An irregular tongue of granitic material, which contains elongate inclusions of gneiss oriented parallel to the banding, extends beneath the field glasses.

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of the primitive area, whereas gneissic rock is dominant in the southern part (pl. 1). However, neither area is underlain wholly by one rock type, so that gneissic bodies are found at many places in the northern part of the primitive area and granite at places in the southern part. Likewise, the boundary between the two areas is a broad indefinite zone of mixed rock. Because of the vast area covered, time limitations, and objective of the study, no attempt was made to map the limits of the individual rock types.

GNEISS AND MIGMATITE

The most conspicuous gneiss is near the southern end of the study area. Excellent exposures may be seen along U.S. Highway 16 near the crest of the Bighorn Range. Other accessible areas are north of West Tensleep Lake and north of the U.S. Forest Service road to Battle Park. Although individual areas, tens or hundreds of feet in longest dimension, appear to be foliated granite, they are variations of the more typical gneiss of the region. Many outcrops show intricate folding, and widely diverse foliation is common throughout the area.

The gneiss varies from dark gray to light gray to pink; the color depends generally on the proportions of white or pink feldspar, or on concentrations of dark foliated biotite or hornblende. Together with quartz, these minerals are the main constituents of the rock. The texture is crystalloblastic and grain size mostly ranges from fine to coarse. Porphyroblasts of white and pink feldspar are common. Some crystals or aggregates of crystals are an inch or more long and give the rock a definite porphyroblastic or augen texture. Elongate augen are alined parallel to the foliation and dark irregular bands or laminae having abundant hornblende, biotite, and chlorite curve around them. A similar gneiss was described east of the primitive area by Hoppin (1961, p. 358). Hand specimens of augen gneiss have strong cataclastic structure. Microscopically, all gneiss is strongly granulated and recrystallized. Fractures in the gneiss commonly are marked by small shattered crystals of quartz and feldspar and bent shreds of biotite and chlorite. Recrystallized elongate quartz grains may be present parallel to the fracture planes. Epidote is a widespread secondary mineral; other typical accessory minerals, which occur widely in small quantities, are clinozoisite, muscovite, apatite, sphene, and garnet. Osterwald (1959, p. 8–11) described gneiss elsewhere in the Bighorn Mountains similar to that in the primitive area.

Intermingled with the gneiss are bodies of granitic rock, some of which may show faint foliation. The granite may occur in the gneiss as compositional layers, ranging from a few inches to many feet thick, or it may cross the gneissic banding. At some localities, as west of Bomber Mountain, the intermingled rock is a migmatite, in which the granite appears to have engulfed the gneiss. The gneiss is present only as chaotic, swirly, drawn out, plasticly deformed remnants. Similar migmatite has been described at other localities of Precambrian rock in Wyoming (Granger and others, 1971, p. F15; Eckelmann and Poldervaart, 1957, p. 1236; Condie, 1969, p. 59).

AMPHIBOLITE AND SCHIST

Hornblende amphibolite and biotite schist are not major rock types in the Bighorn area but are interlayered with gneiss and are exposed at many places as remnants and roof pendants in granitic rocks. Most occurrences are too small to show on the geologic map (pl. 1). Roof pendants of hornblende amphibolite crop out on the ridge south of Paint Rock Creek, where one of the largest is about 200 feet wide and a quarter of a mile long. Other exposures are near the head of Edelman Creek and on the south side of Cross Creek (pl. 1). South of the primitive area, near the head of Beaver Creek, there are lenslike boudins of amphibolite in Precambrian gneiss (Palmquist, 1967, p. 292). Similar rocks were noted by Butler (1966, p. 49) and van de Kamp (1969) in the Beartooth Mountains to the northwest.

GRANITIC ROCKS

Granitic rocks predominate in the northern part of the primitive area and along parts of the western side of the Bighorn Range. Gray, fine- to medium-grained, massive, nonfoliated to strongly foliated biotite granite is the principal rock type. It is prevalent in the vicinity of Dome Peak and along the spine of the range to the south. Locally, as west of Coney Lake, the gray granite grades into dark-gray, biotite quartz diorite. Red, foliated, biotite granite is predominant in the Paint Rock and Medicine Lodge Creeks area and is common elsewhere. The red and gray granites grade from one into the other. Darton (1906a, p. 16) recognized this feature and considered the two types to be parts of the same intrusive. Osterwald (1955, p. 310) studied red and gray granite in the Tongue River area but did not find a definite contact. He concluded that the two rock types are intimately intermingled. Red biotite granite crops out in the vicinity of East Tensleep Lake and at irregular intervals to the east. In the headwaters of East Tensleep Creek, the granite merges with migmatite in such an erratic manner that a definite contact between the two types could not be established. Fine-grained red granite also crops out on the ridge south of Elk Lake and at many other localities.

Large exposures of granite show excellent nonfoliated granitic textures and the strong jointing so common in intrusive rocks. The joints are of diverse orientations and some are filled to thicknesses of one-eighth to one-fourth inch with epidote. Elsewhere, alinement of biotite flakes or of phenocrysts of microcline give the rock the foliated appearance of gneissic granite. Most foliated rocks commonly contain inclusions of gneiss ranging in size from wisp fragments a fraction of an inch wide and a few inches long to large bodies hundreds of feet wide and thousands of feet long. Foliation in the gneissic granite, particularly near smaller inclusions, appears to be swirly and discordant to the foliation of the gneiss. Near larger inclusions, the granite foliation is mostly concordant to that of the gneiss. Dikes and tongues of granite cut across gneissic roof pendants and thus are clearly younger. Chilled textures, common to many intrusive contacts, were not seen at the margins of any granitic rocks in the Bighorn Mountains.

All thin sections of granitic rocks that were studied show evidence of strain. Quartz grains typically show undulatory extinction, and fragmental texture is common, although it does not approach the cataclastic texture that characterizes the gneiss. An average granite consists of microcline, quartz, plagioclase (oligoclase-andesine), and biotite, with hornblende, epidote, chlorite, sphene, and zircon as the common accessory minerals. The distinctive red color of the red granite is a result of the abundant microcline. By contrast, plagioclase is predominant in the quartz diorite, which also contains more biotite and thus has a darker color.

RADIOMETRIC AGES OF GNEISSIC AND GRANITIC ROCKS

The intermingling of different granitic rocks, gradational merging of granitic and gneissic rocks, widespread occurrence of granitic bodies in the gneiss and migmatite, and the absence of clear intrusive contacts suggest the granite was emplaced through the process of granitization of preexisting rocks. Gneiss and amphibolite, which are more deformed, may represent older rocks that were regionally metamorphosed and subsequently subjected to granitizing processes that resulted in partial to complete trans-formation to granitic rocks. On the other hand, Eckelmann and Poldervaart (1957, p. 1249), in describing Precambrian rocks in the Beartooth Mountains that are comparable in all respects to those of the Bighorn Mountains, present clear evidence that the granitic gneiss and migmatite were formed in situ from preexisting sediments. This determination is supported by Gast, Kulp, and Long (1958, p. 327), who made rubidium-strontium and potassium-argon age determinations on several specimens of Precambrian basement rocks from the Bighorn Basin, including a sample of gneiss from a roadcut along U.S. Highway 14 north of the Cloud Peak Primitive Area. They concluded that major regional metamorphism and granitization gave rise to the present rocks during a single geologic event about 2.75 billion years ago.

The most extensive age dating studies in the primitive area are those of Heimlich and Banks (1968), who show rocks in the southern part of the area to be predominately gneissic and those in the north to be granitic. These authors rationalize that formerly the Precambrian rocks were largely a sedimentary rock sequence, which during an episode of regional deformation was folded and recrystallized to gneiss and associated rocks in the southern part of the area and converted to granitic rocks by metasomatism in the northern part. They believe the actions were essentially contemporaneous. On the basis of many potassium-argon determinations, they conclude that the rocks crystallized or were recrystallized during a widespread event that occurred on the order of 2.9 to 3.1 billion years ago.

PEGMATITE AND APLITE DIKES

Pegmatite and aplite dikes intrude both gneissic and granitic rocks in the Bighorn Range. Tabular to lenticular bodies of pegmatite are concordant to gneissic layering at some localities; elsewhere, they cut the layering and the foliation (fig. 4). The pegmatites range in thickness from less than an inch to several feet. Strike length of the dikes varies widely, but normally it is less than 100 feet. In some places, as on the west side of Bomber Mountain, pegmatite dikes are clustered in a swarm that is 200 to 300 feet wide. The pegmatite is coarse grained and contains microcline crystals as much as 4 inches long. Other abundant minerals are quartz, plagioclase and muscovite. Biotite and ilmenite are common accessories. A float sample of pegmatite contained part of a large crystal of beryl but no beryl was seen in place.

White fine-grained aplite dikes ramify gneissic and granitic rocks and cut pegmatites.

FIGURE 4.—Granitic gneiss cut by dikelets of pegmatite and aplite. Three stages of dike intrusion are apparent. The thick pegmatite at lower right is cut and offset by diagonally-trending pegmatite; both are cut by a stringer of aplite visible at the top of the picture. Steeply-dipping foliation on the right is almost perpendicular to faint foliation on left. All foliation is crossed by the dikelets. Scale is 6 inches long.

MAFIC DIKES

Dark-gray to black mafic dikes are conspicuous in the Cloud Peak Primitive Area and cut all other Precambrian rocks. The dikes range in thickness from a few inches to about 500 feet and in strike length from a few feet to several miles. The largest and most continuous dikes cross the Bighorn Range, extending from the vicinity of Paint Rock Creek easterly into the headwaters of Penrose Creek (pl. 1). Several of the dark dikes cross Blacktooth Mountain and probably account for that name. The northeast-trending dike near the top of Blacktooth Mountain was traced for more than 10 miles and is the most continuous dike seen in the entire range. The dikes show two dominant trends that probably were the main fracture systems at the time of dike intrusion. Northeast-trending dikes, which are most numerous and largest, cross the axis of the Bighorn Range, whereas northwest-trending dikes are more or less parallel to the axis of the range (pl. 1). The two sets of dikes are not distinguishable by differing rock types, nor is there evidence that dikes of one set consistently cut those of the other. On the ridge south of Canyon Creek a northwest-trending dike clearly cuts a dike that strikes northeast and would appear to be younger. Further to the northwest, however, the northwest-trending dike is cut by a dike that strikes northeast, which would indicate that it was the older of the two. Crosscutting relationships of the different dikes is generally obscure because dike rock tends to be more deeply weathered at intersections—perhaps because of fracturing and alteration accompanying intrusion of the younger dike—and exposures here are poor.

Many of the dikes are offset by faults, and offset segments of dikes provide one of the principal means of recognizing faults in the area. Offset dikes are particularly common in the northern part of the area west of Hope Lake (pl. 1). The relatively continuous outcrops of the dikes and their prevalent steep dips indicate that they, in large part, follow preexisting faults. A clear example of this is a northwest-trending dike that follows a shear zone across the headwaters of Moraine Creek. Discontinuous veins and lenses of quartz, some of which have been prospected, are in the shear zone adjacent and parallel to the dike. A northwest-striking, vertically dipping dike, about 50 feet thick, extends across the top of Iron Mountain northwest of Medicine Lodge Lakes and probably is responsible for the name of the mountain. Throughout the Bighorn Range numerous prospect pits in the dikes attest to the interest of the prospector in these distinctive linear features. At places, particularly along ridge tops, the dikes weather to a distinctive red-brown soil that may have been mistaken as vein gossan. None of our many samples from prospect pits or from other outcrops of the dikes contained abnormal concentrations of economic minerals.

Previous writers (Darton, 1906a, p. 19; Osterwald, 1959, p. 17) have called the mafic dike rock diabase, in recognition of its pronounced diabasic texture. Most dikes examined during this study, however, have mineral assemblages that are characteristic of quartz dolerite. Central parts of the larger dikes tend to be a coarse-grained gabbroic rock that grades to medium- and fine-grained rock adjacent to the dike walls. Very fine grained chill borders, generally not more than a few millimeters thick, are typical of dike contacts, which in turn are knife-sharp where seen on steep outcrops or on glacially scoured knobs. Plagioclase laths with interspersed pyroxene are the prevalent minerals. They commonly give the rock a salt and pepper appearance, although where pyroxene dominates, the rock is black. Coarse- to medium-grained dikes commonly are altered with development of chlorite and hornblende, which impart a greenish shade to the rock. Some dikes contain plagioclase phenocrysts as much as half an inch in length, which along with other phenocrysts are alined parallel to the dike walls. Where abundant, the phenocrysts give the rock a glomeroporphyritic appearance. Crushing and alinement of crystals suggest that some dikes have been subjected to some metamorphic deformation. Locally, strongly deformed dike segments are altered to hornblende and chlorite and are difficult to distinguish from the amphibolite that is interlayered in the gneiss. These exposures may represent an earlier stage of dike intrusion. For the most part, however, the dikes are relatively fresh and do not show the effects of metamorphism that characterizes the enclosing gneissic rock.

Mr. T. J. Armbrustmacher, U.S. Geological Survey, studied 39 samples of the dike rock, of which he classified 28 as quartz dolerite, nine as metadolerite, and two as amphibolite. Chemical analyses and norms for five of the samples are shown in table 1, as are the modes determined by Armbrustmacher. Most quartz dolerite is subophitic, although the coarser rock is ophitic. Plagioclase, the most abundant mineral, has a composition near An_{55} (labradorite), is complexly twinned and usually zoned more sodic outward. The plagioclase commonly is altered by saussuritization, sericitization, kaolinization or combinations thereof. Pyroxene assemblages in the quartz dolerites are of two types: augite and pigeonite and augite and hypersthene. The latter assemblage characterizes the northeast-trending set of dikes in the vicinity of Blacktooth Mountain. Relatively abundant olivine is also in some of the dikes. In thin section, all of the pyroxenes show some degree of alteration to chlorite and hornblende. Brown biotite occasionally is an alteration product associated with skeletal magnetite. Quartz is present as late interstitial blebs that constitute several percent by volume. Apatite is an accessory mineral.

The metadolerite of Armbrustmacher (written commun., 1971) was classified on the basis of clouding and minor cataclasis of plagioclase. His findings corroborate studies he made of mafic dikes east of the primitive area (Armbrustmacher, 1966; written commun., 1971).

Condie, Leech, and Baadsgaard (1969, p. 903) have made whole rock potassium-argon age determinations of mafic dikes from different areas in Wyoming and conclude that the dikes were emplaced during several periods of intrusion. They recognize three

TABLE 1.—*Chemical composition, normative minerals, and modes of dolerite dikes in the Cloud Peak Primitive Area*

[Chemical analyses by J. W. Elmore, J. L. Glenn, J. Kelsey, and H. Smith; modes by T. J. Armbrustmacher]

Sample No.	78	80	325	467	808
Chemical analyses (weight percent)					
SiO_2	53.20	50.90	51.80	49.70	55.90
Al_2O_3	13.80	7.60	15.00	11.50	14.70
Fe_2O_3	2.90	1.60	2.70	2.00	2.10
FeO	8.80	10.50	10.60	9.70	8.80
MgO	7.40	17.20	5.30	11.60	5.40
CaO	7.30	7.10	8.90	9.50	8.80
Na_2O	3.50	1.80	2.30	1.20	2.10
K_2O	.80	.45	.50	.16	.64
TiO_2	1.30	.78	1.60	.87	.89
P_2O_5	.05	.04	.08	.03	.04
MnO	.18	.20	.23	.21	.18
CO_2	.08	.08	.02	.08	.01
H_2O	.76	.87	1.38	2.16	.92
Total	100.07	99.12	100.41	98.71	100.48
Norms (weight percent)					
Quartz	1.4	0.00	6.1	2.4	11.5
Orthoclase	4.7	2.7	2.9	.96	3.8
Albite	29.6	15.4	19.4	10.3	17.7
Anorthite	19.6	11.4	29.0	25.8	28.6
Wollastonite	6.6	9.7	6.0	8.8	6.0
Enstatite	18.4	31.4	13.1	29.3	13.2
Ferrosilite	11.9	12.5	15.0	15.3	13.2
Forsterite	.00	8.3	.00	.00	.00
Fayalite	.00	3.6	.00	.00	.00
Magnetite	4.2	2.3	3.9	2.9	3.0
Ilmenite	2.5	1.5	3.0	1.7	1.7
Apatite	.12	.096	.19	.072	.094
Calcite	.18	.18	.045	.18	.023
Modes (volume present)					
Quartz	1.1	--	3.2	0.7	--
Plagioclase	54.2	23.2	49.7	32.7	41.8
Augite	21.2	32.4	--	--	--
Augite and pigeonite	--	--	30.0	43.0	30.9
Hypersthene	9.9	17.6	--	--	--
Hornblende	1.7	.3	10.6	2.3	10.5
Biotite	6.2	5.2	2.2	.7	2.7
Olivine	2.0	19.9	--	--	--
Apatite	.2	.1	.3	.1	.2
Magnetite and pyrite	3.1	1.3	3.9	2.8	2.8
Chlorite	--	--	.1	--	--
Chlorite and calcite	.4	--	--	--	--
Chlorite and magnetite	--	--	--	6.0	--
Sericite	--	--	--	11.7	--
Granophyre	--	--	--	--	11.1

possible groupings of Bighorn dikes: about 2.5 b.y. (billion years), 1.9 to 2.2 b.y., and 1.4 to 1.8 b.y. No relation between dike age and dike trend was found. Armbrustmacher (written commun., 1971), in reviewing the age dating of Condie, Leech, and Baadsgaard, notes that their youngest Bighorn sample (1.39 b.y.) was from a somewhat altered rock, from which the radiogenic argon may have escaped, in which case the rock would be older. He considers two generations of mafic dike intrusion in the Bighorns, one about 2.5 b.y. and the other at least 2.2 b.y., as more likely.

PALEOZOIC SEDIMENTARY ROCKS

Paleozoic sedimentary rocks of marine origin crop out along the southwest boundary of the study area. They consist of a sequence of sandstone, shale, dolomite, and limestone striking northwest and dipping gently southwest into the Bighorn Basin. Streams flowing southwest from the Bighorn Range have eroded steep canyons into the sedimentary rocks, and along the canyon walls the more massive units crop out as conspicuous cliffs. On ridges and in less deeply dissected areas, the sedimentary rocks are decomposed into a thick soil cover supporting good stands of grass that is excellent graze for cattle and sheep.

FLATHEAD SANDSTONE

The Flathead Sandstone is the oldest Paleozoic formation in the study area. It unconformably overlies the Precambrian rocks and is part of the unit referred to by Darton (1906a, p. 23) as the Deadwood Formation of Cambrian age. The Flathead crops out along the jeep road that follows Broken Back Ridge southwest of West Tensleep Lake. At that locality the unit consists of about 250 feet of coarse-grained, gray, quartz sandstone that weathers red brown. Lenses of the indurated sandstone are quartzitic and on ridgetops weather to flaggy plates that mantle the surface. The upper 2 feet of the sandstone contains many fossil casts. Conspicuous sandstone outcrops are along the upper reaches of Soldier Creek, at Bellyache Flats, Battle Park, and on Cement Mountain between Paint Rock and Middle Paint Rock Creeks (pl. 1). Near the top of Cement Mountain the lower 8 feet of the formation is conglomeratic and contains quartz pebbles as much as 2 inches across and smaller pebbles and grains of magnetite and ilmenite that are mostly oxidized to hematite, which gives the rock a distinct red color. A sample of the conglomerate, taken at the Precambrian contact, contained 10 percent iron. Both the conglomeratic member and the overlying coarse-grained sandstone are crossbedded.

The uppermost 20 feet of the Flathead Sandstone is a tan, crossbedded, medium-grained quartz sandstone, which crops out as a small resistant ledge along canyon walls.

GROS VENTRE FORMATION AND GALLATIN LIMESTONE

The Gros Ventre Formation and the Gallatin Limestone, undivided, overlie the Flathead Sandstone and originally were classified by Darton (1906a, p. 24) as part of the Deadwood Formation. Rocks of the two formations weather readily and form smooth to hummocky, grass-covered slopes on which landslides and slumps are common (fig. 5). Some landslides, as along the west canyon wall of Paint Rock Creek, are major topographic features. Because of the similarity of the rocks and the scarcity of outcrops no attempt was made to map the two formations as separate units.

The base of the Gros Ventre Formation is placed at the lowermost occurrence of glauconite above the Flathead Sandstone. Above this base are glauconitic medium-grained sandstones and greenish-gray glauconitic shales, which, to the southeast of the mapped

FIGURE 5.—View looking north along Soldier Creek, west side of snow-covered Bighorns. Massive cliffs of Bighorn Dolomite at upper left. Beneath cliffs, left center, are uneven, slumped grass-covered Gallatin Limestone and Gros Ventre Formation. Differential slumping and sliding of the shaly sequence caused the hummocky uneven surface and have rafted large angular blocks of Bighorn Dolomite toward the downcutting Soldier Creek (concealed behind ridge at center).

area (pl. 1), in the Crazy Woman Creek area, are 306 feet thick (Hose, 1955, p. 44). The upper part of the stratigraphic sequence consists of pinkish-gray, slabby thin-bedded silty limestone, a few thin beds of sandstone, and thin beds of edgewise limestone conglomerate. This sequence is equivalent to the Gallatin Limestone of other areas. Along Paint Rock Creek the Gros Ventre and Gallatin units are about 580 feet thick.

BIGHORN DOLOMITE

The Bighorn Dolomite crops out as high prominent cliffs along the western slopes of the Bighorn Range. The dolomite overlies the more easily eroded Gallatin Limestone and is unconformably overlain by the Madison Limestone. A distinct topographic break separates the massive cliffs of the Bighorn Dolomite from the overlying ledge-forming Madison Limestone.

The lowermost unit of the Bighorn Dolomite, as much as 30 feet thick, consists of sandstone with shale layers. This unit is crossed by the Battle Park road about 2,000 feet south of the Soldier Creek Cow Camp and crops out conspicuously at the base of the cliff of Bighorn Dolomite along the west side of Paint Rock Creek. At this locality, in the NW¼ sec. 12, T. 50 N., R. 88 W., the top of the Gallatin Limestone consists of 5 inches of fissile green shale that overlies the more typical thin-bedded limestone of the formation. Above the green shale are 22 inches of green sandy shale, then 6.5 feet of coarse-grained, crossbedded sandstone stained red on the surface by iron oxides. The sandstone is overlain by 1.8 feet of green shale, above which is about 20 feet of white, well-sorted, fine- to medium-grained quartz sandstone containing nodules of hematite that impart a patchy red color to the rock. West of Battle Creek, NW¼ sec. 20, T. 50 N., R. 87 W., about 1,500 feet outside the study area boundary, are two short adits about 100 feet apart that were driven to explore the sandstone. The easternmost of these adits, both of which are caved at the portal, exposes a zone of sandstone about 1 foot thick containing grains and small black nodules of manganese oxide. A sample taken across the zone contained only 3,000 ppm (parts per million) manganese. No other concentrations of elements of possible economic value were detected in the sample, or in samples of the sandstone taken elsewhere.

Above the basal sandstone, the Bighorn is massive, tan to light-gray, high-purity, finely crystalline, cliff-forming dolomite, which, in the vicinity of Paint Rock Creek, is about 200 feet thick. Weathered exposures of the dolomite have a pitted surface, which is a characteristic feature of this formation here and elsewhere in Wyoming and nearby states. The pitted surface is characteristic of finely crystalline high-purity dolomite and apparently is due to slight differences in crystallinity of the dolomite, but on some surfaces it may be due to weathering of dolomite with irregular incipient silicification. A unit of slabby argillaceous dolomite about 30 feet thick overlies the massive dolomite. According to Hose (1955, p. 48) fossils from the middle and upper parts of the Bighorn Dolomite indicate a Late Ordovician age.

MADISON LIMESTONE

The Madison Limestone of Mississippian age caps the ridge between Battle and Paint Rock Creeks and is well exposed in bluffs near the top of the west canyon wall of Paint Rock Creek (pl. 1). In the latter area, the basal unit of the Madison is a pink-gray conglomeratic sandstone about 2 feet thick, in which pebbles of quartz and limestone are in a matrix of poorly sorted, frosted sand. Overlying the sandstone is about 3 feet of gray sandy dolomite above which is about 600 feet of limestone with some interbedded dolomite. Concentrations of nodular gray to white chert are in dolomite beds near the base of the formation. The upper part of the limestone is cavernous in the SW¼ sec. 13, T. 50 N., R. 88 W., the only area where a complete section of the Madison was examined. The cavities are filled with red clay and fragments of red sandstone from the overlying Amsden Formation. Clay-filled solution cavities occur in bluffs more than 100 feet below the top of the limestone. A similar interval of cavernous Madison Limestone, described by Richards (1955, p. 22), crops out in Bighorn Canyon near the Wyoming-Montana line.

AMSDEN FORMATION

The Amsden Formation overlies the Madison Limestone. The lower part of the formation crops out along the western boundary of the study area in sec. 13, T. 50 N., R. 88 W., and consists of thin-bedded, red, fine-grained sandstone and siltstone. Less than 100 feet of the formation was seen in the study area.

TERTIARY GRAVEL

Near the headwaters of Soldier Creek, on the subsummit upland of the Bighorns and at an altitude of about 9,000 feet, are two small deposits of flat-lying bouldery gravel that rest unconformably on Flathead Sandstone and Precambrian gneiss. Subangular to well-rounded boulders of Precambrian granite and gneiss from the Bighorn Range comprise most of the deposit. Some boulders are more than 2 feet across and many, particularly the smaller ones, are friable and decomposed, much more so than boulders in nearby moraines. Poorly sorted sand and gravel forms the matrix of the deposit, which is obscured at the surface by sandy clay soil.

The gravel was recognized as Tertiary in age by Darton (1906a, p. 67), who described these and more extensive deposits south and east of the area. He called attention to the abundance of volcanic ash interbedded in gravels at an altitude of about 9,000 feet near the head of Canyon Creek south of the area and believed the ash came from volcanic eruptions west of the Bighorn Basin. Volcanic ash was not identified in the Soldier Creek gravels; however, about 3 miles to the south, a small clay deposit in landslide debris on Gallatin-Gros Ventre rocks was identified as bentonite that formed from alteration of volcanic ash (p. C58). Volcanic ash must have covered much of the Bighorn Range in Tertiary time, but since then, it has been eroded.

Sharp (1948, p. 1–14) described similar gravels along the eastern front of the Bighorn Mountains where they have been faulted against the Paleozoic rocks. He considers these gravels to be Eocene in age. On the other hand, M. C. McKenna [1] has identified fossils in the volcanic-rich gravels near the head of Canyon Creek as Arikareen (Miocene) and noted that the deposits are possibly equivalent in age to the Monroe Creek and Harrison Formations in eastern Wyoming. The fact that a subsummit pediment is cut in the Arikareen rocks confirms that Canyon Creek, Soldier Creek, and other parts of the Bighorn Range were covered with alluvium by Miocene time. The fossil evidence raises a question of whether the high-level gravels described by Sharp (1948) are not also of Arikareen age, which, if so, would make the faults that displace the gravel along the front of the range post-Miocene in age.

QUATERNARY DEPOSITS

Quaternary deposits are widespread in valleys and on subsummit areas in the Bighorn Mountains (pl. 1). Moraines are common along many of the valleys and intervening ridges; in some valleys they are mantled with alluvium. Boulder fields cover most flat-topped ridges above timberline.

The Bighorn Range was eroded during at least two periods of Pleistocene glaciation. An excellent description of this glaciation

[1] McKenna, M. C., 1968, Preliminary announcement of Arikareen mammals from high-level Tertiary sediments, Bighorn Mountains: New York, Am. Mus. Nat. History, unpub. rept.

is presented by R. D. Salisbury and his assistants Eliot Blackwelder and E. S. Bastin (in Darton, 1906a, p. 71–90), thus only a few salient glacial features are discussed here. Evidence of glaciation is widespread in the high parts of the range and one small glacier remains (fig. 6). Glacially polished and striated rock outcrops are common. The glaciers scoured existing valleys into a characteristic U-shape and deposited extensive moraines. They carved steep-walled cirques at the heads of the valleys, particularly along the eastern side of the range. Classic cirques are to be seen in the vicinity of Cloud Peak and Blacktooth Mountain (fig. 7). Except for man-made reservoirs, all lakes in the study area are the result of glacial action. The lakes either occupy basins scoured in the crystalline rocks by glaciation or they are impounded by moraines. All moraines in the study area appear to have been deposited during the later of the two glacial periods. Glaciation during the last period was widespread above an altitude of 9,000 feet. The glaciers apparently were confined to the valleys and to intervening plateau areas that extend along the front of higher parts of the range. Peaks and higher ridges were above the ice fields.

R. D. Salisbury (in Darton, 1906a, p. 87) described an earlier glacial epoch, the moraines of which are more weathered, have fewer surface boulders, and are more eroded than are moraines of the later epoch. Moraines of this type are in the vicinity of Buffalo Park in the eastern part of the area and along Moraine Creek near the northwestern boundary; they are not distinguished on plate 1.

Lateral moraines are particularly conspicuous along the valley walls of West Tensleep Creek, Paint Rock Creek, Medicine Lodge Creek, South Piney Creek, and North Clear Creek (pl. 1). The moraines consist of angular to rounded rock fragments, with a silt and sand matrix, derived from the Precambrian rocks. The top of some lateral moraines near the valley walls, as along the west valley wall of West Tensleep Creek, have relatively smooth even gradients. Elsewhere, moraine surfaces are hummocky. This is particularly evident where two moraines coalesce, as for example in the South Clear Creek region in the southeasternmost part of the area (pl. 1). In that vicinity and elsewhere along the flanks of the Bighorns rough-surfaced, boulder-strewn moraines support dense stands of lodgepole pine. In these areas and locally along the valleys, patches of moraine too small to be shown on the map are scattered among outcrops of bedrock.

FIGURE 6.—Cloud Peak from the east. Note the small glacier in the high-walled cirque and the serrate, knifelike ridge (arête) to the left. The foreground boulder field (felsenmeer) mantles bedrock. Dolerite dikes cross the ridge at left center.

FIGURE 7.—The effects of alpine glaciation. Glacial ice scoured the two cirques that are separated by the sharp, serrate ridge. The rock-bottomed basin on the right contains Loomis Lake, of which the northern tip may be seen. Rocks at the lake outlet were polished and striated by the glacier. The tip of Blacktooth Mountain is at the upper right of the photograph. A dark dolerite dike (d) is just beneath the top and another dike crosses the cirque wall to the left.

Most flat-topped or slightly inclined surfaces above timberline (about 10,200 feet in the Bighorns) are covered by angular boulders some of which are several feet across. These high-level boulder fields, known as felsenmeer, are the result of frost wedging of underlying rock. The disoriented boulders form a jumpled mass that mantles the bedrock. A thin cover of sandy soil is interspersed with the boulders locally. These patches of soil are

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covered by grass and sometimes by a sparse growth of low-growing plants. Frost and snow action contributes to a slow creeping movement of the jumbled boulders, which, although generally representative of the underlying bedrock, may be hundreds of feet from the original site of dislodgment.

Alluvium derived from eroded Precambrian rocks and from moraines forms a thin veneer along the valleys. Thicker deposits accumulate in areas where the stream gradient is low and many of these, Teepee Pole Flats for example, are beautiful meadows. Alluvium is not differentiated on plate 1.

STRUCTURE

Rocks of the Bighorn Range indicate diastrophism during two widely separated geologic eras, the Precambrian and Cenozoic. The gneissic rocks were formed by metamorphism of sedimentary and igneous rocks during the Precambrian at which time they also were folded and contorted. This flow-folding probably was concurrent with regional metamorphism, as suggested by Palmquist (1967, p. 294). The mafic dikes probably were intruded along fractures and faults that developed during Precambrian time. In some localities, as near as the head of Canyon Creek, along upper Medicine Lodge Creek, and across upper tributaries of Moraine Creek, dikes clearly follow preexisting faults (pl. 1). Locally, the dikes obscure all traces of the fault, but the dikes commonly pinch out, whereas the faults or fracture zones may be traced onward. Metamorphism of some mafic dikes indicate that they predate the latest Precambrian episode of metamorphism. Many of the older faults form pronounced mylonized zones as along Medicine Lodge Creek. The crushed and broken zones commonly are healed by silicification. In places, the introduced quartz has a distinct greenish color, largely from tiny interspersed crystals of epidote. An excellent outcrop of cryptocrystalline green quartz, which in the hand specimen looks like jadeite, is along a major northeast-striking fault zone about 60 feet wide that crosses the range about 2 miles north of Lake Solitude. Some fault zones are marked by abundant secondary reddish feldspar.

A few of the major faults are reflected in the magnetic pattern (pl. 1), either because they mark a major discontinuity in the Precambrian basement or because they are zones where the magnetite in the rock has been destroyed. One of the largest faults in the Bighorns extends along Edelman Creek, crosses the spine of the range at Emerald Lake, and continues southwest along Medicine Lodge Creek. The fault splits near the primitive area boundary. The main segment continues southwest into and along the headwaters of Trout Creek, although a prominent segment continues southwest along Medicine Lodge Creek. A split from the southernmost of the two segments strikes N. 20° E. and offsets a diabase dike northeast of the head of Trout Creek. In the vicinity of Medicine Lodge Creek, the fault is marked by an elongate magnetic low (pl. 1). The magnetic pattern also is disrupted along another major fault zone that extends along the North Fork of Paint Rock Creek, forms an escarpment along the south side of Cliff Lake, and continues northeast across the range south of Lake Elsie. The fault extends along the valley of Kearney Creek to the east end of Kearney Reservoir where it is concealed by a moraine. Dolerite dikes are offset along this fault but no displacement was seen in Paleozoic rocks at the west end of the fault, which suggests it is Precambrian in age. The fault is but one segment of a broad zone of faults and northeast-trending dolerite dikes that cross the range in the vicinity north of Blacktooth Mountain (pl. 1). North of this zone the magnetic pattern is fairly uniform, whereas south of the zone the pattern is much more irregular and complex. The differences in the magnetic pattern over these two areas probably is largely due to differences in magnetic characteristics of the near-surface rocks, which in the south are gneissic whereas those to the north are granitic, as well as to variations deeper within the Precambrian basement.

The degree of Cenozoic faulting cannot be determined with certainty in the study area because of the absence of suitable marker beds. Many faults, however, exhibit decidedly youthful features. At the northern end of the area, a fault along Wilderness Creek strikes N. 20° W. and dips 85° SW. One wall of the fault forms a cliff 30 feet high on which are prominent strike-slip slickensides. To the south, this fault is offset by a major shear zone that strikes N. 72° E., is brecciated and sheared, and is marked by two large silicified zones about 100 feet apart. This shear zone appears to be an old fault that was reactivated in Cenozoic time. Another fault zone of probable Cenozoic age crosses the crest of the range near the head of Porcupine Creek. It strikes N. 15° E. and is composed of several segments having right lateral displacement, as evidenced by offsets of a large dolerite dike. Faults that strike about N. 15° E. also offset a

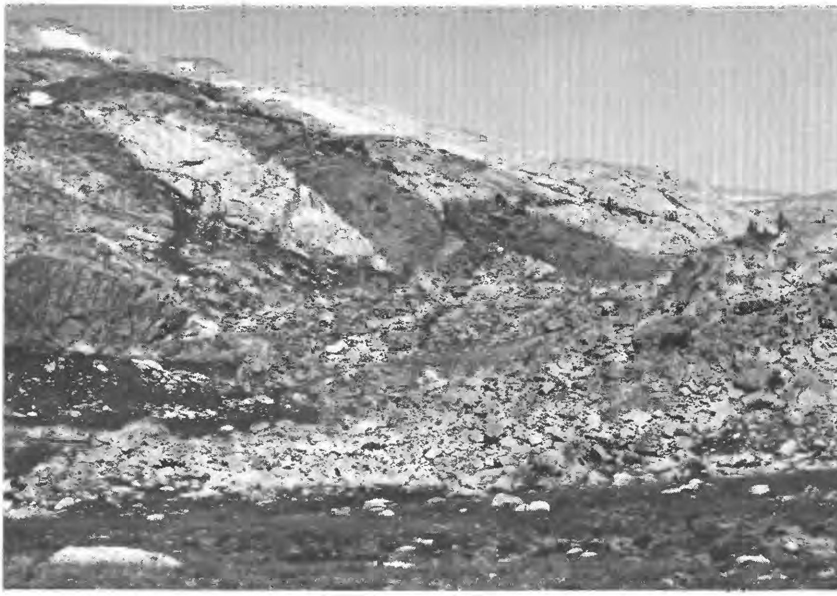

FIGURE 8.—Faulted dolerite dike south of Geneva Pass. The dike strikes west, dips 80° N., is about 100 feet thick, and has been offset south about 100 feet by a north-striking fault.

dolerite dike near Granite Lake, south of Geneva Pass (pl. 1, fig. 8). Hoppin (1961, p. 365) and Hudson (1969, p. 294) described a system of faults along the eastern side of the Bighorns, striking from N. 10° to 17° E., as being of Precambrian age. Faults of similar trend in the Geneva Pass area may also have formed during the Precambrian, but these faults were reactivated during Cenozoic uplift of the range.

Most faults in the study area fall into two general systems; those in one system strike northeast and those in the other strike northwest. Evidence of major displacement was not seen along any of the faults. The fracture patterns are what would be expected from stresses set in the rocks through vertical uplift of the northwest-trending range. Thus, the faults may be Laramide or younger in age. The fact that some faults of probable Precambrian age have cut younger structures suggests that some old faults were reactivated during Cenozoic uplift.

AEROMAGNETIC INTERPRETATION

An aeromagnetic survey of the Cloud Peak Primitive Area was flown by the U.S. Geological Survey as part of the evaluation of the mineral potential of the area. The chief purpose of this survey was to search for geologic environments that might be associated with buried mineral deposits and which could not be detected by conventional geologic mapping or by geochemical sampling. The survey, flown in 1970, covers an area of approximately 354 square miles of the region between lat 44°7′30″ to 44°37′30″ N. and long 107° to 107°22′30″ W. (pl. 1). Flightline spacing was about 1 mile, and barometric flight altitude was 14,000 feet. The north-south flightlines are shown on plate 1. The magnetic data obtained in the survey were compiled at the scale of 1:24,000 and reduced to 1:63,360 for inclusion on the geologic map (pl. 1).

The magnetic characteristics, susceptibility and remanent magnetism, were determined for five unoriented rock samples (table 2). Although these samples are far too few to allow evaluation of magnetic properties of the dominant rocks of the Cloud Peak area, they do give an idea of the relatively great range in susceptibility and remanent magnetism of Precambrian rocks of similar lithology. The dolerite dike rock contains more magnetite than the enclosing gneiss or granite and is expectably the most strongly magnetic of the five specimens. Nevertheless, the overall magnetic pattern of the area is probably due to variations in the magnetic properties in the Precambrian basement, which consists chiefly of gneiss and granite, rather than to the dolerite dikes. These dikes generally do not influence the magnetic pattern, as is indicated on plate 1. This has been noted in other Precambrian terranes in Wyoming and has been attributed to the narrowness of the dikes relative to height and spacing of the flights during the aeromagnetic survey (R. E. Mattick, in Pearson and others, 1971, p. B26).

The Cloud Peak Primitive Area is characterized by two regions of distinctly different magnetic patterns, which also are regions of significantly different relative amounts of the two dominant rock

TABLE 2.—*Magnetic properties of selected rocks from the Cloud Peak Primitive Area*

Sample No. (pl. 2)	Magnetic susceptibility $\times 10^{-6}$ (cgs)	Remanent magnetism $\times 10^{-6}$ (cgs)	Magnetic moment $\times 10^{-6}$ (cgs)	Rock type
390	1,160	497	5,330	Granite.
433	340	635	6,790	Granite.
461	287	125	1,360	Gneiss.
594a	4,540	2,640	28,300	Dolerite dike.
634a	1,290	1,890	20,400	Gneiss.

types, granite and gneiss. The northern area, dominantly granite, has a broad, relatively smooth magnetic gradient that increases westward, whereas the southern area, of dominantly gneissic rocks, has a more complex pattern culminating in magnetic highs over the central and generally topographically highest part of the Bighorn Mountains. The boundary between these two regions is marked by a linear zone more or less parallel to the zone of large dolerite dikes and faults (pl. 1). This zone may represent a major structural discontinuity in the Precambrian basement.

The magnetic patterns (pl. 1) apparently are unrelated to rock masses that might be associated with mineral deposits. They are probably the result of variations in the magnetic properties of the exposed rocks and in topography, as well as concealed masses at depth within the Precambrian basement. Depth estimates to the magnetic sources of the anomalies are somewhat uncertain because of highly irregular topography. However, the sources of most of the short wavelength magnetic anomalies, such as those over the central part of the range near the center of the map area (pl. 1), are a result of magnetic sources at or within several thousand feet of the surface. Longer wavelength patterns, such as the inclined magnetic gradient in the northern part of the map area, reflect a deeper magnetic source. The influence of still deeper rocks in the Precambrian basement is probably masked by the near-surface rocks in the Bighorn Range.

The magnetic pattern of the northern zone (illustrated by a relatively smooth magnetic gradient of about 50 gammas per mile on pl. 1) originates from a deep-seated source and only locally reflects the Precambrian granite. The effect of topographic relief on the granite is reflected by local small-amplitude anomalies superimposed on the regional gradient over higher altitudes. The fact that the local magnetic anomalies due to topography are small is a good indication that, for the most part, the granitic rocks east of the crest of the range have relatively low susceptibilities. The apparent culmination of the anomaly occurs over and west of the crest of the Bighorn Mountains, at altitudes in the range of 9,000 to 11,000 feet. Local gradients in this area indicate that the source of this anomaly is near the surface. The anomaly probably reflects a larger more mafic mass of granite, similar to the small exposure of quartz diorite that crops out west of Coney Lake.

The distinctive east-trending zone separating the northern region of rather simple magnetic pattern from the southern region of much more complex pattern probably is a zone of major Precambrian faulting. This zone, which is 3 to 4 miles wide, is marked by many dolerite dikes, including the largest dikes in the area, and by large faults that probably first developed in the Precambrian and were reactivated during Laramide deformation. The zone culminates in a magnetic high over the crest of the Bighorns in the area of Cloud Peak and Blacktooth Mountain. The large dolerite dikes at Blacktooth Mountain are reflected in the magnetic pattern, imposing or enhancing a magnetic high that is more directly related to the more widespread and deeper Precambrian gneissic rock. The westward continuation of this dike complex is associated with a magnetically-low east-trending trough (pl. 1), which reflects the topographically lower area of North Paint Rock and Canyon Creeks, thus obscuring the magnetic effect related to the dikes. The magnetic highs over Blacktooth Mountain partly reflect the abundance of large dikes but more probably reflect a large deep-seated mafic intrusion that was the source of the dikes. Another magnetic low to the north, along upper Medicine Lodge Creek (p. C27, pl. 1), probably reflects both the topographic low and the alteration along the major northeast-trending fault there (pl. 1).

A small negative anomaly to the west of Cloud Peak has a closure of 20 to 30 gammas (pl. 1), and it appears to be associated with an east-trending troughlike anomaly that passes between Cloud Peak and Bomber Mountain. The origin of these anomalies is not clear; they appear to be due to a linear element that depth estimates would place at or near the surface. However, no such element or structure was observed in the field. Perhaps this linear zone of relatively low magnetic intensity is related to deformation and intrusion along a Precambrian fault that is no longer readily apparent in the metamorphic terrane.

The broad negative anomaly to the east of Cloud Peak also reflects a near-surface source of unknown origin. This is an area of Precambrian gneissic rock partly covered by moraine. The anomaly either reflects variation in magnetic characteristics of the rock exposed or a concealed near-surface mass, perhaps a granite instrusion, of relatively low magnetic susceptibility.

The southern part of the primitive area (pl. 1) is characterized by a broad magnetic high that culminates in three 10- to 50-gamma closures over the crest of the Bighorn Mountains, near Bomber Mountain, Mather Peak, and Lake Angeline, and a salient crest that extends westward from Mather Peak. The overall high appears to be a regional anomaly, the source of which lies at a depth of several thousand feet to a few miles. It may be a gneissic rock, within the Precambrian basement, that has greater average magnetic susceptibility than that of the average gneiss exposed elsewhere in the map area, or it may be a large mafic intrusion.

The high-amplitude closed magnetic highs on the broad magnetic high in the southern region reflect sources at or near the surface. They probably reflect a combination of effects due to topography, to a higher susceptibility of the exposed granite and gneiss, and possibly, to different rock types at depths of not more than a few thousand feet. The three magnetic closures, over or near the highest peaks and ridges along the crest of the range, probably reflects variations in magnetic characteristics of exposed rocks, as well as topography. The small elongate magnetic anomaly (closure of about 40 gammas) some 4 miles west-southwest of Bomber Mountain (pl. 1) is centered over Elk Mountain, a northeast-trending ridge that is 1,000 to 1,500 feet above the surrounding terrain. This anomaly also is probably due to topography or relatively mafic gneiss.

In the southern part of the map area, the magnetic gradient, which decreases southward at a relatively uniform rate, is interrupted by a broad negative anomaly having a closure of 20 to 30 gammas (pl. 1) that may be related to flattening of the magnetic gradient along an east-west zone. This zone in part is over a quartz diorite intrusion that was mapped by Heimlich and Banks (1968, p. 182). We did not delineate such an intrusion here but did find a red microcline granite to be a dominant rock type in part of the area. Such a granite might have low magnetic susceptibility in relation to the surrounding gneiss and therefore might cause flattening of the magnetic gradient.

Other small magnetic highs in the southern part of the area are associated with topographic highs. The magnetic high showing a closure of about 20 to 30 gammas, just south of the above-mentioned broad magnetic low, is over a high peak on the crest of the Bighorn Mountains. A smaller closed magnetic high 2 miles east is over another peak.

MINERAL RESOURCES

The purpose of this study was to determine the extent and nature of any mineral resources in the Cloud Peak study area and to appraise the potential for commercial mineral production. To meet these objectives, the geology was mapped in a reconnaissance fashion and the area was examined closely for evidence of mineral deposits. Fracture zones, dikes, or other rocks that showed evidence of alteration or mineralization were given special attention and were sampled. Major rock types and sediments from streams that drain the area were sampled extensively. The rocks were tested throughout the area for abnormal radioactivity. An aeromagnetic survey was made of the area to search for geologic environments favorable for mineral deposition. A search of county courthouse records was made for information on mining claim locations and all claims and prospect workings found in the field were examined and sampled.

MINERAL SETTING

The Cloud Peak study area has been prospected extensively in the past, but there is no record of metal production from it. Elsewhere in the Bighorn Range, mineral production has been limited to a small amount of gold from at least two localities. According to Darton (1906a, p. 112), attempts were made to mine gold from basal gravel of the Deadwood Formation (Flathead Sandstone) near Bald Mountain, about 25 miles northwest of the primitive area, but the results were not encouraging. The highest assays were $2 of gold per ton (Darton, 1906b, p. 307). Gold in the basal Flathead also was reported by Darton (1906a, p. 113) near the head of Kelley Creek, southwest of Buffalo, but attempts at mining were not profitable. Osterwald, Osterwald, Long, and Wilson (1966, p. 90) described the Mosaic claim in T. 54 N., R. 87 W., north of the primitive area, as containing minor gold, silver, and tungsten. Three samples from the property contained from 0.025 to 0.04 ounce per ton gold, and 0.36 to 0.50 ounce per ton silver; two grab samples contained 0.10 percent and 0.26 percent WO_3.

A quartz vein 6 inches thick crops out in gneiss, north of U.S. Highway 16 at Powder River Pass about 1 mile southeast of the primitive area. Malachite is scattered along the vein (Osterwald and others, 1966, p. 54). Other nonproductive copper prospects are southeast of the primitive area.

A monazite deposit near Bald Mountain, about 25 miles northwest of the primitive area, was drilled in 1952 by the U.S. Bureau of Mines. Ninety-two holes, averaging 22 feet in depth, were drilled in the basal Flathead Sandstone, which was found to contain an average of 2.162 lb of monazite per ton of sandstone. Material from individual holes contained as much as 19.484 lb of monazite per ton (Osterwald and others, 1966, p. 220). Presumably, this deposit is near the Bald Mountain gold prospect mentioned above.

The Bighorn Range is flanked on the east by the Powder River Basin and on the west by the Bighorn Basin. Oil and gas are produced from both basins, and both contain coal fields. Extensive resources of gypsum and bentonite also occur in the basins. The rocks that contain these commodities have been eroded from the Cloud Peak study area.

The only active mining operation near the area is a pit near Spanish Point, west of the study area, where agate was mined in 1970 for sale as rock specimens and for use in jewelry.

SAMPLING AND ANALYTICAL TECHNIQUES

Sampling and analytical techniques used in this study area were designed to obtain maximum information consistent with rapid coverage of the area. Most effort was devoted to sampling the stream sediments that result from weathering and which therefore reflect the metal content of rocks being eroded in the various drainage basins. Such sediment sampling permits large areas to be tested quickly. Samples containing unusual quantities of metals can be evaluated as to the geologic environment and the metals possibly traced to their source.

All major streams and most tributaries in the study area were sampled (pl. 2). Each sample consisted of a couple of handfuls of fine-grained sediment, preferably clay or silt, which tend to adsorb and thus concentrate metal ions that are in solution. The samples were dried and sieved, and the minus 80-mesh portions were analyzed.

Panned concentrates of sediments were also made to search for heavy minerals or metals such as gold; these were examined visually and subsequently analyzed.

Major rock types, dikes, fracture and altered zones, and mineralized rocks were sampled and analyzed. All sample sites are shown on plate 2.

All stream-sediment and panned-concentrate samples were analyzed by six-step semiquantitative spectrographic analyses, and the gold, silver, copper, lead, and zinc content of the samples was checked by atomic absorption analysis. Rock samples also were analyzed spectrographically. Most samples from veins, shear zones, and altered or mineralized zones were analyzed chemically, by atomic absorption, or by fire assay. Semiquantitative spectrographic analyses were made for the following 30 elements: Fe, Mg, Ca, Ti, Mn, Ag, As, Au, B, Ba, Be, Bi, Cd, Co, Cr, Cu, La, Mo, Nb, Ni, Pb, Sb, Sc, Sn, Sr, V, W, Y, Zn, and Zr. Colorimetric analyses for uranium were determined on 136 stream-sediment and panned-concentrate samples, but no uranium in quantities of as much as 20 ppm was detected. All analytical results, except those determined by fire assay and colorimetric uranium were stored on magnetic tape via an IBM 360 computer. The taped data are available from the National Technical Information Service.[2]

EVALUATION OF SAMPLE DATA

None of the samples taken in the study area contain unusual concentrations of metals nor do they indicate mineral deposits of commercial value. Mean log-normal distribution values of the most frequently occurring elements in the samples are shown in table 3.

TABLE 3.—*Mean of log-normal distribution values of semiquantitative spectrographic analyses of selected elements in stream-sediment, granite and gneiss, dolerite, and panned-concentrate samples, Cloud Peak Primitive Area, Wyo.*

[Number of samples analyzed is given in parentheses. Results, in parts per million, are reported to the nearest number in the series 1, 0.7, 0.5, 0.3, 0.2, 0.1, and so forth, which represents approximate midpoints of group data on a geometrical scale]

Element	Stream sediments (608)	Granite and gneiss (63)	Dolerite (32)	Panned concentrate (28)
Co	10	15	50	15
Cr	50	30	200	100
Cu	15	20	70	10
La	50	30	—	100
Ni	20	15	100	30
Pb	20	15	—	20
Sc	10	7	20	15
V	70	30	150	100
Y	20	15	20	50

Several metals in stream sediments may be seen in table 3 to be similar in value to those in granite and gneiss. Granitic rocks are not separated from gneissic rocks in the table because our analyses show the two types to be similar compositionally, differing appreciably only in calcium, of which there is more in the gneiss. Dolerite contains more cobalt, chromium, copper, nickel, and vanadium than does granite and gneiss, as would be expected. The rare earth metals lanthanum and yttrium show higher values in the panned concentrates. They probably occur in monazite or sphene, both of which are accessory minerals in the granitic rocks and which tend to concentrate along with zircon, magnetite, and ilmenite, as heavy minerals in the black sand fraction of panned concentrates.

[2] Kiilsgaard, T. H., and others, 1972, Magnetic tape containing semiquantitative spectrographic analyses and some selected chemical analyses of rocks and stream sediments from the Cloud Peak Primitive Area, Wyoming: Rept. PB2-10928, National Technical Information Service, U.S. Department of Commerce, Springfield, Va. 22151.

Stream-sediment analyses are given in table 4. This table shows upper-range values for the same elements shown in table 3. The upper-range values are equivalent to the mean values plus two standard deviations. All values are within the expected range of values for rock types exposed in the drainage basins sampled. For example, the upper-range value of copper is 50 ppm, yet the average copper value of dolerite is 70 ppm, and values of as much as 200 ppm Cu were found. Even copper values of several hundred parts per million would not be abnormal for dolerite. All upper-range copper values shown in table 4 are from samples taken below

TABLE 4.—*Upper-range values of selected elements in stream-sediment samples, Cloud Peak Primitive Area, Wyo.*

[Semiquantitative spectrographic analyses (ppm)]

Sample Number	Co (30)	Cr (200)	Cu (50)	La (150)	Ni (100)	Pb (50)	Sc (20)	V (150)	Y (50)1/
32	--	500	--	--	150	--	--	--	--
34	--	300	--	--	100	--	--	--	--
43	--	--	--	--	--	--	20	--	--
66	--	--	--	--	100	--	--	--	--
67	--	--	--	--	--	70	--	--	--
77	30	300	--	--	150	--	--	--	--
85	50	1,000	--	--	500	--	--	--	--
86	50	300	--	--	500	--	--	--	--
87	30	200	--	--	200	--	--	--	--
110	--	--	--	--	--	--	70	--	--
111	--	--	--	150	--	--	--	--	--
143	--	--	--	200	--	--	--	--	--
149	--	--	--	--	--	50	--	--	--
153	--	200	--	--	150	--	--	--	--
154	--	200	--	--	100	--	--	--	--
175	--	--	--	150	--	--	--	--	--
188	--	--	--	150	--	--	--	--	--
193	--	--	--	150	--	--	--	--	--
194	--	--	50	200	--	--	--	--	50
195	--	--	--	150	--	--	--	--	--
196	--	--	--	--	--	--	20	150	--
198	--	--	70	--	--	--	--	--	--
200	--	--	--	300	--	--	--	--	50
206	--	--	--	--	--	--	--	--	7
208	--	200	--	--	--	--	--	--	-
218	30	200	50	--	150	--	--	--	--
221	--	--	50	--	--	--	--	--	--
223	--	200	--	--	100	--	--	--	--
238	--	--	--	--	100	--	--	--	--
293	--	--	--	--	--	--	--	--	50
307	--	--	--	--	150	--	--	--	--
310	--	--	--	--	--	150	--	--	--
312	50	500	--	--	700	--	--	--	--
313	30	300	--	--	500	--	--	--	--
314	--	--	--	--	--	--	20	--	--
323	--	--	--	--	--	70	--	--	--
324	--	--	--	--	--	50	--	--	--
328	--	--	--	150	--	--	--	--	--
336	--	200	--	--	--	--	--	--	--
337	--	200	--	--	--	--	--	--	--
340	--	--	100	--	100	--	--	--	--
369	--	--	--	--	--	70	--	--	--
408	30	--	--	--	150	--	20	--	--
421	--	--	50	--	--	--	--	--	--
451	--	--	--	--	--	--	50	300	70
452	--	--	50	--	--	--	--	--	--
455	--	--	--	300	--	--	30	--	--
460	50	700	70	--	300	--	20	--	--
462	--	--	50	--	--	--	--	--	--
473	--	--	--	--	--	--	20	--	--
474	--	--	--	--	--	--	20	150	--
477	--	--	--	--	--	--	20	--	50
478	--	--	--	--	--	--	20	150	--
487	--	--	50	--	--	--	--	--	--
490	--	--	--	200	--	--	--	--	50
492	--	--	--	150	--	--	--	--	--
494	--	--	--	--	--	--	50	--	--
576	--	--	--	--	--	--	--	--	50
577	--	--	--	--	--	--	--	--	50
589	--	200	--	--	--	--	--	200	--
624	--	--	70	--	100	--	--	--	--
630	--	--	--	--	--	--	20	--	--
631	--	--	70	--	--	--	--	--	--
633	--	--	--	--	--	--	--	150	--
634	--	--	--	--	--	100	20	--	--
636	--	--	50	--	--	--	--	150	--
638	--	--	--	--	--	--	--	--	50
641	--	--	--	--	--	--	--	150	--
643	--	--	50	--	--	--	--	--	--
653	--	--	--	--	--	--	--	--	50
659	--	--	--	--	--	--	--	150	50
660	--	--	50	--	--	--	--	--	--
666	--	--	50	--	--	--	--	--	--
684	--	--	--	200	--	--	--	--	--
687	--	--	50	--	--	--	--	30	--
690	--	--	50	--	--	--	--	--	--
705	--	--	--	300	--	--	--	--	50
711	--	--	50	--	--	--	20	150	--
712	--	--	--	--	--	--	20	150	--
721	--	--	--	--	--	--	--	150	--
725	--	--	--	--	--	--	--	--	70
731	30	--	--	2/	--	--	30	200	150
734	--	--	50	--	--	--	--	--	--
737	--	--	70	--	--	--	--	--	--
740	--	--	50	--	--	--	--	--	--
741	--	--	70	--	--	--	--	--	--
744	--	--	--	--	100	--	--	--	--
745	--	--	--	--	--	--	20	--	50
750	--	--	50	--	--	--	--	--	--
756	50	--	50	--	--	--	--	200	--
758	--	--	50	--	--	--	--	--	--
764	--	--	--	--	100	--	--	150	--
806	--	--	--	--	--	--	--	--	50
823	--	--	--	150	--	--	--	--	--

1/ Upper-range values.

2/ More than 1,000 ppm La.

eroding dolerite dikes, and none of them are representative of unusual upstream concentrations of copper.

Cobalt, chromium, nickel, scandium, and vanadium are common substitute elements in minerals such as pyroxene, amphibole, biotite, and magnetite, which are common in the dolerite dikes. It therefore is not surprising that upper-range values for these elements in sediment samples compare closely with mean values of the dolerite rock sample (table 3). Most samples that contained upper-range values of these elements were taken below dike outcrops, and the few that were not, were probably taken downstream from dikes that were not recognized in the field or from gneissic rocks that contained anomalous amounts of mafic minerals. None of the values of these elements are above what would be expected from rocks that are being eroded in the basins.

The lead values shown in tables 3 and 4 are normal for rocks of the area.

Early day prospectors in the Bighorns searched primarily for gold, and since prospect pits were found at several localities, it was assumed that gold, if present in the area, would be found in panned-concentrate samples. The two best panned samples, however, contained only 0.4 ppm Au, a concentrate that does not indicate a placer material of value. None of the panned samples are indicative of gold concentrations, either in placer or lode deposits.

MINING CLAIMS AND PROSPECTS

No patented mining claims and no oil and gas leases are located in or near the primitive area, according to records of the U.S. Bureau of Land Management. Courthouse records of Big Horn, Johnson, and Sheridan Counties were examined for location notices of unpatented mining claims. Those claims that could be located in the field were examined and sampled. Mining claims, prospect workings, and mineral occurrences that were examined during the field investigation are described in the following section of the report. The localities that were investigated are shown in figure 9 and many of them are shown on plate 1. Analytical data on samples is given in tables 5 and 6; sample localities are shown on plate 2.

CLAIMS AND PROSPECTS WITHIN THE CLOUD PEAK STUDY AREA

WILDERNESS CREEK AREA

Sheridan County records show that a mining claim, the Diamond Lode, was located in 1942 on Wilderness Creek 1½ miles upstream from Dome Lake, thereby placing it in sec. 9, T. 53 N., R. 87 W.

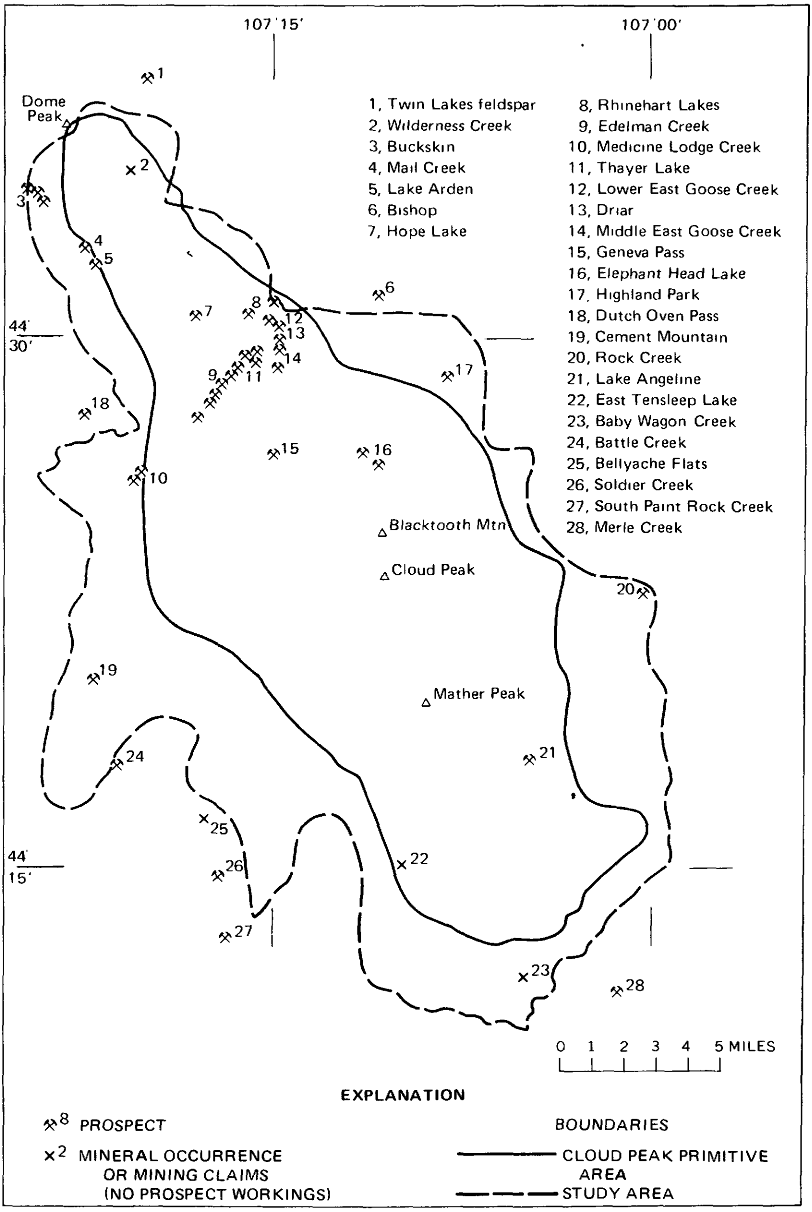

FIGURE 9.—Sketch map showing location of mining claims, prospects, and mineral occurrences, Cloud Peak study area.

(fig. 9, loc. 2). We were unable to find evidence of prospecting or claim monuments in this area. However, at the approximate position described for the claim, several hundred feet southwest of a large meadow, a diabase dike crops out for about 200 feet, is 30 feet wide, strikes S. 18° W., and has a near vertical dip. The diabase weathers to a gray-green granular material. Sample 908, chipped at 5-foot intervals across the dike, does not contain an unusual concentration of metals.

BUCKSKIN PROSPECT

The Buckskin prospect (fig. 9, loc. 3), consisting of the Buckskin Nos. 1 and 2 claims, is southeast of Willett Creek, in the W½ sec. 13, T. 53 N., R. 88 W. Prospect workings include several shallow pits and trenches and a caved adit. Most of the workings are within the study area but the adit and some pits are just west of the boundary. Some workings are along dolerite dikes but others are on quartz veins.

The southeasternmost trench, about 10 feet long and 2 feet deep, is on the east side of a ridge between two tributaries of Moraine Creek. It explores a white quartz vein that ranges in width from 2 to 6 feet, strikes N. 45° W., and may be traced on the surface about 450 feet. The quartz is stained irregularly with iron oxides and contains sparse specks of pyrite. A sample (425, pl. 2 and table 5), taken across a 4-foot width of the vein does not show anomalous metal content.

Talus and soil conceal the northwest end of the vein, but in this vicinity, several pits are along a prominent dolerite dike that strikes N. 15° W., dips 50° NE., and is about 50 feet thick. A sample (426, pl. 2) of dike material from a pit contains metal values that would be expected for this type of rock.

Further to the northwest, near an old cabin, is an adit that was caved at the portal, but which from the size of the dump was estimated to be about 25 feet long. The adit was driven along a quartz vein about 5 feet thick that strikes N. 45° W. and dips 85° SW. From footwall to hanging wall, the vein consists of a 10-inch zone of intensely sheared and crushed granite, 4 feet of greenish, massive, ledge-forming quartz, and a 5-inch zone of dark quartz containing fine-grained pyrite and sparse flecks of galena. Sample 427, taken across the 5-inch zone of dark quartz, sample 428, taken across the 10-inch crushed zone, and sample 429 of selected dump fragments, did not contain appreciable metal values (pl. 2, table 5).

TABLE 5.—*Analyses of samples of altered or*

[Gold and silver determinations are by atomic absorption detection (AA), as are copper, lead, and zinc determinations followed by the letter A. All samples were analyzed by six-step semiquantitative spectrographic analyses and the determinations are reported to the nearest number in the series 1, 0.7, 0.5, 0.3, 0.2, 0.15 and 0.1, which represent approximate midpoints of group data on a geometric scale. The assigned groups for the series will include the quantitative value about 30 percent of the time. The data should not be quoted without stating these limitations. The symbol N indicates the element was looked for but not found; L indicates that an undetermined amount of

Samples		AA (ppm)		Semiquantitative spectrographic analyses (ppm)								
Number	Location T. R. S.	Ag (0.2)	Au (0.02)	B (10)	Ba (10)	Be (1)	Co (5)	Cr (10)	Cu (5)	La (20)	Mo (5)	Ni (5)
60	51-87-24	N	N	N	100	N	5	L	5	N	N	L
248	52-87-33	N	N	N	500	L	5	10	5	N	N	5
249	52-87-33	<.2	<.02	15	300	1	5	30	5	20	N	10
252	52-87-27	N	N	N	50	N	5	L	5	N	N	10
256	52-87-32	<.2	<.02	N	20	N	10	15	10A	L	N	L
268	53-87-20	<.2	<.02	L	150	N	N	L	2A	N	N	5
365	52-87-33	<.2	<.02	L	300	L	50	30	10	30	N	20
368	52-87-23	<.2	<.02	N	100	L	100	L	5	L	N	5
392	52-87-16	N	N	L	300	1	5	L	5	20	N	5
393	52-87-16	N	N	N	500	N	5	L	10	N	N	L
397	53-87-34	N	N	L	200	L	5	L	5	N	N	L
409	52-87-19	<.2	<.02	--	L	N	5	15	20A	L	N	L
410	52-87-19	2.5	<.02	--	50	L	30	15	1,500A	L	N	L
425	53-88-13	<.2	<.02	L	150	N	70	150	6A	N	N	50
427	53-88-13	.2	<.02	L	100	N	10	70	3A	N	N	30
428	53-88-13	.2	<.02	L	150	N	10	70	5A	N	N	30
429	53-88-13	.4	.02	L	150	L	10	70	3A	N	N	50
463	52-85-18	<.2	<.02	10	2,000	1.5	70	300	100	300	N	150
468	52-87-2	N	N	15	70	N	70	300	70	N	N	150
469	52-87-2	<.2	<.02	N	L	L	N	N	15	N	N	L
470	52-87-2	<.2	<.02	N	L	L	N	N	L	N	N	L
471	52-86-31	<.2	<.02	10	20	L	150	300	10	N	N	150
472	52-86-31	<.2	<.02	10	100	L	100	200	15	N	N	150
502	53-87-33	N	N	L	200	L	5	L	5	N	N	5
522	52-87-12	N	N	N	300	L	5	10	5	20	N	7
523	52-87-12	N	N	L	150	L	10	30	50	70	N	50
524	52-87-12	N	N	L	100	L	200	L	200	N	7	20
525	52-87-12	N	N	L	100	L	200	30	10	N	7	50
526	52-87-15	N	N	L	150	L	50	10	100	20	15	10
527	52-87-15	N	N	L	50	L	100	L	500	N	N	15
528	52-87-15	N	N	L	150	L	50	L	2,000	N	N	10
529	52-87-14	N	N	L	20	L	50	20	10	N	N	20
530	52-87-14	N	N	L	20	L	20	L	10	N	N	5
540	52-86-6	N	N	10	500	L	50	100	150	20	N	100
541	52-86-6	N	N	L	300	L	50	30	100	20	N	20
545	52-86-18	N	N	10	300	L	10	30	50	20	N	20
558	52-86-31	N	N	L	N	L	70	20	7	N	N	10
578	53-86-35	<0.2	<0.02	N	20	N	N	L	L	N	N	5
579	53-86-35	<.2	<.02	N	30	1.5	L	150	L	20	N	15
580	53-86-35	<.2	<.02	N	300	N	10	L	L	L	N	L
611	52-86-27	<.2	<.02	10	50	1	15	150	50	30	N	15
612	52-86-27	<.2	<.02	N	70	L	7	L	20	L	N	15
613	52-86-27	<.2	<.02	10	70	1.5	5	10	L	30	N	10
615	52-86-27	<.2	<.02	N	50	1	7	10	L	50	N	15
616	52-86-27	<.2	<.02	10	70	1.5	20	70	15	70	N	20
619	52-86-35	<.2	<.02	20	150	L	100	70	15	20	N	100
620	52-86-24	N	N	10	700	1	20	30	15	30	N	50
622	51-86-10	<.2	<.02	N	20	L	10	N	L	20	N	10
658	49-86-1	<.2	<.02	N	L	N	10	100	5	20	N	70
715	49-85-17	N	N	N	200	N	7	10	10	N	N	30

The quartz vein continues northwest from the adit, and in a distance of about 700 feet, it increases in width to about 20 feet. The massive greenish-gray quartz is laced with veinlets of white quartz and forms a conspicuous promontory on a ridgecrest. The quartz is not iron stained and no sulfide minerals were observed. Further northwest, the vein is a silicified zone about 50 feet wide, *mineralized rock, Cloud Peak Primitive Area, Wyo.*

the element is present below the sensitivity limit shown in parentheses beneath the elemental symbol at the top of each column. The symbol < means less than the number shown. Samples are located according to township (T.), range (R.), and section (S.). Analyses for arsenic, bismuth, cadmium, niobium, antimony, tin, tungsten, yttrium, and zirconium revealed no significant values and no determinations are shown. Analysts: J. G. Frisken, J. D. Hoffman, R. W. Leinz, C. Forn, C. Smith, G. W. Day, E. F. Cooley, J. H. Reynolds, R. M. O'Leary, R. L. Miller, and R. R. Carlson]

Sample	Semiquantitative spectrographic analyses (ppm)						(Percent)				Remarks
	Pb (10)	Sc (5)	Sr (100)	V (10)	Zn (200)	Mn (10)	Fe (0.05)	Mg (0.02)	Ca (0.05)	Ti (0.002)	
60	N	N	N	10	N	50	0.3	0.1	0.2	0.03	Green qtz.
248	N	5	N	30	N	150	2	.5	.1	.15	Qtz. vein.
249	20	5	150	50	N	700	1.5	.5	.5	.2	Do.
252	N	5	N	10	N	70	.3	.3	L	.03	Do.
256	LA	L	L	10	5A	--	.3	.1	.1	.02	Do.
268	<5A	L	N	10	5A	50	.2	.2	L	.03	Do.
365	N	10	100	70	N	200	10	1	.5	.5	Pyritized rock.
368	N	L	N	10	N	--	2	.05	L	.02	Do.
392	L	5	200	20	N	150	1	.3	.5	.1	Fault breccia.
393	20	N	N	L	N	50	.2	.02	.1	.02	Qtz. vein.
397	L	5	500	50	--	150	2	.03	2	.1	Granite w/epidote
409	L	N	N	10	5A	20	.15	.03	L	.02	Qtz. vein.
410	5A	5	N	50	15A	50	2	.03	L	.05	Do.
425	5A	5	N	70	10A	50	2	.2	L	.1	Qtz. vein.
427	5A	5	N	20	25A	100	2	.5	.05	.1	Do.
428	10A	7	100	30	25A	150	2	1	.1	.15	Do.
429	<5A	5	N	30	25A	150	2	.5	.05	.1	Prospect dump.
463	30	30	700	200	N	1,500	3	3	5	.5	Qtz. vein.
468	10	30	300	200	N	1,500	3	3	7	.3	Alt. dike.
469	N	N	N	N	L	50	.2	.15	.07	.015	Qtz. vein.
470	N	N	N	L	L	20	L	.02	.05	.007	Do.
471	L	30	N	150	N	700	3	2	.07	.3	Do.
472	10	20	100	100	N	700	3	1.5	.3	.2	Prospect dump.
502	L	L	N	10	N	70	.7	.2	.1	.03	Fe-stain shear zone.
522	L	5	150	20	N	150	1	.5	.5	.1	Prospect dump.
523	L	7	150	70	N	200	3	2	.7	.5	Pyritized granite.
524	N	5	N	15	N	20	3	.05	L	.03	Pyrite vein.
525	N	7	N	70	N	70	7	.2	.05	.05	Pyritized dump rock.
526	N	5	N	50	N	50	5	.2	.1	.1	Prospect dump.
527	N	5	N	10	N	20	5	.02	.05	.02	Qtz. & pyrite, dump.
528	N	5	N	10	N	10	5	.02	L	.01	Qtz. vein.
529	L	5	N	20	N	100	2	.5	.1	.15	Qtz. & pyrite.
530	10	5	N	10	N	100	2	.3	L	.03	Qtz. & granite.
540	N	10	200	100	N	500	5	2	.5	.2	Qtz. & pyrite.
541	N	5	300	30	N	100	.7	.5	.2	.1	Do.
545	30	7	200	70	N	200	1.5	1	0.7	0.2	Prospect dump.
558	N	5	N	15	N	100	2	.2	L	.02	Qtz. & pyrite.
578	N	N	N	10	N	30	.3	.15	.05	.02	Qtz.
579	L	5	300	30	N	200	1	.7	1	.1	Qtz. & alt. rock.
580	30	N	100	10	N	10	.7	L	.07	.03	Altered rock.
611	10	30	700	70	N	300	1.5	1.5	7	.3	Green qtz. & granite.
612	L	L	100	10	N	30	.5	.2	.3	.03	Qtz. & alt. rock.
613	N	5	500	50	N	150	1	1	2	.15	Iron stn. rock, dump.
615	N	7	300	50	N	100	1	1.5	1	.15	Do.
616	L	20	300	70	N	300	2	3	1.5	.3	Do.
619	L	30	200	200	N	1,000	3	3	.7	.5	Do.
620	10	15	1,000	200	N	700	2	2	5	.3	Granite w epidote.
622	L	5	500	50	N	50	1	.3	1.5	.05	Do.
658	N	15	300	150	N	200	2	.7	3	.5	Vuggy qtz.
715	N	N	N	10	N	500	.3	.15	.07	.3	Qtz. vein.

in granite. Parts of the zone are streaked with iron oxides and specular hematite. Grab samples 904 and 905 (pl. 2, table 6), taken from pits in this area, do not show anomalous metal values. The silicified zone narrows to the northwest and at a distance of about 2,500 feet from the adit it passes beneath glacial till. Near the northwest end, a claim notice identifies the Triple S No. 8

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TABLE 6.—*Analyses of Bureau of Mines*

[Gold and silver assay determinations and chemical analyses shown in parentheses are by U.S. Bureau of Mines or commercial assayer. All other determinations are six-step semiquantitative spectrographic analyses by U.S. Geological Survey. (See heading under table 5 for further information on spectrographic determinations.) Under the

	Samples		Assay oz/ton		Semiquantitative spectrographic analyses (ppm)								
Number	Width (ft.)	Type	Au (0.02)	Ag (0.2)	B (10)	Ba (10)	Be (1)	Co (5)	Cr (10)	Cu (5)	La (20)	Mo (5)	Ni (5)
900	--	G	Tr	Tr	N	70	L	15	100	50	L	N	20
901	20	CP	Tr	.05	--	--	--	--	--	(.026)	--	--	(.070)
902	15	CP	Tr	.05	--	--	--	--	--	(.028)	--	--	(.086)
903	10	CP	Tr	Tr	20	100	L	70	150	150	N	N	70
904	--	G	Tr	Tr	L	70	L	10	30	10	20	N	10
905	--	G	Tr	Tr	N	100	N	10	50	10	20	N	7
906	--	G	Tr	Tr	--	--	--	--	--	--	--	--	--
907	--	G	Tr	Tr	L	30	L	150	30	15	N	10	7
908	30	CP	Tr	Tr	L	100	L	70	1,500	10	20	N	300
909	3	CP	--	--	N	L	N	N	30	7	N	N	7
910	3	CP	Tr	Tr	N	N	N	N	30	5	N	N	5
911	4	CN	Tr	Tr	L	150	L	N	L	10	20	N	5
912	--	G	Tr	Tr	L	300	1	15	100	7	30	5	30
913	--	G	Tr	Tr	L	100	N	30	500	5	50	N	150
914	4	CP	Tr	Tr	L	300	1	5	15	5	20	N	5
915	--	G	Tr	Tr	L	300	1	7	20	15	50	N	15
916	--	G	Tr	Tr	L	50	L	50	70	20	N	N	50
917	--	G	.005	Tr	L	200	1	20	15	30	N	N	30
918	--	G	Tr	Tr	L	500	L	5	10	5	50	N	5
919	--	G	Tr	Tr	L	150	1	20	200	50	30	N	100
920	--	G	Tr	Tr	L	500	1	30	150	70	50	N	100
921	--	G	Tr	.1	L	150	N	10	50	L	20	N	20
922	--	G	Tr	Tr	L	100	N	7	10	5	N	N	5
923	--	G	Tr	Tr	L	100	N	20	50	30	N	5	30
924	--	G	Tr	Tr	L	50	N	50	20	L	N	30	15
925	--	G	Tr	Tr	L	300	N	5	15	5	50	N	5
926	4	CN	Tr	Tr	L	50	N	N	15	5	N	N	N
927	--	G	Tr	Tr	L	70	N	10	20	15	N	N	20
928	20	CP	Tr	Tr	L	100	N	50	1,500	100	N	N	500
929	1	CN	Tr	Tr	L	70	N	5	10	15	N	N	10
930	--	PC	Tr	Tr	L	200	--	--	--	--	--	--	--
931	--	PC	Tr	Tr	--	--	--	--	--	--	--	--	--
932	6	CN	Tr	Tr	--	200	N	30	150	150	N	N	100
933	--	G	.005	Tr	L	1,000	N	7	15	7	30	N	5
934	--	G	--	--	L	100	L	15	50	7	50	N	50
935	3	CP	Tr	Tr	--	--	--	--	--	--	--	--	--
936	0.8	CP	Tr	Tr	N	50	L	5	30	5	20	N	10
937	1	CN	Tr	Tr	150	50	7	20	70	10	50	N	30
938	0.1	CP	Tr	Tr	N	--	--	--	--	--	--	--	--
939	1.3	CP	Tr	Tr	--	--	--	--	--	--	--	--	--
940	1.2	CP	Tr	Tr	10	L	N	100	150	10	N	N	70
941	--	G	Tr	Tr	--	--	--	--	--	--	--	--	--
942	10	CP	Tr	Tr	--	--	--	--	--	--	--	--	--
943	5	CP	Tr	Tr	--	--	--	--	--	--	--	--	--
944	--	G	Tr	Tr	--	--	--	--	--	--	--	--	--
945	--	G	Tr	Tr	--	--	--	--	--	--	--	--	--

claim, staked in 1960 by George Scott, Stevan Scott, and Ralph L. Scheriak.

Neither the field examination nor analytical data from the samples indicate a mineral deposit of commercial value at the Buckskin mine.

MAIL CREEK PROSPECT

One mining claim, Male [sic] Creek No. 1 (fig. 9, loc. 4), was recorded as located in 1956 near the headwaters of Mail Creek. Several unmarked posts and one shallow pit were found on the *samples, Cloud Peak Primitive Area, Wyo.*

heading gold (Au) the abbreviation Tr (trace) indicates that gold is present in amounts less than 0.05 oz per ton. The symbol N indicates not detected, L indicates detected but below the sensitivity limit. Under the type of sample, CN indicates a channel sample, CP a chip sample, G a grab sample, and PC a panned concentrate]

	Semiquantitative spectrographic analyses (ppm)						(Percent)				
Sample Number	Pb (10)	Sc (5)	Sr (100)	V (10)	Zn (200)	M (10)	Fe (0.05)	Mg (0.02)	Ca (0.05)	Ti (0.002)	Remarks
900	L	5	200	50.	N	300	1.5	1.5	1	.15	Gneiss & epidote.
901	--	--	--	--	--	--	--	--	--	(.78)	Mafic dike.
902	--	--	--	--	--	--	--	--	--	(.78)	Do.
903	N	50	150	200	L	1,500	3	.2	5	(.84)	Do.
904	N	7	N	30	N	200	1	.3	.07	.2	Altered granite.
905	N	7	N	50	N	150	1.5	.3	.07	.2	Do.
906	--	--	--	--	--	--	--	--	--	--	Green qtz. vein.
907	N	N	N	30	N	50	1.5	.1	L	.03	Qtz. vein w/pyrite.
908	L	20	150	30	N	700	2	3	5	.1	Mafic dike.
909	N	N	N	L	N	70	.5	.05	.05	.005	Pegmatite dike.
910	N	N	N	L	N	50	.5	L	L	L	Do.
911	L	L	300	30	N	150	.7	.3	.7	1.5	Altered granite.
912	20	10	300	100	N	300	3	1	1.5	.2	Granite.
913	20	15	100	200	N	500	7	2	.5	.5	Mafic rock
914	20	N	300	30	N	100	1.5	.2	.2	.07	Granite.
915	15	7	300	70	N	200	1.5	.7	1	.2	Do.
916	10	7	N	70	N	300	3	.7	.1	.2	Granite, qtz, pyrite.
917	10	15	300	150	N	700	3	1.5	2	.5	Granite
918	10	N	300	50	N	100	1.5	.5	.7	.15	Do.
919	10	15	300	100	N	300	3	1.5	1.5	.3	Granite & qtz.
920	N	15	1,000	200	N	500	7	2	2	0.7	Do.
921	N	L	100	70	N	200	2	1.5	.15	.15	Granite.
922	N	N	N	30	N	150	1.5	.7	.07	.07	Vein qtz. & granite.
923	10	7	N	70	N	200	3	2	.15	.2	Iron stn. granite.
924	N	5	N	70	N	70	3	.2	.05	.1	Iron stn. qtz., pyrite.
925	15	N	200	70	N	150	2	.5	.5	.1	Granite.
926	N	N	N	L	N	50	.5	.1	.05	.02	Qtz. vein.
927	N	5	N	50	N	300	1.5	.3	.3	.2	Do.
928	10	20	200	200	N	1,000	7	5	2	.5	Mafic dike.
929	N	N	N	20	N	150	1	.5	.05	.1	Qtz. vein.
930	--	--	--	--	--	--	--	--	--	--	Panned conc.
931	--	--	--	--	--	500	5	1	.7	.2	Do.
932	10	15	150	100	N	100	1	.15	.7	.07	Iron stn. gneiss.
933	30	N	300	30	N	300	7	1.5	1.5	.7	Granite w/epidote.
934	N	15	300	100	N	--	--	--	--	--	--
935	--	--	--	--	--	--	--	--	--	--	Granite, qtz, pyrite.
936	L	L	N	30	N	200	1.5	.7	.2	.2	Do.
937	15	10	200	150	L	500	(22.2)	.1	.2	.07	Sandstone & hematite.
938	--	--	--	--	--	--	--	--	--	--	Qtz. vein.
939	--	--	--	--	--	--	--	--	--	--	Qtz. vein w/pyrite.
940	L	10	N	50	N	300	3	1.5	.07	.2	Do.
941	--	--	--	--	--	--	--	--	--	--	Do.
942	--	--	--	--	--	--	--	--	--	--	Altered granite & qtz.
943	--	--	--	--	--	--	--	--	--	--	Qtz. vein w/pyrite.
944	--	--	--	--	--	--	--	--	--	--	Iron stn. qtz.
945	--	--	--	--	--	--	--	--	--	--	Granitic rock.

north side of the creek at an altitude of about 9,800 feet, in the NE¼ sec. 30, T. 53 N., R. 87 W. The pit is in granite and dolerite dike rubble, in which there are scattered pieces of white quartz. A random grab sample (906, pl. 2 and table 6) of loose material from the pit did not show anomalous amounts of metals.

LAKE ARDEN VICINITY

Old prospect workings were reported east of Lake Arden, but only three small pits dug along diabase dikes were found (fig. 9, loc. 5). Neither veins nor metallic minerals were seen at the pits or along the dikes. Along Buckley Creek, near the head of the stream, an iron-stained shear zone of brecciated and altered biotite granite strikes N. 80° W. and dips vertically. Quartz veinlets as much as 1 inch thick are in the shear zone. A sample (502, pl. 2) of the quartz and the sheared rock did not contain unusual amounts of metals.

About 2 miles northeast of Lake Arden, along the crest of the Bighorns, a large shear zone crosses the divide between Moraine and Wilderness Creeks. The zone of brecciated and faintly foliated biotite granite is about 200 feet wide, strikes N. 72° E., and dips steeply to the south. A continuation of the zone crosses the ridge east of Wilderness Creek more than 2 miles to the east. Two silicified zones, one about 30 feet wide and the other about 100 feet wide are in the shear zone. White massive quartz is abundant in these silicified zones. The quartz is streaked by greenish quartz, which in turn is brecciated and laced with veinlets of clear to white quartz. Splotchy areas of the quartz are stained by iron oxides. A grab sample of quartz (268, pl. 2), selected as the most likely to be mineralized, was analyzed by atomic absorption and it contained 0.02 ppm Au, 0.2 ppm Ag, 2 ppm Cu, 5 ppm Pb, and 5 ppm Zn, indicating a metal content too low to be of economic value.

HOPE LAKE PROSPECT

In the W½ sec. 2, T. 52 N., R. 87 W., about 1 mile southwest of Hope Lake, are several prospect pits (fig. 9, loc. 7) along an epidotized dolerite dike and in a zone of white, finely crystalline quartz veinlets adjacent and parallel to the dike. The three principal pits are shown on plate 1. Quartz veinlets, cutting chloritized biotite granite beside the dike, range from one-fourth inch to 4 inches thick, strike about N. 55° W., and dip 60° to 70° NE. The zone is from 75 to 200 feet wide and was traced about half a mile along the strike. Three samples were taken at the locality: Sample 468 was taken from a trench in the epidotized dike, which is about 75 feet thick at the site of the trench; sample 469 is quartz from the zone of veinlets on the northeast side of the dike; and sample 470 was taken from white quartz near the southeast end of the zone. None of the samples contained unusual quantities of metals.

RHINEHART LAKES AREA

Two small prospect pits about 100 feet apart are a short distance southwest of some old cabins, on the south side of the trail, about 1 mile southwest of the Rhinehart Lakes (pl. 1 and fig. 9, loc. 8). They are near the center of the E½ sec. 1, T. 52 N., R. 87 W. Sample 929 (table 6), from the upper prospect pit, is a channel sample from a 1-foot vertical quartz vein striking N. 40° E. Sample 938 (table 6) from the lower pit is from a 0.1-foot-wide near-vertical quartz vein that strikes N. 55° E. About 200 feet southwest and downhill from the lower prospect pit, a sample (930, pl. 2. and table 6) was panned from stream gravel, but the sample assayed only a trace of gold.

EDELMAN CREEK PROSPECTS

Many prospect pits and several short adits explore the major fault zone that extends along Edelman Creek (pl. 1 and fig. 9, loc. 9). This fault, one of the more persistent faults in the study area, extends from upper Paint Rock Creek northeastward to Big Goose Creek, a total distance of about 15 miles (pl. 1). The fault zone strikes generally N. 35° to 55° E. and dips nearly vertically.

The fault zone appears to have a maximum width of about 50 feet and to consist generally of unaltered to altered, brecciated or sheared biotite granite or quartz diorite. At places the fault zone contains discontinuous, relatively narrow silicified and pyritized zones. Elsewhere the zone consists of sheared and irregularly pyritized and silicified granitic rock as much as 50 feet wide. Samples of mineralized rock from the fault zone (pl. 2 and table 5, samples 522–530) and from prospect dumps (pl. 2 and table 6, samples 907, 922–925, 941–944) do not differ materially in content from samples of wallrock of the area, except that the former contain slightly more copper and iron. Pyrite is the most common sulfide mineral seen in the field and the analyses are consistent with field observations.

No location notices of mining claims on Edelman Creek appear in the Johnson County records. Judging from the condition of workings and old cabins in this area, the prospecting dates from late in the last century or early in the present one.

The principal prospect workings are along the lower reaches of Edelman Creek; they explore pyritized and iron-stained zones of the Edelman Creek fault. In the SE¼ sec. 12, and N½ sec. 13, T. 52 N., R. 87 W., there are at least three adits, two of which are caved at the portal, and several prospect pits and shallow shafts. The adit that was open at the time of our examination is on the west side of the Edelman Creek trail about one-fourth mile southwest of the junction with the Thayer Lake trail. The adit was driven N. 55° W., for 60 feet; it cuts across the Edelman Creek fault. Fresh biotite granite is exposed in the adit but no veins were seen. Rock samples 522 (pl. 2, table 5) and 925 (pl. 2, table 6) were taken from the dump of this adit.

Of the two caved adits, one about one-fourth mile upstream (southwestward) from the open adit is about 60 feet long, judging from the size of the dump. This adit explored an iron-stained pyritized zone that strikes N. 40° E. and dips vertically. Sample 524 (pl. 2, table 5) consists of selected pyritized and iron-stained granitic rock and sample 944 (pl. 2, table 6) is a grab sample from the dump. Sample 943 (table 6) is a chip sample of a 5-foot-wide zone of silicified and pyritized rock taken from the portal of the adit. The other caved adit is about 500 feet farther upstream. The size of the dump indicates this adit is about 100 feet long. The adit was driven to cut across the iron-stained fracture zone of the Edelman Creek fault, which here is at least 50 feet wide. Analysis of selected iron-stained pyritized granite from the dump (sample 525, table 5) did not show anomalous amounts of base or precious metals. Samples 923 and 924 (table 6), grab samples of dump material at this adit, are essentially equivalent to local wallrock in metal content. Sample 941 (table 6), taken across 10 feet of iron-stained quartz about 100 feet southwest of the caved adit, and sample 942, taken across 10 feet of altered granite about 150 feet northeast of the portal, gave correspondingly low values.

Several prospect pits and short shafts along the west side of Edelman Creek, W½ sec. 13, T. 52 N., R. 87 W., explore the discontinuous, narrow pyritized and iron-stained zones along the Edelman Creek fault. At a prospect pit at sample site 526 (pl. 2), the fault is 10 feet wide, strikes N. 33° E., and dips 80° SE. A sample of pyrite and quartz from the pit contained 100 ppm copper. Sample 527 (pl. 2, table 5), from a pit about 500 feet upstream from sample site 526, contained 500 ppm Cu, and sample 528 (pl. 2, table 5) 100 feet still farther upstream contained 2,000 ppm copper. Sample 528 consisted of selected fragments of quartz and pyrite taken from a zone 10 to 20 feet wide. The copper content is the highest of any sample from the study area, but no other ususual quantities of metal were detected.

A small prospect pit, just west of Edelman Creek, on the line between sec. 14 and 23, T. 52 N., R. 87 W., was sunk on a mineralized part of the Edelman Creek fault that here strikes N. 55° E. and dips 80° NW. The mineralized zone is about 5 feet wide and consists of fractured and brecciated biotite granite in which are veins one-eighth to 12 inches wide of white quartz and disseminated pyrite. Sample 530 (table 5), of selected quartz fragments and granite from the dump, does not contain anomalous metal values.

About three-fourths mile east of Edelman Pass, on the west side of Edelman Creek, there is a pit or shallow shaft in a moraine near a diabase dike. The dike is about 20 feet wide, strikes N. 65° W., and dips 65° SW. Locally, it contains veinlets and disseminated grains of pyrite and epidote. Samples 531 and 532 (pl. 2), the former of dike rock containing pyrite and the other of altered dike rock at the contact with enclosing granitic rock, lack unusual metal values, as does grab sample 922 (pl. 2, table 6) from the dump.

A shaft about 12 feet deep is at the headwaters of Edelman Creek, a few hundred feet northeast of Emerald Lake (pl. 1). It is in a silicified and pyritized, iron-stained shear zone 10 to 20 feet wide, which is part of the Edelman fault. The zone strikes N. 35° E., dips vertically, and was traced for more than 100 feet to the northeast along Edelman Creek. Selected samples of pyritized rock and quartz from the dump (samples 368 and 907, tables 5 and 6) do not contain anomalous metal values.

MEDICINE LODGE CREEK PROSPECTS

Several prospect pits are along the upper reaches of Medicine Lodge Creek in silicified and pyritized zones associated with splits of the Edelman Creek fault (pl. 1). One prospect is near the primitive area boundary, north and alongside the trail leading to Edelman Creek (fig. 9, loc. 10). Here, a vein 6 inches to 2 feet wide extends about 250 feet N. 52° E. along the north segment of the Edelman Creek fault. Vein material is quartz and altered, dark, chloritized mafic dike rock that is impregnated with pyrite, much of which has oxidized to limonite, which stains the biotite granite wallrock. At the southwest end of the outcrop, a pit about 10 feet across and 3 feet deep is on the vein. Samples 248 and 249 (pl. 2) were taken at the prospect, one (248) of selected specimens at the pit and the other of fragments taken along a 200-foot strike length of the vein. Neither sample contained unusual quantities of metals (table 5).

Sample 252 (pl. 2) also is from the Edelman Creek fault zone near the head of Medicine Lodge Creek. The sample was chipped across a brecciated zone about 4 feet wide, which is cemented by clear greenish quartz, the fracture surfaces of which are iron-stained. No unusual quantities of metals were detected in the sample by either spectrographic (table 5) or atomic absorption methods.

About 1,000 feet southwest of the primitive area boundary, south of the Edelman Creek trail, there is a prospect pit about 100 feet deep, 6 feet wide, and 10 feet long that exposes a mineralized fracture zone striking N. 60° E. and dipping vertically. The zone is several feet wide and consists of silicified and pyritized dark-green rock that may be an altered mafic dike. The wallrock is biotite granite. Two samples were taken from the prospect. One (365, table 5) was pyritized rock from the dump, and the other was an 0.8-foot chip sample (936, table 6) across the iron-stained, silicified, and pyritized zone on the east side of the pit. Neither sample contains anomalous metal values.

The silicified and pyritized zone continues westerly and was explored about 600 feet from the above pit by a trench 12 feet long, 4 feet wide, and 4 feet deep. A sample (935, pl. 2 and table 6) was chipped across a 3-foot width of the silicified and pyritized zone, which here strikes N. 80° W. The analysis of this sample shows no unusual metal values.

The north segment of the Edelman Creek fault is exposed on the south bank of Medicine Lodge Creek, about 1¼ miles southwest of the primitive area boundary. Here, the fault strikes N. 80° E. and dips 82° SE. It is about 5 feet wide and contains much green quartz that is iron strained along fractures, probably owing to oxidation of small amounts of pyrite. A chip sample (256, pl. 2) across the fault did not contain anomalous metal values.

THAYER LAKE PROSPECTS

Two short adits and a shaft are at the east side of the Thayer Lake trail, about one-fourth mile from its junction with the Edelman Creek trail, in the SW¼ sec. 7, T. 52 N., R. 86 W. (fig. 9, loc. 11). These workings are along a northeast-trending fault that splits from the Edelman Creek fault zone near the junction of Edelman Creek and East Goose Creek (pl. 1). The northernmost adit was driven 36 feet in a S. 15° W. direction. A random grab sample (945, pl. 2 and table 6) of granite from the dump does not show unusual metal values.

The second adit, about 500 feet south of the one described above and east of the remains of a wooden flume, is about 10 feet long. A shaft 10 feet in front of the adit portal and a winze inside the adit were both partly caved and flooded. Neither the shaft nor the winze appeared to be more than 10 feet deep. A sample (933, pl. 2 and table 6), taken at the portal of the adit, contained 0.005 ounce of gold per ton, far below a value that would entice further exploration.

About one-fourth mile north of Thayer Lake, on the east side of the trail in the SE¼ sec. 12, T. 52 N., R. 87 W., is a small discovery pit. A grab sample (934, pl. 2 and table 6) from the small dump at the pit did not contain anomalous metal values.

GOOSE CREEK AREA

Several adits and prospect pits are along the East Fork of Big Goose Creek. According to Darton (1906a, p. 113) work in several prospects in the headwaters of East Fork of Big Goose Creek began in 1898. He refers to assays of $4 in gold per ton and to one prospect where values of $12 in gold and $7 in silver per ton were found. Using 1906 prices of $20.672 per troy ounce for gold and $0.67 per troy ounce for silver, the higher grade material referred to by Darton would have assayed 0.58 ounce gold and 10.45 ounces silver per ton, but nothing approaching such values was found in any of the many samples taken in the study area. A search of the records failed to reveal any metal production from the locality and nothing was seen at any of the prospect sites to indicate that ore had been produced.

Very few mining claim location notices for this locality appear in the Johnson County records. Of the five notices found, four contained descriptions adequate to locate the approximate claim sites in the field. The four claims are the Steve Smith, Pot Handle, Edelman lode, and Driar. A fifth claim, the Hatchet, supposedly is near the Pot Handle claim.

Lower East Goose Creek prospects

An adit, caved at the time of our examination, was driven N. 72° W., on the west side of East Fork of Big Goose Creek, about one-fourth mile southwest of the primitive area boundary, in the SW¼ sec. 32, T. 53 N., R. 86 W. On the basis of courthouse records, this adit would be at the site of the Steve Smith claim. Judging from the size of the dump, the adit was about 60 feet long. A grab sample (912, pl. 2 and table 6) from the dump, which is mostly bleached granitic rock, did not contain anomalous metal values. A panned sample (931, pl. 2 and table 6) taken a few hundred feet to the east, from East Fork Big Goose Creek at the Rhinehart Lake trail crossing, assayed only traces of gold and silver.

Four adits were driven within a distance of about 350 feet, on the west side of the East Fork Big Goose Creek, below the mouth of Edelman Creek, near the center of sec. 6, T. 52 N., R. 86 W. (fig. 9, loc. 12). According to courthouse records, these workings are in the approximate locality of the Pot Handle and Hatchet claims. Of the two northernmost adits of the group, the lower one was caved, but it appeared to have been driven N. 72° W. for an estimated 80 feet. Grab sample 913 (pl. 2, table 6) was taken from the dump. The other adit, about 35 feet above, is 20 feet long and enters the hill in a N. 80° W. direction. Sample 914 (pl. 2, table 6) is a 4-foot chip sample taken directly above the portal of the upper adit. Neither sample contained anomalous quantities of metals.

About 200 feet south of these two adits, there is a third adit which was partly flooded at the time of our examination. This adit was driven in granite on a N. 65° W. bearing and is estimated to be about 80 feet long. Grab sample 915 (pl. 2, table 6) from the dump shows no unusual metal value. The fourth adit, about 150 feet farther south, was caved but had been driven N. 68° W. for about 150 feet, judging from the size of the dump. Sample 921 (pl. 2, table 6) was collected on a 10-foot grid on the dump, which is mostly granite. The sample assayed 0.10 ounce silver per ton.

About one-fourth mile southeast of the mouth of Edelman Creek, east of and near the trail along the East Fork of Big Goose Creek, in SE¼ sec. 6, T. 52 N., R. 86 W., is a caved adit, a partly filled shaft, and some small prospect pits. According to courthouse records, the workings are approximately at the site of the Edelman lode. The prospect workings explore irregular masses and veins of white quartz and dikes of light-gray granite and pegmatite that cut dark-gray, contorted biotite gneiss. The adit was driven into a small boulder field at the base of broken cliffs, and judging from the dump, it was about 100 feet long. The shaft is 30 feet above and 60 feet northeast of the adit and probably was about 20 feet deep. It was sunk on an iron-stained 4-foot shear zone that strikes N. 60° E. To the northeast, near the cliffs, there is a prominent fault that strikes N. 10° E. and dips 65° SE., which is part of a major fault zone along the East Fork of Big Goose Creek. A few specimens of quartz and pegmatite on the dumps of the shaft and adit contain sparsely disseminated pyrite, but most dump material is barren of sulfide minerals. Samples 540 and 541 (pl. 2, table 5) and 919 and 920 (pl. 2, table 6) are grab samples that represent average material on the two dumps. They do not show unusual metal values.

A few hundred feet south of the above-described workings, near the trail, is another caved adit that was driven S. 45° E., in a field of large blocks of granitic rock. The size of the dump indicates the adit was about 25 feet long. Further south, near the intersection of the East Fork of Big Goose Creek and Duncan Lake trails there is another small prospect that appears to have been the start of an adit.

Driar prospect

At the north end of a small lake in the SE¼ sec. 6, T. 52 N., R. 86 W. (pl. 1), there is a small prospect cut that appears to be the start of an adit (fig. 9, loc. 13). This working is in a garnet-bearing iron-stained gneiss. Sample 932 is a channel sample taken vertically across the west face of the cut. About 300 feet southeast of this cut and on the east side of the trail, a location notice was found at the discovery workings of the Driar claim.

Middle East Goose Creek prospects

A caved adit near the trail, a few hundred feet south of the Edelman lode (fig. 9, loc. 14) is in field of large blocks of granitic rock. It is near the southern edge of the SE¼ sec. 6, T. 52 N., R. 86 W. Sample 918 was collected on a 10-foot grid from a 75-ton dump at the adit. It did not contain anomalous metal values.

Three other prospects are south along the trail to Lake Geneva. Two small prospects are near the trail in the E½ sec. 7, T. 52 N., R. 86 W. (pl. 1). Neither expose mineralized rock or vein material. A small caved adit that was driven N. 85° W. is at the trail on the west side of the East Fork of Big Goose Creek about 1 mile north of Lake Geneva. The portal of the adit is in moraine. Samples 545 (table 5) and 917 (pl. 2, table 6) are of dump material at this adit, and they show no unusual concentration of metals.

Geneva Pass prospect

A pyrite- and quartz-bearing vein crops out at the head of the East Fork of Big Goose Creek about one-fourth mile north of Geneva Pass in the NE¼ sec. 31, T. 52 N., R. 86 W. (pl. 1 and fig. 9, loc. 15). The vein is explored by a short adit, the dump of which is crossed by the East Fork of Big Goose Creek trail (fig. 10). The vein is 1 to 1½ feet wide and is in an iron-stained, pyritized, and chloritized shear zone about 5 feet wide. It strikes N. 85° E., dips 65° to 70° NE., and cuts foliated biotite gneiss. The vein contains about 20 percent pyrite and is the most intensely mineralized deposit seen in the Cloud Peak study area. The pyrite is fine grained and massive or is disseminated as grains and euhedral cubes as much as one-fourth inch across. No other sulfide minerals were seen.

FIGURE 10.—View looking north from Geneva Pass. Dump and adit of Geneva Pass prospect in center. Vein is along line of dark rock at top of talus, extending east from the dump.

The adit is 55 feet long, and near the face there is a water-filled winze that may be 10 feet deep. The mineralized zone in which the vein occurs can be traced on the surface for about 200 feet. It pinches out eastward and is offset against a fault to the west (pl. 1). Several samples of selected vein material were collected from the adit and the dump. Samples 940 and 471 (tables 6 and 5) were chipped across the 1.2-foot-wide vein at the portal of the adit; sample 939 was chipped across a 1.3-foot width of the vein at an outcrop 200 feet to the east. Sample 916 (pl. 2, table 6) is a grab sample taken on a 10-foot grid across the dump, whereas samples 472 and 558 (table 5) were of selected mineralized dump fragments. None of the samples contain unusual quantities of metals.

ELEPHANT HEAD LAKE PROSPECTS

A caved adit, estimated to be more than 100 feet long, and several prospect pits are between Elephant Head Lake and Silver Lake, in the SE¼ sec. 27 and the SW¼ sec. 26, T. 52 N., R. 86 W. (fig. 9, loc. 16). The workings explore an iron-stained, epidotized, and silicified shear zone in brecciated and chloritized biotite gneiss. The zone contains red feldspathic masses and irregular lenses and stringers of white to light-green quartz, strikes N. 80° E., dips

60° to 70° SE., and is as much as 50 feet wide. The prospect workings are in a 200- to 300-foot length of the fault zone, which extends westward along the south side of Silver Lake through the cirque at the head of the lake.

Local inhabitants refer to the Elephant Head Lake occurrence as a copper prospect and prospectors may have thought the green epidotized rock was copper ore. Several samples of altered material chipped from the zone and taken from the dumps, however (samples 609–616, pl. 2), do not contain anomalous concentrations of metals.

Another small prospect pit is near the mouth of a small lake about one-half mile southeast of Elephant Head Lake, in the NW¼ sec. 35, T. 52 N., R. 86 W. The pit is in an irregularly iron stained, epidotized fracture zone that strikes N. 10° W. and dips vertically. The zone is about 5 feet wide. Sample 619 (pl. 2, table 5) of typical iron-stained epidotized rock from the zone does not contain anomalous concentration of metals.

HIGHLAND PARK PROSPECT

A prospect pit 12 feet across and 6 feet deep is at the crest of a ridge about 1½ miles northeast of Highland Park, in the center of sec. 18, T. 52 N., R. 85 W. (fig. 9, loc. 17). The pit is on a diabase dike 2 to 3 feet thick, which strikes N. 70° E. and which cuts epidotized, gneissic biotite granite. No mineralized material was seen in the pit, nor was there evidence of oxidation or alteration. A sample (463, pl. 2 and table 5) of selected fragments from the dump did not contain unusual metal values.

CEMENT MOUNTAIN PROSPECT

In 1947, a 160-acre placer claim, the Eureka Placer, was located in E½ sec. 6, T. 50 N., R. 87 W. (fig. 9, loc. 19). This claim covers a high ridge, known as Cement Mountain, between the North and Main Forks of Paint Rock Creek. Several shallow bulldozer cuts are on the ridge, which is chiefly brownish conglomeratic Flathead Sandstone (pl. 1). Outcrops of sandstone on the west side of the ridge weather to a white quartz sand and may have been the reason for the claim location. If so, equivalent sand is available from countless more accessible Flathead outcrops. Thus, as a producer of silica the property does not appear to be of commercial value. No indications of other mineral deposits were seen at the locality.

ROCK CREEK PROSPECT

A prospect on a tributary of the South Fork of Rock Creek, southeast of Elk Lake, in the eastern part of the study area in sec. 19, T. 51 N., R. 84 W., is known as the Payseno property after the mining claims locator (fig. 9, loc. 20). The property consists of seven mining claims of which four, the Walter Nos. 1 and 2 and Jean Nos. 1 and 2 are shown on plate 2. The other claims, Homer Nos. 1 and 2 and Payseno Quartz, are not shown on the map.

A curved trench about 200 feet long and from 6 to 8 feet deep is at the end of a wagon road to the claims. Four small pits and trenches are north of this trench. The long trench has the appearance of a placer prospect; however, there is no evidence of sluicing or of any other attempt at mining.

Alluvium panned from the trench showed an abundance of black sand but no visible gold. Heavy minerals identified in the concentrate were magnetite, ilmenite, zircon, hematite, garnet, monazite, and rutile, but none were found in commercial quantities. The long trench ends abruptly at the outcrop of an olivine-bearing diabase dike, which strikes N. 70° W. and is probably the source of much of the magnetite and ilmenite in the panned concentrate. Three samples were taken from the dike: Sample 902 is a 15-foot chip sample across the dike at the end of the trench; sample 901 is a 20-foot chip sample across the dike about 2,500 feet west of sample 902 (table 6); and sample 911 is a 4-foot horizontal channel sample of decomposed granitic gneiss from the trench wall at the north side of the dike. None of the samples contain anomalous quantities of metals.

LAKE ANGELINE PROSPECT

A prospect near Middle Clear Creek, about three-quarters of a mile east of Lake Angeline, consists of an 18-foot adit, bearing S. 40° W., and a shallow opencut above the adit (fig. 9, loc. 21). These workings are in the NE¼ sec. 22, T. 50 N., R. 85 W. They evidently were opened to explore pegmatite dikes. Two samples were taken: a 3-foot chip sample (909, pl. 2) across white quartz exposed in the opencut, and a 3-foot chip sample (910, table 6) across a body of white quartz near the portal of the adit. The samples did not contain unusual quantities of metals.

EAST TENSLEEP LAKE PROSPECT

Stringers and irregular masses of vuggy quartz crop out at the north end of a small lake in the S½ sec. 1, T. 49 N., R. 86 W., about

1 mile north of East Tensleep Lake (fig. 9, loc. 22). The silicified zone, several feet wide and several tens of feet long, contains stringers of quartz as much as 1 foot wide, which are parallel to foliation of enclosing dark-gray mica schist. The schist is a small pendant about 30 feet wide and 100 feet long in faintly foliated granitic gneiss.

A pile of iron-stained fragments of quartz indicates that the occurrence has been of interest to someone, but workings and claim location notices were not found. Sample 658 (pl. 2, table 5) was taken from the pile of iron-stained quartz. No unusual quantities of metals were detected in the sample.

BABY WAGON CREEK CLAIMS

Johnson County records show that four mining claims, Barbara Nos. 1 and 2 and Carrie Nos. 1 and 2, were located in 1943 near the head of Baby Wagon Creek in the N½ sec. 27, T. 49 N., R. 85 W., in an area of gneissic rocks (fig. 9, loc. 23). Examination of the area disclosed only one rock monument with no markings. No workings and no vein outcrops or other evidence of mineralization were seen. No samples were taken.

CLAIMS AND PROSPECTS NEAR BUT OUTSIDE THE STUDY AREA

TWIN LAKES FELDSPAR PROSPECT

Over a period of years, many mining claims have been located northwest of Twin Lakes in the southern part of T. 54 N., R. 87 W. (fig. 9, loc. 1). In the SE¼ sec. 28 and the SW¼ sec. 27, about 1 mile northwest of the lakes and a few hundred feet north of the forest road, several pegmatite dikes have been prospected by pits and trenches, probably for feldspar. The central pit was excavated in a feldspar outcrop, which, although not clearly defined, covers an area of about 20 by 30 feet. About 50 feet northwest of this pit, a Geiger counter reading at an outcrop of pegmatite containing large magnetite crystals showed 0.15 mr per hr (milliroentgens per hour). This radioactive reading is more than would be expected from granitic rocks, but not abnormal for a pegmatite. A radiometric analysis of a sample of the outcrop indicated no unusual concentration of uranium or thorium.

BISHOP MINE

The Bishop mine is in S½ sec. 35, T. 53 N., R. 86 W., near the headwaters of the West Fork of Little Goose Creek (pl. 2; fig. 9, loc. 6). Six claims are located at the property—the Washington

Nos. 2 and 5, and the Washington Independent Nos. 1, 3, 4, and 6 (pl. 2). Mine workings consist of a caved adit, a trench, and some prospect pits. Judging from the condition of the workings and a couple of old cabins, the prospecting was done many years ago. The adit was driven on a quartz vein, which is 4 feet thick, strikes about N. 60° E., and dips vertically. The size of the dump indicates the adit was about 200 feet long. The quartz is part of a silicified zone that was traced for about 200 feet on the surface. It ranges from a few feet to about 50 feet wide and averages about 20 feet. The zone contains both white quartz and green epidote-bearing quartz and is at or near the contact of a chloritized dolerite dike. Light-gray to light-red granitic rock is cut by the dike. Several samples (578, 579, 926, and 927, pl. 2 and tables 5 and 6) of the quartz and silicified rock were collected from the vein and from the dump at the adit. Grab sample 928 is a chip sample of the diabase dike exposed in the trench 200 feet southwest of the adit. Grab sample 580 is of iron-stained granite from the contact of the same dike. None of the quartz or the dike samples contain anomalous metal values.

DUTCH OVEN PASS PROSPECT

A caved adit and several prospect pits are along a prominent quartz vein about one-half mile north of Dutch Oven Pass, SE¼ sec. 19, T. 52 N., R. 87 W. (pl. 1 and fig. 9, loc. 18). The size of the dump indicates the adit may have been about 30 feet long. No work appears to have been done on the property for many years and no mining claim location notices were found.

The vein strikes N. 60° E., dips steeply, ranges from 2 to 5 feet thick, and may be traced at the outcrop for at least 700 feet. It consists of white, fine-grained quartz that is somewhat iron stained from oxidation of sparsely disseminated pyrite. In a prospect pit near the pass above the adit, small aggregates of chalcopyrite, partly oxidized to malachite, were seen in the quartz. Sample 410 (pl. 2, table 5) represents selected fragments of this material. In addition to copper values that are higher than were found at most veins, the sample also contains 2.5 ppm silver. Sample 409, taken from the vein at the highest prospect pit, did not contain unusual quantities of metals, nor did sample 411, which was a panned concentrate of material taken from the adit dump. Sediment sample 412, taken from a stream that drains the lower part of the vein outcrop also did not contain anomalous metal values.

BATTLE CREEK PROSPECT

Near the headwaters of Battle Creek, NE¼ sec. 20, T. 50 N., R. 87 W., are two caved adits, both of which were driven to explore the sandstone member at the base of the Bighorn Dolomite (fig. 9, loc. 24). The two adits are about 100 feet apart and about 20 to 30 feet long. No claim location notices were found.

At the portal of the northernmost of the two adits there is a 1-foot layer of sandstone having a darkened salt and pepper appearance from pellets and grains of manganese oxide. The pellets have a black metallic luster and probably were the stimulus for the prospecting. A sample (38, pl. 2) of the more metallic appearing material contained 3,000 ppm manganese, which is anomalous for rocks of the area but is insignificant in terms of an exploitable manganese deposit. A second sample (37, pl. 2) of sandstone from the southern adit did not contain unusual quantities of metals.

BELLYACHE FLATS HEMATITE

Red oolitic hematite in buff Flathead Sandstone crops out in the NE¼ sec. 35, T. 50 N., R. 87 W., on the ridge between Soldier and Buck Creeks, about one-half mile west of the study area boundary (fig. 9, loc. 25). A 1-foot channel sample (937, pl. 2 and table 6), from the most mineralized part of the iron-bearing sandstone at a roadcut, contains 22.2 percent iron. This grade of material is not minable. Other outcrops of the Flathead may contain iron in quantities of as much as this, but no outcrops of the sandstone were seen that warrant exploration as a source of iron ore.

SOLDIER CREEK PROSPECT

At Soldier Creek in the SE¼ sec. 2, T. 49 N., R. 87 W., a glauconitic layer near the base of the Gros Ventre Formation has been explored by a 10-foot-deep inclined shaft (fig. 9, loc. 26). This layer is about 2 feet thick; it consists of green pelletal glauconite in a sandy matrix and contains thin beds, ⅛–¼ inch thick, of maroon sandstone and yellowish clayey sandstone that strike N. 45° W. and dip 10° SW. The glauconite may have been mistaken for green copper minerals. Sample 8, cut across the width of the bed, does not contain anomalous amounts of copper or other metals.

MERLE CREEK PROSPECT

Johnson County records show that two mining claims, BD No. 1 and Princess, were located on Merle Creek upstream from the

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road to the Sheep Mountain Fire Lookout (fig. 9, loc. 28). The claims are about 1½ miles east of the southeastern corner of study area, in the NE¼ sec. 25, T. 49 N., R. 85 W., and in the NW¼ sec. 30, T. 49 N., R. 84 W. The only working observed was a 5 by 30 foot partly caved trench, 10 feet deep, about 1 mile upstream from the road. Sample 900 (pl. 2, table 6), taken on a 3-foot interval from the trench dump, consists mostly of gneiss. Spectrographic analysis of the sample shows no unusual concentrations of metal.

SOUTH PAINT ROCK CREEK CLAY PROPERTY

Several unpatented claims are located on a clay deposit in the SW¼ sec. 13, T. 49 N., R. 87 W., near the headwaters of South Paint Rock Creek, about 1 mile southwest of the study area boundary (fig. 9, loc. 27). The claims are known as the Pascal group, after the original locator. Recent holders of the claims are Mr. Roy Pendergraft and Mr. Carl Sneed of Worland, Wyo. Two adits, both caved, were driven for a few feet northwest along the northern side of the deposit, but the principal exploration workings are bulldozed trenches that explore a landslide, one of several on the property.

The clay deposit explored by the bulldozed cuts is in landslide debris underlain by Gallatin-Gros Ventre rocks. Cliffs of Bighorn Dolomite are just north and east of the deposit and at higher altitudes. Bedding was not seen in the jumbled clay, which contains pieces of green glauconitic shale and pink platy limestone of the Gallatin-Gros Ventre and fragments of Flathead Sandstone. Angular blocks of Bighorn Dolomite are strewn over the deposit. The debris of lower Paleozoic rocks and local topography suggest the clay was moved by landslides down gulches extending northeast and east from the claims and from the foot of a spur ridge between the gulches. The landslide mantle has protected the clay from rapid erosion. No similar clay deposits were seen on uplands of the vicinity.

A sample of the clay was investigated by Sam H. Patterson of the U.S. Geological Survey, using X-ray and microscopic methods. He found (oral commun., August 1971) the clay to be a bentonite that consists of about 80 percent montmorillonite and the nonclay fraction to be mainly very finely divided angular quartz and fresh feldspar. The fine-grained feldspar in the bentonite is too fresh to be of early Paleozoic age. The clay is much younger than that in the underlying lower Paleozoic rocks, which are glauconitic rather than montmorillonitic. The clay probably formed from weathering and decomposition of volcanic ash that blanketed much of the region during middle Tertiary time. The clay is about 8 feet thick at the northeasternmost bulldozed cut. It probably does not extend below the bottom of the gulch along the north side of the deposit nor beyond the limits of the landslide area, which is about 10 acres in extent. No attempt was made to estimate the tonnage of clay in the deposit but it would not be large.

According to local reports, the clay was used by the Indians for medicinal purposes, who are said to have called it Ee-Wah-Kee, purported to translate as "the mud that heals." Recent small-scale mining attempts at the deposit have been for the purpose of producing a "curative" health material. Our studies of the clay, however, did not reveal any unusual physical or chemical properties. It is similar in physical characteristics to clay in other deposits that have formed from alteration of volcanic ash. The deposit is small, remote, and could not compete as a source of industrial clay with larger clay deposits mined in nearby parts of Wyoming.

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